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Assessment and Management of Animal Damage in Pacific Northwest Forests: An Annotated Bibliography

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Foreword

This bibliography was developed to provide a state-of-the-knowledge resource for forest land managers and others concerned with animal damage management and as a reference for the authors of a compendium expected in December 1990. The compendium will be titled *A Silvicultural Approach to Managing Animal Damage in Pacific Northwest Forests* and will be authored by experts in various aspects of animal damage management and silviculture. It will provide a synthesis of published information and operational experience for preventing or avoiding most animal damage to reforestation and older stands through improved vegetation management and silvicultural practices. It is not intended to supplant traditional methods of animal damage management that rely on protection via direct population reduction, use of barriers, etc., but to emphasize prevention of animal damage, and meet timber, wildlife, and other resource management objectives. The goal of these combined publications is to provide a process for developing integrated silvicultural prescriptions to limit animal damage.

The compendium will include a historical review of animal damage problems related to reforestation in the Pacific Northwest and the development of methods to control damage, including recent concepts of integrated forest protection. General principles of plant and animal ecology pertaining to stand establishment and stand management will be included to provide background for both forest and wildlife managers, and other users. Other sections will include chapters on the influence of silvicultural practices on animal habitat and animal damage; influence of forest management practices on wildlife species causing damage to forest stands, including guidelines for managing damage; procedures for developing integrated silvicultural prescriptions to limit animal damage; and social, political, legal, and ethical aspects of animal damage management. This "user friendly" publication will provide a basis for sound, cost-effective decisions regarding animal damage management.

Charles W. Philpot
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Abstract

Loucks, Donna M.; Black, Hugh C.; Roush, Mary Lynn; Radosevich, Steven R., tech. coords. 1990. Assessment and management of animal damage in Pacific Northwest forests: an annotated bibliography. Gen. Tech. Rep. PNW-GTR-262. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 371 p.

This annotated bibliography of published literature provides a comprehensive source of information on animal damage assessment and management for forest land managers and others in the Pacific Northwest. Citations and abstracts from more than 900 papers are indexed by subject and author. The publication complements and supplements *A Silvicultural Approach to Animal Damage Management in Pacific Northwest Forests*, a compendium focusing on interactions between silviculture and animal damage management. The bibliography compiles the current knowledge and experience about managing animal species causing damage to forest stands, the response of those species to silvicultural practices, and manipulation of silvicultural practices to prevent or limit animal damage.

Keywords: Bibliographies (forestry), animal damage, Pacific Northwest.

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Introduction

Animal damage is an important concern for forest land managers in the Pacific Northwest. This bibliography, scheduled to be published in December 1990, was compiled to provide a comprehensive source of information on animal damage management for practicing foresters and others in this region. The publication will complement and supplement *A Silvicultural Approach to Animal Damage Management in Pacific Northwest Forests*, a compendium scheduled to be published in December 1991. The bibliography contains the current prescriptions to limit animal damage. The bibliography contains the current knowledge and experience about managing animal species that cause damage to forest stands, the response of the species to silvicultural practices, and manipulation of silvicultural practices to prevent or limit animal damage.

The citations and abstracts from more than 900 papers are organized by animal species and indexed by subject and author. Within each section, citations are grouped into three major topics. Citations in the general section include monographs, symposia, and bibliographies. Citations on the ecology of each species include their life history, activity, population dynamics, feeding habitat requirements, and responses to habitat changes and silvicultural practices. Citations in the damage and management sections include levels and types of animal damage, damage identification and assessment, management tools, and the economics of animal damage and animal damage management.

We found the animal damage literature to be broad and diverse. Our greatest concern was to avoid omitting key animal damage literature and, at the same time, to avoid overburdening the bibliography with superfluous references. Most of the citations included in this bibliography pertain to the Pacific Northwest; however, we sometimes included citations from other regions if they were reasonably applicable to the Pacific Northwest. We believe the bibliography is a comprehensive document that includes most of the key current literature on this topic, and that it will provide a useful resource for land managers and researchers who are concerned with managing animal damage in Pacific Northwest forests.

General

1. Bailey, Vernon. 1936. The mammals and life zones of Oregon. North Amer. Fauna 55. U.S. Department of Agriculture, Bureau of Biological Survey. 416 p.

The physiographic features and life zones of Oregon and described, based on field work done by the Bureau of Biological Survey since 1888. For each mammal species, distribution, habitat, general habits, breeding, and food habits are reviewed.

2. Black, Hugh C.; Taber, Richard D. 1977. Mammals in western coniferous forest ecosystems: an annotated bibliography. Bull. 2. Seattle, WA: Coniferous Forest Biome, U.S./International Biological Program. 199 p.

Compiled to provide access to the literature on mammals as it pertained to the interest of the Biome investigation. Number of references was limited to 1,000, emphasizing those in the Pacific Northwest and on productivity and effects of forest manipulation. Arranged alphabetically by author, taxonomic and subject indexes.

3. Brown, E. Reade, ed. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. Pub. R6-F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 2 vol. 634 p.

Summarizes pertinent information concerning fish and wildlife habitats in the managed forests of western Oregon and Washington, shows how these habitats are altered by forest management activities, and discusses some of the alternatives to benefit fish and wildlife that are available to land managers when making decisions concerning the management of timber resources.

4. Carraway, Leslie N.; Verts, B.J. 1982. A bibliography of Oregon mammalogy. Spec. Rep. 644. Corvallis, OR: Agricultural Experiment Station, Oregon State University. 47 p.

This bibliography covers published sources of information on Oregon mammals from 1890 to 1980. Bibliographic citations are listed alphabetically, then numbered sequentially. Species-subject and author indexes refer to the numbers.

5. Dalquest, Walter W. 1948. Mammals of Washington. Mus. Nat. Hist. Publ. 2. Lawrence, KS: University of Kansas. 444 p.

Physiographic provinces, distributional areas, climate, vegetation, life zones, ecology, and geologic history are discussed. For each genus of mammals, a general description on their characteristics is followed by details on each species, including measurements and distribution. Includes distribution maps and a few photographs of the mammals.

6. Ingles, Lloyd G. 1965. Mammals of the Pacific States: California, Oregon and Washington. Stanford, CA: Stanford University Press. 506 p.

Chapters are divided by orders. For each order, there is a taxonomic key and for each species, a description of size and identification characteristics, a line drawing, and a distribution map.

7. Larrison, Earl J. 1976. Mammals of the northwest: Washington, Oregon, Idaho, and British Columbia. Seattle, WA: Seattle Audubon Society. 256 p.

This nontechnical handbook contains brief descriptions of each mammal covering size, description, range, and habitat and with a line drawing. Also included is a section on animal tracks and a section of color photographs with mammals in their natural surroundings.

8. Maser, Chris; Mate, Bruce R.; Franklin, Jerry F.; Dyrness, C.T. 1981. Natural history of Oregon coast mammals. Gen. Tech. Rep. PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 496 p.

Presents detailed information on the biology, habitats, and life histories of the 96 species of mammals of the Oregon coast. Soils, geology, and vegetation are described and related to wildlife habitats for the 65 terrestrial and 31 marine species.

9. Thomas, Jack Ward, ed. 1979. Wildlife habitats in managed forests—the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture. 512 p.

Includes chapters on plant communities and successional stages; riparian zones; edges; snags; dead and down woody material; cliffs, talus, and caves; deer and elk; silvicultural options; and impacts on wood production.

Ecology

10. Bunnell, Fred L.; Eastman, Don S. 1976. Effects of forest management practices on wildlife in the forests of British Columbia. In: 16th IUFRO World Congress proceedings, Division 1; 1976 June 20-July 2; Oslo, Norway; Oslo, Norway: International Union of Forestry Research Organizations: 631-689.

In British Columbia, several mammals, birds, amphibians, and fish are directly or indirectly influenced by the nature of the forest cover. The diversity of forest types and wildlife precludes specific analysis of the influence of each forestry management practice on each wildlife species. Acknowledging this diversity, a general model of the changes in major resources required by any wildlife species after complete removal of the tree overstory is presented. The resources considered are energy, nutrients, water, temporary shelter, habitation, escape cover, and space. The general model is evaluated for specific resources required by selected species, and its applicability and limitations are documented. Because it presents a general pattern resulting from autogenic, secondary succession, the model can be used as a framework to examine influences of particular forest management practices on wildlife species. The value of the model is that it provides a device for relating scattered observations on many wildlife species in many forest types and offers a vehicle for extrapolating generalities to areas that have not been studied extensively. It thus provides a forest manager with a convenient device for evaluating the potential impacts of proposed management practices.

11. Hooven, Edward F. 1973. A wildlife brief for the clearcut logging of Douglas-fir. *Journal of Forestry* 71(4): 211-214.

Objections to clearcutting of Douglas-fir in northwest Oregon have included possible detrimental effects upon wildlife. Observations recorded here show that the abiotic and vegetative changes occurring from staggered clearcut logging are temporary and beneficial to forest wildlife. Many species, from insects to big game, increase.

12. Hungerford, Kenneth E. 1969. Influence of forest management on wildlife. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium*; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 39-41.

Examines the effects of forest management practices on wildlife populations. The impact of clearcutting in large blocks and the effects of modification of the pattern and size of clearcuttings on wildlife are described. The effects of such regeneration practices as slash disposal, site preparation, herbicide application, and fertilization on animal populations are mentioned. Experiments with thinnings in coniferous stands in northern Idaho are discussed, with reference to their effects on production of food for wildlife. The investigation of microenvironments in relation to wildlife is described as

the most promising approach to ecologic controls. Investigation of microclimatic changes after stand manipulation demonstrated that the pattern of dew deposition may be modified. The significance of changes in dew accumulation in habitats of ruffed grouse in northern Idaho is reported. The conclusion is that intensive management of the forest increases opportunities for improvement of wildlife habitat, and research on the microenvironmental effects of clearcutting in small blocks is needed.

13. Lawrence, W.H. 1967. Effects of vegetation management on wildlife. In: Symposium proceedings, herbicides and vegetation management in forests, ranges, and noncrop lands; 1967 September 7; Corvallis, OR. Corvallis, OR: Oregon State University: 88-93.

Reviews some wildlife-herbicide interactions, specifically (1) maintenance of suitable habitat (2) conversion of an existing vegetation pattern to another vegetative type and (3) ecological control of animal numbers through habitat manipulation.

14. Morrison, Michael L.; Meslow, E. Charles. 1983. Impacts of forest herbicides on wildlife: toxicity and habitat alteration. In: Sabol, Kenneth, ed. Transactions of the 48th North American wildlife and natural resources conference; 1983 March 19-24; Kansas City, MO. Washington, DC: Wildlife Management Institute: 175-185.

This review indicates that the response of wildlife to herbicide-induced habitat change is extremely varied. Variations in response by wildlife are understandable because plants respond in a species-specific manner to the chemical applied, the rate and time of application, and various environmental constraints. Generalizations that can be drawn: First, certain animals respond to habitat alteration by increasing their use of undamaged vegetation. Other species, however, are seemingly unable to compensate for habitat loss and thus decline in density. Other species respond to habitat change by increasing in density. An increase in density by certain species after treatment is not necessarily desired. Increasing deer browse through herbicide application, for example, would also cause a decreased habitat availability for other species. The general response of wildlife to herbicide application can frequently be predicted, and anticipated changes can be alleviated by careful planning of the treatment. What is generally deemed desirable is retention of the natural variety of vegetation types so that managed lands can supply a diversity of vegetation and wildlife through time.

15. Anonymous. [In press]. Animal damage control handbook. For. Serv. Handb. FSH 2609.22. Portland, OR: U.S. Department of Agriculture, Forest Service.

A comprehensive handbook covering animal response to habitat changes, damage identification, and damage control of the various mammals and birds that damage conifers.

16. Baumgartner, David M.; Mahoney, Ronald L.; Evans, James [and others]. 1987. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University. 164 p.

Pertinent papers are listed separately under appropriate species.

17. Black, H.C.; Hooven, E.F. 1978. Animal damage and animal damage control. In: Cleary, Brian D.; Greaves, Robert D.; Hermann, Richard K., eds. Regenerating Oregon's forests: a guide for the regeneration forester. Corvallis, OR: Oregon State University Extension Service: 192-200.

Reviews types of damage caused by various animals (clipping, browsing, budding, barking, pulling, trampling, and rubbing) and methods of control (population reduction, chemical deterrents, mechanical deterrents, and habitat manipulation).

18. Black, Hugh C. 1969. Animal damage to forest regeneration in the ponderosa pine region of Oregon and Washington. In: Hermann, R.K., ed. Regeneration of ponderosa pine: Proceedings of a symposium; 1969 September 11-12; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 105-118.

Reviews correct identification of wildlife injuries and describes status and control of damage by pocket gophers, porcupines, deer and elk, livestock, and hares and rabbits in the pine region.

19. Black, Hugh C.; Dimock, Edward J., II; Dodge, Wendell E.; Lawrence, William H. 1969. Survey of animal damage on forest plantations in Oregon and Washington. In: Trefethen, James B., ed. Transactions of the 34th North American wildlife and natural resources conference; 1969 March 2-5; Washington, DC. Washington, DC: Wildlife Management Institute: 388-408.

A survey of animal damage to forest plantations in Oregon and Washington was begun in 1963, under the direction of the Cooperative Animal Damage Survey Committee. The survey is scheduled to end in 1969. Cooperators installed 210 randomly located sampling plots. After four growing seasons, survival of uncaged seedlings in the first series of plots averaged 60% for Douglas-fir and 52% for ponderosa and Jeffrey pine. Average survival of uncaged seedlings in the second series after only three growing seasons was similar for Douglas-fir (58%) but higher for pine (56%). Based on differences between survival of caged and uncaged seedlings, animals caused 35% of the mortality in Douglas-fir and 51% in the pines. Browsing and clipping of stems were the principal causes of seedling injury. Animals that injured seedlings, ranked by frequency of damage in 1968, were big game, hares and rabbits, grouse, mountain beavers, pocket gophers, domestic stock, porcupines, microtine rodents, and moles. Animal damage markedly reduced the height growth of unprotected seedlings. After 4 years, the mean height of uncaged Douglas-fir was 23.4 inches, compared with mean height for caged seedlings of 33.1 inches.

20. Black, Hugh C.; Dimock, Edward J., II; Evans, James [and others]. 1979. Animal damage to coniferous plantations in Oregon and Washington. Part I. A survey, 1963-1975. Res. Bull. 25. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University. 44 p.

Mammal and bird damage recorded on Douglas-fir and ponderosa pine plots—randomly established in Oregon and Washington during 1963-64, and then observed for 5 to 10 years—was evaluated for impact on survival and growth. In all, 194 plots were installed, and 10 of the 100 seedlings on each plot were caged to protect them

from animals. All trees were examined after planting and after bud burst each year for 5 years. A selected sample of 45 Douglas-fir plots was observed another 5 years for long-term patterns and effects of severe plantation damage. Survival and growth were compared for caged and uncaged trees. The agents, kind, amount, and distribution of animal damage were evaluated by state, by subregion, and by relation to site features. Results indicate that stand damage in plantations exposed to heavy animal use, especially during seedling establishment, warrants expenditure for protective measures.

21. Brodie, Douglas; Black, Hugh C.; Dimock, Edward J., II [and others]. 1979. Animal damage to coniferous plantations in Oregon and Washington. Part II. An economic evaluation. Res Bull. 26. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University. 45 p.

Regression models of height growth and survival were fitted to aggregate data for trees, protected and not protected from animal damage, that had been surveyed in Oregon and Washington. Animal damage significantly affected both height and survival. Dynamic programming analysis was used to derive (1) optimal economic regimes for managing stands with full and depressed stocking levels; (2) management guidelines for protection expenditure and stand replacement, and (3) physical impacts on volume yield. At current rates of planting in Oregon and Washington and at a 3% discount rate, animals cause an estimated \$60 million annually in damage, thereby reducing the new capitalized value of the timber resource by \$1.8 billion. Likewise, present net worth decreases by 18% and growth and yield by 13%. Several other discount rates showed different proportional impacts from animal damage.

22. Campbell, Dan L. 1982. Influence of site-preparation on animal use and animal damage to tree seedlings. In: Baumgartner, David M., ed. Site preparation and fuels management on steep terrain: Proceedings of a symposium; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension: 93-101.

A review of the literature on the interrelations of animal use of steep slopes, aspects, methods of site preparation, and habitats showed that few, if any, factors determine animal use as much as habitat and quality of available forage. Generally, burning or mechanical slash disposal improves forage quality. Usually, increased forage abundance and availability will result in less animal damage to conifers by big game and livestock. Damage by pocket gophers, however, may increase with increased availability of certain food plants. Site requirements for harmonious existence of mountain beavers in forest systems without conifer damage have not been identified. A study of experimental seedings of forage plants and Douglas-fir on steep slopes indicated high establishment potential; covering seed with soil improved establishment of most species. Specific comparisons of site-preparation methods and use are needed to better evaluate animal interactions with planned reforestation.

23. Campbell, Dan L.; Evans, James. 1984. Wildlife-reforestation problems and seedling protection methods in western Oregon: review and current knowledge. T/N: OR-4. Portland, OR: U.S. Department of the Interior, Bureau of Land Management. 46 p.

Methods used by BLM and other forest land managers to protect forest seedlings from animal damage are reviewed. Black-tailed deer, mountain beaver, and elk caused most damage; mountain beavers caused most tree mortality. At least seven other wildlife species, including snowshoe hare, brush rabbit, and pocket gophers also damaged tree seedlings. Livestock also damaged plantations. Methods of control are discussed. The primary methods used in 1982-83 were protection of individual seedlings with mechanical barriers and repellents and kill trapping mountain beaver. Current studies and research needs about forest-animal damage relations are summarized.

24. Canutt, Paul R. 1969. Relative damage by small mammals to reforestation in Washington and Oregon. In: Black, Hugh C., ed. Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 55-59.

Relative damage to reforestation by five groups of small mammals is reviewed. Data are based mainly on interviews with forest managers and researchers concerned with problems of forest and wildlife. The animals, ranked in order of importance, are porcupines, pocket gophers, hares and rabbits, mountain beavers, and dusky-footed woodrats. For each group, distribution, population trends, damaged areas and trends in damage, priority of damage problems, and current research on these problems in the Pacific Northwest are discussed. Present distribution of each species and locations of recognized areas with problems in Oregon and Washington also are mapped.

25. Crouch, Glenn L. 1969. Animal damage to conifers on National Forests in the Pacific Northwest region. Resour. Bull. PNW-28. Portland, OR: U.S. Department of Agriculture. Forest Service, Pacific Northwest Forest and Range Experiment Station. 13 p.

Animal damage to growing trees was more common on Oregon National Forests than on Washington National Forests. More problem areas were reported from western Oregon than from western Washington or east-side forests. Regionwide, foliage browsing was the most common type of damage, followed in order by barking, root gnawing, clipping, trampling, and loss of trees. Problem animals in order of importance were deer, porcupine, gophers, hare and rabbits, elk, livestock, small rodents, mountain beaver, and bear.

26. Crouch, Glenn L. 1976. Wild animal damage to forests in the United States and Canada. In: 16th IUFRO World Congress proceedings, Division 2; 1976 June 20-July 2; Oslo, Norway. Oslo, Norway: International Union of Forestry Research Organizations: 467-478.

Briefly reviews the various birds and mammals that damage seeds, seedlings and larger trees, methods of control, and the economic importance of the damage.

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27. Crouch, Glenn L. 1980. Plastic cages to protect Douglas-fir seedlings from animal damage in western Oregon. Res. Pap. PNW-271. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.

Effects of plastic mesh cages designed to protect Douglas-fir seedlings from animals were evaluated in western Oregon. In two tests over 5-year periods, caging increased survival by 0 and 13% and increased height growth by 0.8 and 1.2 feet compared with uncaged trees. Benefits from caging might have been greater if damage had been more prevalent during the tests.

28. deCalesta, David. 1982. Effectiveness of control of animal damage to conifer seedlings. In: Hobbs, S.D.; Helgerson, O.T., eds. Reforestation of skeletal soils: Proceedings of a workshop; 1981 November 17-19; Medford, OR. Corvallis, OR: Forest Research Laboratory, Oregon State University: 102-104.

Effectiveness of animal damage control operations is measured by the benefit-cost ratio of the operation. A method for calculating the benefit-cost ratio is described. Information required by the calculation includes fraction of area damage occurs on seedling stocking rate and number of years damage occurs. The method assumes damage is constant from year to year and that precommercial and commercial thinning are conducted.

29. Dimock, Edward J., II. 1974. Animal populations and damage. In: Cramer, Owen P., ed. Environmental effects of forest residues management in the Pacific Northwest: a state-of-knowledge compendium. Gen. Tech. Rep. PNW-24. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: O1-O28.

Living and nonliving residues remaining after timber harvest exert both favorable and unfavorable influences on forest animal populations. Residue situations usually improve habitats for animals likely to damage regenerating forest crops. Evidence suggests that most residue treatments further enhance the habitats already improved for problem animals by timber harvesting and increase the probability of serious animal damage. Practical treatments that modify residues least appear most promising for attaining timber, range, and wildlife production goals with a minimum of interference by damaging animals.

30. Dimock, Edward J., II; Black, Hugh C. 1969. Scope and economic aspects of animal damage in California, Oregon, and Washington. In: Black, Hugh C., ed. Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 10-14.

How do land managers assess damage caused by animals on public and private forests in California, Oregon, and Washington? Estimates of timber volumes lost and of animals chiefly responsible vary considerably—reflecting a diversity of problems by locality and land ownership, as well as differing approaches to appraising damage.

31. Dodge, Wendell E. 1969. Protective measures: a review of chemical, mechanical, and other means of controlling damage by animals. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 60-62.

Reviews the present program of chemical screening at the research centers of the Bureau of Sport Fisheries and Wildlife at Denver and Olympia. Summarizes the techniques and materials available or under development for alleviating damage to seedlings by animals. Methods of prevention applicable to deer, pocket gophers, porcupine, mountain beavers, snowshoe hares, and meadow mice are discussed. Future problems and needs in research also are considered.

32. Evans, James. 1976. Wildlife damage and western hemlock management in the Pacific Northwest. In: Atkinson, William A.; Zasoski, Robert J. *Western hemlock management conference: Proceedings; [n.d.]; [Place held unknown].* Seattle, WA: College of Forest Resources, University of Washington: 148-154.

Discusses the impact that wildlife are likely to have on establishment and stocking of western hemlock under intensive management and culture programs in western Washington and Oregon. Reviews damage by mammals that will be a serious threat to managed stands of hemlock. Chemical, mechanical, ecological, and cultural approaches to control animal damage are summarized. The implications are that mountain beaver and black bear will conflict with programmed stocking levels in precommercially thinned stands and that hare, black-tailed deer, elk, and mountain beaver will cause establishment delays and failures and affect stocking when hemlock is planted. The information in this report can help foresters amend some of these conflicts.

33. Evans, James. 1982. General biology of ten mammals that affect reforestation in southwestern Oregon. In: Hobbs, S.D.; Helgerson, O.T., eds. *Reforestation of skeletal soils: Proceedings of a workshop; 1981 November 17-19; Medford, OR.* Corvallis, OR: Forest Research Laboratory, Oregon State University: 30-36.

Reviews general biology, damage, and status of black-tailed deer, elk, bear, snowshoe hare, brush rabbit, pocket gopher, mountain beaver, porcupine, dusky-footed woodrat, and western gray squirrel.

34. Evans, James; Campbell, Dan L.; Lindsey, Gerald D. [and others]. 1981. Distribution of animal damage in southwestern Oregon forests. *Wildl. Leaflet* 514. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 12 p.

A survey was conducted in Coos, Curry, Douglas, Jackson, and Josephine Counties of southwestern Oregon. Twelve species were identified as agents causing problems. Those most frequently causing damage were black-tailed deer, elk, livestock, pocket gophers, hares and rabbits, and mountain beavers. Other species causing lesser damage were porcupines, blue grouse, and several small rodents such as woodrats, voles, and ground squirrels.

35. Hallett, James G.; Gilbert, Frederick F. 1987. Secondary poisoning—effects in animal damage control. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. *Animal damage management in Pacific Northwest forests*; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 49-54.

Small mammals can impair forest regeneration by feeding on seeds or seedlings. Currently the most cost-effective means of reducing numbers of these animals is the use of poison. The secondary consequences for species which feed upon poisoned animals are not well known, and additional field examinations of the risks of secondary poisoning should be conducted.

36. Harestad, Alton S.; Bunnell, Fred L.; Sullivan, Thomas P.; Andrusiak, Lorraine. 1986. *Key to injury of conifer trees by wildlife in British Columbia*. Victoria, BC: British Columbia Ministry of Forests, Research Branch. WHR-23. 38 p.

Covers damage characteristics and field signs of pika, rabbits and hares, mountain beaver, tree squirrels, pocket gophers, beaver, woodrats, voles, mice, porcupine, bear, deer, elk, moose and blue grouse. Includes line drawings of each animal, their droppings, tracks, and type of damage.

37. Hegdal, Paul L. 1987. Primary and secondary hazards associated with rodent control. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. *Animal damage management in Pacific Northwest forests*; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University. 47 p.

Compound 1080 can result in primary poisoning of nontarget rodents and rabbits, but most birds are relatively resistant to 1080. The use of strychnine baits can result in significant primary hazards to seed-eating birds as well as nontarget rodents and rabbits. The hazard to birds can be drastically reduced by placing the bait underground. The primary hazard of zinc phosphide to nontarget rodents, rabbits and seed-eating birds can be substantial, but secondary hazards are minimal. Increasing environmental concerns dictate that we provide control measures with the least hazard to nontarget species.

38. Hermann, Richard K. 1969. Animal damage problems and their relation to reforestation. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium*; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 6-9.

Reviews economic, sociologic, and biologic aspects of damage by wildlife on regenerating forest lands. Planning for reduction of damage by animals should give greater consideration to environmental management as a means of control and place less emphasis on direct control of wildlife.

39. Kaukeinen, Dale. 1982. A review of the secondary poisoning hazard potential to wildlife from the use of anticoagulant rodenticides. In: Marsh, Rex E., ed. Proceedings, 10th vertebrate pest conference; 1982 February 23-25; Monterey, CA. Davis, CA: University of California: 151-158.

The usefulness and characteristics of the family of anticoagulant rodenticides are reviewed, including the new members difenacoum, bromadiolone, and brodifacoum. General considerations are given in investigating the likelihood of nontarget poisoning with rodenticides. The literature dealing with secondary poisoning studies and concerns with the use of anticoagulant rodenticides is reviewed. The usefulness of laboratory toxicity data versus field-generated exposure data is compared. Considerations of secondary poisonings by anticoagulants are reviewed as pertains to parameters such as specific predator-prey systems, biotopes, rodenticide use patterns, and risk-benefit assessments. Finally, examples of appropriate field studies proposed to assess specific secondary poisoning risk situations associated with particular anticoagulant usage patterns are exemplified by reference to studies conducted by Imperial Chemical Industries and outside researchers with brodifacoum rodenticide bait formulations.

40. Larson, John E.; Campbell, Dan L.; Evans, James; Lindsey, Gerald D. 1979. Plastic tubes for protecting seedlings from browsing wildlife. Missoula, MT: U.S. Department of Agriculture, Forest Service, Equipment Development Center; Equipment Development and Test Program (ED&T) 2217. 19 p.

Protecting seedlings from damage by wildlife is becoming more important as forest management intensifies. The Missoula Equipment Development Center (MEDC) evaluated various methods of seedling protection and found plastic mesh tubes to be most effective for reducing wildlife damage to tree seedlings. There are problems in supporting the tubes vertically to insure longer lasting protection. Several support mechanisms were evaluated, and improved installation methods are suggested. MEDC concluded that plastic mesh tubes present an excellent interim solution to animal damage while the search for a permanent method of protecting seedlings continues.

41. Lawrence, William H. 1958. Wildlife damage control problems on Pacific Northwest tree farms. In: Trefethen, James B., ed. Transactions of the 23d North American wildlife conference; 1958 March 3-5; St. Louis, MO. Washington, DC: Wildlife Management Institute: 146-152.

Discusses types of animal damage problems that occur as foresters attempt to regenerate forests in the Pacific Northwest.

42. Lawrence, William H.; Kverno, Nelson B.; Hartwell, Harry D. 1961. Guide to wildlife feeding injuries on conifers in the Pacific Northwest. Portland, OR: Western Forestry and Conservation Association. 44 p.

A guide to assist foresters in the field identification of wildlife-caused injuries. Injuries are grouped according to the stage in tree development on which they occur: (1) cone and seed losses, (2) seedling and sapling injuries, and (3) mature tree injuries. Descriptive keys of injuries direct the user to the appropriate section. A description of injury, sketch of animal responsible, and pertinent facts on range and habits are included for each animal.

43. Mitchell, Glenn E. 1950. Wildlife-forest relationships in the Pacific Northwest region. *Journal of Forestry* 48(1): 26-30.

Reviews the mammals found in the forests of Washington and Oregon and the damage that they cause to forests.

44. Moore, A.W. 1940. Wild animal damage to seed and seedlings on cut-over Douglas fir lands of Oregon and Washington. Tech. Bull. 706. Washington, DC: U.S. Department of Agriculture. 28 p.

Describes the damage to seeds and seedlings done by many different animals, including deer mice, shrews, squirrels, grouse, rabbits, porcupines, deer, and elk.

45. Radwan, M.A. 1963. Protecting forest trees and their seed from wild mammals (A review of the literature). Res. Pap. PNW-6. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 28 p.

Summarizes some published research on the control of mammal damage to forest trees, including biological control, trapping and shooting, poison baits, contact and systemic poisons, cultural practices, mechanical protection, and repellents. Includes bibliography with 172 citations.

46. Rochelle, James A.; Bunnell, Fred L. 1979. Plantation management and vertebrate wildlife. In: Ford, E.D.; Malcolm, D.C.; Atterson, J., eds. *The ecology of even-aged forest plantations: Proceedings of the meeting of Division I, International Union of Forestry Research Organizations; 1978 September 3-9; Edinburgh, U.K.* Cambridge, U.K.: Institute of Terrestrial Ecology: 389-411.

A variety of forest types containing many vertebrate species with specific habitat requirements occur in North America. In this paper we have attempted to treat species or groups of species which illustrate the major kinds of forestry-wildlife interactions that occur. Plantation management may enhance forage supplies during several stages in the life of the stand, but these periods may be shortened relative to natural forest succession. Vegetative diversity is reduced in plantations since dominance of the site by crop trees is an objective. Rotation lengths are short with the result that forests older than 100 years will continue to diminish in area and will not be replaced. Along with this change will occur a corresponding decrease in populations of species dependent on mature forest and specialized habitats, such as snags. In cases where

wildlife interferes with plantation management, traditional methods of control such as population reduction or the use of repellents or physical barriers are employed, along with indirect controls through habitat manipulation. Consideration of forestry and wildlife trade-offs during the stage of development of management plans will identify more opportunities for integrated approaches.

47. Teegarden, Dennis. 1969. Economics of reforestation in relation to wildlife. In: Black, Hugh C., ed. *Wildlife a reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 15-21.

Economic criteria for choosing strategic and tactical goals for the control of damage by wildlife to forest plantations are discussed. Nonmarket values and ecological side effects present major obstacles to the economic analysis of alternative levels of damage control. Three hypothetical situations are analyzed with particular emphasis on procedures for estimating benefits of damage-control practices. Examples include consumption of seeds by rodents and damage to seedlings by animals such as deer, rabbits, or mountain beaver. Economic criteria for determining whether control is practical in each situation is illustrated.

48. Timm, Robert M. 1983. *Prevention and control of wildlife damage.* Lincoln, NB: University of Nebraska, Cooperative Extension Service and Great Plains Agricultural Council.

For each species, includes information on identification, range, habitat, food habits, reproduction, behavior, damage identification, and various methods of cultural, chemical, or mechanical control.

Black Bear

General

49. Poelker, Richard J.; Hartwell, Harry D. 1973. *Black bear of Washington.* Biol. Bull. 14. Olympia, WA: Washington State Game Department. 180 p.

A comprehensive study of black bear biology, covering reproduction, physical characteristics, food habits, disease and parasites, and population characteristics. Includes information of forest relationships, specifically damage characteristics and control, and on management methods.

Ecology

50. Amstrup, Steven C.; Beecham, John. 1976. Activity patterns of radio-collared black bears in Idaho. *Journal of Wildlife Management* 40(2): 340-348.

Activity patterns of 13 radio-collared black bears in west-central Idaho were studied between June 1973 and December 1974. Bears did not react in a significant way to the disturbances of an investigator. Females were more active than males during the early spring and later fall. Bears were primarily diurnal and crepuscular; however, they were less active and more nocturnal in early spring and later fall than in summer. Phenological patterns of seven key food plants appeared to govern bear movements and habitat preferences. Bears occupied well-defined home ranges that remained stable from year to year. Home range areas of adults varied from 16.6 to 130.3 square km. Daily movements and home range areas of males were usually larger than those of females. Overlap of home ranges was extensive. Bears entered dens between October 8 and November 27 and emerged in April.

51. Beecham, John. 1980. Some population characteristics of two black bear populations in Idaho. In: Martinka, Clifford J.; McArthur, Katherine L., eds. Bears—their biology and management; papers from the 4th international conference on bear research and management; 1977 February; Kalispell, MT. Kalispell, MT: Bear Biology Association conference series 3: 201-204.

Two geographically discrete populations of black bears in Idaho were studied during 1973-76. The Council population, located in west-central Idaho, has a history of heavy hunting pressure, accessibility, and liberal hunting seasons. The Lowell population, in north-central Idaho has relatively light hunting pressure, poor accessibility, and liberal hunting seasons. An analysis of the male and female age structures indicated that adult males were more susceptible to hunting than other segments of the population. Sex composition differed significantly between subadult and adult segments of the two populations but not between populations. Mean litter size was 1.9 at Council and 1.7 at Lowell. Productivity (number of young produced per year) appears to be density-independent and a function of habitat quality and the number of adult females present in the population.

52. Beecham, John J. 1983. Population characteristics of black bears in west-central Idaho. *Journal of Wildlife Management* 47(2): 405-412.

Population characteristics of black bears were studied in west-central Idaho from 1973 through 1977. A total of 175 bears were captured 509 times. Estimated density of bears on the 130-square-km study area was about 1 bear per 1.3 square km. Capture-recapture records revealed that 2.5-year-old males were captured in higher numbers than were 2.5-year-old females but were recaptured less frequently. No differences were observed in recapture rates among other sex and age-classes. The oldest bears captured were older than 20 years of age. The only age-class in which the sex ratio differed from unity was among 2.5-year-old bears. Both extrinsic and intrinsic factors were involved in the regulation of black bear numbers. Annual variation in reproductive success is the main factor influencing short-term population fluctuations. Climate, with its resultant influence on habitat, seems to be the primary extrinsic factor controlling long-term population size.

53. Beecham, John Jackson, Jr. 1980. Population characteristics, denning, and growth patterns of black bears in Idaho. Missoula, MT: University of Montana. 132 p. Ph.D. dissertation.

Population characteristics, denning, and growth patterns were studied in 175 bears captured 509 times at Council, Idaho, and 156 bears captured 206 times at Lowell, Idaho. Analyses of Council data revealed that 2.5-year-old males were captured in higher numbers than were 2.5-year-old females but were recaptured less. No difference was noted in recapture rates between 3.5-year-old males and females, adult males and females, or subadults and adults. The oldest female captured was 24 years old; the oldest male was 20; the median age of the population was 2.5 years. The estimated density of bears on the 130-square-km study area was 1 bear per 1.33 square km. Annual variation in reproductive success is the main factor influencing short-term population fluctuations. Climate, with its resultant influence on

habitat, appears to be the primary extrinsic factor operating to control long-term population size. Time of entrance into and emergence from dens varied among bears and years. The denning season extended from mid-October until mid-April. Forty-seven (72%) of the 65 dens were ground dens excavated into a hillside or under the base of a tree, stump, or shrub. Thirteen dens (20%) were located in the base of hollow trees and 5 (8%) in hollow logs or rock cavities. Growth in bears is curvilinear and characterized by an initial phase of rapid growth until puberty, followed by a series of seasonal weight changes. Sexual dimorphism in weight and total length was apparent in the Council population at 2.5 years but did not occur until 5.5 years at Lowell. Habitat quality appeared to be the primary factor limiting growth rates.

54. Greer, Scott Quentin. 1987. Home range, habitat use, and food habits of black bears in south-central Montana. Bozeman, MT: Montana State University. 91 p. M.S. thesis.

Black bear (*Ursus americanus*) food habits, home range, movements, and habitat use were studied in the Beartooth Mountains of south-central Montana in 1983 and 1984. Twenty-two bears were instrumented with radio transmitters and located aeri-ally every 7 to 10 days. Adult males and females had average home range sizes of 163 square km and 14 square km, respectively. Adult females used areas less than their annual home ranges each season except summer. Adult males appeared to occupy the same amount of area each season. Adult females had significantly smaller home ranges in 1984 than in 1983. Annual home ranges of females ap-peared to be geographically stable between years. Females were believed to be mutually exclusive of each other, although overlap between home ranges did occur. Adult females recorded their largest average movements in July and August; adult males, subadult males, and subadult females were variable in their movements. Habitat use was determined by 152 adult female relocations. On an annual basis, females preferred habitat types *Picea/Pysocarpus malvaceus* and *Abies lasiocara/Calamagrostis rubescens* in mosaic with *Abies lasiocarpa/Vaccinium scoparium-Calamagrostis rubescens* and the habitat group forest/mixed shrubs. Nonforest, limber pine/bunch grass, and whitebark pine forests were avoided. Low elevations, areas close to water, and gentle slopes were preferred; high elevations and areas far from water were avoided. All aspects were used in proportion to availability. Graminoids and whitebark pine nuts were of primary importance in the 1983 diet. Berries were the most frequent food item and comprised the greatest percentage of total scat volume in 1984. Forbs, insects, and carrion played minor roles in the diet for both years. Important bear habitat appears to be related to moist areas. Manage-ment recommendations are presented.

55. Grenfell, William E., Jr.; Brody, Allan J. 1983. Seasonal foods of black bears in Tahoe National Forest, California. California Fish and Game 69(3): 132-150.

Black bear food habits were determined by analyzing 395 fecal samples collected from 1978 through 1980. Colonial insects were eaten consistently throughout the year, and other animal food items were used sporadically. Consumption of plant material varied with phenology. Grasses and forbs were consumed in the spring, manzanita berries in the summer, and acorns eaten in the fall.

56. Jonkel, Charles J.; Cowan, Ian McT. 1971. The black bear in the spruce-fir forest. Wildl. Monogr. 27. Washington, DC: The Wildlife Society. 57 p.

From a study conducted June 1959 through May 1966 in an area near Whitefish, Montana, home range, dispersal, reproduction, mortality, behavior, and population characteristics are reviewed.

57. Jonkel, Charles Joseph. 1967. The ecology, population dynamics, and management of the black bear in the spruce-fir forest of northwestern Montana. Vancouver, BC: University of British Columbia. 170 p. Ph.D. dissertation.

This research was designed to test the hypothesis that extrinsic factors caused fluctuations in black bear populations and to develop principles for the management of bears. The home ranges of adult bears on the area are small, and they stay the same size from year to year. As resident males mature, however, their ranges increase in area. Bears congregate but do so only where there is an overlap in their home ranges; even then, they do not form compact groups but keep at least 50 yards between individuals. Many adult females do not have young because of the failure of females to ovulate, prenatal mortality, and early mortality. Tentative conclusions suggest that seasonal restrictions in nutrition delay the physical maturity and thereby the sexual maturity of some bears. These restrictions are caused by the climate of Big Creek and are detrimental even to adult females on certain years. Inadequate nutrition is also suggested by the observation that some yearlings inhibit estrus for 2 years by suckling up to 16 months of age. The nutrition of adult males and of many adult females is excellent, however. The survival of cubs is high (95%) from 1/2 to 1-1/2 years of age while they are with their mothers, but all subadults are physically weak in late spring, and natural loss is considerable among subadults 1-1/2 to 3-1/2 years old. They appear especially vulnerable to changes in climate, parasitism, predation, food quantity and quality, and the behavior of adult bears. Many subadult bears disperse from the area. The numbers of adults on the area remain relatively constant from year to year.

58. Kellyhouse, David G. 1980. Habitat utilization by black bears in northern California. In: Martinka, Clifford J.; McArthur, Katherine L., eds. Bears—their biology and management; papers from the 4th international conference on bear research and management; 1977 February; Kalispell, MT. Kalispell, MT: Bear Biology Association Series 3: 221-227.

A study was conducted during May-September 1974 as an integral part of a comprehensive population of black bears in Trinity County, California. Habitat types on the study area were delineated and evaluated, and the selection and use of each type by black bears were estimated from all fresh bear sign encountered during trapping and radiotracking activities. Scats were collected and analyzed for frequency of occurrence and percentage volume of food items. Bear sign in wet meadows accounted for 55% of all sign found during May although wet meadows comprised less than 1% of the study area. Mixed conifer forest received heavy bear use during all periods except late August, when bears foraged for insects in decayed logs and stumps in high elevation partial cuts. Black bears used manzanita brush habitats extensively during late summer and fall to feed on manzanita berries. A failure of the

manzanita berry crop in 1973 was believed to have caused a higher rate of subadult mortality and a lower rate of cub production in 1974.

59. Lindzey, Frederick G.; Meslow, E. Charles. 1976. Characteristics of black bear dens on Long Island, Washington. *Northwest Science* 50(4): 236-242.

Dens of 11 transmitter-equipped black bears in southwestern Washington were investigated. Preferred den sites were natural cavities under stumps or snags which could be used with little preparation. Adult bears denned in areas cut before 1955; yearlings denned generally in areas cut after 1966. Adult females collected greater amounts of vegetative material for nests than did yearlings.

60. Lindzey, Frederick G.; Meslow, E. Charles. 1976. Winter dormancy in black bears in southwestern Washington. *Journal of Wildlife Management* 40(3): 408-415.

Despite relatively mild weather, black bears in southwestern Washington entered and remained in dens for an average of 126 days. Bears entered their dens during a 5-week period that began on October 21. A significant difference was found among the average dates of den entrance of adult females, yearlings, and adult males. Adult females were the first bears to enter their dens; yearlings entered next, and adult males entered last. The stimulus to enter a den probably was provided by the cumulative effect of weather. The actual period of winter dormancy was preceded and followed by periods of increased inactivity. Inactivity during the predenning and postdenning periods was correlated with daily weather, principally maximum daily temperature and precipitation.

61. Lindzey, Frederick G.; Meslow, E. Charles. 1977. Home range and habitat use by black bears in southwestern Washington. *Journal of Wildlife Management* 41(3): 413-425.

Movement and activity of 16 black bears of a population of 23 were monitored by radio telemetry between March 1973 and October 1975 on an island in southwestern Washington. Average home range sizes of adult males (505 ha) and females (235 ha) were markedly smaller than home range estimated for bears in other parts of the U.S. Richness of habitat on the island presumably allowed smaller home ranges. Home ranges of sex and age groups overlapped, with use of shared areas determined by a social hierarchy. Males varied more than females in seasonal use of their home ranges. Bears used certain vegetation types on the island disproportionately to their availability, selecting for areas logged since 1963 and against areas logged before 1935.

62. Lindzey, Frederick G.; Meslow, E. Charles. 1977. Population characteristics of black bears on an island in Washington. *Journal of Wildlife Management* 41(3): 408-412.

Twenty-three black bears were captured on Long Island, Washington. Age structure of the population indicated that it was young and growing and that breeding was relatively synchronized. Density of bears over a year of age (1 bear per 67-89 ha) on the island was high in comparison to estimates of density elsewhere in North America.

63. Lindzey, Frederick G.; Meslow, E. Charles. 1980. Harvest and population characteristics of black bears in Oregon (1971-74). In: Martinka, Clifford J.; McArthur, Katherine L., eds. Bears—their biology and management; papers from the 4th international conference on bear research and management; 1977 February; Kalispell, MT. Kalispell, MT: Bear Biology Association conference series 3: 213-219.

Information was collected by questionnaires sent to people known to have killed bear and from teeth and reproductive tracts saved by sportsmen and control hunters. Most females bred as 3- or 4-year-olds but produced fewer cubs in their first litter than were produced by bears older than 5 years. Survival of females in age-classes 1-5 was significantly higher than survival of males in the same age-classes. Survival did not differ between sexes in bear older than 6 years.

64. Lindzey, Frederick G.; Thompson, Steven K.; Hodges, John I. 1977. Scent station index of black bear abundance. *Journal of Wildlife Management* 41(1): 151-153.

To test the feasibility of using scent stations to index black bear numbers, the scent station technique for indexing coyotes was modified to make it more selective for black bears. Scent stations were made by clearing a circle of 100-cm radius around the base of a small tree and raking the soil to allow subsequent recognition of tracks. The stations were located 0.81 km apart and within 10 m of a road. A bait was suspended from the tree at each station, 150-170 cm about the ground; baits were replaced only if taken. Each bait consisted of 31 cm of fermented egg attractant and 31 cc of vermiculite, mixed and rolled in cheesecloth. A station was considered visited if at least one bear track was present in the cleared area. The line of 21 stations was run daily. The results indicate that the scent station technique is a feasible means of indexing black bear abundance, but more work is needed to establish the relationship between the index and population size. The variation observed among four periods throughout the year suggests that lines should be run at similar times each year to accurately monitor population size.

65. Lindzey, Frederick Grier. 1976. Black bear population ecology. Corvallis, OR: Oregon State University. 105 p. Ph.D. dissertation.

Despite relatively mild weather, black bears in southwestern Washington entered and remained in dens for an average of 126 days. Bears entered their dens during a 5-week period which began on October 21. The actual period of winter dormancy was preceded and followed by periods of decreased activity. Preferred den sites were natural cavities under stumps or snags which could be used with little preparation. Movement and activity of 16 black bears were monitored by radio telemetry and visual observation between March 1973 and October 1975. Average home range sizes of adult males (505 ha) and females (235 ha) were markedly smaller than home range estimates for other parts of the U.S. Richness of habitat presumably allowed these small home ranges. Teeth and reproductive tracts were collected from bears killed in Oregon from 1971 to 1974. Analysis of female reproductive tracts indicated that females did not breed before the age of 3 and that 23.4% did not breed first as 3-year-olds.

66. Piekielek, William. 1975. A black bear population study in northern California. *California Fish and Game* 61(1): 4-25.

Forty-three bears were culvert trapped, immobilized, and tagged in a limited area in Trinity County, California, during the summer and fall of 1972. Eleven depredation bears were trapped and tagged throughout the county. Sex and age distribution and physical characteristics of these 54 animals are summarized. Summer movements and home ranges of the marked bears were small. Average known maximum summer movement was 1.85 miles, increasing in fall to 6.1 miles. Adult females with cubs appeared to have smaller yearly ranges than other sex and age classes. Summer density of the bear population in the study area was approximately two bears per square mile. Thirty-six percent of the adult females were with cubs, the average litter 1.67. Summer food habits are reported, based on analysis of 106 scats.

67. Reynolds, Doyle G.; Beecham, John J. 1980. Home range activities and reproduction of black bears in west-central Idaho. In: Martinka, Clifford J.; McArthur, Katherine L., eds. *Bears—their biology and management; papers of the 4th international conference on bear research and management; 1977 February; Kalispell, MT*. Kalispell, MT: [Place of publication unknown]: Bear Biology Association conference series 3: 181-190.

Home range activities of 21 adult, 1 subadult and 10 yearling black bears were studied between March 1975 and December 1976. Adult males occupied significantly larger and less stable home ranges and ranged farther between radio-locations than adult females or yearlings. Habitat selection and movements were governed primarily by the distribution, availability, and phenology of key food plants. Home ranges overlapped extensively within and between sex classes. Females separated from their yearling offspring about 1 June; however, occasional reassociations occurred shortly after the initial breakup. Dispersal appeared to occur primarily in the 2.5-year-old age group. The nondenning period extended from about the second week of April to about the last week of November. Time of entrance into and emergence from dens was highly variable among bears and between years. The minimum breeding age for females was 3.5 years; regular alternate year breeding was not noted. Breeding began in late May, peaked in June, and extended through late July. Mean litter size was 1.9 cubs with a nearly even sex ratio. The reproductive rate was 0.782.

68. Rutherglen, R.A.; Herbison, B. 1977. Movements of nuisance black bears (*Ursus americanus*) in southeastern British Columbia. *Canadian Field-Naturalist* 91(4): 419-422.

The existence of poorly managed garbage dumps in southeastern British Columbia has created problems for both humans and black bears. A total of 236 nuisance bears were tagged between June 1968 and October 1973. Data from recaptures and resightings of tagged bears indicate a high mobility for some bears. Several bears returned to the original capture location one or more times. Bears were found to have traveled distances ranging from 10 to 99 km (straight-line distance) at rates of up to

11 km per day. In some instances, the apparent rate of travel was much slower. The topography was generally mountainous and rugged which may have influenced the rate and direction of return for certain individuals. Bears were found to have crossed bodies of water approximately 1 km wide, but observations of three tagged bears indicate a tendency for the animals to walk around Kootenay Lake, which measures approximately 5 km across.

69. Tisch, Edward L. 1961. Seasonal food habits of the black bear in the Whitefish Range of northwestern Montana. Bozeman, MT: Montana State University. 108 p. M.S. thesis.

A study of the food habits of the black bear was conducted from June 1959 to November 1960. The primary objectives were to determine the seasonal foods of bears on a definite area of land; to correlate food availability with food intake; and to determine the relationship of seasonal feeding activity to vegetation types. A permanent collection route was cleared of bear scats at 2-week intervals and analyzed for food item remains. Scats were grouped to represent four periods: spring, summer, fall, and late fall. Vegetative material formed the bulk of spring food remains. Grasses, umbellifers, and horsetails were important. The eight major items in 1959 in order of frequency of occurrence were *Gramineae*, *Angelica dawsoni*, *Osmorhiza* spp., *Equisetum* spp., *Formicidae*, *Trifolium* spp., *Heracleum lanatum*, and *Taraxacum officinale*. Summer scats consisted mainly of herbaceous remains until the various fruits mature in the middle of July. Berries and pine nuts comprised most of the fall diet; however, *Angelica dawsoni* and *Luzula glabrata* ranked high in the stem and leaf category. *Sorbus* spp. occurred in 93% of the late fall scats in 1960. Plant material occurred in 99.9% of the 819 samples, insects in 45.3%; mammals in 5%, and birds in 0.4%. Animal material formed a very minor portion of the fecal remains. There appeared to be some correlation between huckleberry availability and intake in the fall periods, but no positive correlation existed between pine-nut availability and occurrence in scats. Of 19 cambium wounds noted, eight occurred on *Abies lasiocarpa*, four on *Pinus albicaulis*, and four on *Pinus contorta*. Seven dated wounds were inflicted between June 19 and July 31.

70. Unsworth, James W. 1984. Black bear habitat use in west-central Idaho. Bozeman, MT: Montana State University. 96 p. M.S. thesis.

Black bear habitat-use patterns were studied in west-central Idaho from 1982 to 1983. Ten adult female bears were instrumented with radio transmitters. Bears were relocated 640 times during the study. Uncut timbered sites were important bedding areas, and timber components along drainages served as travel corridors. Open timber components were used in spring as foraging areas. Open timber-shrubfield components were used as foraging areas and bedding sites. Riparian areas were preferred as feeding sites and used as travel corridors. Aspen components were preferred by bears with cubs. They provided dense horizontal cover and were often adjacent to shrubfields. The meadow component was used in the spring as a foraging area for grasses and forbs. Rock-talus and sagebrush-grass components were avoided. Selection cut-shrubfield components were preferred as feeding sites for

berry species. Other selection cut components were used in proportion to the availability. Clearcuts were avoided. *Abies grandis/Vaccinium globulare*, *Abies grandis/Acer glabrum*, and *Pseudotsuga menziesii/Physocarpus malvaceus* habitat types received over 90% of the use. The *Abies grandis* habitat types were important food producers, and the *Pseudotsuga menziesii/Physocarpus malvaceus* habitat type was most often used for bedding. Topographic features that enhance the growth of mesic vegetation were preferred. Female bears preferred areas in cover but would venture from cover to seek food. Timber and hunting management recommendations are presented.

71. Young, Barry F.; Ruff, Robert L. 1982. Population dynamics and movement of black bears in east central Alberta. *Journal of Wildlife Management* 46(4): 845-860.

Demographic and spatial parameters of a high-density black bear population were studied with radio-telemetry and live-capture techniques. During previous studies, the population on a 218-square-km study area closed to sport hunting had doubled from a mean of 80 bears in 1968-71, to 175 in 1973 after the removal of 23 adult males in 1971 and 1972. The increase was attributed to increased subadult survival and ingress. By 1975 the population decreased to 137, and the adult male cohort was numerically restored. The subadult cohort remained large, however. Average weights of bears of the same age did not decrease when the population increased, thereby suggesting that food was not in short supply at the higher densities. Size estimates for annual home ranges of males and females averaged 119 and 1.6 square km, respectively. Size of male home ranges was not affected by the density increase, but size of female home ranges may have decreased. Areas occupied by 24 male bears of different ages overlapped extensively. Adult females appeared to be territorial toward one another but tolerated bears of other sexes and ages. Mobility of male bears decreased from spring through fall and was likely influenced by seasonal food availability and breeding behavior. More subadult males moved off the study area than did adult males. Male bears selected aspen and garbage dump areas but avoided muskeg habitat. Subadult males were located at garbage dumps twice as often as did adult males.

72. Young, Donald D. 1984. Black bear habitat use at Priest Lake, Idaho. Missoula, MT: University of Montana. 66 p. M.S. thesis.

Black bear habitat-use patterns were studied in northern Idaho between June 1980 and November 1981 as part of a long-term ecological study. Habitat-use patterns were established from radio locations of nine adult black bears (four males and five females). Both male and female black bears used several habitat components and habitat types, but both males and females exhibited selection for and against certain vegetative units. Black bears selected for selection cuts during spring, summer, and fall. Clearcuts were selected against during all seasons. Female black bears used the timbered habitat component significantly more than did males. Roads were selected against by female black bears but were used in proportion to their availability by males. Black bears selected selection cuts and riparian zones for feeding and timber and selection cuts for bedding. Bears selected for the hemlock *Pachistima*-habitat type during spring, summer, and fall. A strong correlation existed between the mean elevation of bear locations and the phenological development of key bear food plants. Management recommendations are presented.

73. Childs, Thomas W.; Worthington, Norman P. 1955. Bear damage to young Douglas-fir. Res. Note 113. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 4 p.

Damage to newly-formed sapwood of young conifers is common in several localities in western Oregon and Washington and is occasionally severe enough to seriously interfere with reforestation. The worst features of bear damage are that it is most frequent in stands already seriously understocked, it is most often on the larger trees, and Douglas-fir is usually attacked in preference to other species. Serious damage to young Douglas-fir appears to consist principally of killing by complete girdling. Where girdling is only partial, damage to the tree is usually slight.

74. Dorrance, Michael J.; Roy, Lawrence D. 1978. Aversive conditioning tests of black bears in beeyards failed. In: Howard, Walter E.; Marsh, Rex E., eds. Proceedings, 8th vertebrate pest conference; 1978 March 7-9; Sacramento, CA. Davis, CA: University of California: 251-254.

This study evaluated the effectiveness of emetic compounds (lithium chloride and cupric sulfate) in honey baits as a technique for preventing black bear damage in fenced beeyards. Lithium chloride and cupric sulfate did not reduce black bear damage. Our experience indicates that lithium chloride is not a suitable emetic for producing taste aversions in free-ranging black bears.

75. Flowers, Ralph H. 1987. Supplemental feeding of black bears in tree-damaged areas of western Washington. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 147-148.

Tree damage by bears occurs shortly after the bear's emergence from its winter den, when nutritious food is scarce. A supplemental feeding study was implemented in 1985 as a possible partial solution to the tree stripping problem. A food pellet was developed that is extremely attractive to the bear's taste while providing much of its need for sugar, protein, calcium, fiber, trace elements, and vitamins. Studies will be continued and expanded to determine whether damage is reduced by supplemental feeding.

76. Fritz, Emanuel. 1951. Bear and squirrel damage to young redwood. *Journal of Forestry* 49(9): 651-652.

In the redwood region, young redwood trees from pole-size to about 30 inches d.b.h. are being stripped from the ground line up to a point where the diameter is about 4 inches and the trunk is not strong enough to support a bear. The upper limit of stripping may be over 50 feet from the ground. The damage is limited to the spring season and was first noticed in 1946. Altogether more than 10,000 trees have been killed, and this damage, unless controlled, may become a serious deterrent to forestry in the redwoods.

77. Gilbert, Barrie K.; Roy, Lawrence D. 1977. Prevention of black bear damage to beeyards using aversive conditioning. In: Phillips, Robert L.; Jonkel, Charles, eds. Proceedings of the 1975 predator symposium; 1975 June 16-19; Missoula, MT. Missoula, MT: Montana Forest and Conservation Experiment Station, University of Montana: 93-102.

A study of the effectiveness of an emetic compound, lithium chloride, in the prevention of black bear damage to beeyards was initiated in the Peace River area of the province of Alberta. The sample studied consisted of 60 beeyards, divided approximately equally into four categories: unfenced unbaited, unfenced baited, fenced unbaited, and fenced baited. Each beeyard was visited an average of 3.3 times by bears. The resulting average damage was 4.34, 2.04, 0.68, and 0.24 hives damaged per visit, respectively, for each beeyard category. The lithium chloride in combination with electric fences effected 94%.

78. Giusti, Gregory A. 1988. Recognizing black bear damage to second growth redwoods. In: Crabb, A. Charles; Marsh, Rex E., eds. Proceedings, 13th vertebrate pest conference; 1988 March 1-3; Monterey, CA. Davis, CA: University of California: 188-189.

Black bears have been known to cause severe damage to second-growth redwoods. The damage is seasonal and is often associated with logging roads, skid trails, or other openings in the forest. Signs of damage are characteristic and cannot easily be confused with other species of wildlife that damage redwoods.

79. Glover, Fred A. 1955. Black bear damage to redwood reproduction. *Journal of Wildlife Management* 19(4): 437-443.

The study was instigated in second-growth redwood in Humboldt County, California, to determine what animal was responsible for the stripping damage, to determine the severity of the damage, and to determine whether the damage was increasing or decreasing. The black bear was responsible for most of the bark and cambium damage found. There was a steady increase in extent and intensity to the peak year of 1950, with a slight decrease in 1951 and 1952. Second-growth timber 10-30 years old was injured most, but there were indications that the 5- to 10-year age class was being damaged with increased intensity. The annual tree damage period occurred during spring and summer and varied from 75 to 120 days.

80. Hartwell, Harry D. 1973. A survey of tree debarking by black bear in Capitol Forest. DNR Note 7. Olympia, WA: Washington Department of Natural Resources. 7 p.

Observations indicate that bear debarking in Capitol Forest originated in rapidly developing second-growth stands, predominantly Douglas-fir, and increased to a significant level approximately two decades later than in a similar bordering forest to the north. Douglas-fir is the only tree species on which debarking has been observed. Bear debarking increased or spread over the entire forest in a period of 10 years after it was first detected on a single tree in 1960. Although there are no reliable techniques

for assessing bear numbers, observations of bear sign suggest an average population density of considerably less than one bear per square mile. Traditionally, there has been no specific effort to protect trees from debarking on Capitol Forest. The data presented here indicate that debarking is a problem and should be reduced in some parts of the forest. In 1973, sport bear hunting has been focused on 16 areas in western Washington (including Capitol Forest) where damage is significant.

81. Lauckhart, J. Burton. 1956. The effect of logging old-growth timber on bear. In: Proceedings, Society of American Foresters meeting; 1955 October 16-21; Portland, OR. Washington, DC: Society of American Foresters: 128-130.

With the cutting of old-growth timber and its replacement by new growth of sub-climax species, bear increase in population in response to the greater food supply. They increase to the extent that most of the good bear foods get used, and as second growth reproduction starts to crowd out these plants, competition for food increases, and they resort to substitute foods. This paper reviews the history and current status of bear depredations on forest reproduction in western Washington, western Oregon, and northern California.

82. Maser, Chris. 1967. Black bear damage to Douglas-fir in Oregon. *Murrelet* 48(2): 34-38.

Black bear damage to young Douglas-fir forests has been extensive enough in some areas to cause concern for the timber crop. On the other hand, thousands of acres of such forests harbor populations of black bear and sustain no damage. It seems, therefore, that factors other than the mere presence of the bear are involved. This paper is an evaluation of the factors concerning black bear damage, including identification of the damage, species preferred, and the mechanics of damage. Factors influencing damage: (1) Fire and overshadowing: damage thought to occur because of a shortage of food. (2) Tree density: damage occurs when crowns extend the length of the trunk and is nearly nonexistent where density has reduced the crown to approximately 1/2 the length of the bole. (3) Tree growth rate: damage occurs to trees with the fastest growth rate. (4) Taste: certain bears may have developed a taste for sapwood because not every bear damages trees. (5) Topography: topography influences travel and feeding routes, and most damage occurs along the routes, usually on southeastern, southern, and southwestern slopes rather than on northern slopes. Douglas-fir stands of uniform age, dense enough to shade out the lower half of the crown before the trees reach 15 years of age, will not sustain bear damage. In areas where bear damage is known to occur, precommercial thinning should include limb removal to discourage bear damage.

83. Mason, Andrew C.; Adams, David L. 1987. Black bear damage to managed timber stands in northwest Montana. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 137-144.

Black bear damage was compared between 50-year-old thinned and unthinned blocks in northwest Montana. Bear damage was up to three times higher in the

thinned blocks. Only western larch, lodgepole pine, and Engelmann spruce were damaged. Sixty-three percent of all trees damaged and 92% of the trees killed were western larch. Damaged trees ranged from 4 to 13 inches d.b.h.; the 6- to 8-inch d.b.h. class accounted for 63% of the damage. Stand projections showed up to a 17% reduction in board-foot yield after 50 years due to bear damage, compared with hypothetical undamaged stands. Thinned stands with high levels of damage may still yield significantly more board feet than unthinned stands with lower damage levels. Damage control should be considered.

84. Mason, Andrew C.; Adams, David L. 1989. Black bear damage to thinned timber stands in northwest Montana. *Western Journal of Applied Forestry* 4(1): 10-13.

Bear damage was at least five times higher in thinned blocks than in adjacent unthinned blocks of western larch, lodgepole pine, and Engelmann spruce on the Kootenai National Forest in northwest Montana. Western larch suffered the greatest damage (63% of all trees damaged and 92% of the trees killed). Damaged larch ranged from 4 to 13 inches d.b.h.; the 4- to 8-inch d.b.h. class accounted for 85% of the damage. Douglas-fir, western redcedar, subalpine fir, western white pine, and western hemlock were not damaged. Stand projections showed up to a 17% reduction in board-foot yield from bear damage, after 50 years, compared with hypothetical undamaged stands.

85. Nelson, E.E. 1989. Black bears prefer urea-fertilized trees. *Western Journal of Applied Forestry* 4(1): 13-15.

Feeding damage by black bears to urea-fertilized 25-year-old Douglas-firs in the Mount Hood National Forest, Oregon, resulted in tree mortality four times as severe as among unfertilized trees. Damage was most apparent after application of urea at 448 kg N/ha in 1972 and 224 kg N/ha in 1977. Only Douglas-fir, the dominant species in the stand, was attacked. Attacked trees were somewhat larger than the stand average, but the difference was not significant. Bears appeared to be attracted to the more vigorous trees, which were on fertilized plots.

86. Pierson, Douglas J. 1966. Washington's black bear problem. In: *Proceedings of the 46th annual conference of the Western Association of State Game and Fish Commissioners*; 1966 July 12-15; Butte, MT. [Place of publication unknown]: [Publisher unknown]: 96-100.

A cooperative study was undertaken in 1963 to collect data on the biology, ecology, and history of the black bear for development of management techniques and to study the interrelation of black bear and coniferous forests, with emphasis on forest reproduction. Studies to date indicate that the bear are causing the damage during the spring, which is the critical period for black bear. There is a period of weight loss from April through June, until the berries and other highly nutritional foods become available. The more severe areas of bear damage correspond with large clearcuts done in the early 1900s. In earlier years, the large logged areas were prime habitat for bear and all forest browsers, but as the secondgrowth began to increase, habitat conditions declined, and damage problems occurred. It is our hope to develop management techniques which will eliminate the need for control programs.

87. Poelker, Richard J.; Parsons, Lowell D. 1980. Black bear hunting to reduce forest damage. In: Martinka, Clifford J.; McArthur, Katherine L, eds. Bears—their biology and management; papers from the 4th international conference on bear research and management; 1977 February; Kalispell, MT. [Place of publication unknown]: Bear Biology Association conference series 3: 191-193.

Before 1973, the State of Washington had a spring black bear season from 1 April to 30 June throughout most of the area west of the Cascade Range in an attempt to alleviate damage to forest tree reproduction. Extensive efforts by professional control hunters were still needed to keep damage at an acceptable level. Indications that sport hunting might be more effective in controlling damage resulted in the effort to concentrate sport hunting in problem damage areas. The general spring season was discontinued, and a system of special hunts, by unit, was established. The extent of the area open to hunting was reduced by about 75%. Success of the program was evaluated by comparing 3 years' data collected under the unit system with 3 years' data from the general open season. The bear kill increased from an average of 503 per year in the general open season to 740 per year under the unit system. Bear tag sales increased by 81% during the same period.

88. Radwan, M.A. 1969. Chemical composition of the sapwood of four tree species in relation to feeding by the black bear. *Forest Science* 15(1): 11-16.

The contents of sugars, nitrogen, and mineral elements, and the kinds of sugars and soluble nitrogenous compounds in the sapwood of 20- to 30-year-old Douglas-fir, western hemlock, western redcedar, and red alder were determined on two areas in western Washington. One area was subject to considerable tree damage by black bear, and the other showed very little damage. On both areas, there were significant differences among species in contents and kinds of some chemical constituents, but total sugars and ash were the only components which seemed to be related to bear preference. There were only minor differences within species between the two areas, however. Chemical analysis alone, therefore, was not sufficient to explain the problem of bear feeding on tree sapwood.

89. Resnor, O.L. 1953. Damage to conifers by bear. In: Proceedings of the 33d annual conference of the Western Association of State Game and Fish Commissioners; 1953 June 1-3; Long Beach, CA. [Place of publication not available]: [Publisher unknown]: 109-111.

Bear damage to conifers in western Washington hit an all-time high spring and summer of 1951. Timber area surveys showed evidence of severe damage in Mason, Grays Harbor, and Clallam Counties. All species of conifers were attacked, although there appeared to be a decided preference for Douglas-fir, even in stands where other species predominate. In some stands poles under 12-inch diameter are preferred; in other stands the smaller trees are passed up for larger ones up to 26-inch diameter. Likewise there seemed to be little correlation between stand density and intensity of damage. It appears that the population increase of bear, which has occurred over a period of years, has caused the bear to seek other types of food than the usual. It also appears that not all bear girdle trees; only certain individuals are addicted to the tree destroying habit.

90. Scheffer, Theo H. 1952. Spring incidence of damage to forest trees by certain mammals. *Murrelet* 33(3): 38-41.

Describes the damage caused by three mammals in the second-growth forests of the Puget Sound area. Western gray squirrels girdle tree tops in the spring when the sap is rising and the bark is looser. Mountain beaver prune seedlings and sometime slender saplings to a height of 10 feet or more, leaving stubs of severed branches as a ladder. The black bear strips the bark from boles of trees to get at the cambium layer soon after the animals come out of hibernation. It appears that damage by bears has increased recently.

91. Wray, Pat. 1987. Black bears and timber trees. *American Forests* 93(9-1): 34-35, 70.

Describes the damage that bear can do to Douglas-fir plantations, and describes the feeding experiments being conducted by the Washington Forest Protection Association.

92. Brown, Ellsworth Reade. 1961. The black-tailed deer of western Washington. *Biol. Bull.* 13. Olympia, WA: Washington State Game Department. 124 p.

From 1959 to 1969, black-tailed deer were studied in the Willapa Hills of Grays Harbor and Pacific Counties, an area which is being managed for production of timber. All successional stages, from freshly logged to climax vegetation, were represented. The objectives of the study were to determine food habits and preferences; to determine populations in various habitats and show whether they could be correlated with logging or fire history; to determine reproductive rates and mortality factors; to study the ecological succession after logging and show how it affects deep population; to determine the nutritive value of important browse species; and to collect as much information as possible on the life history of the species.

93. Cowan, Ian McTaggart. 1956. Life and times of the coast black-tailed deer. In: Taylor, Walter P., ed. *The deer of North America*. Harrisburg, PA: Stackpole Company and Washington, DC: Wildlife Management Institute: 523-617.

A comprehensive review covering breeding activities, reproductive life, hybridization, physical characteristics, longevity, populations, food and feeding habits, home range, migration, senses, social behavior, natural mortality, parasites and disease, predators, management and hunting.

94. Dalke, Paul D., comp. 1968. *Bibliography of the elk in North America*. Moscow, ID: Idaho Cooperative Wildlife Research Unit. 87 p.

An attempt to assemble the literature on the elk of North America into a ready reference. Consists of two sections, one arranged by subject and one arranged by author, covering the literature through 1965.

Deer and Elk

General

95. Einarsen, Arthur S. 1956. Life of the mule deer. In: Taylor, Walter P., ed. The deer of North America. Harrisburg, PA: Stackpole Company and Washington, DC: Wildlife Management Institute: 363-390.

A comprehensive review of breeding activities, reproduction, fawn development, antlers, and winter survival, described as a seasonal narrative.

96. Gould, Marie L. 1965. Wildlife habitat in western Oregon and Washington and northwestern California forests chiefly for blacktail deer and Roosevelt elk: 1930-1965—a bibliography. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 10 p.

Contains 64 references on Roosevelt elk and black-tailed deer that were published between 1930 and 1965.

97. Graf, William. 1955. The Roosevelt elk. Port Angeles, WA: Port Angeles Evening News. 105 p. [Identical to author's Ph.D. dissertation, Natural history of the Roosevelt elk. Corvallis, OR: Oregon State University. 1943. 222 p.]

A comprehensive study of early records and descriptions; range, distribution and habitat; social habits and behavior; home range; food; disease, predators and parasites; development; the rut; conservation, past and present; and hunting, past and present.

98. Mackie, Richard J.; Hamlin, Kenneth L.; Pac, David F. 1982. Mule deer (*Odocoileus hemionus*). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 862-877.

Reviews distribution, description, physiology, reproduction, behavior, movements and home range, population ecology, and management of *Odocoileus hemionus* and its various subspecies, including *O. h. hemionus* and *O. h. columbianus*.

99. Murie, Olaus J. 1951. The elk of North America. Harrisburg, PA: Stackpole Company and Washington, DC: Wildlife Management Institute. 376 p.

Reviews the taxonomy of the various *Cervus* species, their migration, physical characteristics, reproduction, enemies, parasites and diseases, food habits, behavior, population, and management by people.

100. Packee, Edmond C. 1975. Roosevelt elk (*Cervus canadensis roosevelti* Merriam)—a bibliography with comments pertinent to British Columbia. For. Res. Note 2. Nanaimo, BC: MacMillan Bloedel Limited. 58 p.

A brief review of elk nutrition and cover needs, followed by an extensive bibliography of citations beginning with a reference by Sir Francis Drake in 1578. Much of the literature cited is unpublished references, governmental reports, and popular articles.

101. Peek, James M. 1982. Elk (*Cervus elaphus*). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 851-861.

Reviews distribution, description, population characteristics, reproduction, food habits, movement, behavior, and management of *Cervus elaphus* and its various subspecies, including *C. e. nelsoni* and *C. e. roosevelti*.

102. Thomas, Jack Ward; Toweill, Dale E. 1982. Elk of North America: ecology and management. Harrisburg, PA: Stackpole Books. 698 p.

Includes the chapters: "Classification and distribution"; "Elk and Indians: historical values and perspectives"; "Physiology"; "Diseases and parasites"; "Adaptive behavioral strategies"; "Population characteristics"; "Migration; Nutritional requirements and food habits"; "Habitat requirements and evaluations"; "Relationships of elk and other large herbivores"; "Elk and land management"; "Refuges and elk management"; "Recreational use of elk"; "Regulated elk populations and hunter harvests"; "The future of elk and elk hunting".

103. Wallmo, Olof C., ed. 1981. Mule and black-tailed deer of North America. Lincoln, NE: University of Nebraska Press. 605 p.

A comprehensive treatise on the species, covering distribution, habitats, morphological and physiological characteristics, nutrition and metabolism, diseases, behavior and adaptive strategies, and population. Food habits and habitat are discussed separately for desert and chaparral, Rocky Mountain and intermountain, plains, and coniferous forest areas.

Ecology

104. Adams, A.W. "Bud". 1986. Elk habitat effectiveness from Landsat imagery for three study areas in the south coast range of Oregon. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 171-183.

To test the effectiveness of the westside habitat model, three areas in the Coos Bay area were selected. Instead of determining the various factors manually from aerial photographs and orthophotoquads, Landsat imagery was used. After assignments of spectral classes to stand-conditions classes were made, the remaining steps were done on the computer. Maps and acreage tables were printed by stand conditions, elk-habitat class, and distance from edge of forage and cover areas. Some refinement is still needed, but the method is a good tool for elk management.

105. Allen, Eugene O.; Chrest, Howard R., co-chairmen. 1973. Proceedings of the biennial conference of the Western States Elk Workshop; 1973 February 20-21; Bozeman, MT. [Place of publication unknown]: Western Association of State Game and Fish Commissioners. 151 p.

Provides written documentation of presentations and discussions, as transcribed from tapes of the meeting. Session topics included Montana's elk habitat; quality hunting; calf:cow ratios; elk habitat use and preferences; and impact of logging and roads.

106. Anderson, David A. 1983. Reproductive success of Columbian black-tailed deer in a sewage-fertilized forest in western Washington. *Journal of Wildlife Management* 47(1): 243-247.

Seven experimental (foraging on sludge-amended sites) and five control black-tailed deer does were identified by radio-telemetry. All experimental animals intensively foraged for grass on sludge-amended sites in all seasons except summer, when cool-season grasses were mature. Adequate dietary nitrogen is essential for growth, maintenance, lactation, and regular estrus. Fertilization of nitrogen-poor deer ranges with nitrogen-rich sewage sludge should result in increased reproductive recruitment. Sludge amendment resulted in a near doubling of the nitrogen content of the most abundant grasses preferred by deer. Late winter in western Washington is typically a time of increasing protein requirements and decreasing protein availability, but experimental deer had access to high-quality forage through the winter season. As a result, deer productivity increased by 40%. This benefit would be negated if sludge-borne pathogens or heavy metals proved deleterious to the health of the deer, but to date, no significant heavy metals have been found.

107. Anderson, David Alfred. 1981. Response of the Columbian black-tailed deer to fertilization of Douglas-fir forests with municipal sewage sludge. Seattle, WA: University of Washington. 186 p. Ph.D. dissertation.

Six major hypotheses pertaining to sludge fertilization were examined: (1) plants growing on sludge should be highly preferred by deer; (2) sludge sites should be preferentially used as foraging areas; (3) seasonal home ranges of sludge-using deer should be smaller than those of control animals; (4) sludge fertilization should increase reproductive success; (5) elevation in hematological parameters should result from forage improvement; (6) sludge-using deer should show heavy metal accumulations in organ tissues in excess of those for controls. The nitrogen contents of forbs, shrubs, and grasses were all elevated as a result of sludge application, while forage production was increased as a result of the great proliferation of cool-season grasses. Sludge-using deer consumed substantially more grass than did control deer except in summer. Heavy use of sludge sites occurred in late fall, winter, and early spring, when cool-season grasses were young and succulent. The home ranges of sludge-using deer were larger than home ranges of controls, contrary to expectation. This result was consistent with the notion that female deer are food-energy maximizers; these deer were characterized by an improvement in diet, an increase in family group size, an increase in the frequency of exploratory excursions, and the annexing of distant sludge sites to core foraging areas. Sludge-using deer raised significantly more fawns to the six-month age class than did controls. Hemoglobin, red blood cell count, and hematocrit were all elevated among sludge users; heavy metal accumulations did not exceed those of controls.

108. Armleder, H.M.; Dawson, R.J.; Thomson, R.N. 1986. Handbook for timber and mule deer management co-ordination on winter ranges in the Cariboo forest region. *Land Manage. Handb.* 13. Victoria, BC: British Columbia Ministry of Forests. 98 p.

This field guide provides managers with the information necessary to coordinate mule deer and timber management on deer winter range. It is intended to aid managers in

weighing the options for winter range management. If a decision has been made to harvest, the handbook describes how it should be done and includes detailed instructions for the logging contractor.

109. Asherin, Duane A. 1976. Changes in elk use and available browse production on north Idaho winter ranges following prescribed burning. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 122-134.

Effects of prescribed burning on browse production and availability and on big game use of burned versus nonburned areas were evaluated from 1969 to 1971. The initial loss of redstem ceanothus production, a highly palatable low-growing shrub, is more than offset by the increased available production of such palatable tall-growing shrubs as willow, mountain maple, and serviceberry. Preference for burned sites was still present 4 years after burning. Burning too few areas or too small an area on a tract of winter range results in heavy summer use of preferred browse species by resident animals, which lowers winter availability, seedling survival, and possibly the future vigor of the shrub community.

110. Baglien, John W.; Biggins, Dean E. 1976. A plan for elk management by habitat manipulation. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 81-84.

A plan for manipulating vegetation on elk winter range by using logging as the primary tool is presented. Information from radio-marked elk, habitat typing, and snow studies was incorporated into the development of this plan.

111. Beall, Robert C. 1974. Winter habitat selection and use by a western Montana elk herd. Missoula, MT: University of Montana. 209 p. Ph.D. dissertation.

Winter habitat selection and use by a western Montana Rocky Mountain elk herd was evaluated over 3 years. Objectives were to evaluate habitat selection and use in terms of activities, ambient meteorological and radiation conditions, and seasonal changes. Movements and habitat use were affected by snow, meteorological conditions, and radiation conditions. Elk occupied elevations with less than 18 inches of snow. High elevations were used during years of light snow, and low elevations were used during heavy snow years. Other components of habitat selection remained the same at the various elevations. Elk react to changing ambient air temperature and solar and thermal radiation conditions by selecting bedding sites which enhance control of body temperature. Eighty-six percent of elk bed sites evaluated were associated with clumps on the upper one-third of a slope. In colder periods, elk tended to bed on the south side of the stands during the day and on the north side at night. In warmer periods, elk bedded on the north side of timber clumps during the day, and on the south side at night. In all cases of habitat selection under varying meteorological conditions, a closer correlation was found with thermal and solar radiation intensities than with ambient air temperature. Logging activity caused an initial avoidance

response by elk. They then appeared to become conditioned to it and resumed normal activity after about 2 weeks. The altering of elk habitat, however, creates an adverse ecological situation which is avoided by elk. Areas logged on the study area received light to medium use of winters prior to logging and no use the winter after logging.

112. Bentley, Wallace William. 1959. The range relationships of Roosevelt elk, *Cervus canadensis roosevelti* (Merriam), at Prairie Creek Redwoods State Park, Humboldt County, California, in 1958. Arcata, CA: Humboldt State College. 97 p. M.S. thesis.

The range relationships of Roosevelt elk were investigated on Boyes Prairie in Prairie Creek Redwoods State Park from May 1958 to May 1959. Particular attention was given to the prairie's vegetative composition, condition, and trend. Other aspects investigated were soil, forage, forage preference of the elk, elk census methods, calf survival, and management. A few Roosevelt elk moved onto a small grassland prairie of approximately 170 acres in 1937. Under park protection, the elk adapted to this existence and became semidomesticated. The herd increased to approximately 180 by 1949, and then began to die off. In 1951, the elk population was 43 animals; subsequent controlled herd reductions have kept the herd at approximately 40 head. The physical condition of the elk has remained poor, and calf survival has remained low; these circumstances have culminated in the need for information concerning the relationships of the elk to the range. The condition of the range was poor judged from a livestock perspective. Studies of food habits showed that the elk generally took plants according to their abundance, thus using the poorer forage. The range was excessively grazed during the winter. Soil and plant tissue analysis indicated an extremely low value for phosphorus, which may cause lactation difficulties for the cow elk and low survival among calves. Further herd reduction and measures to improve the condition of the range are suggested.

113. Black, Hugh; Scherzinger, Richard J.; Thomas, Jack Ward. 1976. Relationships of Rocky Mountain elk and Rocky Mountain mule deer habitat to timber management in the Blue Mountains of Oregon and Washington. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 11-31.

The consequences of timber-management decisions on potential for deer and elk use by land type are developed and displayed. A model is constructed on the basis that the ratio of cover to forage areas is the integrating factor that best describes elk and deer habitat. The optimum habitat is described as a ratio of 40% cover to 60% forage areas. This optimum is predicted on a series of definitions and constraints. The constraints are prescriptions of the sizes of cover patches and forage areas and their juxtaposition. A series of tips is given that will help in optimizing elk habitat in areas subject to roading and timber management.

114. Bodurtha, Timothy S.; Peek, James M.; Lauer, Jerry L. 1989. Mule deer habitat use related to succession in a bunchgrass community. *Journal of Wildlife Management* 53(2): 314-319.

Habitat use patterns of mule deer in northeastern Oregon relative to the successional stages of the bluebunch wheatgrass (*Agropyron spicatum*)/Sandberg bluegrass (*Poa secunda*) habitat type and other vegetative types was investigated from June 1983 to June 1985. Stands approximating the composition of the climax community, which contained highest vegetative diversity, were preferred by deer. Communities most preferred in summer were on north- and east-facing slopes. Mule deer use of habitats in spring was related to early spring plant growth on steep south- and west-facing slopes.

115. Bohne, Joseph R. 1974. Food habits, seasonal distribution, and habitat utilization of elk in the South Fork of Fish Creek, Lolo National Forest, Montana. Missoula, MT: University of Montana. 187 p. M.S. thesis.

From July 1970 to May 1972, an elk study was conducted in the Petty and South Fork of Fish Creek drainages in the Bitterroot Mountains before logging of summer and fall ranges. The study area is a mosaic of old burns, dense stands of young conifers, and mixed remnant stands of mature ponderosa pine, Douglas-fir, and western larch. Elk used a winter range, summer range, and spring-late fall transitional range. Calving occurred on upper portions of the winter range and on the transitional range. Movements from the winter range were influenced by green-up of grasses and forbs at higher elevations. Fall movements to the winter range were influenced by deep snow on summer and transitional ranges. Elk were found on southeast- to west-facing aspects at 4,300 to 5,000 feet during winter. During spring and summer, elk shifted to higher elevations and dispersed over all aspects. Open cover types were used during winter and spring. As summer progressed, elk used timber during the day and clearings at night. Use of timber-cover types was greatest during rutting and hunting seasons. Food habits were determined from feeding-site examinations and rumen analysis. The most important shrubs were evergreen ceanothus, serviceberry, chokecherry, willow, and maple. The limiting factor for the elk population was availability of escape cover during hunting season. It is recommended that proposed timber sales be broken into smaller units, that 10 years be allowed between logging in large drainages, and that roads be kept at a minimum and closed when logging is completed.

116. Borrecco, John E.; Black, Hugh C.; Hooven, Edward F. 1972. Response of a black-tailed deer to herbicide-induced habitat changes. In: Proceedings of the 52d annual conference of the Western Association of State Game and Fish Commissioners; 1972 July 16-19; Portland, OR. [Place of publication unknown]: Western Association of State Game and Fish Commissioners: 437-451.

On three areas in western Oregon, half of each area was treated with a combination of herbicides, principally Atrazine and 2,4-D to control herbaceous vegetation. Small mammals were live-trapped, deer pellets counted, browsing damage to Douglas-fir observed, and vegetation analyzed on both treated and untreated areas. Vegetation

changes were pronounced, primarily a reduction in grasses and forbs and an increase of the growth of Douglas-fir and most shrubs on the treated areas. The response of small mammals to changes in vegetation depended on habitat preferences. Those that prefer red grassy habitats were less abundant on treated plots, and those that prefer red brush habitats were more abundant on treated plots than on untreated plots. Vegetation changes after herbicide treatment affected the seasonal usage of plots by deer. More pellet groups were counted on treated plots during the growing seasons than on untreated plots. No significant differences in browsing of Douglas-fir, however, were observed because of changes in habitat.

117. Borrecco, John Edward. 1972. The response of animals to herbicide-induced habitat changes. Corvallis, OR: Oregon State University. 92 p. M.S. thesis.

The objectives of this investigation were to examine the changes in vegetation resulting from application of herbicides and to study the effects of these vegetative changes on the abundance and composition of small-mammal populations and on deer usage of treated and untreated plots. On three areas in Oregon, half of each was treated with a combination of herbicides designed to control grasses and forbs without injuring Douglas-fir. Small mammals primarily associated with grass or meadow habitats decreased in abundance. The Oregon vole was the species most affected by the reduction in grassy vegetation. Species that find optimum habitat in brushy areas increased in abundance on treated plots. The deer mouse was the most common species to demonstrate a positive response on treated plots. Deer activity, as measured by pellet-group counts, was greater on treated plots during the growing seasons. No significant differences were found in the occurrence of browsing as a result of herbicide-induced habitat changes. Browsing was influenced by season. Herbicide treatments improved deer habitat during the growing season without significantly increasing the browsing of Douglas-fir seedlings.

118. Bowyer, R. Terry. 1976. Social behavior of Roosevelt elk during rut. Arcata, CA: Humboldt State University. 122 p. M.S. thesis.

A study of the social behavior of Roosevelt elk was conducted at Prairie Creek Redwoods State Park, California. Elk were observed for 12 months with emphasis placed on describing and quantifying their behavior during rut. The purpose of this study was to determine whether selection favoring sexual dimorphism in elk resulted in similar differences in social behavior and to interpret these differences in terms of sexual selection. Behavior patterns were divided into general, maternal, vocalization, sexual, advertising, agonistic, and submissive. Roosevelt elk bulls formed a near linear dominance hierarchy, and cows exhibited hierarchical behavior. It was suggested that a bull's position in the dominance hierarchy influences the type of agonistic acts he exhibits. Elk employed behavior that tended to maximize their individual reproductive success regardless of their sex or age class. Master bulls expended the majority of their effort attempting to breed cows. Bachelor bulls emphasized agonistic acts among themselves to establish dominance and gain the opportunity to become a master bull.

Spikes spent most of their time avoiding dominant males, and cows and calves emphasized care giving and seeking behavior. Roosevelt elk were strictly harem breeders. It was suggested that a harem breeding system evolved in response to a particular set of environmental conditions. The costs and benefits of a harem breeding system to an individual elk also were discussed. Roosevelt elk did not exhibit any form of territorial behavior. The hypothesis that sexual dimorphism in ungulates was the result of a polygynous breeding system was tested by comparing data for nine species of ungulates.

119. Bowyer, R. Terry. 1981. Activity, movement, and distribution of Roosevelt elk during rut. *Journal of Mammalogy* 62(3): 574-582.

Activity and movement patterns of Roosevelt elk during rut (August-November) were studied at Prairie Creek Redwood State Park, Humboldt County, California, in 1973. Elk inhabited open dunes adjacent to creeks and marshes and were primarily grazers. Activities of sex and age classes of elk were highly synchronized and tended to be crepuscular. Rates and types of behavioral acts performed by master bulls and their lower rate of feeding were related to their loss of physical condition during rut. Elk traveled a mean distance of 2.4 km per 24 hours. Their home range was 400 ha. Climatic factors and tourists had little influence upon elk activities.

120. Brazda, Arthur R. 1953. Elk migration patterns, and some of the factors affecting movements in the Gallatin River Drainage, Montana. *Journal of Wildlife Management* 17(1): 9-23.

Elk calves in the Gallatin Drainage were marked with permanent colored tags in 1949, 1950, and 1951. Sightings and kill records of marked elk have allowed the accumulation of data on movement and migration. Elk reach the limit of their upward, summer migration during July and that of their downward winter migration by December. Specific migration routes are outlined.

121. Brunt, Kim. 1987. Man-made forests and elk in coastal British Columbia. *Forestry Chronicle* 63(3): 155-158.

The potential for integrated management of timber and elk in coastal forests is discussed. The basic habitat requirements of elk for food, security cover, thermal cover, and snow interception cover are presented, and the influences of various common forestry practices on these requirements are examined. Clearcutting, slash burning, planting, precommercial thinning, commercial thinning, species conversion, weeding, and fertilizing all strongly influence the ability of forests to satisfy elk requirements. In most instances, the impacts of these activities are neither all together good nor bad, and a team approach between forest and wildlife managers needs to be taken when planning forestry activities. A brief overview of the effects of elk on regenerating forests is presented, and a potential solution is offered to the problem of browsing damage through the provision of alternative forage. Elk and wood production are compatible in the human-made forest if both forest and wildlife managers are willing to accept realistic compromises to achieve the goals of integrated management.

122. Brunt, Kim; Ray, Cheryl. 1986. Seasonal range habitat suitability index models for Vancouver Island Roosevelt elk. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 117-144.

Models for the assessment of Vancouver Island Roosevelt elk seasonal range habitat suitability are presented. The general physiographic characteristics, preferred forage availability, and interspersions of seasonal forage and cover requirements of an area are considered in the calculation of habitat suitability index (HSI) values. Mathematical relationships are presented to develop seasonal HSI values on spring ranges, summer/fall ranges, and low and high snowpack winter ranges. A discussion of the problems and proposed future development of the models is included.

123. Buechner, Helmut K.; Swanson, Carl V. 1955. Increased natality resulting from lowered population density among elk in southeastern Washington. In: Trefethen, James B., ed. Transactions of the 20th North American wildlife conference; 1955 March 14-16; Montreal, Quebec. Washington, DC: Wildlife Management Institute: 560-567.

Evidence of pregnancy among yearlings based on location in females 2-1/2 years old in the Blue Mountains of Washington is presented. Yearling pregnancies are unusual in natural populations of elk. Although the available data do not prove that an increase in natality resulted from lowered population density, the evidence of more than 50% pregnancies among yearling elk strongly suggests this possibility. Harvest and age-composition data indicate a young, vigorously increasing population. Presuming nutrition to be the principal underlying factor responsible for increased natality, it is significant that the vegetation has not changed appreciably in recent years. Apparently, the increase in natality reflects better nutrition through greater availability of forage per individual rather than improvement in the condition of the vegetation.

124. Bunnell, F.L.; Harestad, A.S. 1983. Dispersal and dispersion of black-tailed deer: models and observations. *Journal of Mammalogy* 64(2): 201-209.

The term dispersal is used to include individual movements out of an area larger than a home range that exhibit no predictable return; many models examining dispersal incorporate time explicitly. Dispersion is defined as the distribution of animals in space, ignoring time since birth. Direction, distance, and age at dispersal were examined for black-tailed deer on Vancouver Island, British Columbia, and in western Washington. Empirically, movements over 5 km were dispersive. Dispersive movements showed significant directionality as a function of topography; nondispersive movements showed none. Dispersive movements averaged 15.2 and 12.2 km for males and females, respectively; comparable values for nondispersive movements were 1.8 and 1.7 km. Movements greater than 12 km were rare (5 to 10%) and generally were made by males. Dispersal was greatest at 1-2 years of age. The sex and age distribution of dispersing individuals suggested that increased access to mates could explain observed patterns. When models were compared statistically with observations, the latter showed neither attributes of a random walk or diffusion process nor normal distribution about birth sites. Observed patterns suggest two phenotypes—"nondispersers" and "dispersers".

125. Bunnell, F.W. 1985. Forestry and black-tailed deer: conflicts, crises, or cooperation. *Forestry Chronicle* 61(2): 180-184.

Before 1970, it was assumed that deer populations responded positively to the increased forage generated by timber harvesting, and forestry was assumed to be beneficial to black-tailed deer. Research in areas of high snowfall obtained contrary results; in fact, old-growth forests were found to be valuable habitats for deer. Old-growth forests provide ideal winter habitat because of reduced costs of locomotion in snow; lower rates of food burial; provision of arboreal lichen; and a more heterogeneous, fine-grained environment. Initial research findings encouraged harvesting guidelines that temporarily reserved tracts of old-growth as winter ranges. Current solutions to the conflict include intensive, specific silvicultural practices to imitate old-growth features in managed stands. Review of the conflict provides several lessons of broader applicability.

126. Bunnell, Fred L. 1979. Deer-forest relationships on northern Vancouver Island. In: Wallmo, Olof C.; Schoen, John W., eds. *Sitka black-tailed deer: Proceedings of a conference; 1978 February 22-24; Juneau, AK. Ser. No. R10-48.* [Place of publication unknown]: U.S. Department of Agriculture, Forest Service, Alaska Region: 86-101.

Provides an overview of major findings of several studies that have taken place on Vancouver Island during the past decade. Doctoral and masters studies by Rochelle, Jones, Harestad, Stevenson, and Gates are summarized (cited separately in this bibliography).

127. Bunnell, Fred L.; Jones, Greg W. 1984. Black-tailed deer and old-growth forests—a synthesis. In: Meehan, William R.; Merrell, Theodore R., Jr.; Hanley, Thomas A., eds. *Fish and wildlife relationships in old-growth forests: Proceedings of a symposium; 1982 April 12-15; Juneau, AK.* [Place of publication unknown]: American Institute of Fishery Research Biologists: 411-420.

In regions of high snowfall in the Pacific Northwest, old-growth forests provide better winter habitat for black-tailed deer than do immature stands. The value of old growth to deer increases with the frequency of deep snowfalls. In more northerly areas, abundance of important winter browse species in immature stages is only 5-55% of that in old-growth stands. Nutrient contents are generally about 10% lower in immature stages, and highly digestible arboreal lichens are absent. When deer have access to both clearcuts and old growth, they maintain a daily intake of digestible energy of about 1.6 basal metabolism rate (BMR), even in severe winters. When snow conditions restrict deer to old-growth forest, energy intake falls to 1.4 BMR but would approximate 0.0 for deer in clearcuts under deep snow. Heterogeneous old-growth canopies intercept significant snowfall and increase snow density, thereby reducing costs of deer movement significantly while still permitting abundant understory vegetation. Thus, energy input is sustained while energy costs are reduced. These relationships are examined in a simple model, and management guidelines are offered.

128. Campbell, Dan L.; Evans, James; Lindsey, Gerald D. [and others]. 1981. Acceptance by black-tailed deer of foliage treated with herbicides. Res. Pap. PNW-290. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 31 p.

Black-tailed deer in an enclosure in Washington were exposed to Douglas-fir seedlings and salal treated with standard formulations of 2,4,5-T, 2,4-D, atrazine, dalapon, fosamine and glyphosate herbicides in diesel oil or water carriers. Tests were run from November 1977 to 1978. Deer readily browsed most formulations, although seedlings treated with glyphosate, which was later shown to be phytotoxic, were less acceptable. There were no noticeable health problems in the test animals.

129. Campbell, Erick G.; Johnson, Rolf L. 1983. Food habits of mountain goats, mule deer, and cattle on Chopaka Mountain, Washington, 1977-80. *Journal of Range Management* 36(4): 488-491.

The seasonal food habits of mountain goats, mule deer, and cattle on Chopaka Mountain, Washington, were determined by fecal analysis. Graminoids represented 84% of the fall diet of cattle, the only period when cattle occurred within the mountain goat range. Mountain goats consumed used graminoids (42%) and shrubs (31%) primarily; whereas, mule deer consumed shrubs (45%) and conifers (29%). Dietary overlap was greatest between mountain goats and mule deer (37%) and mountain goats and cattle (32%), and was minimal between mule deer and cattle (15%). Considerable intraseasonal and interseasonal variation was experienced for all three species.

130. Chatelain, Edward Frank. 1947. Food preferences of the Columbian black-tailed deer *Odocoileus hemionus columbianus* (Richardson) on the Tillamook Burn, Oregon. Corvallis, OR: Oregon State University. 64 p. M.S. thesis.

The Tillamook Burn in Tillamook County, Oregon, is an area of about 300,000 acres which originally burned in 1933 and burned again in 1939. When the study began in 1940, the area was covered with burned snags and logs. The plant cover at the time of the investigation consisted primarily of bracken fern, fireweed, and many browse species. Deer were present throughout the burned area. Transects were set up, and the results of deer use on the plants in each transect were noted. The deer used 56 species of plants during the investigation. Browse plants were the most important source of deer food. More forb species were taken than any other class of plants. Two forbs, fireweed and figwort, were important as deer food. Of the other plants, sword fern, grasses, and sedges were important as deer food, particularly in the winter. Four reputedly poisonous plants—bleeding heart, wild cherry, lupine, and red elderberry—were taken by deer. Bracken fern, one of the most common plants on the area, was not observed to be eaten. No feeding was observed on conifers.

131. Constan, Kerry J. 1972. Winter foods and range use of three species of ungulates. *Journal of Wildlife Management* 36(4): 1068-1076.

A study was conducted in Gallatin Canyon, southwestern Montana during January-March 1967 to obtain quantitative data on range use, food habits, and interspecific

relationships of bighorn sheep, mule deer, and elk. Bighorn sheep, mule deer, and elk mostly used the bunchgrass, Douglas-fir, and sagebrush vegetation types, respectively. Grass and grasslike plants made up 72 and 63% of the plants used by bighorns and elk at feeding sites, respectively. Browse made up 62% of the plants used by mule deer. Measured usage of bunchgrass and sagebrush indicated excessive use of bunchgrass and 53% use of sagebrush. The data indicated at least some competition between bighorns and mule deer. Competition between bighorns and elk was slight during the study, but the similar food habits of the two animals could cause severe competition if elk increased their use of the range of the bighorn sheep. Intraspecific competition may have been present among the bighorns.

132. Constan, Kerry John. 1967. Food habits, range use and relationships of bighorn sheep to mule deer and elk in winter, Gallatin Canyon, Montana. Bozeman, MT: Montana State University. 43 p. M.S. thesis.

A study was conducted in Gallatin Canyon, southwestern Montana, during January-March 1967 to obtain quantitative data on range use, food habits and interspecific relationships of bighorn sheep, mule deer, and elk. The estimated minimum mule deer population using the winter range was 113. Observations indicated a doe:fawn ratio of 100:62. An estimated minimum elk population of 65 consisted of native elk and elk that migrated onto the study area from Yellowstone National Park. Observations on the bunchgrass, sagebrush, and Douglas-fir vegetation types for bighorns was 69, 9 and 20%; for mule deer, 10, 33 and 48%; and for elk, 18, 48 and 34%, respectively. Grass and grasslike plants, forbs, and browse made up 72, 17 and 8% of the plants used by bighorns; 7, 29 and 62% by mule deer; and 63, 10 and 30% by elk, respectively. *Agropyron spicatum* and *Festuca idahoensis* together provided over 1/2 of the total diet of both bighorns and elk. *Artemisia tridentata* provided 30% of the total diet of mule deer, and it was the most used browse plant by both bighorns and elk. Among forbs, *Artemisia frigida* and *Lupinus* spp. ranked first and second in usage, respectively, for both bighorns and elk and first and third for mule deer. Use of bunchgrass and sagebrush indicated 92-96% use of bunchgrass and 53% use of sagebrush. The data indicated at least some competition between bighorns and mule deer. Competition between bighorns and elk was slight during the study, but the similar food habits of the two animals could cause severe competition if elk increased their use of bighorn range.

133. Coop, Kenneth Joe. 1971. Habitat use, distribution, movement, and associated behavior of elk, Little Belt Mountains, Montana. Bozeman, MT: Montana State University. 61 p. M.S. thesis.

A study was conducted during two summers and one fall on an area of 125,000 acres in the eastern Little Belt Mountains of central Montana to obtain data on use of habitat, distribution, movements, and associated behavior of elk before logging within this area. Three major habitat types—open park, broken park, and timber—were delineated on the basis of tree crown densities of 0-15, 16-75, and 76-100%, respectively. Habitat use in both the Douglas-fir and spruce-fir zones was determined by 5,720 observations of elk. During summer, use of open park types predominated over all others. Decreased use of these natural parks (average size 57 acres) was noted in late summer through fall. When disturbed in open parks, elk ran an average distance of 374 feet to use escape timber. Escape cover timber stands were fully stocked

with an average crown density of 85%. Use of timber types and zones varied in fall as related to hunting pressure and other factors. In summer, elk distributed themselves across the heads of three major drainages from about 7,500 to 8,000 feet high, with distribution occurring at slightly lower elevations during fall. Elk moved off the winter range through the transition range and onto summer range by the first week in July. This appeared to be correlated with green-up of vegetation and recession of snow. More than 36% of 84 elk banded in the winter of 1968-69 returned to the same winter range the following winter. One area was found to serve as summer range for elk wintering on two distinct and separate ranges. Clearcuts receiving greatest use were approximately 30 acres in size and 8-10 years old.

134. Cowan, I. McT. 1945. The ecological relationships of the food of the Columbian black-tailed deer, *Odocoileus hemionus columbianus* (Richardson) in the coast forest region of southern Vancouver Island, British Columbia. Ecological Monographs 15(2): 109-139.

On southeastern Vancouver Island, out of eight major plant communities studied, two associates, the deciduous pioneer forest (*Arbutus-Spiraea-Gaultheria* associates) and the coniferous pioneer forest (*Pseudotsuga-Gaultheria* associates) were the most desirable deer habitats. They supported populations of 20-30 deer per square mile but exhibited overgrazing where 40 per square mile were present. On these areas, the Columbian black-tailed deer was a browser with 67% of the annual diet consisting of leaves and twigs of trees and shrubs, a further 15% contributed by lichens, 11% by herbaceous plants, 5% by mushrooms, and 2% by grasslike plants, and ferns. The three most important foods in the annual diet are Douglas-fir, salal, and beard moss (*Usnea barbata*). In the critical winter period, the fir and *Usnea* provide a combined total of 83% of the diet. Heavy deer populations constituted a serious threat to effective reforestation of thinly seeded or artificially replanted cutover land where Douglas-fir is the major species concerned. Western hemlock was not eaten under any circumstances. A summary of management suggestions derived from the study is given.

135. Crews, Arthur Kendrick. 1939. A study of the Oregon white-tailed deer, *Odocoileus virginianus leucurus* (Douglas). Corvallis, OR: Oregon State College. 46 p. M.S. thesis.

The purpose of investigating the life history and habits of the Oregon white-tailed deer was to secure information to form the basis of future management in western Oregon. Very little was known about the Oregon white-tailed deer before this study. The original range of the deer in Oregon extended from about Grants Pass on the south to the Columbia River on the north, and from the foothills of the Cascades to the Pacific Ocean. The present range is limited to the refuge, northeast of Roseburg. The deer was first described by David Douglas in 1829. From observations, the Oregon white-tailed deer appeared to be smaller in size than the Columbian black-tailed deer. The physical characteristics which differentiate this species from other white-tailed deer are given in detail. The deer runs with a smooth gait and carries itself low to the ground. They can jump most fences on the refuge. Sense of smell seems to be the most highly developed sense. The deer will often lay very still and sneak out in the opposite direction. No evidence of yarding was observed. No seasonal migration takes place. Antlers usually appear during the second year of the

male's life. Antlers are shed in January through March; new ones start to grow immediately and reach maturity in June and July. Velvet is shed in September. Breeding takes place in late October through early December. The fawns are born in May, June, and July. There is a very low ratio of males to females. There are presently 200 or more deer on the white-tailed deer refuge of 19,500 acres.

136. Crouch, Glenn L. 1974. Interaction of deer and forest succession on clear-cuttings in the Coast Range of Oregon. In: Black, Hugh C., ed. *Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium; 1973 September 11-12; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 133-138.

Reviews the history of human interest in deer and forest succession from presettlement indifference to present day concern and conflict. Various aspects of deer-forest relations are discussed, based on tentative findings from a study of clearcut blocks logged from 1 to 10 years before the study. Pellet-counts indicate that deer use peaks shortly after logging and declines thereafter. Thus, sustained clearcutting should maintain adequate populations of deer for hunters and nonconsumptive users. High levels of deer use were associated with reduced height growth and stocking levels of Douglas-fir regeneration, but moderate use appeared to have little adverse impact.

137. Crouch, Glenn L. 1979. Food habits of black-tailed deer on forested habitats in the Pacific Northwest. In: Wallmo, Olof C.; Schoen, John W., eds. *Sitka black-tailed deer: Proceedings of a conference; 1978 February 22-24; Juneau, AK.* Ser. R10-48. [Place of publication unknown]: U.S. Department of Agriculture, Forest Service, Alaska Region: 53-59.

Food habits of coastal deer are limited by availability of plants both overall and seasonally, and availability varies greatly with latitude and elevation. Forested black-tail ranges are characterized by the presence of plants that are green all year. Evergreen shrubs, like salal and Oregon grape and ferns, occur as understory cover in timber stands and often make up a sizable portion of the vegetation present after logging or burning. Other evergreen and semievergreen species including tobacco-brush and Pacific blackberry, as well as Douglas-fir and other conifers, also occur after logging or fires. Unless covered by snow, these plants offer year-round green feed. In general, black-tails prefer green leafage which is most available to them during the growing season when most plants have leaves and succulent stems. Evergreen and semievergreen shrubs like salal and Pacific blackberry are characteristics of the region and provide leafage year-round in many locations. Conifers also offer year-round green feed when small trees are within reach of deer or when snow or wind breaks limbs from larger trees. Browse provides the plant parts most eaten through the range and increases in importance northward through the range. Grasses have long been recognized as an important feed but decline dramatically in importance from south to north in the coast range. Black-tails usually have abundant forage late spring, summer, and fall, but in winter feed may be restricted by inaccessibility or poor early growth.

138. Dalke, Paul D.; Beeman, Robert D.; Kindel, Frederic [and others]. 1965. Seasonal movements of elk in the Selway River drainage, Idaho. *Journal of Wildlife Management* 29(2): 333-338.

Seasonal movements of Rocky Mountain elk in the lower 35 miles of the Selway River drainage in Idaho were ascertained by pellet-group counts and 38 aerial surveys for 4 years. Elk followed the retreating snow line but descended to the lower slopes with the first appearance of new growth of grasses, sedges, and forbs. After this distinct downward trend in April, elk gradually worked upward to the summer range. The advent of herbaceous spring vegetation had a greater effect on elk movements than did artificial salt during April and May. Because of the steep topography of the Selway country, migrations from high mountain meadows to winter range do not exceed 20 miles, and for many elk the distance would not be more than 8 or 10 miles. Fall movements of elk occur not only from higher to lower elevations but laterally along the lower slopes of the Selway River, both upstream and downstream. On 10 of 25 northside drainages, these fall and winter movements caused concentrations of elk which reached 9.1 animals per 100 acres on some winter ranges.

139. Dasmann, Raymond F.; Taber, Richard D. 1956. Behavior of Columbian black-tailed deer with reference to population ecology. *Journal of Mammalogy* 37(2): 143-164.

Mobility, group structure, aggression, territorial behavior, and other density-related behavioral aspects were studied in Columbian black-tailed deer in Lake County, California, during 1948-55. The deer were nonmigratory and tended to occupy restricted home ranges throughout the year. Movements beyond home range boundaries were infrequent and consisted of rutting season travels, wandering and dispersal. Deer could not be driven from their home range nor did they leave them to seek qualitatively superior forage. Adult does were found to be mutually intolerant when the fawns were young. Centers of activity of adult does were spaced well apart, much as if they were defended territories. Aggression between does was a factor causing one adult to avoid the activity center of another. Aggression, alarm behavior, and play were all related to population density. When density was higher, there was more strife and alarm flight and less play. Territorialism and density-dependent behavior may prevent populations from increasing to the maximum that the food supply might otherwise sustain.

140. Davis, Jerry Allen. 1966. Reproduction of the Cassia deer herd in Idaho. Moscow, ID: University of Idaho. 60 p. M.S. thesis.

This study of the reproductive rate of mule deer was conducted in the Cassia Mountains of south-central Idaho. The purpose was to compare the current reproductive rate with that found during a previous productivity study of the herd in 1953. The population was estimated at 12,000 animals in 1953; however, it appears to have recently stabilized at about 6,000 animals. Herd composition counts throughout 1965 indicated a sex ratio of 72 bucks per 100 does. The early spring

counting period provided a ratio of 58.8 fawns per 100 does. In late summer and winter, the ratio was 102:100 and 75.4:100, respectively. Age-class distribution indicated the proportion of 2-year-old animals to be larger than that of yearlings. Grouped age distributions indicated that there are presently more young animals in the herd than there were in 1953. Fetal samples showed the 1964 breeding season ranged from November 11 through December 9. The range of the 1965 breeding season was from October 20 to November 22. Ovulation rates averaged 1.33 per yearling doe, 2.05 for 2-year-olds, 1.90 among prime does, and 2.00 in the old group. Average ovulation rates for all age classes increased from 1.56 in the previous study to 1.82 in 1965. Breeding among fawns was not significant. Breeding success for yearling does was 94.4%, compared to 54.3% in 1953. The fertilization and embryonic survival rate for all age classes was 89.7%, and prenatal mortality of fetuses was 1.64%. Combined weighted natality equaled 1.60 fawns per doe compared to 1.42 fawns per doe in 1953. The early fawn loss was 14.4% compared to 19.9% found in the previous study. The improvement in reproduction appears to result from changing range conditions and decreased competition.

141. Davis, Jerry L. 1970. Elk use of spring and calving range during and after controlled logging. Moscow, ID: University of Idaho. 51 p. M.S. thesis.

The 2-year study assessed the effects of controlled logging on the patterns of elk use and obtained additional information on elk ecology. Data collected during (March-July 1968) and after (March-July 1969) logging was compared by chi-square tests. The number of elk observed in the same number of trips and the number of pellet groups counted during the 2 years showed that there was no significant difference in the total elk use of the control and treated areas combined. But both types of counts showed that the two control areas received significantly less use after logging, one of the treated areas received the same amount of use, and one received more use. Sampling intensity for the pellet group counts was significant at the 95% confidence level for an error risk of 0.10 of the mean. Calving occurred in the same area during both years. Forage usage, measured by clipping and weighing vegetation on 1/1000-acre plots, showed less than 10% forage removal on the heaviest used areas on spring and summer range. Soil disturbance by elk trampling was not attributed to spring range deterioration. Examination of 57 feeding sites showed that elk used many plant species during the spring and summer, depending primarily on availability and phenology.

142. Davison, Michael A. 1979. Columbian white-tailed deer: status and its potential of off-refuge habitat. [Place of publication unknown]: Washington Game Department; Columbian white-tailed deer study, completion report, Project E-1, Study 2, Jobs 3, 4, and 5. 73 p.

The primary objective of this study was to examine the current Columbian white-tailed deer population status on off-refuge habitat, its range, and potential for reintroduction into suitable habitat. Specific objectives were (1) to survey 32 Columbia River islands to identify previously unconfirmed populations of the deer in geographical area considered historical range of the species; (2) to collect and correlate data relative to the biological status of off-refuge deer populations; (3) to provide the

Columbia white-tailed deer Recovery Team with descriptive habitat data on specific islands under consideration as potential deer transplant sites; (4) to document the ownership and land use status of Columbia River islands included in the study; and (5) to make recommendations specific to the management of lower Columbia River populations of white-tailed deer based on study findings.

143. Day, Thomas Alfred. 1973. Use of clearcuts by elk in the Little Belt Mountains, Montana. Bozeman, MT: Montana State University. 70 p. M.S. thesis.

A study was conducted during two summers and one fall in the southeastern Little Belt Mountains of central Montana to obtain data pertaining to use by elk of clearcuts located in extensive stands of lodgepole pine. Secondary objectives were to record data on movements and summer distributions of two separate elk herds that winter on the south slopes and to note areas used by cattle. Elk used clearcuts only when they were located within or near traditional summer range areas. Observations and pellet group counts indicated the most suitable conditions for elk were present when the block was located the greatest distance from human disturbance, closest to extensive stands of timber cover, adequately treated for disposal of slash, and of younger age (2-10 years). The size of opening appeared to be a negligible factor of influence. Ninety-two percent of 1,816 observations of elk using 26 clearcuts were made in four of them; all conditions must be suitable for a block to receive appreciable elk use. Elk wintering on one area of the south slopes moved along two major routes to summer range where they concentrated activities in three main areas which they shared with elk from a larger herd that wintered on the north slopes. Elk wintering on another area of the south slopes moved along one main route to one summer area of activity upon which they were separated from the other segments. Competition between elk and cattle was relatively unimportant on higher summer range but appeared significant on the lower winter range areas of the south slopes.

144. Dealy, J. Edward. 1975. Management of lodgepole pine ecosystems for range and wildlife. In: Baumgartner, D.M., ed. Management of lodgepole pine ecosystems, symposium proceedings; 1973 October 9-11; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 556-568.

Large-scale clearcutting reduces wild ungulate use because hiding cover is too far from most feeding sites. Human harassment is an important factor in causing wild ungulates to shun large clearcuts. Foraging by wild ungulates occurs throughout clearcuts which are 40 acres or less in diameter. Alternate-strip clearcutting three chains wide with equal width leave strips is optimum for natural regeneration of lodgepole pine in Oregon and is favored by deer in Colorado. If harvesting is done in strips, care should be taken to prevent development of "shooting lanes" by interrupting the strips at reasonable distances. If the clearcut is block-shaped, rectangular leave patches should be arranged to minimize the open areas that can be seen from any one point. Thinning and clearcutting can dramatically increase forage production for ungulates, but manipulation of livestock use may be necessary to insure forage for winter deer use.

145. Dealy, John Edward. 1959. The influence of logging practices on Columbian black-tailed deer in the Blue River area of Oregon. Corvallis, OR: Oregon State University. 65 p. M.S. thesis.

The main objectives of this study were to determine migration habits, distribution patterns, and site preferences of deer, and to evaluate the suitability of habitat changes in the area for deer. A nutritional project on deer browse related quality to exposure, season, elevation, and light intensity. This program was activated in an attempt to learn the influence, if any, the nutritional value, as indexed by crude protein content, has on deer movements and distribution. Observations and sampling work on deer migrational patterns, population trends, movements within the research area, elevation and slope preference, seasonal habits, and the effects of food availability on population movements to and from the forest were also included. Newly logged areas have numerically increased, and deer generally favor new openings which are in different stages of plant succession. Since many of these timbered areas have been and will be cut in the Cascade Range under the sustained yield plan of forest management, it would be advantageous to the game manager to understand the vegetative potential of this region for supporting deer.

146. Dood, Arnold Robert. 1978. Summer movements, habitat use, and mortality of mule deer fawns in the Missouri River breaks, Montana. Bozeman, MT: Montana State University. 57 p. M.S. thesis.

A study of mule deer fawns was conducted in the timbered breaks adjacent to the Missouri River, north-central Montana, during the summers of 1976 and 1977. Radio telemetry was used to obtain information on the causes, extent, and timing of neonatal mortality. *Pinus-Juniperus*, *Artemisia-Apropyron*, and *Pseudotsuga-Juniperus* vegetation types received over 90% of the recorded fawn use during both summers. Highly significant difference in vegetation-type use were evident between years and from early to late summer during the same year. Measurements of the vegetation in the immediate vicinity of fawn bed sites indicated a uniform cover of 50% or more to a height of 3 dm was a constant characteristic of fawn bedding sites. Mortality rates were 36% and 32% in 1976 and 1977, respectively, with predation by coyotes accounting for the majority of the mortality which occurred. No instances of mortality due to starvation or disease were recorded, and accidents accounted for only one death. In 1976, mortality was confined to the first 45 days of life, and the majority of mortality in 1977 occurred after this period. Differential mortality by sex was not observed. Possible relationships between fawn behavior, movements, habitat use, bedding site selection, and mortality were discussed.

147. Dublin, Holly T. 1980. Relating deer diets to forage quality and quantity: the Columbian white-tailed deer (*Odocoileus virginianus leucurus*). Seattle, WA: University of Washington. 135 p. M.S. thesis.

This study focused on the feeding patterns of the Columbian white-tailed deer. The methodology and procedures were aimed at (1) determining seasonal forage availability and quality on the Columbian White-tailed Deer National Wildlife Refuge; (2) determining patterns of forage consumption by resident deer; and (3) deriving seasonal patterns of forage preferences and selection. Data from this study suggest that a new look at management strategy on the refuge must be considered. Current

policies which promote the production of cultivated grasses and forbs may not address the seasonal variation in deer forage demands. The possible benefits of grazing by cattle are not disputed in those seasons when deer clearly prefer grass regrowth. The use of dry stems and leaves by cattle does stimulate the immediate growth of new tissue and allows greater regeneration potential for shrubs. However, there is no indication from our data that this new growth is sought by the deer in all seasons. Their heaviest use of grasses corresponds more closely to climatically determined phenology in the spring than to the regrowth stimulated by cattle grazing in the fall and winter. Current plans to increase pasture area should be reconsidered in light of these findings. Although deer indisputably consume grasses and clovers, they do not appear to be quantity limited. It is the quality of available preferred forage that must be managed if we are to protect the nutritional status of the deer. The management of forage quality will be most important in demanding times such as fall, winter, and early spring.

148. Eberhardt, Lester E.; Hanson, Eric E.; Cadwell, Larry L. 1984. Movement and activity patterns of mule deer in the sagebrush-steppe region. *Journal of Mammalogy* 65(3): 404-409.

The movements and activity patterns of radio-collared mule deer were studied from 1980 to 1982 in the sagebrush-steppe region of south-central Washington. The average home range size for adult deer was 39.3 ± 26.5 square km (n=34). Home range sizes for male and female deer were not significantly different. Intensity of use of home range area by deer was not uniform, and physical features within the home range, such as trees and large bodies of water, influenced deer movements. Three (8%) of 37 monitored deer dispersed from their original home ranges during approximately 25 deer-years of monitoring. In addition, 7 (19%) deer made sporadic, temporary wandering movements of up to 15 km beyond their normal home range boundaries. Based on rate of movement, deer had clearly defined crepuscular activity patterns.

149. Eby, James R. 1986. Elk habitat effectiveness modeling in the Soleduck region of the Olympic Peninsula. In: Eastman, Dan L., ed. *Proceedings of the 1986 western states and provinces elk workshop*; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 185-193.

The need to quantify the impacts to elk habitat from habitat changes caused by logging is a high priority. Such information is needed to evaluate timber sale layout alternatives and in planning long-term strategies for elk habitat and timber management. This digital-analysis procedure described in this paper provides the analysis method to supply managers with habitat evaluations based on the model developed by Wisdom and others (1986). The overall habitat-effectiveness index is a composite expression of habitat quality from a set of variables. The interspersions of the thermal cover and forage areas (known as size and spacing) is one effectiveness variable. Effectiveness variables are developed for thermal cover based on quality and for forage areas based on harvest type and postharvest treatment. The final effectiveness variable is the road density in lineal measure per square unit of habitat. The overall effectiveness index is computed by mathematically considering the effectiveness ratings of size and spacing, thermal-cover quality, forage quality, and roading for any prescribed study area.

150. Edge, W. Daniel. 1982. Distribution, habitat use and movements of elk in relation to roads and human disturbances in western Montana. Missoula, MT: University of Montana. 98 p. M.S. thesis.

Elk movements and habitat use in relation to roads and human disturbances were studied in the Chamberlain Creek area between May and December during 1980 and 1981. Twenty-seven cow elk, equipped with radio transmitters, were located from airplanes a total of 846 times. An additional 61 locations were made by ground tracking 9 elk between August 12 and September 30, 1981. Elk response to open roads varied with season, traffic volume, and vegetative and topographic cover. Elk were displaced from heavily traveled roads to a greater extent than lightly traveled roads, from calving through rutting season. Topographic barriers between the elk and the nearest open road or disturbance aided in reducing the amount of displacement. Elk use was depressed within 750 m of roads and 1,000 to 1,500 m of human activity. Elk movements were modified by logging activity; movements were greater when elk moved away from logging than when moving towards it. Elk were significantly closer to logging units on weekends than on weekdays. Elk maintained a buffer zone of at least 500 m from logging activity. This buffer zone effectively reduced the availability of habitats of elk. Elk response to roads and human activity during the hunting season was of two types: (1) general displacement within 2,000 m and an associated use of topographic barriers and (2) use of safety zones closed to hunting in close proximity to human habitation. Roads designed to avoid natural openings and to take advantage of topographic barriers will benefit elk habitat effectiveness.

151. Edge, W. Daniel. 1985. Habitat use and food habits of elk in western Montana: a multivariate approach. Missoula, MT: University of Montana. 83 p. Ph.D. dissertation.

A study to identify the important components of elk habitat through discriminant comparisons of elk-selected and random habitat samples was conducted between mid-June and mid-October 1982 and 1983. Seventeen variables were measured from aerial photographs, maps, or in 375 square-m plots for 354 radio, and 172 random locations. Stepwise discriminant analysis was used to test the hypothesis of equal mean vectors between monthly elk and locations and random sites. All monthly elk locations differed from one another and from random locations. The most important variables were distance to open roads and human disturbance, and the amount of foraging area within 200 m of each location. Site-specific habitat selection appears to be primarily a function of maximizing forage quantity or quality. Summer habitat for elk can be adequately evaluated from maps and aerial photographs. Monthly food habits were studied by using feeding site analysis with the 375-square-m circular plots. Forbs and shrubs accounted for the majority of monthly elk use from mid-June to mid-October. Sixteen forage species were used by elk in 10% or more of the feeding sites and were used in additional analysis. Stepwise discriminant analysis was used to test the hypothesis of equal mean vectors for percent cover of the 16 forage species between feeding and random sites. Percent coverage of these forage species differed between feeding sites and random locations during each month. Elk showed a pattern of selection for feeding sites based on availability of preferred forage species and selection of forage species within feeding sites.

152. Edge, W. Daniel; Marcum, C. Les. 1985. Movements of elk in relation to logging disturbances. *Journal of Wildlife Management* 49(4): 926-930.

Elk movements in relation to logging activities were studied in Chamberlain Creek, Montana, between August 12 and September 30, 1981. Fifty-six aerial and 61 ground telemetry locations were obtained for 9 cow elk. Normal elk movements in the Chamberlain Creek area were short and probably related to forage availability. Movements away from disturbance were significantly longer than those toward disturbance, but the sequence of movements was random with respect to source of disturbance. Elk tended to move into areas of logging activity on weekends during nonactive periods, but these movements were probably a response to increased accessibility of some habitat factor rather than habituation to the disturbance. A buffer zone of 500-1000 m separated areas of high elk use from areas of disturbance. Habituation may decrease this buffer zone. This displacement of elk may cause substantial reductions in habitat availability.

153. Edge, W. Daniel; Marcum, C. Les; Olson, Sally L. 1985. Effects of logging activities on home range fidelity of elk. *Journal of Wildlife Management* 49(3): 741-744.

The objective of this study was to quantify the home ranges of nonmigratory cow elk and to assess the effect of logging activities on home-range fidelity. We define home-range fidelity as overlap in an individual's home range during successive years. Thirty-nine cow elk were radio tracked for two or more complete field seasons; 31 were tracked for 2 consecutive years during which 1 year had logging disturbance within the home range. Our results showed an insignificant decrease in home range size due to logging disturbances. Cow elk will not abandon traditional home ranges because of logging activities when extensive areas of cover remain available within their home range. Disturbances may alter habitat selection by increasing use of areas that provide cover, but this will occur within the traditional home. In areas where cover is limited, logging activity may increase home range size and reduce home-range fidelity.

154. Edge, W. Daniel; Marcum, C. Les; Olson-Edge, Sally L. 1987. Summer habitat selection by elk in western Montana: a multivariate approach. *Journal of Wildlife Management* 51(4): 844-851.

A study to identify the important components of elk habitat, through discriminant comparisons of elk-selected and random habitat samples, was conducted between mid-June and mid-October 1982 and 1983. Seventeen variables were measured from aerial photographs, maps, or in 375-square-m plots for 354 radio-monitored and 172 random locations. Stepwise discriminant analysis was used to test the hypothesis of equal mean vectors between monthly elk locations and random sites. Elk locations differed between months and from random locations. The most important variables were slope, the amount of foraging area within 200 m of each location, and distance to open roads and human disturbance. Site-specific habitat characteristics were not apparent in the data because elk made broad use of available habitats. Summer-long habitat for elk can be evaluated from maps and aerial photographs.

155. Edgerton, Paul J. 1972. Big game use and habitat changes in a recently logged mixed conifer forest in northeastern Oregon. In: Proceedings of the 52d annual conference of Western Association of State Game and Fish Commissioners; 1972 July 16-19; Portland, OR. [Place of publication unknown]: Western Association of State Game and Fish Commissioners: 239-246.

Logging is dramatically changing the character of big game summer ranges in the mixed conifer forests of northeastern Oregon and southeastern Washington. Animal use and habitat changes were documented in recently logged clearcuts, adjoining uncut and nearby partial-cut forest stands. Elk use was highest in the clearcuts, lowest in the partial-cut areas. Deer showed essentially the same order of preference, but differences between habitats were much smaller. Forage was the obvious attraction in the clearcuts. Adjoining uncut stands provided excellent cover. The partial-cut stands lacked both the volume and variety of forage in the clearcuts and hiding cover found in the uncut areas.

156. Edgerton, Paul J. 1987. Influence of ungulates on the development of the shrub understory of an upper slope mixed conifer forest. In: Provenze, Frederick D.; Flinders, Jerran T.; McArthur, E. Durant, comps. Proceedings—Symposium on plant-herbivore interactions; 1985 August 7-9; Snowbird, UT. Gen. Tech. Rep. INT-222. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 162-167.

The role of deer and elk in forest succession was investigated in a recently harvested clearcut in the Blue Mountains of Oregon. Grazing prevented shrub establishment and favored development of grasses and forbs. Abundant shrubs developed within a fenced enclosure. Results suggest that by considering forage and cover requirements in silvicultural plans, managers can use ungulate foraging as a vegetation management tool.

157. Edgerton, Paul J.; McConnell, Burt R. 1976. Diurnal temperature regimes of logged and unlogged mixed conifer stands on elk summer range. Res. Note PNW-277. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.

Temperature profiles for unlogged, partial-cut, and clearcut stands showed that removal of all or a portion of the tree canopy resulted in cooler nights and warmer days. Range of temperature extremes was greatest in the clearcut and least in the unlogged stand. Differences in canopy cover between the unlogged and partial-cut stands were relatively small, but there was a noticeable difference in thermal regimes. Daytime temperatures in the partial-cut stand were warmer, but nocturnal temperatures were somewhat cooler than in the unlogged stand. These differences influence selection of thermal cover by elk.

158. Edgerton, Paul J.; Smith, Justin G. 1971. Seasonal forage use by deer and elk on the Starkey Experimental Forest and Range, Oregon. Res. Pap. PNW-112. Portland, OR: U.S. Department of Agriculture, Pacific Northwest Forest and Range Experiment Station. 12 p.

Seasonal forage use by mule deer and Rocky Mountain elk was determined in the three major habitats—open forest-dense forest, and grassland—that characterize the ponderosa pine/Douglas-fir vegetation type of the Blue Mountains of eastern Oregon. Food grades derived from data on diet and forage abundance were used to compare the habitats as sources of forage. Open forest land rated highest in spring, summer, and fall. This habitat had a season-long abundance of forage, particularly elk sedge (*Carex geyeri*), a highly preferred grasslike plant. Grassland rated second in the spring when succulent forbs were abundant but dropped to third during the summer and fall when grassland plants were largely dry and unpalatable. Deer and elk then sought food as well as cover in the forest habitats. Although low-growing shrubs contributed most to the dense forest food grade, that habitat was probably more important as cover than as a source of food.

159. Eustace, Charles Dean. 1967. Food habits, range use and relationships between elk and livestock in the Gravelly Mountains, Montana. Bozeman, MT: Montana State University. 55 p. M.S. thesis.

A study of food habits, range use, and relationships between elk and livestock was made in 1965-66 on a 130-square-mile area of the Gravelly Mountains, southwestern Montana. The vegetation was divided into three zones: fescue-wheatgrass, Douglas-fir, and spruce-fir. Each zone was divided into several types. Quantitative measurements of canopy coverage and plant density were made for many of the types. Use of each vegetation zone by elk and livestock was evaluated. Food habits were determined from the examination of feeding sites. The diet in winter for elk consisted of 97% grasses and 2% forbs, and in summer it consisted of 67% forbs and 33% grasses. The canopy coverage of individual plant species was recorded at each feeding site. This provided a measure of abundance. A statistical analysis was conducted to determine the relationship between abundance of individual plant species and their significance in the diets of the animals. Negative, neutral, and positive food preferences were indicated. The summer range data for each of the three animal classes indicated that the average canopy coverage was highest for those plants for which the animals showed a negative preference. This may imply that the abundance of some or all of these plants was so great that it more than satisfied the needs of the animals and was not an actual indication of negative preference. Clipping results indicated an almost equal percentage of use of total vegetation by elk and cattle on winter range. There appeared to be little competition between cattle and elk on the winter range and none on the summer range; however, competition may exist between elk and sheep on summer range.

160. Franklin, W.L. 1968. Herd organization, territoriality, movements and home range in Roosevelt elk. Arcata, CA: Humboldt State College. 89 p. M.S. thesis.

This study was conducted to determine the interrelationships between the behavior of Roosevelt elk and their use of habitat at Prairie Creek Redwoods State Park, California. Cow herds were socially organized and semistable associations. Elk entered and left the herd without difficulty. The adult females and their calves appeared to form the most constant part of the herd. Other sex and age classes showed lesser degrees of attachment to this cow-calf nucleus. Older females usually dominated younger ones. Cow herd composition was most stable from November through May. Division of cow herds into smaller units was high during calving, postcalving, and rutting periods. As males matured from yearlings to adults, they left the herd and joined male groups. Only adult males were observed separately, and this occurred in only 3% of the observations. Males associated with the cow herd more often in winter than during other seasons. The size of elk groups was largest on the prairies, smallest in the brushland, and most variable in cutover redwood forest. Home range size was about 1.2 square miles. More than half the observations of the beach herd were made within the central third of its home range. This central region, which contained an abundance of preferred forage, was possibly a territory. No active defense was observed, but it was exclusively occupied by the tagged beach herd, and other elk could have entered but were not known to do so. Sign-posting behavior was observed, but its functional significance is unknown. Recently, sign-posted trees were more abundant within the territory than elsewhere in the home range.

161. Franklin, W.L.; Mossman, A.S.; Dole, M. 1975. Social organization and home range of Roosevelt elk. *Journal of Mammalogy* 56(1): 102-118.

Social organization of Roosevelt elk and its interrelationship to habitat use was studied at Prairie Creek Redwoods State Park, California. Behavior and movements were observed in the Gold Bluffs Beach herd, whose size ranged between 2 and 27 and averaged 16 members. This matriarchal herd was a semistable association in which elk entered and left the group freely. The adult females and their calves formed the most constant part of the herd. Other sex and age classes were less attached to this cow-calf nucleus. Older cows usually dominated younger ones. Cow herd composition was most stable from November through May. Division of the cow herd into smaller units was high during calving, postcalving, and rutting periods. As males grew older from yearlings to adults, they left the herd and joined groups of males. Males associated with the cow herd more often in winter than during other seasons. The size of groups of elk was largest on the prairies, smallest in the brushland, and most variable in cutover redwood forest. The home range was a 9.6 km long and 100- to 450-m wide strip of beach and coastal prairie with a surface area of three square km. Use of the home range's three ecological regions was highly correlated with available forage. The herd spent more than half its time within the central 1/4 of its home range, an area with a relative abundance of preferred herbaceous perennial forage. Although no active defense was observed, the central area was exclusively occupied by the tagged study herd.

162. Ganskopp, David; Vavra, Martin. 1987. Slope use by cattle, feral horses, deer, and bighorn sheep. *Northwest Science* 61(2): 74-81.

Patterns of slope use by cattle, feral horses, Rocky Mountain mule deer, and California bighorn sheep were monitored to compare their distributions to the topographic compositions of their respective habitats. The hypothesis that each species use slope classes in proportion to the topographic compositions of their respective habitats was rejected. Bighorn sheep activities were not impaired by slopes of up to 80%. Cattle, horses, and deer demonstrated negative curvilinear responses to increasing slope with initial site avoidance exhibited on 20, 30, and 40% slopes, respectively. Where large expanses of level topography were available, cattle and horses made less use of steep slopes than their counterparts inhabiting more rugged terrain. These data demonstrate that cattle, horses, and deer should not be expected to make random use of forage resources in rugged terrain.

163. Gates, Bryan Rodd. 1968. Deer food production in certain seral stages of the coast forest. Vancouver, BC: University of British Columbia. 105 p. M.S. thesis.

This study was designed to determine which seral stages of the regenerating coast forest are most efficient at converting radiant energy into energy available as seasonal deer foods and whether the most efficient stages are most intensively used by deer. Seasonal forage preferences were determined through rumen content analysis. Cover composition up to 4 feet in height and summer and winter estimates of quantity, variety, and nutrient quality of the important food species were obtained in different seral stages. These data were then related to the intensity to which deer use each seral stage. An early salal-catsear (*Gaultheria-Hypochaeris*) association develops 3 to 5 years after slash burning. This type was preferred by deer during spring and early summer. A salal-Douglas-fir (*Gaultheria-Pseudotsuga*) association develops 12 to 15 years after slash burning and was preferred during autumn and winter. The crude protein, mineral, and ash contents of the important evergreen foods were higher when eaten (autumn-winter) than at other times. Heaviest deer use occurred in the seral stages where there evergreens were most available. The nutrient content of key foods changes significantly with season, and there was evidence of selection by deer of the most nutritious plants available. The numbers of deer within a logged unit are affected by the efficiency at which food is produced. Numbers within the whole community are affected by availability of ideal food-producing units for each season. Sustained populations cannot be expected because seral succession in logged coastal forests will inevitably cause regression of range quality.

164. Gavin, Thomas A.; Suring, Lowell H.; Vohs, Paul A. [and others]. 1984. Population characteristics, spatial organization, and natural mortality in the Columbian white-tailed deer. *Wildl. Monogr.* 91. Bethesda, MD: The Wildlife Society. 41 p. Supplement to *Journal of Wildlife Management* 48(4): 1984 October.

Population ecology of Columbian white-tailed deer was studied on a refuge in southwestern Washington during 1972-77. Quality of habitat was considered good for

these deer, and total population size remained between 164-230 as determined by mark-recapture methods. Sex ratio at birth did not differ significantly from 1:1, but females outnumbered males 3:1 among yearlings and adults. Fawn:doe ratios ranged from 35 to 60 fawns per 100 does in November. Mean home range size for females was 158.5 ha; for males, mean area of home ranges was 192.2 ha. They were not migratory and were, in fact, remarkably sedentary. Winter mortality of yearling and adult males was significantly higher than expected relative to females, and 77% of all fawn carcasses located died during summer. A higher mortality rate for males over 1 year old resulted in the skewed sex ratio favoring females. Causes of death included automobiles, bacterial infections, coyotes, dogs, drowning, nutritional stress, and accidents. Based on the timing of mortality for males and females, stress due to breeding activities and fawning, respectively, were the ultimate causes of death.

165. Gavin, Thomas Alan. 1979. Population ecology of the Columbian white-tailed deer. Corvallis, OR: Oregon State University. 160 p. Ph.D. dissertation.

A population of Columbian white-tailed deer was studied on a refuge (790 ha) in southwestern Washington during 1972-77. Quality of habitat was considered good, and total population size remained between 164 and 230. Population size declined significantly between the winters of 1974-75 and 1975-76. All sex-age classes exhibited a contagious dispersion on the study area; the locations of high density areas among these classes differed slightly. Sex ratio at birth did not differ significantly from 1:1, but females outnumbered males 3:1 among yearlings and adults. Fawn:doe ratios ranged from 35 to 60 fawns per 100 does in November. From 1972 to 1977, yearling and adult males comprised 18-21% of the November population, yearling and adult females 50-60%, and fawns 21-31%. Winter mortality of yearling and adult males was significantly higher than expected, and 77% of all fawn carcasses located were estimated to have died during summer. In 1975-76, female mortality was concentrated in a central portion of the study area where habitat quality had presumably declined. Median ecological longevity was 2.97 for males and 4.87 for females. Causes of death included automobiles, bacterial infections, coyotes, dogs, drowning, nutritional stress, and accidents. The Columbian white-tailed deer were not migratory and exhibited remarkable sedentary tendencies. Mean home range size for females was 112.9 ha by using the convex polygon method and 158.5 ha with the determinant method; for males, mean area of home ranges with each method was 137.7 ha and 192.2 ha, respectively. Home ranges tended to become smaller with increasing age among females but larger for males.

166. Grkovic, Nicholas. 1976. Montana-Idaho elk migration and key-use area study—Salmon, Beaverhead, and Bitterroot National Forests. Missoula, MT: University of Montana. 128 p. M.S. thesis.

Elk were trapped during winter 1973-74 and 1974-75, radio- or rope-collared, and ear-tagged. Movements were followed aerially and on the ground from February 1974 until December 1975. Migration routes from Idaho winter ranges to Montana summer ranges were located by biotelemetry. Some radio-collared elk from the

Hughes Creek trap migrated to Montana summer range, and others remained near the Idaho winter range or moved locally to higher elevations. Radio-collared elk from the Wagonhammer trap all migrated to Montana summer ranges. Spring migrations, triggered by snow-melt and green-up, began about mid-May and were complete by about mid-June. Fall migrations were triggered by fall snowstorms and were completed by the first week in December. Resting and feeding sites along migration routes and calving and rutting areas were established by clusters of radio-transmitter locations. Radio-collared elk moved to roadless areas during hunting seasons. Radio- and rope-collared elk were shot in both states. Grass winter ranges on the study area were used more extensively the first winter than during the second when snow depths were greater. Forage in and near tree cover was heavily used the second winter. Winter range boundaries varied due to snow depth, cover, slope, aspect, and human disturbance. Habitat types were sampled in key-use areas and along migration routes. Use of clearcuts was not established, and some radio-collared elk-cattle competition was noted. Recommendations were submitted for management of elk and timber harvest on the study area.

167. Grover, Karl E.; Thompson, Michael J. 1986. Factors influencing spring feeding site selection by elk in the Elkhorn Mountains, Montana. *Journal of Wildlife Management* 50(3): 466-470.

Elk spring feeding-site selection as influenced by 12 environmental variables was investigated in the Elkhorn Mountains of southwestern Montana during 1983-84. Variables included cattle use, plant community descriptions, distance to disturbance sources, and topographic descriptors. In multiple regression, we were able to account for 68% of the variation in elk spring feeding-site selection. Elk selected feeding sites that were previously grazed by cattle and supported relatively high densities of bunchgrass plants. Elk made the greatest use of these sites when they were located near cover and away from visible roads.

168. Hammond, Gary R. 1980. Elk-logging relationships in Long Tom Creek (Nutritional characteristics of the vegetation of clearcut and uncut sites on summer-fall elk range). Bozeman, MT: Montana State University. 71 p. M.S. thesis.

A study was established to evaluate forage characteristics and a possible influence on elk distribution and use of logged and uncut sites in Long Tom Creek of southwestern Montana. Composite samples from forbs and graminoids were selectively harvested in both uncut and cut-through wet meadows dry parks and forested sites. Nutritional quality of forage was at a seasonal high during early summer on all sites. Overall, through summer, forbs demonstrated higher quality than grasses and sedges. Since forage quality was similarly high on all sites examined, forage availability was probably more important than quality in early summer elk habitat selection. Both uncut and cut-through dry parks and wet meadows, which represented the most productive and species-diverse types available during early summer, also received the greatest elk use. Good nutritional quality, high forage production, high security and thermal cover, and a diverse species composition all contributed to the overall importance of wet meadows to summering elk. Opening up the forest canopy by

clearcutting increased forage production and species diversity. Cattle use, concentrated on uncut and cut-through dry parks and wet meadows, removed from 64 to 88% of the available herbage on these types by October. Clearcutting did not appear to increase the amount of dry park habitat on the study area. This highly nutritious but limited quantity of forage on forested sites coupled with high energy provided by dry site grasses and sedges enabled elk to maintain a high-quality diet into early fall.

169. Hanley, Thomas A. 1982. Cervid activity patterns in relation to foraging constraints: western Washington. *Northwest Science* 56(3): 208-217.

Foraging group size and temporal-spatial patterns of activity by reproductive female Rocky Mountain elk and black-tailed deer were related to seasonal changes in forage availability and quality during May through October. Seasonal patterns of daily activity regimes indicated that food selection, consumption, and processing were the major factors constraining elk and deer habitat use. Both elk and deer reacted similarly to these constraints. Seasonal activity patterns and foraging group sizes indicated that searching effort increased as forage quality decreased, and that in September and October foraging emphasis shifted from individual plants to microhabitats where plant phenology was delayed relative to average conditions.

170. Hanley, Thomas A. 1983. Black-tailed deer, elk, and forest edge in a western Cascades watershed. *Journal of Wildlife Management* 47(1): 237-242.

Forest edge, particularly that created by clearcut logging, is believed to be of high value to mule deer and elk and has been recommended as a basis for planning "optimal" clearcut logging patch sizes. Conflicting results in studies of deer and elk habitat use relative to clearcut patch size, however, suggest relationships of a greater complexity than a simple function of distance from edge. Actual tests of the hypothesis that deer and elk prefer clearcut forest edges have been few; this study tests that hypothesis. Habitat use by four deer and four elk was monitored three times daily by radio telemetry. The data support the concept of an "edge effect," however, in the sense that habitats furthest into clearcuts or forest were used proportionately less than were habitats between these extremes. Neither deer nor elk, however, appeared to be reacting to clearcut forest edge. The results highlight the need for a better understanding of the resources that animals actually respond to in their choice of habitat.

171. Hanley, Thomas A. 1984. Habitat patches and their selection by wapiti and black-tailed deer in a coastal montane coniferous forest. *Journal of Applied Ecology* 21(2): 423-436.

Cervus elaphus and *Odocoileus hemionus* were studied during May to October in a partially logged Pacific silver fir forest on the west slope of the Cascade Range in Washington. Six major plant-community types were identified from multivariate analysis and floristic data, principally associated with soil moisture and stand age gradients. *Odocoileus hemionus* preferred xeric patches dominated by browse and forbs, whereas *C. elaphus* preferred mesic patches dominated by graminoids and forbs.

172. Hanley, Thomas A.; Bunnell, Fred L.; Starkey, Edward E. [and others]. 1984. Habitat relationships of Cervidae (deer) in old-growth forests. In: New forests for a changing world: Proceedings, 1983 Society of American Foresters; 1983 October 16-20; Portland, OR. [Bethesda, MD]: Society of American Foresters: 361-367.

Most species of North American deer have been considered to be associated with early successional stages of forest vegetation. Black-tailed deer, Roosevelt elk, and woodland caribou, however, sometimes exhibit habitat preferences for old-growth forest over young stands. The most important feature of old-growth forest for all three species is the combination of a productive, nutritious understory with a well-developed overstory capable of providing cover, intercepting snow, and producing arboreal lichens. Whether or not old-growth forest is a habitat requirement depends on many factors: characteristics of old-growth and alternative habitats, local climate, potential limiting factors for the populations, and desired levels of productivity. Silvicultural research is needed on manipulating second-growth stands to produce the characteristics of habitat naturally provided by old-growth forest.

173. Hanley, Thomas A.; Taber, Richard D. 1980. Selective plant species inhibition by elk and deer in three conifer communities in western Washington. *Forest Science* 26(1): 97-107.

Vegetation inside and outside four ungulate exclosures was compared in a western slope watershed of the Cascade Range, west-central Washington. One site was located in a flood-plain community dominated by mature red alder; another was in a recent Douglas-fir and western hemlock clearcut; and two were on an electrical power line right-of-way corridor. Age of the exclosures ranged from 4 to 8 years, and significant differences in species composition inside and outside were demonstrated at each. A similar pattern of vegetation response to elk and deer use was identified at all four sites. Shrubs were less abundant, and graminoids were much more abundant outside than inside exclosures. Stem densities of Douglas-fir regeneration were greater outside than inside exclosures. Plant species responses to elk and deer use were interpreted as the result of a plant-by-plant replacement process and an advantage incurred by trampling-resistant growth forms.

174. Hanley, Thomas Andrew. 1980. Nutritional constraints on food and habitat selection by sympatric ungulates. Seattle, WA: University of Washington. 185 p. Ph.D. dissertation.

This dissertation consists of two parts, one outlining and testing a food-selection model and the other extending the model to habitat selection. In the first part, principal hypotheses were (1) large ungulates are more limited by time than are small ungulates; (2) high rumino-reticular volume-to-body-weight ratio is an adaptation to exploiting thick cell walled, high cellulose diets (that is graminoids); (3) low rumino-reticular volume-to-body-weight ratio is an adaptation to exploiting thin but lignified cell walled diets (that is browse). The model was tested for five sympatric ungulates in northeastern California and northwestern Nevada. In the second part, habitat selection by female Rocky Mountain elk and Columbian black-tailed deer were studied in a partially logged *Abies amabilis* forest on the west slope of the

Cascade Range. Hypotheses were (1) graminoids would constitute a greater proportion of elk diets than deer diets, and browse would constitute a greater proportion of deer diets than elk; (2) elk would prefer habitat with greatest graminoid and forb availability, and deer would prefer greatest browse and forb availability. Observations and telemetry data showed that deer preferred xeric habitat patches, and elk preferred mesic habitat patches, which was consistent with hypothesis two. The results were consistent with expectations based on the food-selection model and support the validity of extending the food-selection model to a habitat-selection model.

175. Happe, Patricia J.; Jenkins, Kurt J.; Starkey, Edward E. [and others]. 1986. Preliminary nutritional comparisons of browse in clearcuts and old-growth forests, Olympic Peninsula, WA. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 275-277.

Browse nutritional quality in old growth and clearcuts on the Olympic Peninsula was compared. Species response to clearcutting was variable, but no consistent increase in nutritional quality in clearcuts was found.

176. Harestad, A.S.; Rochelle, James A.; Bunnell, Fred L. 1982. Old-growth forests and black-tailed deer on Vancouver Island. In: Sabol, Kenneth, ed. Transactions of the 47th North American wildlife and natural resources conference; 1982 March 26-31; Portland, OR. Washington, DC: Wildlife Management Institute: 343-352.

On northern Vancouver Island, black-tailed deer show modest increases when some types of old-growth forests are cut, but population declines may occur when old-growth forests used as winter range are cut. The different responses to forest harvesting derive from ecological differences between northern and southern regions. We propose a simple model of habitat selection based on tradeoffs between energy expended for locomotion and energy acquired from forage. The ecological relationships of black-tailed deer in a region of deep snowfall are summarized. By using these relationships and the model, we discuss the role of old-growth forests and forestry practices in the management of black-tailed deer in regions of deep snowfall.

177. Harestad, Alton S. 1984. Seasonal movements of black-tailed deer. In: Meehan, William R.; Merrell, Theodore R., Jr.; Hanley, Thomas A., eds. Fish and wildlife relationships in old-growth forests: Proceedings of a symposium; 1982 April 12-15; Juneau, AK. [Place of publication unknown]: American Institute of Fishery Research Biologists: 403-409.

Columbian black-tailed deer were radio-tagged in a deep snowfall region on northern Vancouver Island and monitored to determine seasonal movements and habitat use. A model of habitat selection is proposed in which seasonal movements occur by deer moving to more favorable habitats. Habitat selection, and thus seasonal movements, result from tradeoffs between energy obtained from available forage and energy expended for locomotion. Deer exhibited either resident or migratory movement patterns. Each seasonal movement pattern, although spatially different, resulted from habitat selection influenced by the same causal factors, availability and expenditure of energy.

178. Harestad, Alton S. 1985. Habitat use by black-tailed deer on northern Vancouver Island. *Journal of Wildlife Management* 49(4): 946-950.

In regions of deep snowfall, winter ranges are frequently old-growth forests in which logging is believed to be detrimental to black-tailed deer. This study examines habitat use by black-tailed deer during various weather conditions and seasons. Some old-growth forests were heavily used by deer and provided digestible dry matter densities that exceeded those of young seral stages. Other types of old-growth forest provided little forage and had little deer use. Findings reported will allow development of forest harvesting prescriptions more beneficial to black-tailed deer in deep snowfall regions.

179. Harestad, Alton S.; Bunnell, Fred L. 1983. Dispersal of a yearling male black-tailed deer. *Northwest Science* 57(1): 45-48.

A male black-tailed deer inhabited a home range of 11.1 ha during May and June while 10 to 11 months old. In late June, near its first birthday, it dispersed 16.8 km in 8 days to occupy a new home range of 8.7 ha in similar habitat. Its movements were nonrandom and highly directional.

180. Harestad, Alton Sidney. 1979. Seasonal movements of black-tailed deer on northern Vancouver Island. Vancouver, BC: University of British Columbia. Ph.D. dissertation.

Columbian black-tailed deer were radio-tagged in a deep snowfall region on northern Vancouver Island, British Columbia. These deer were monitored to determine seasonal movements and habitat use. Deer exhibited either resident or migratory movement patterns. Resident deer made seasonal shifts in their home range centers, but their seasonal home ranges overlapped. In migratory deer, summer home ranges were separated from both spring and winter home ranges, although their spring and winter home ranges overlapped. Altitudinal migrations occurred by deer moving between high and low elevation habitats. Horizontal migrations occurred by deer moving between a small tributary valley and the main valley. Seasonal movements of black-tailed deer result from habitat selection by deer seasonally moving to more favorable habitats as determined by more available energy and nutrients and lower risk of predation. The causal differences between vertical and horizontal migrations as well as seasonal shifts in home range centers can be resolved by a model of habitat selection based on these factors. An abundance of deer food in high-elevation habitats suggests that forest harvesting in high elevations will not affect deer populations if their other habitat requirements are met. In areas where forested summer ranges already exist, low-elevation logging will provide deer with sources of food closer to their winter ranges. Use of these food sources may result in a redistribution and not an increase in the population. Habitat management must include provision of mild winter range and severe winter range.

181. Harn, Joseph H. 1961. Natality and mortality of Roosevelt elk in northern California. In: Proceedings of the 40th annual conference of the Western Association of State Game and Fish Commissioners; 1960 June 20-22; Salt Lake City, UT. [Place of publication unknown]: [Publisher unknown]: 220-223.

This study was conducted in northern California from 1956 to 1958. Calf production and mortality was investigated. A high ratio of calves to cows was produced during the 1957 and 1958 calving seasons. Calf mortality was high during both years. Malnutrition and poaching were the two most important factors in elk loss. Of 107 known elk deaths, malnutrition accounted for 19.6%, and illegal kill accounted for 17.8% of the total. Mature females were affected most by all factors combined with calves, and mature males also were highly affected. Habitat improvement and reduction of elk on overstocked areas are essential measures needed to insure the perpetuation of a healthy elk population in northern California.

182. Harn, Joseph Harry. 1958. The Roosevelt elk, *Cervus canadensis roosevelti* (Merriam), at Prairie Creek Redwoods State Park, Humboldt County, California. Arcata, CA: Humboldt State College. 99 p. M.S. thesis.

The ecology, social behavior, distribution, and abundance of the Roosevelt elk was investigated in Humboldt and Del Norte Counties, California, during 1956 through 1958. The population density of elk ranged between 24 and 32 animals per square mile at the Prairie Creek study area. Poaching is the major factor in elk mortality. Calves were the most severely affected age class when total mortality is considered. Natality was high in 1957 with 0.93 calves per cow on the study area. Eight of the calves succumbed to unknown causes. The elk in the study area form groups. Three distinct group types were noted; the family group of a cow and her offspring; the cow group, which consists of many family groups; and the bull group, consisting mainly of bulls 2 years old and older. The elk are nonmigratory and occupy relatively small areas throughout the year. Males use a larger area than do cow groups. The movements of the group are somewhat geared to the abundance of food. The rutting season causes a change in group movement patterns. Mature bulls searching for cows may move over 2 miles in one day. Groups may move out of their normal activity range during times of food shortage. Evidence shows there is some exchange between adjacent groups. Grasses, forbs, and ferns are the most important forage plants for elk. Shrubs are used during fall and winter in certain areas. Man and domestic animals compete with elk for habitat. Logging practices may improve elk habitat. Management of elk should include further investigations on habitat improvement and population dynamics.

183. Harper, James A. 1962. Daytime feeding habits of Roosevelt elk on Boyes Prairie, California. *Journal of Wildlife Management* 26(1): 97-100.

The study was undertaken to identify the forage plants used by the Roosevelt elk in northwestern California and to determine the seasonal variation of plants consumed. Orchard grass (*Dactylis glomerata*), sweet vernal grass (*Anthranthum odoratum*), and redtop (*Agrostis alba*) were the leading forage species recorded. In general, grasses dominated the herd's diet with browse plants second and forbs third in importance. Species were not necessarily consumed in relation to their availability in the plant cover.

184. Harper, James A. 1964. Movement and associated behavior of Roosevelt elk in southwestern Oregon. In: Proceedings of the 44th annual conference of Western Association of State Game and Fish Commissioners; 1964 July 6-8; San Francisco, CA: 139-141.

In April 1963, a cooperative agreement was established between the Oregon State Game Commission and the Weyerhaeuser Timber Company to study the Roosevelt elk herds in the Millicoma forest of southwestern Oregon. Primary factors to be determined in the study were movements and behavior of individual animals and herds, population numbers, reproduction, and elk use related to date of logging and treatment of logging debris. Results from February 1963 through May 1964 have shown that the movement of elk is affected by food availability, topography, and weather. The movements vary from the daily wandering of feeding animals through the interchange of animals between herds, to the far-reaching wanderings of bulls in the fall and spring months. Sixty-three percent of the observations of tagged animals were recorded less than 1 mile from the point of tagging. Only 1% of these animals have moved more than 5 miles.

185. Harper, James A. 1966. Ecological study of Roosevelt elk. Game Res. Rep. 1. Portland, OR: Oregon State Game Commission, Research Division. 29 p.

In January 1963, a cooperative agreement was established between the Oregon Game Commission and the Weyerhaeuser Company to study Roosevelt elk herds on the Millicoma Tree Farm in Coos and Douglas Counties in southwestern Oregon. This publication reports on the research conducted from January 1963 through May 1966. During this period, 478 elk were immobilized and tagged. Home range information was obtained by recording daily observations of tagged animals. Elk use of logged areas was studied in burned and unburned units. Elk use increased gradually after the timber was removed, reaching a peak 5 to 7 years after logging. On the unburned areas, the 5-year-old logged units were used most extensively by feeding elk during all 3 years of the study. The data comparing elk use on burned versus unburned areas strongly indicated that burning extends the period that an area produces elk forage. In areas that were not burned, the shrub species grew rapidly and were soon out of reach of feeding animals and also shaded or crowded out more desirable forage species. A preliminary food-habit investigation revealed that grasses, trailing blackberry, and false dandelion were the leading food items consumed. By plotting the feeding activities of elk in relation to the direction of slope on which they were feeding, it was apparent that the season of the year, and its accompanying weather, largely governed which slope was used. Population level was estimated by two different techniques.

186. Harper, James A. [and others]. 1987. Ecology and management of Roosevelt elk in Oregon. [Portland]: Oregon Department of Fish and Wildlife. 70 p.

Updates the 1971 publication "Ecology of Roosevelt Elk" in accord with changes that have occurred from timber harvesting in western Oregon. Reviews population, movement, reproduction, diseases, hunting, forage usage, and enhancement, damage control, use of logged timberland, and management recommendations.

187. Harper, James A.; Harn, Joseph H.; Bentley, Wallace W. [and others]. 1967. The status and ecology of the Roosevelt elk in California. Wildl. Monogr. 16. Washington, DC: The Wildlife Society. 49 p.

The report summarizes the findings of over 4 years research on Roosevelt elk at Prairie Creek, Redwoods State Park. Distribution, physical characteristics, food habits, reproduction, natality, mortality, and general behavior are described.

188. Harper, James A.; Swanson, Donald O. 1970. The use of logged timberland by Roosevelt elk in southwestern Oregon. In: Proceedings of the 50th annual conference of Western Association of State Game and Fish Commissioners; 1970 July 13-16; Victoria, BC. [Place of publication unknown]: [Publisher unknown]: 318-341.

A cooperative study was initiated in January 1963 to investigate Roosevelt elk and their use of logged timberland. Factors considered included age of logged units, treatment of logging debris, type of logging activity, plant community, distance from standing timber, aspect, gradient, and distance from water. Elk use of logged units reaches a peak 6 to 8 years after timber removal. Burning of logging debris and heavy soil disturbance at time of logging extend forage production and animal use. Elk use in relation to a plant community is in direct proportion to the amount of forage produced by that community. Burning of logging debris as well as soil disturbance could increase elk forage production in plant communities that normally produce low amounts of forage. Logged units adjacent to standing timber received heavy use which decreases as the distance from timber increases. Of 1,233 acres receiving use sufficient to retard Douglas-fir reproduction, 95% were adjacent to standing timber. On six study units totaling 452 acres, elk use was reduced by 55% through the removal of adjacent timber stands. Elk use in relation to aspect was governed by vegetative changes brought about by seasonal changes in weather. In the winter, use was lightest on the north slopes, moderate on east and south slopes, and heaviest on the west. During summer months, north slopes were used the heaviest, followed by east and west slopes. In respect to slope gradient, little difference was noted in areas used by elk until steepness exceeded 80%.

189. Harper, James Albert. 1961. Food habits and life history observations of the Roosevelt elk at Prairie Creek Redwoods State Park, Humboldt County, California. Arcata, CA: Humboldt State College. 90 p. M.S. thesis.

Grasses and slough sedge combined were the leading species occurring in 4,795 minutes of food-habit observations. Browse plants were second and forbs were third in importance. Orchard grass and sweet vernal grass were the major grasses used while salmonberry and trailing blackberry were the dominant browse plants in the diet. The leading forbs were narrow-leaved plantain and hairy cats ear. Social behavior during rutting season and reproduction activity was also observed and reported.

190. Harshman, Edmund P. 1986. Habitat production index. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 145-148.

The Habitat Production Index (HPI) is a method of evaluating the productivity of deer and elk habitat and is based on the concept of maximizing energy intake and minimizing energy use by deer and elk; in other words, adequate forage is available next to adequate cover. The evaluation is based on the effect of human activity (that is, logging, recreation) on the amount of "HPI forage acres" available and on the amount of forage used.

191. Hash, Howard S. 1973. Movements and food habits of the Lochsa elk. Moscow, ID: University of Idaho. 76 p. M.S. thesis.

This investigation was directed toward two objectives: to further delineate movement and migration patterns of the Lochsa elk herds and to describe the seasonal food habits of this population. Four types of general migration patterns were described in relation to distance and direction traveled from the winter ranges. Widespread variability was observed in the migrations of individual animals regarding onset dates, duration, direction, and distance. To investigate the seasonal food habits of the population, 139 rumen samples were analyzed and 143 feeding sites examined. Browse; graminoids; forbs, lichens, and mushrooms contribute 64, 25, and 10%, respectively, to the total annual forage intake. The winter diet consisted of approximately 90% woody browse composed of shrub and conifer terminal growth. The spring forage was composed of approximately 43% browse, 45% grasses and grasslike plants, and 12% forbs, lichens, and mushrooms. Grass use was most extensive during the midspring. The summer forage intake contained 40% browse, 39% grasses and grasslike plants, and 21% forbs. The summer browse consisted primarily of new branch growth and flowering parts of the plants. The fall forage was about 55% browse, 14% grasses, and 30% forbs, lichens, and mushrooms. The use of coniferous browse became minor during early spring and was not used significantly until late fall. During abnormally deep snow conditions, conifer and coarse browse consumption was significantly higher while grass and the forb group were taken in minor amounts. Small amounts of arboreal lichens were ingested during the winter months. Considerable variability of forage preference was noted among individual animals.

192. Hayden-Wing, Larry D. 1979. Distribution of deer, elk, and moose on a winter range in south-eastern Idaho. In: Boyce, Mark S.; Hayden-Wing, Larry D., eds. North American elk: ecology, behavior and management: Proceedings of a symposium; 1978 April 3-5; Laramie, WY. Laramie, WY: University of Wyoming: 122-131.

The distribution of mule deer, Rocky Mountain elk, and Yellowstone moose was studied on a winter range of stabilized dune sand in Fremont County, Idaho, during the winter of 1961-62. Both visual observations and pellet group counts indicated very little overlap in the areas used by these three species. Deep snow evidently restricted deer distribution to the few south-facing slopes on the area. The available

browse on these slopes reflected the cumulative impact of years of intensive winter deer concentrations and was less vigorous than elsewhere. Elk distribution appeared to be influenced primarily by human activities and secondarily by snow depths and vigor of browse. Within those portions of the winter range farthest removed from human activities, elk concentrated on areas of moderate snow depth where good browse forage was available. The distribution of moose was affected most by the vigor and distribution of chokecherry on the range.

193. Hayden-Wing, Larry D. 1979. Elk use of mountain meadows in the Idaho Primitive Area. In: Boyce, Mark S.; Hayden-Wing, Larry D., eds. North American elk: ecology, behavior and management: Proceedings of a symposium; 1978 April 3-5; Laramie, WY. Laramie, WY: University of Wyoming: 40-46.

Elk usage of forage on five mountain meadows in the Payette National Forest was studied during the summers of 1966, 1967, and 1968. Average amounts of forage removed were calculated by comparing the air-dried weights of clipped vegetation from caged and open 4- by 4-foot plots, and varied between meadows from 62 to 680 pounds per acre. Approximately 70% of all forage removed by elk came from the moist cover type, 26% from the dry, and 4% from the wet. Systematic visual observations showed that the hourly frequency of occurrence of elk on the meadows between the hours of 5 a.m. and 11 p.m. was highest during mid-June, when observations commenced, dropped rapidly during the summer, and were nearly zero by late August. Throughout the summer, the frequency of occurrence of elk activity was highest from 5 p.m. to 11 p.m., lowest from 11 a.m. to 5 p.m., and intermediate from 5 a.m. to 11 a.m. The incidence of elk usage of plant species was recorded on 1- by 4-foot plots along randomly located transects. Forbs were the most frequently used plants, sedges second, grasses third, and shrubs least. The most frequent use of sedges occurred early in the summer, and both grasses and forbs were most frequently used during July. Forb usage was most frequent near the full bloom period of the respective species, but most grass use occurred well in advance of blooming.

194. Helwig, Lawrence L. 1957. The value of conifers as a winter feed for elk (*Cervus canadensis nelsoni*) determined under controlled conditions. Bozeman, MT: Montana State University. 79 p. M.S. thesis.

During winter 1955-56, a controlled elk feeding study was undertaken to obtain information on conifer browse consumption by elk. The main objectives were to secure consumption rates, obtain weight responses, and learn the calving success of elk on diets containing Douglas-fir and lodgepole pine. Healthy female elk between the ages of 3 and 7 were exposed to diets of varying proportions of Douglas-fir and lodgepole pine and two control diets of meadow hay and deciduous browse. One of the control diets was made up of 100% meadow hay and the other of willow and serviceberry. The diets were used on paired animals unless otherwise indicated. The meadow hay percentage in each diet was based on the percentage of an estimated maintenance diet of 2.2 pounds of meadow hay per 100 pounds of body weight. This estimate was based on studies on elk in previous years conducted at these same

pens. All the browse species were presented ad libitum. Elk fed 100% meadow hay and 66% meadow hay, 33% conifers maintained their weights at about the same level. Elk fed 100% conifers or 100% deciduous browse lost from 50 to 100 pounds per animal. Immediately after the specific feeding trials, the animals were presented the feeds on a free-choice basis; meadow hay was the preferred food. Lodgepole pine was the preferred browse species, followed closely by willow. Douglas-fir and serviceberry were used the least of all the feeds.

195. Hershey, Terry J.; Leege, Thomas A. 1976. Influences of logging on elk on summer range in north-central Idaho. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 73-80.

A study of elk distribution, movements, and habitat selection with respect to clearcuts, roads, and human disturbance was conducted on summer range in north-central Idaho in 1974 and 1975. Clearcuts received the greatest use by elk in July and November and the least in October. Elk did not show preference for clearcuts during daylight hours in any month. Clearcuts less than 10 years old were used in proportion to availability, but cuts older than 10 years were avoided. Elk preferred to use clearcuts larger than 200 acres. Eighty percent of all elk observed in clearcuts were within 50 yards of a timbered edge. Elk avoided using areas within 1/4 mile of primary and secondary roads and showed a high preference for areas farther than 1/4 mile from a road. Opening of the general elk season did not influence elk distribution nor did elk move away from low intensity, short-term logging disturbance.

196. Hershey, Terry J.; Leege, Thomas A. 1982. Elk movements and habitat use on a managed forest in north-central Idaho. Wildl. Bull. 10. Boise, ID: Idaho Department of Fish and Game. 24 p.

Seasonal elk movements, distribution, and habitat preferences were investigated on a managed forest in north-central Idaho from June 1974 through August 1977. Elk summering in Newsome and Leggett Creek drainages were migratory animals from at least four distinct winter ranges. Distances between winter and summer ranges varied from 6 to 33 km. Elk that frequently were associated together on summer and winter ranges migrated along the same routes but not in the same groups nor at the same time. During spring migration, bulls showed highly erratic and rapid movements over long distances. Cow movements, although just as abrupt and swift, were restricted to traditional migration routes. Fidelity of elk to summer and winter areas of former use was strong for cows and weak for bulls. Old-growth grand fir were important habitat features during late summer and early fall. Clearcuts received greatest use in spring, early summer, and late fall. When using clearcuts, elk selected areas where slash was removed by broadcast burning and areas within 92 m of timber. Disturbance from human activity was an important factor influencing elk distribution. Displacement occurred from hunting, logging, and motor vehicles; degree of displacement appeared to be related to proximity, intensity, and duration of disturbance.

197. Hett, Joan; Taber, Richard; Long, James; Schoen, John. 1978. Forest management policies and elk summer carrying capacity in the *Abies amabilis* forest, western Washington. *Environmental Management* 2(6): 561-566.

Recognized successional sequences and other cover types were used to construct a computer simulation of the Cedar River catchment area. Information on the use and selection of community types by the resident elk herd was incorporated into the simulation and used to predict elk numbers resulting from different forest management policies. Cessation of timber harvesting led to a decline in numbers due to a reduction of summer habitats; a constant harvesting rate gave no change in elk numbers; and felling all old-growth trees during the first 10 years, with no further harvesting, resulted in an initial increase in numbers followed by a sharp decrease within 50 years.

198. Hill, Ralph R. 1956. Forage, food habits, and range management of the mule deer. In: Taylor, Walter P., ed. *The deer of North America*. Harrisburg, PA: Stackpole Company and Washington, DC: Wildlife Management Institute: 391-414.

Discusses food mule deer need by seasons, the role of protein and other nutritional requirements, and why deer become poor in winter. Different types of mule deer range are outlined, and ways and means of management whereby the range as well as the deer can be improved are stated.

199. Hines, William W. 1973. Black-tailed deer populations and Douglas-fir reforestation in the Tillamook burn, Oregon. *Game Res. Rep. 3*. Corvallis, OR: Research Division, Oregon State Game Commission. 59 p.

The investigation was undertaken to study ecological relationships between black-tailed deer in the 350,000-acre Tillamook burn of northwestern Oregon and the Douglas-fir plantations established to reforest the area. Concern over the effects of widespread browsing by deer prompted the study. Data were collected from July 1958 through May 1970. Deer showed a preference for the vine maple/swordfern community at all seasons of the year. When the enclosure contained a high density of deer in winter, animals used the less-preferred forage rather than moving to other vegetation types at higher elevations. The primary influence regulating use on Douglas-fir was the quantity of more palatable forage available in relation to the number of deer present. Management recommendations are made for ways to maximize reforestation success.

200. Hines, William W. 1975. Black-tailed deer behavior and population dynamics in the Tillamook Burn, Oregon. *Wildl. Res. Rep. 5*. Corvallis, OR: Oregon Wildlife Commission. 31 p.

The Cedar Creek study was initiated to determine ways of reducing the levels and effects of browsing by black-tailed deer on Douglas-fir plantations. The study area was in the 350,000-acre Tillamook burn, and data were collected from July 1958 through May 1970. This report discusses behavior and population dynamics of deer in the study area.

201. Hines, William W.; Lemos, James C. 1979. Reproductive performance by two age-classes of male Roosevelt elk in southwestern Oregon. Wildl. Res. Rep. 8. Portland, OR: Oregon Department of Fish and Wildlife. 54 p.

Reproductive performance of a Roosevelt elk herd inhabiting a 462-acre elk enclosure in southwestern Oregon was monitored for 9 years, 1967 through 1975. Primary emphasis was given to documenting calf production when conception was totally dependent on yearling bull service as compared to when older bulls were used. There was a relationship between herd calving success and the age of male breeders. Success was highest when 2- and 3-year-old bulls served cows. Calf production was lower when complete dependence was placed on yearling male breeders. The collective influence of weather, forage availability, and recent reproductive history did not mask the consistent relationship between calving success and bull age. Calves were born later when complete dependence was placed on yearling male breeders. Estrus in the female began before most yearling bulls reached puberty. This delay would explain the lag in calf production when only yearling males were used as herd sires.

202. Hines, William W.; Lemos, James C.; Hartmann, Norbert A., Jr. 1985. Male breeding efficiency in Roosevelt elk of southwestern Oregon. Wildl. Res. Rep. 15. Portland, OR: Oregon Department of Fish and Wildlife. 25 p.

Breeding performance tests of two age classes of male Roosevelt elk with a 477-acre enclosure indicated that calf production was reduced and average birth date delayed when all breeding was by yearling males. Low posthunting season bull:cow ratios near the enclosure prompted the current study of male breeding efficiency in free-ranging populations. Management practices assume that a total harvest of antlered bulls is permissible since in Oregon, breeding precedes harvest and male calves at heel at the time of harvest can function as efficient breeders the next year. We tested this rationale in free-ranging herds by using pregnancy rates and projections of parturition dates to assess breeding efficiency. Yearling bulls frequently reach puberty after the onset of estrus in cows and rutting activities by older bulls. This could result in relatively late-born calves being characteristics of yearling bull matings. Older bulls are needed to serve cows when estrus first occurs. Delays in conception could result in reduced herd productivity by suppressing calf growth and survival, subsequent cow fertility, and increasing age of puberty in both sexes. Millicoma studies indicate that the optimum level of breeding support is greater than two and not more than 10 two-year and older bulls per 100 cows. It is recommended that the breeding ratio for free-ranging herds include 6 of these older bulls per 100 cows.

203. Irwin, Larry L. 1976. Effects of intensive silviculture on big game forage resources in northern Idaho. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 135-142.

A study of forb and shrub production after various silvicultural treatments in three habitat types of the cedar-hemlock zone of northern Idaho indicated broadcast-burned

clearcuts produced the most coverage of herbs and shrubs. Stands treated by the shelterwood method produced nearly as much herbaceous cover as clearcuts. No significant differences in composition were noted among the three types, but clearcuts in each type produced the most available and palatable twigs for big game, and partial cuts produced the least. Clearcuts produced an average of five times more shrub biomass than shelterwood cuts, selective cuts, and thinnings, but all treatments appeared capable of producing more shrubs than a 100-year-old uncut stand.

204. Irwin, Larry L.; Peek, James M. 1979. Relationship between road closures and elk behavior in northern Idaho. In: Boyce, Mark S.; Hayden-Wing, Larry D., eds. North American elk: ecology, behavior and management: Proceedings of a symposium; 1978 April 3-5; Laramie, WY. Laramie, WY: University of Wyoming: 199-204.

From 1975 through 1977, a radio-tracking study of elk-habitat use patterns in relation to forest management, hunters, and roads was conducted in western hemlock and grand fir forest in northern Idaho. Vehicular access was unrestricted in 1975 and prohibited from September 1 to November 1 in a 40-square-km area in 1976 and a 75-square-km area in 1977. Although six of the nine radio-collared elk were harvested during the 3 years, it was undetermined whether or not hunting success changed because of the road closures. General areas of use and habitat selection by elk within those areas during the hunting season appeared to be governed primarily by previous traditions and social behavior associated with the rut. During each season, hunters displaced elk from preferred areas to areas of similar but more extensive habitat. Road closures allowed elk to remain longer within preferred areas.

205. Irwin, Larry L.; Peek, James M. 1983. Elk habitat use relative to forest succession in Idaho. *Journal of Wildlife Management* 47(3): 664-672.

Home range use and habitat selection by a nonmigratory elk herd in relation to forest succession in the cedar-hemlock zone of northern Idaho were studied through use of radiotelemetry. In spring, elk preferred grass-shrub and seral shrub successional stages for feeding and tall seral brushfields or pole timber stands for resting. Elk fed in clearcuts and seral shrub communities in summer and rested primarily within pole timber stands on ridges. In autumn, elk shifted to pole timber communities on mesic slopes. No significant selection patterns occurred on winter range. Elk preferred to rest in areas over 400 m from traveled roads in all seasons. Home ranges contained more foraging area (35% vs. 20%) and less thermal and hiding cover (64% vs. 79%) than present in the study area overall. Selection of home ranges was related to forage production in seral stages of succession. Cover and human disturbance were important in habitat use in autumn.

206. Irwin, Larry Lynn. 1978. Relationships between intensive timber culture, big game habitats, and elk habitat use patterns in northern Idaho. Moscow, ID: University of Idaho. 300 p. Ph.D. dissertation.

Habitat use and forage-use patterns of elk were studied in western hemlock and grand fir habitat types, 1975-77. Successional stages included clearcuts, grass-shrub types, brushfields, poletimber, mature timber, and old growth. Clearcuts and

brushfields created by wildfires produced the most forb biomass and shrub cover, respectively. Elk exhibited distinct habitat preferences between seasons and daily periods. They preferred different foods while feeding in areas with different successional stages. In spring, elk preferred south slopes where large quantities of early growing forage were available. The most important forage species were bluebunch wheatgrass (*Agropyron spicatum*), elk sedge (*Carex geyeri*), and butterweeds (*Senecio* spp.). In summer, elk preferred the grand fir habitat type and shrub fields during the morning and evening activity periods. Clearcuts were used in proportion to their availability during active periods but were selected against during resting periods. Forage plants in clearcuts were highly variable, but fireweed (*Epilobium angustifolium*) made up nearly 1/3 of the diet. During fall, there was less variation in habitat use patterns. Areas within the pole stage of the western hemlock habitat type were preferred, as were areas adjacent to water but greater than 400 m from traveled roads. *Pachistima myrsinites* and *Coptis occidentalis* were the most valuable forage species in fall. In winter, elk were restricted by deep snow to a west-facing slope dominated by decadent shrubs interspersed with a few timber stands. *Salix scouleriana* was the dominant food item.

207. Janz, D.W. 1980. Preliminary observations on seasonal movements and habitat use by Vancouver Island Roosevelt elk. In: Macgregor, W., ed. Proceedings of the Western States elk workshop; 1980 February 27-28; Cranbrook, BC. [Victoria, BC]: British Columbia Ministry of Environment, Fish and Wildlife Branch: 115-142.

The purpose of this paper is to report on some aspects of field studies on Roosevelt elk initiated by the British Columbia Fish and Wildlife Branch in 1975-76. Objectives of the project were (1) to monitor seasonal movements and habitat use; (2) to obtain quantified information on the determinants of seasonal movement and habitat use; (3) to obtain indices of animal condition; and (4) to relate animal and range condition to animal productivity. Radio telemetry is being used to monitor individual animal movements and habitat use. The present interpretation is preliminary, and only specific components are presented to illustrate some observations that appear consistent and important to management. The use of forage and cover types during the winter period demonstrates the importance of habitat diversity and interspersion. While logging does provide important winter forage areas, the availability of security and escape cover in the form of coniferous regeneration and mature timber is an important factor influencing the use of forage sites. During periods of deep snow, mature forests allow greater mobility due to decreased snow depths and provide forage in the form of litterfall and understory browse. The ability of second-growth stands to provide similar forage characteristics, especially under 60- to 90-year rotations, appears low. The limited distribution of important wet habitat types implies stringent protective measures are needed.

208. Janz, D.W.; Becker, D.Q. 1986. Vancouver Island elk—animal and use characteristics. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 279-305.

Information related to population dynamics and habitat use of Roosevelt elk on Vancouver Island is reviewed. Pregnancy rates of 85.5% were estimated for cows 2.5 years old and older. Annual calf mortality rates range from 0.46 to 0.85 for the

herds under study. Adult mortality rates were estimated at 0.082 for 2- to 10-year-old cows, and 0.201 for cows older than 10 years. Corresponding rates for bulls were 0.110 and 0.219, respectively. Late winter calf:cow ratios over the past decade were significantly related to winter severity. Wolf predation is another important source of natural mortality. During mild winter conditions, major causes of adult mortality are human harvest. Current harvest regulations, designed to provide a quality hunt experience by limiting the number of hunters on a herd-unit basis, are considered to be conservative. Movement and habitat-use relationships have been investigated in two study areas with differing logging histories (old-growth/early seral versus second-growth forests). Seasonal range and individual home range sizes were related to the abundance and distribution of important resources, primarily forage and adjacent cover. Estimates of diet quality indicated that levels of digestible energy over winter were substantially below maintenance requirements. Habitat relationships are being incorporated into habitat suitability models and management handbooks to evaluate the relative impacts of forest development on elk habitat.

209. Jenkins, Kurt J.; Starkey, Edward E. 1984. Habitat use by Roosevelt elk in unmanaged forests of the Hoh Valley, Washington. *Journal of Wildlife Management* 48(2): 642-646.

Little is known of primeval distribution patterns of Roosevelt elk. Now they inhabit primarily forested uplands which are managed for timber production, and additionally, they are hunted throughout most of the range. The exception is in Olympic National Park where a major population of unharvested Roosevelt elk exists in unharvested forest. The objective of the study was to describe habitat use by Roosevelt elk in an unmanaged riverine ecosystem with a significant old-growth component. Nine elk were radio-collared and monitored for three seasons: summer (June-September); winter (January-February); and late winter (March). Six vegetation types were mapped and relative availabilities of each were determined. Vegetation types were used in disproportion to availability. Vegetation types on the valley floor were selected as a group over the upland western hemlock type. Selection of flood-plain vegetation types was similar in summer and winter seasons when hardwood stands of red alder and bigleaf maple and the coniferous spruce-hemlock were favored. Use of the western hemlock vegetation was greatest in winter and on south-facing slopes, apparently in response to lower snow depths and thermal advantages. In late winter, occupancy of side slopes decreased markedly, whereas red alder and spruce/ cottonwood types received peak use. In synchrony with this concentration of elk, grasses and forbs in hardwood stands initiated new spring growth. Our findings support the hypothesis that primevally, elk in coastal temperate forests were most abundant in flood plains, deltas, beaver meadows, and other areas of fluvial activity.

210. Jenkins, Kurt Jeffrey. 1979. Home range and habitat use by Roosevelt elk in the Olympic National Park, Washington. Corvallis, OR: Oregon State University. 94 p. M.S. thesis.

This research provides information on the distribution of an unexploited Roosevelt elk population in unaltered habitat. Radiotelemetry was used to document home range and habitat use by 11 adult cow elk in the Hoh Valley in portions of 1978 and 1979. That information provides a baseline for comparison with managed herds adjacent to

the park and identification of long-term changes in the distribution of elk in the Hoh Valley. Four groups of cow elk were identified in the study area. Cow groups were stable; elk within a group used a common home range and were highly associated. Home ranges of elk from adjacent groups overlapped, but there was no permanent interchange of collared elk between groups during the study. There was no significant difference between mean summer and mean winter home range size; however, summer home range was larger than winter home range in five of seven comparisons. Average home range area of collared elk was 1,034 ha during summer and 1,003 ha during winter. Daily movement of elk was greater during summer than during winter; minimum daily movement distance averaged 843 m during summer and 676 m during winter. Movement of cow elk with newly born calves in June was considerably less than movement of elk without calves. Collared elk were found primarily in the valley floor during both seasons. Alder flats were selected by each collared elk during late winter and were identified as important elk habitat because use of such areas was prevalent during a nutritionally important time of year for cow elk. Other patterns of habitat use were discussed in relation to thermal and nutritional characteristics of the watershed.

211. Jenkins, Kurt Jeffrey. 1985. Winter habitat and niche relationships of sympatric cervids along the north fork of the Flathead River, Montana. Moscow, ID: University of Idaho. 199 p. Ph.D. dissertation.

Winter habitat and niche relationships were evaluated for white-tailed deer, elk, and moose. Deer selected habitats with the shallowest snow, primarily late-seral coniferous forests. Elk selected lodgepole savannahs and late-seral forests during a harsh winter and open vegetation types during a mild winter. Mature coniferous forests were important winter habitats whenever snow depths exceeded species-specific thresholds. Dietary characteristics were determined from fecal analyses. Deer consumed the greatest amount of low evergreen subshrubs, whereas elk and moose consumed the most grasses and deciduous shrubs, respectively. Conifers were dietary staples for deer and elk during both winters. Dietary crude protein was marginally adequate for winter maintenance of cervids, but digestible energy was inadequate, especially during a harsh winter. Potential energetic constraints were assessed by comparing energetic attributes of habitats based on the availability and quality of deciduous browse and the energy costs of cervid foraging. It was concluded that (1) deer selected habitats where forage quality appeared to be greatest and where digestive constraints on energy balance were minimized; (2) moose selected habitats where forage quantity was highest and where the temporal constraints on energy acquisition was minimized; and (3) digestive and temporal constraints on energy acquisition in elk were intermediate to those in deer and moose. High degree of spatial, habitat, and dietary overlap occurred between the species, which may promote interspecific competition during harsh winters.

212. Jones, Greg. 1974. Influence of forest development on black-tailed deer winter range on Vancouver Island. In: Black, Hugh C., ed. *Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium*; 1973 September 11-12; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 139-148.

Discusses the response of deer in winter to various types of logged and unlogged habitats on northern Vancouver Island. Habitat selection by deer was monitored

during a severe and a mild winter. In both winters, deer use of unlogged, mature timber habitats was higher than use of logged habitats. In the severe winter, substantial deer use of mature timber was a result of shallow snow. In the mild winter, high deer use of certain habitat types in mature timber was probably a function of the density of the shrub cover. In the mild winter, deer use of logged habitats was low in January and increased linearly through April. Deep snow severely restricted deer use of logged habitats during the severe winter. Under conditions of deep snow, deer require mature timber as shelter. In mild winters, deer prefer habitats with the best food supply, usually mature timber habitats with open crown cover.

213. Jones, Greg W.; Bunnell, Fred L. 1984. Response of black-tailed deer to winters of different severity on northern Vancouver Island. In: Meehan, William R.; Merrell, Theodore, R., Jr.; Hanley, Thomas A., eds. Fish and wildlife relationships in old-growth forests: Proceedings of a symposium; 1982 April 12-15; Juneau, AK. [Place of publication unknown]: American Institute of Fishery Research Biologists: 385-390.

In the mountainous interior of Vancouver Island, British Columbia, snow was the greatest single factor influencing habitat selection by black-tailed deer in winter. The tree canopy of old-growth forests intercepted falling snow, and consequently snow was much shallower than in adjacent logged habitats. The deep, soft snow in cutover areas prevented deer movement and restricted deer to old-growth winter ranges during a severe winter. Deer were more widely distributed in a mild winter having less snow. The severe winter-restricted diets worsened the condition of the deer, caused mortality, reduced juvenile recruitment, and reduced production of fawns the following summer. Identification of the necessity of old growth as winter habitat resulted in efforts to protect important winter ranges from logging in watersheds having periodic severe winters.

214. Jones, Gregory William. 1975. Aspects of the winter ecology of black-tailed deer (*Odocoileus hemionus columbianus* Richardson) on northern Vancouver Island. Vancouver, BC: University of British Columbia. 78 p. M.S. thesis.

Black-tailed deer were studied in the Nimpkish Valley on northern Vancouver Island to determine the effects of clearcut logging upon the ecology of the deer in winter. The study was done during the winters of 1971-72 and 1972-73. The first winter was severe and had heavy snowfall, and the second winter was mild and had light snowfall. If deer sink deeper in snow than their chest height, they have a hard time moving. Fawns have chest heights of about 17 inches and adults from 22 to 23 inches. During the first winter, snow in the logged habitats averaged 4 feet deep, but in mature timber habitats snow averages less than 2 feet. During the severe winter, only mature timber habitats, at low elevations with crown closures greater than 65% were used heavily by deer. Deer also used mature timber habitats heavily during the mild winter. Deer made more use of timber habitats having a shrub understory than those having a conifer understory, probably because there was more food available in the former. Generally, deer made light use of the logged habitats during both winters, but they used them heavily in the spring. Most other studies of black-tailed deer have concluded that logging is beneficial to deer. However, continued clearcut logging in the regions of Vancouver Island having high snowfall will eliminate deer winter range and

reduce deer populations. It is recommended that logging companies leave strips of mature timber, going from the subalpine to the valley bottom, and including winter range habitats, in all those areas where deer populations are desired.

215. Jordan, Jack W.; Vohs, Paul A., Jr. 1976. Natality of black-tailed deer in McDonald State Forest, Oregon. *Northwest Science* 50(2): 108-113.

Natality of black-tailed deer in McDonald State Forest was evaluated by examination of 147 reproductive tracts. Yearlings collected from November 1968 to May 1970 averaged 0.79 corpora lutea per doe, and adults averaged 1.76. Yearlings collected during spring in 1969 and 1970 averaged 0.88 fetus per doe; adults averaged 1.61 fetuses per doe. The peak of breeding, established from ovarian examination in late fall, occurred from November 1 to 16, during both years of study. After a severe winter in 1968-69, the rates of ovulation and fetuses per doe were lower than those after the mild winter, but the differences were not statistically significant.

216. Joslin, Gayle Lynne. 1975. Behavior and environmental selection by elk (*Cervus canadensis nelsoni*) during summer and fall in the first and second Yellow Mule drainages, Madison County, Montana. Bozeman, MT: Montana State University. 65 p. M.S. thesis.

A study was conducted during summer and early fall of 1973 and 1974 to investigate ecological aspects of elk. The study area was divided into park, broken park, and timber-cover types covering 31, 13, and 56% of the area, respectively. Six habitat types were delineated on the timbered regions. Large, mixed-sex bull-cow groups observed in late July dispersed to form small single-sex bull groups and cow groups which increased in size to late August. Environmental features recorded to compare areas selected by each elk group type were cover type, habitat type, timber type, distance to water, distance to the next closest cover type, downfall, sight distance, location, topography, elevation, aspect, and slope. Significant differences existed between preferences of group types for topography, aspect, and location, but selection of other features was not statistically different. Bulls abandoned their environmental preferences in late summer to join cow groups in their preferred habitat. Percentage moisture of forbs and grasses was determined every 2 weeks. Forbs at elk feeding sites had significantly greater moisture contents than forbs in all meadow and most timber sites. Elk, however, moved into the timber in September, coincident with the rut, and reappeared in high open parks in October. Based on relative percentage moisture content, movement into the timber solely for succulent vegetation would not be founded; therefore, during this study, it appeared that security requirements of elk were involved in this fall movement into the timber.

217. Kie, John G. 1984. Deer habitat use after prescribed burning in northern California. Res. Note PSW-369. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 3 p.

Prescribed burning was used to improve black-tailed deer habitat in Trinity County, northern California. Deer response was measured by comparing pellet group deposition on one burned and three unburned areas. Pellet group counts were highest

on the burned area for 3 years after burning. One year after burning, pellet group deposition on unburned areas was lowest adjacent to the burned area. By using control areas adjacent to the burn, an overestimate of increase in deer activity occurred. Prescribed burning caused some increase in deer activity, but it is difficult to quantify because annual deer habitat use and defecation rates vary. Any beneficial effects of burning did not appear to continue into the 4th year.

218. Kie, John G.; Burton, Timothy S.; Menke, John S. [and others]. 1983. Food habits of black-tailed deer, *Odocoileus hemionus columbianus*, in Trinity County, California. California Fish and Game 70(3): 183-186.

Rumen contents from 40 black-tailed deer from the Weaverville and Hayfork herds in Trinity County, California, were analyzed to determine their food habits. During early winter, Weaverville deer diets, by volume consisted of browse (91%), forbs (3%), and grasses (6%). *Ceanothus* species made up 71% of the diet. Hayfork deer ate less browse (63%), and more forbs (11%) and grasses (26%) early in winter. White fir (10%) and Douglas-fir (13%) contributed substantially to Hayfork deer diets in early winter but less to diets of Weaverville deer. During late winter through early spring, consumption of different forage classes was nearly identical for both herds (55% browse, 6-9% forbs, and 36-39% grasses). Species of browse and forbs eaten by each herd differed, however. The Weaverville deer are in poorer physical condition than are Hayfork deer. Prescribed burning and seeding of a grass-forb mixture is suggested to provide abundant herbaceous forage in early winter.

219. Kirsch, John Ballard. 1962. Range use, relationship to logging, and food habits of the elk in the Little Belt Mountains, Montana. Bozeman, MT: Montana State College. 43 p. M.S. thesis.

An elk study was conducted in the Little Belt Mountains of central Montana during summer 1960 and spring, summer, and early fall 1961 to investigate distribution, movement, range use, relationships to block clearcut logging of lodgepole pine and food habits. Elk movements and range use were discussed in relation to broadly designated plant communities and more specific vegetative types if heavily used by elk. Size, age, and moisture conditions of the lodgepole pine clearcuts were correlated with elk usage. A vegetational analysis of two clearcuts and the adjoining uncut lodgepole pine was used to compare the changes resulting from logging. Food habits during spring, summer, and early fall were determined from 95 feeding sites examined. Supplementing the feeding observations was the inclusion of data from 41 elk rumens, most of which were collected during the late fall and winter of 1955 and 1956.

220. Klebenow, Donald A. 1962. Ecology and productivity of a montane forest winter deer range, western Montana. Missoula, MT: University of Montana. 93 p. M.S. thesis.

A winter range study of the Rocky Mountain mule deer was conducted north of Missoula during the winters of 1960-61 and 1961-62. The objectives were to determine the effect of succession on the winter range and to describe the present

condition of the range and the forage species that occur there. The winter range is an area of 2 square miles, located on a ridge that was burned by a forest fire in 1919. The vegetation of the winter range was sampled to determine the past and present tree abundance as reflected by the trees on the winter range now and the stumps and boles left from the fire. The botanical composition of the area was determined, and the amount of forage production and use was sampled. A nutrient analysis was run on the main browse species. The number of deer in the winter herd was estimated, and their food habits were determined from rumen samples. The winter range is mainly covered with shrub and tree vegetation. Grasses and herbaceous plants are plentiful, but their importance is secondary. Snowbrush ceanothus (*Ceanothus velutinus*) and ninebark (*Physocarpus malvaceus*) are the two most common shrub species and produce the greatest amount of current annual growth. Snowbrush is used moderately, and ninebark is not used at all for forage. Serviceberry (*Amelanchier alnifolia*) and chokecherry (*Prunus virginiana*) are the key forage species on the winter range. Although serviceberry and chokecherry are the preferred forage species, snowbrush is the staple food item. Range improvement is necessary because plant succession is changing the range from a shrub type to a coniferous stand of trees.

221. Klebenow, Donald A. 1965. A montane forest winter deer habitat in western Montana. *Journal of Wildlife Management* 29(1): 27-33.

A study of a mule deer winter range was conducted on an area in western Montana which had been burned in 1919 and where a shrub vegetation type developed. Estimates of present tree densities and of tree densities before the fire indicate that about as many trees are present now as were present in 1919, but the present stands are younger. Browse sampling reveals that four shrubs provide the major amount of browse; one of the most common shrubs, ninebark (*Physocarpus malvaceus*), is not used. Usage data show that forage plants on the portions of the winter range with the greatest density of trees are less used by the mule deer than those on the more open portions of the range. A continued increase in the size and density of the tree vegetation is expected, with a resultant decrease of forage plants and amount of usable winter range.

222. Knight, Richard R. 1970. The Sun River elk herd. *Wildl. Monogr.* 23. Washington, DC: The Wildlife Society. 66 p.

An investigation was conducted on the Sun River elk herd in west-central Montana from 1960 through 1965 to determine causes of low calf production. Early phases of the investigation were concentrated on forage preferences and range relationships. Later phases included the definition of migration routes and population characteristics of different segments of the herd through the use of individually marked animals. Spring range use was characterized by heavy use of grassland types; forage preferences indicated early use of grasses in April and changed to heavy use of forbs in June. Summer range use was concentrated on high altitude forb and burn areas with increasing use of timber late in the season. Preferred forages on summer range were forbs and grasses in equal amounts. Fall range use was observed to be heaviest on grass, but the relatively small number of elk observed in October and November indicated that most of the elk were using timber habitats where they were not easily

observed. Winter range use was concentrated on grass and savannah areas and was quite variable among years according to weather patterns. No nutritional deficiency on winter range was found. Eight winter range areas were examined with respect to population characteristics of the animals using them. Calf:cow ratios varied between years and areas. Animals exhibited a tendency to return to the same winter range area each year. Composition of winter population groups was independent of that of summer population groups. Elk acted individually when migrating to a particular summer or winter range.

223. Korfhage, Robert C.; Nelson, Jack R.; Skovlin, Jon M. 1980. Summer diets of Rocky Mountain elk in northeastern Oregon. *Journal of Wildlife Management* 44(3): 746-750.

Forested areas provide most of the summer range for Rocky Mountain elk in the Blue Mountains of northeastern Oregon, but no detailed information is available on food habits of elk in these upper slope types. The study was performed in the Umatilla National Forest northeast of La Grande, Oregon. Elk diets consisted of nearly equal amounts of graminoids, forbs, and woody plants. Seasonally, however, elk preferred grasses and forbs from open parks in the spring, but shrubs and forbs from natural and modified forests in late summer. Land managers should promote practices and strategies that maintain balance among forested habitats, thus encouraging preferred late-season food plants for elk.

224. Korfhage, Robert Coyle. 1974. Summer food habits of elk in the Blue Mountains of northeastern Oregon based on fecal analysis. Pullman, WA: Washington State University. 117 p. M.S. thesis.

Food habits of elk in the Blue Mountains of northeastern Oregon were studied during the summers of 1972 and 1973. Fecal analysis, a technique involving microscopic identification of composite fecal samples, was employed to determine species composition and frequency of occurrence of food plants in the diet at biweekly intervals. Results indicate that the diets of Blue Mountain elk, at least in the vicinity of Bobsled Ridge and Goodman Ridge, are similar to diets of elk on browse range in other parts of the West. Grasses and sedges made up the major portion of the diet during late spring and early summer, 57% in 1972 and 63% in 1973. However, as summer progressed, use of forb and browse species increased. Highest use of forbs occurred during August 1972, 42.3%, and July 1973, 48.8%. Greatest browse use occurred in August of both years, 42.4% and 39.0% for 1972 and 1973, respectively. Photomicrographs of reference slides and a dichotomous key were made to facilitate identification of plant materials found in elk feces and are presented in this paper.

225. Krueger, William C.; Winward, A.H. 1974. Influence of cattle and big game grazing on understory structure of a Douglas-fir-ponderosa pine-Kentucky bluegrass community. *Journal of Range Management* 27(6): 450-453.

A Douglas-fir/ponderosa pine/Kentucky bluegrass community was studied 14 years after grazing by cattle and big game, by big game, and no cattle or big game grazing. Heavy season-long use by cattle and big game resulted in retrogression. The herbaceous component of the community was substantially changed by cattle and big

game grazing but not by big game grazing alone. Grazing by cattle and big game and big game only had similar effects on the browse components of the community.

226. Kufeld, Roland C. 1973. Foods eaten by the Rocky Mountain elk. *Journal of Range Management* 26(2): 106-113.

Forty-eight food-habits studies were combined to determine what plants are normally eaten by Rocky Mountain elk and the relative value of these plants from a manager's viewpoint based on the response elk have exhibited toward them. Plant species are classified as highly valuable, valuable, or least valuable on the basis of their contribution to the diet in food-habits studies where they were recorded. A total of 159 forbs, 59 grasses, and 95 shrubs are listed as elk forage and categorized according to relative value.

227. Lawrence, William H. 1969. The impact of intensive forest management on wildlife populations. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 72-74.

Effects of certain forest management practices on populations of black-tailed deer in coastal stands of Douglas-fir are the basis for a model that represents the carrying capacity of land for deer over rotations of 40 and 80 years. Intensive forest management practices, such as rapid regeneration, shortened rotations, stocking control, and fertilization, raise the carrying capacity of Douglas-fir stands for black-tailed deer. For example, shortening the rotation from 80 to 40 years may double the carrying capacity for deer. Benefits of management outweigh the constraints that might be imposed on deer populations. Cooperative research is needed by foresters and game biologist on the biological and economic carrying capacity of managed forests. A critical need is an effective repellent for protecting seedlings from deer damage.

228. Leach, Howard R.; Hiehle, Jack L. 1957. Food habits of the Tehama deer herd. *California Fish and Game* 43(3): 161-178.

A food-habits study was made of a migratory herd of Columbian black-tailed deer which summers in the mountains of the Cascade Range and Sierra Nevada and winters on the foothill slopes of eastern Tehama County, California. The stomach analyses of 96 deer collected on the winter range reveal a seasonal use of food plants as influenced by the changes in range forage composition. Browse appears to constitute the staple item of diet throughout the winter. The leafage and acorns of the deciduous oaks contribute heavily to the early fall diet, and as the foothills "green up" with the advent of fall rains, the deer graze heavily on the annual grasses and forbs. This annual forage production reaches its height in March, when it contributes most to the diet of the deer. Early in April the browse plants begin to leaf out with new growth, and the deer appear to switch entirely to a browse diet. The preferred browse species consist of mountain whitethorn, squaw carpet, greenleaf manzanita, western serviceberry, and snowbrush.

229. Leckenby, Donavin A. 1984. Elk use and availability of cover and forage habitat components in the Blue Mountains, northeast Oregon, 1976-1982. Wildl. Res. Rep. 14. Portland, OR: Oregon Department of Fish and Wildlife. 40 p.

This project has provided an evaluation of relationships between elk use, elk productivity, and habitat components in the Blue Mountains. About 650 hours of use were recorded while watching elk in 1,755 described habitat stands on five summer and four winter ranges; 60% of those stands met the definition of forage areas, 34% were thermal cover and 4% were hiding cover. The proportion of the home ranges in cover averaged 56%. Elk use of cover was proportionately greater than its availability at ratios less than 35%. Summer home ranges of elk were 100 acres smaller with each unit increase in the cover percentage and about 150 acres smaller for a similar increase in the thermal cover percentage. Cover ratios from winter home ranges averaged 40%. Use of cover was in proportion to its availability at ratios less than 40%. Winter home-range size did not depend on cover or thermal cover ratios. Cover and forage stands no less than 400 feet and no more than 1,200 feet wide encourage maximum use of the maximum area at high densities of elk. Elk prefer to use the portion of a cover or forage stand that lies close to its edge. Nearly 100% of elk use of thermal cover in summer and winter was observed within 400 yards of an edge with forage. The average canopy closure, 76%, and average stand height, 79 feet, of bedding sites selected by elk on summer range both satisfied the minimum guidelines defined for optimum thermal cover; 73% of all bedding sites met that definition. Thermal cover, comprising 67% of the total, received 90% of the use observed in summer.

230. Leckenby, Donavin A.; Sheehy, Dennis P.; Nellis, Carl H. [and others]. 1982. Wildlife habitats in managed rangelands—The Great Basin of southeastern Oregon. Mule deer. Gen. Tech. Rep. PNW-139. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 40 p.

Relationships of mule deer behavior and physiology to management of shrub-steppe plant communities in the Great Basin of southeastern Oregon are presented for application in land use planning and habitat management. Communities are considered as they are used by mule deer for thermal cover, hiding cover, forage, fawning, and fawn rearing.

231. Leckenby, Donavin A.; Thomas, Jack Ward; Adams, Arthur W. [and others]. 1985. Management of forests and elk in the Blue Mountain province of northeast Oregon. In: Workman, Gar W., ed. Western elk management: a symposium; 1984 April 19-20; Logan, UT. Logan, UT: Utah State University, College of Natural Resources: 83-98.

The forests of Oregon are presently a laboratory for a silvicultural experiment based on linear predictions that simulate conditions in fully regulated forests around the year 2020. Models of the effectiveness of habitats for elk are being coordinated with

the productivity and harvesting models. Existing models of habitat effectiveness for summer ranges in the Blue Mountains have been refined and simplified; their rationale has been extended to winter ranges. Data on (1) moderation of microclimate by stand structure and size, (2) effects of microclimate on energy budgets of ruminants and phenology of plants, (3) effects of stand composition on forage quality and quantity, and (4) response of animals to disturbance from human activities were indexed to scales of potential use of habitat by represented relationships of practical value to planners, managers, and researchers. The use of thermal cover, hiding cover, and forage area habitat components for planning and management was demonstrated.

232. Leckenby, Donavin A.; Thomas, Jack Ward; Henjum, Mark G. [and others]. 1986. An index to evaluate forage quantity and quality interactions: one of four variables proposed for modeling elk habitat effectiveness on winter ranges in the Blue Mountains of Oregon and Washington. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 195-212.

New research and current land-use planning requirements make it clear that a model of habitat effectiveness (HE) for winter ranges of Rocky Mountain elk is needed with which managers may assess likely effects of and results from proposed or executed alternative actions. In this article, we examine the forage variable of a four-variable HE model developed for the Blue Mountain province of Oregon and Washington. Derivation and calculation of the forage variable are emphasized, and some range treatments to improve forage are compared from the point-of-view on which this variable is founded. Interaction of quantity and quality is indexed by relationships derived from data specific to decreaser forages, Idaho fescue and bluebunch wheatgrass, that are key elk foods and common dominants in plant communities on winter ranges throughout the northwest.

233. Leege, Thomas A. 1968. Prescribed burning for elk in northern Idaho. In: Proceedings, 8th annual Tall Timbers fire ecology conference; 1968 March 14-15; Tallahassee, FL. Tallahassee, FL: Tall Timbers Research Station: 235-253.

Elk numbers are slowly decreasing in many parts of northern Idaho, and the decline is closely tied to the vegetation upon which they depend. This paper reviews the historical records and then reports on prescribed burning studies that are underway to halt the elk decline by altering the vegetation. Spring and fall burning have been tried, with spring burning proving better suited.

234. Leege, Thomas A. 1976. Relationship of logging to decline of the Pete King elk herd. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 6-10.

Winter elk counts in the Pete King Creek drainage of north-central Idaho declined from 408 in 1957 to 63 in 1974. A study of the winter range indicated that elk numbers had decreased at a faster rate than forage had. Circumstantial evidence linked the accelerated elk decline to overharvest by hunters and the shifting of animals to different winter ranges. Causes were related to the construction of logging roads and the increased access they provided.

235. Leege, Thomas A. 1979. Effects of repeated prescribed burns on northern Idaho elk browse. *Northwest Science* 53(2): 107-113.

A seral shrub community was treated with three prescribed spring burns at 5-year intervals. All shrub species responded with basal sprouts and seedlings after each burn. Results indicated that repeated spring burns at the recommended interval of 10 to 15 years would have little effect on density and composition of most species. Redstem (*Ceanothus sanguineus*), however, will increase when seedlings survive, whereas bitter cherry (*Prunus emarginata*) may decrease because of adult mortality.

236. Leege, Thomas A. 1984. Guidelines for evaluating and managing summer elk habitat in northern Idaho. *Wildl. Bull.* 11. Boise, ID: Idaho Department of Fish and Game. 37 p.

Provides information on seasonal habitat preferences and food habits of elk during spring, summer, and fall months in northern Idaho. Recommendations are made for coordinating logging, road building, and livestock grazing with elk habitat preferences. An evaluation procedure is provided for estimating the effects of proposed land management activities on the quality of elk habitat. Computations take into consideration such things as quality, quantity, and distribution of cover, forage, and security areas; and the density of open roads and livestock.

237. Leege, Thomas A.; Hickey, William O. 1977. Elk-snow-habitat relationships in the Pete King drainage, Idaho. *Wildl. Bull.* 6. Boise, ID: Idaho Department of Fish and Game. 23 p.

For five consecutive winters, 1967 through 1971, data were collected on elk distribution patterns and how they were related to snow depth, aspect, elevation, slope, a winter severity index, and vegetation type in north-central Idaho. Snow depth and quantity of forage were the two major factors regulating the location of wintering elk. Snow depths in excess of 1.5-2.0 feet caused elk to move to areas or vegetation types with shallower snow, if available. Elk ranges with less than 1.5 feet of snow on the ground during most days of an average winter are given highest priority for habitat improvement activities. Adult bulls ranged at elevations slightly higher on the winter range than other age and sex classes of elk. During the course of several winters, however, there was competition for forage between adult bulls and the other elk.

238. Lemke, Thomas O. 1975. Movements and seasonal ranges of the Burdette Creek elk herd, and an investigation of sport hunting. Missoula, MT: University of Montana. 127 p. M.S. thesis.

Locations of unmarked and 22 individually marked elk provided information concerning movement patterns and seasonal range of elk using the Burdette Creek winter range, 25 miles west of Missoula, Montana. Marked elk were located on 383 occasions, and 1,428 unmarked elk were observed from April 1970 to May 1975. Data were also gathered on population structure, elk bio-activity centers, and sport hunting activity. Winter range was the smallest and most homogeneous seasonal elk

habitat used, and use was concentrated on steep south- and west-facing brush-covered slopes. During the first 2 weeks of June, most elk suddenly moved west onto summer range, up to 11 miles distance. A small portion of the herd remained on winter-spring ranges during summer. Fall elk range, the largest of seasonal areas (270 square miles) was quite heterogeneous. Some radio-collared elk made erratic long distance moves in September and October that were attributed to hunting activity. All marked elk used the same winter-spring range, and some returned to summer-fall range used before. The average size of winter-spring and summer-fall range was 3.7 and 11.4 square miles, respectively. Recommendations include protecting winter range and elk bioactivity centers from further disturbance, burning portions of the winter range to improve browse conditions, and regulating the number of hunters in the Clearwater Crossing area to protect against overcrowding.

239. Lemos, James C. 1971. Roosevelt elk utilization of redwood forest cutovers in relation to regrowth and forest management. Arcata, CA: Humboldt State College. 110 p. M.S. thesis.

The study was initiated to provide a better understanding of elk-forest management relationships in and adjacent to Prairie Creek Redwoods State Park. Use of forage on these areas and the value of different ages of regrowth to Roosevelt elk were analyzed from June 1967 to June 1968. The major objectives were (1) to determine if the Kirsch area supported a vegetative complex and an elk population satisfactory for visitor observation; (2) to determine the forage present in different ages of regrowth after clearcutting of redwood forest areas; and (3) to determine the impact of elk on forest regeneration of recent cutovers. A secondary objective was to determine the relationship of the surrounding cutover lands to the activities of the Boyes Prairie herd. Two different-aged redwood forest cutovers were chosen. Kirsch had undergone secondary succession for 15 years without human interference; Arco had undergone strict forest management practices for 5 to 7 years. The elk carrying capacity of Arco is much greater than Kirsch at present. The small population on Kirsch is within the carrying capacity of forage as is evidenced by the good calf-cow ratio and the use of the forage. The large population on Arco may be at or near carrying capacity, but even at this high concentration, damage to tree seedlings is slight. Logging practices provide a prime habitat for elk, and slash burning further enhances it by starting succession at a lower stage. The dependence of large numbers of elk on large areas of cutover will lead to a population level in direct response to the clearcuts available to them.

240. Leslie, David M., Jr.; Starkey, Edward E. 1985. Fecal indices to dietary quality of cervids in old-growth forests. *Journal of Wildlife Management* 49(1): 142-146.

Determination of dietary quality for wild ungulates can be both time-consuming and expensive. A simpler approach is to measure a chemical characteristic of fecal material that bears a relationship to the quality or quantity of ingested diets. Fecal nitrogen is a common index that has been shown to be positively correlated with intake. This paper summarizes the relationships of fecal nitrogen and fecal phosphorus to dietary nitrogen, dietary phosphorus, and dietary digestibility of Roosevelt elk and Columbian black-tailed deer in old-growth, coniferous forests of western Washington.

241. Leslie, David M., Jr.; Starkey, Edward E.; Smith, Bradley G. 1987. Forage acquisition by sympatric cervids along an old-growth sere. *Journal of Mammalogy* 68(2): 430-434.

The ranges of Roosevelt elk and Columbian black-tailed deer overlap broadly in the coastal Pacific Northwest. Coexistence of these species may be facilitated if they forage on different food types or in different habitats. It is hypothesized that deer, to maximize nutrient intake, select a diet of early seral forages to a greater extent than elk. Alternatively, it has been proposed that deer favor older stages of a sere and elk prefer younger stages. This note examines cervid forage acquisition along an unmanaged old-growth sere to determine which hypothesis is empirically supported. The first hypothesis that deer would select a diet of greater seral affinity than elk was not strongly supported. The alternative hypothesis that deer would seek a diet of browse in older stages was supported by our observations. Contrary to previous models of this hypothesis, elk did not show any greater affinity for young seral stages than did deer.

242. Leslie, David M., Jr.; Starkey, Edward E.; Vavra, Martin. 1984. Elk and deer diets in old-growth forests in western Washington. *Journal of Wildlife Management* 48(3): 762-775.

Dietary quality and overlap of sympatric Roosevelt elk and Columbian black-tailed deer were investigated in old-growth forests of the Hoh Valley, Olympic National Park. Diets of both cervids were comprised mainly of common old-growth flora, particularly in winter. High dietary overlap suggested competitive interactions for food, especially in winter when forage resources were least available. Few significant differences in seasonal dietary qualities were demonstrated between elk and deer. The collective cervid population (and its habitat) in the Hoh Valley is unmanaged and probably at equilibrium with its food resource or at ecological carrying capacity. Results are discussed in light of herbivore-habitat interactions at equilibrium densities.

243. Leslie, David McAfee. 1983. Nutritional ecology of cervids in old-growth forests in Olympic National Park, Washington. Corvallis, OR: Oregon State University. 141 p. Ph.D. dissertation.

Nutritional ecology of un hunted and sympatric populations of Roosevelt elk and Columbian black-tailed deer was investigated in old-growth forests of the Hoh Valley from September 1979 to November 1981. Seasonal diets of both cervids generally were comprised of common forages; relative availabilities of other preferred forages minimized their contributions to the diet of either ungulate. Hemlock, swordfern, oxalis, and alder were the most common dietary components on an average annual basis. Protein and phosphorus appeared to be adequate in diets but low in vitro digestibilities suggested that digestible energy may be limited. Levels of sodium and selenium were low in most forages and suggested that dietary levels also were low. No significant differences in seasonal diet quality were demonstrated between deer and elk. Sympatry of elk and deer was typified by (1) an high degree of dietary overlap; (2) diets that seemed to afford little opportunity for partitioning plant parts; (3) a

similar pattern of food acquisition in major forest types; and (4) heavy use of the forage base to the point of restricting distributions of preferred forages and influencing the physiognomy of the shrub layer in some forest communities. Cervids probably were limited by undernutrition and low reproduction, both consequences of maximum density and theoretically low forage availability and quality.

244. Lindzey, James S. 1943. A study of Columbian black-tailed deer *Odocoileus hemionus columbianus* (Richardson), and its habitat in Oregon. Corvallis, OR: Oregon State College. 62 p. M.S. thesis.

The purpose of this paper is to present results of a habitat study of the Columbian black-tailed deer in western Oregon. A report summarizing the available data on the life history and habits of the species is included, supplemented by observations made while resident in Tillamook County, Oregon, during the spring and summer of 1942. Sightings from personnel of various agencies were tabulated and mapped. These records show the regions favorable to the species and the areas of low deer populations and thus will provide a basis for future studies by indicating preferred types and zones in western Oregon. Additional material includes notes on the life history, habits, disease, and general characteristics obtained from various publications. General observations were added after field work. Although the material is general in nature, it is hoped that this study will aid in the management of the species by adding information pertinent to range use.

245. Loft, Eric R.; Burton, Timothy S.; Menke, John W.; Peterson, Gary E. 1988. Characterization of black-tailed deer habitats in a northern California oak-conifer zone. *California Fish and Game* 74(3): 154-171.

Hardwoods, especially California black oak, *Quercus kelloggii*, provide a valuable food source for Columbian black-tailed deer in conifer forests of northern California. A detailed vegetation survey conducted at elevations of 600-1,500 m in the Shasta-Trinity National Forest resulted in description of seven oak-conifer habitat types. Black oak was of greatest abundance and basal area (22 square feet/acre) in Douglas-fir dominated forests of low to moderate canopy closure. Oak basal area was lowest in dense canopy forest types. Seedling, sapling, and mature black oak trees were all present in four conifer dominated habitat but not in recent clearcuts which had negligible levels of hardwood retention. Deer use, as determined from pellet-group densities, was highest in mature conifer types with lowest canopy closure. Deer use was positively associated with oak basal area, which explained 29% of the variation in observed deer pellet-group densities. Hardwoods in conifer forests are likely an important contributor to deer herd productivity, especially in areas where important winter range habitats are limiting or have been eliminated by development.

246. Loft, Eric R.; Menke, John W. 1984. Deer use and habitat characteristics of transmission-line corridors in a Douglas-fir forest. *Journal of Wildlife Management* 48(4): 1311-1316.

A transmission-line corridor in mature Douglas-fir forest on the winter range of the Weaverville black-tailed deer herd was evaluated as deer habitat. Sixteen habitat

variables were used to separate deer usage classes (indicated by pellet groups) and evaluate important habitat components. Low tree canopy closure and high cover of deerbrush ceanothus (*Ceanothus integerrimus*), total herbaceous vegetation, and blackberry (*Rubus* spp.) as well as high hiding cover were attributes that accounted for 82% of the variance in deer usage differences between low- and high-use habitats. With three classes of deer usage, eight habitat variables explained 90% of the variation in plot use. Opening created for transmission lines are more attractive to deer in winter than is Douglas-fir forest.

247. Loft, Eric R.; Menke, John W.; Burton, Timothy S. 1984. Seasonal movements and summer habitats of female black-tailed deer. *Journal of Wildlife Management* 48(4): 1317-1325.

Completion of Trinity and Lewiston reservoirs, Trinity County, California, inundated 6,980 ha of deer winter range and altered traditional migration routes. Twenty adult female Columbian black-tailed deer were radio-collared near these reservoirs and monitored from February 1981 through June 1982 to determine present migration routes, chronology of movements, and selection of seasonal ranges and habitats. Sixteen deer migrated to higher elevations, and four deer maintained year-round home ranges at elevations of 800-980 m. Radio-collared does selected riparian areas both day and night, especially as fawning cover, but generally used the more open clearcut and south slope areas only at night. Dense forest was selected more often during the day than at night in the summer. Does that inhabited the most diverse areas maintained smaller summer home ranges.

248. Loft, Eric Richard. 1982. Seasonal migration of black-tailed deer in northern California. Davis, CA: University of California. 44 p. M.S. thesis.

The completion of Trinity and Lewiston Reservoirs, Trinity County, California, in 1963 inundated 6,985 ha of deer winter range and blocked traditional overland migration routes. Twenty adult female Columbian black-tailed deer were radio-collared near these reservoirs and monitored from February 1981 through May 1982 to determine present migration route, chronology of movements, and seasonal ranges. In spring, 5 deer migrated to high elevation (2,070-2,160 m); 11 migrated to intermediate elevations (900-1,520 m), and 4 maintained year-round home ranges southwest of the lake (800-900 m), shifting from south aspect open slopes in winter, spring, and fall to densely forested drainages and north aspect slopes in summer. Spring migration began in early April and was correlated with maximum daily air temperature. Radio-collared migratory deer swam 1-1.5 km across Trinity Lake, traveled as far as 35 km, and used up to 3 holding areas en route to summer ranges. Elevations of migratory deer summer ranges varied between 910-2,160 m, with seven does summering at elevations that were 30-120 m lower than their winter ranges. Radio-collared deer selected riparian areas both day and night but generally used the more open clearcut and south slope areas only at night. Riparian areas were an essential component of summer ranges, especially as fawning habitat. Densely forested areas were selected more often during the day than at night. Fall migration began in October although some deer remained on summer ranges until December 17. Radio-collared deer traveled the same routes used during spring migration and returned to the same winter ranges.

249. Logsdon, H. Stevan. 1965. The immobilization and movements of the Roosevelt elk. Arcata, CA: Humboldt State College. 89 p. M.S. thesis.

From April 1964 to February 1965, 89 Roosevelt elk in the Prairie Creek region of northern California were immobilized and tagged for studying movements. The habitat in the study area ranged from virgin redwood forest, cutover timber, brushland, and grassland to the riparian vegetation of the creeks. Observations of tagged elk revealed two distinct herds, the Gold Bluff Beach herd and the Boyes Prairie herd, which occupied home ranges that were linear in form. The Beach herd, with a larger home range, was more mobile than the Boyes Prairie herd. The longest movement in two consecutive days for the Beach herd was 3.0 miles and the average 1.4 miles. The Boyes Prairie herd's longest movement was 0.75 mile, and the average distance was 0.31 mile. In both the herds studied, the home range overlapped with the home range of other elk herds. In each case, the overlapping portion of the herds under study was one of the less frequently used parts of the home range and constituted only a small amount of the total area the herd occupied. Natural features, such as a stream or steep slope, appeared to delineate the boundaries of the home range. The dispersion and wandering of elk, other than bulls during the rut, was observed only in younger animals. Observations during the rut showed that bulls can and do temporarily divide and combine adjacent herds. Observations of tagged animals, however, indicate that these animals return to their respective herd's home range after the rutting period. The separation of the main herd into two subgroups was occasionally observed. The composition and number of the subgroups was not consistent, but one was always larger than the other.

250. Lonner, Terry N. 1976. Elk use-habitat type relationships on summer and fall range in Long Tom Creek, southwestern Montana. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 101-109.

Findings for the Long Tom Creek phase of the Montana Cooperative elk-logging study, initiated in 1970, are discussed in this paper. Seasonal (summer and fall) variations of elk use within and between habitat types, some intrahabitat-type variations of elk use within and between seasons, a review of the habitat-type concept in relation to elk and timber management, and a brief discussion of the importance of interspersed and diversity are included.

251. Lovaas, Allan L. 1958. Mule deer food habits and range use, Little Belt Mountains, Montana. *Journal of Wildlife Management* 22(3): 275-283.

A mule deer-food habits-and range-use study was conducted in the Little Belt Mountains, Montana, from summer 1956 to spring 1957. The four main vegetative types represented in the area were prairie, ponderosa pine, lodgepole pine, and spruce. Deer moved to higher elevations during the summer, and a downward movement was noted in September. The most important winter range was found in the prairie type. Forbs were the most prominently used forage class in the summer, and browse

and forbs use were about equal in the fall. Browse was the most prominent class in the winter and was still prominent, along with grass, in the spring. Common juniper and creeping juniper were the most used winter browse species. Deer wintering in the overused creeping juniper areas took a higher percentage of forbs and were in poorer physical condition than those wintering where less used common juniper was prevalent.

252. Lyon, L. Jack. 1971. A cooperative research program effects of logging on elk in Montana. In: Proceedings of the 51st annual conference of the Western Association of State Game and Fish Commissioners; 1971 July 19-23; Snowmass-at-Aspen, CO; [Place of publication not available]: 447-457.

Provides a brief review of the Montana Cooperative Elk-Logging Study undertaken in 1970.

253. Lyon, L. Jack. 1975. Coordinating forestry and elk management in Montana initial recommendations. In: Sabol, Kenneth, ed. Transactions, 40th North American wildlife and natural resources conference; 1975 March 16-19; Pittsburgh, PA. Washington, DC: Wildlife Management Institute: 193-201.

As a result of the initial 4 years of investigation by the Montana Cooperative Elk-Logging Study, five recommendations have been made for coordination of timber management and elk management: (1) Planning for timber sales on elk summer range should provide for a security area immediately adjacent to the disturbed area during active logging and road construction. (2) Five specific habitat types have been identified as key components of summer elk range; they should be managed to maintain the overall integrity of the elk habitat. (3) Area closures restricting motor vehicles can improve the quality of elk hunting, but proposed closures should be carefully evaluated in terms of elk management objectives because all results are not necessarily desirable. (4) The location and design of transportation system should include provision of secure road crossing areas for elk. (5) Decisions involving the construction or closure of roads should be evaluated on a case-by-case basis with specific elk management objectives in mind. These recommendations are preliminary and subject to further modification, but it has been shown that elk are disturbed by, and may move a considerable distance to avoid, activities and noise associated with logging and vehicular traffic on forest roads.

254. Lyon, L. Jack. 1976. Elk use as related to characteristics of clearcuts in western Montana. In Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 69-72.

Elk use of clearcuts, as indicated by pellet groups, is determined by the size and age of the opening but is also strongly influenced by the amount of slash and down timber in and around the opening.

255. Lyon, L. Jack. 1979. Habitat effectiveness for elk as influenced by roads and cover. *Journal of Forestry* 77(10): 658-660.

Pellet counts conducted over an 8-year period confirmed that elk in western Montana tend to avoid habitat adjacent to open forest roads. The area avoided increases where the density of tree cover is low. Forest roads open to traffic cause available habitat to be less than fully effective. A method for determining the losses of effective habitat is presented.

256. Lyon, L. Jack. 1979. Influence of logging and weather on elk distribution in western Montana. Res. Pap. INT-236. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 11 p.

Distribution of elk pellet groups on an area of 80 square miles was examined for 8 years. Recorded changes in annual distribution describe both elk movement in response to disturbances in the forest environment and elk habitat selection in response to weather conditions. During the study, the most important influence on elk distribution was weather. Severity of winter weather determined the location and extent of winter range. Snowfall during the hunting season resulted in elk concentrating in the least accessible areas available. Hot, dry summer weather forced selection of habitat areas providing cool, moist conditions. The second determinant of elk distribution was logging. Elk consistently moved away from areas in which active logging was in progress. The distance moved and the time required for return varied depending on the location and duration of logging activity. Recommendations intended to reduce the time during which habitat is unavailable to elk are presented.

257. Lyon, L. Jack. 1980. Coordinating forestry and elk management. In: Sabol, Kenneth, ed. Transactions of the 45th North American wildlife and natural resources conference; 1980 March 22-26; Miami Beach, FL. Washington, DC: Wildlife Management Institute: 278-287.

Reviews the results of 10 years of research in the Montana Cooperative Elk-Logging study. Elk habitat requirements and the important characteristics of effective elk habitat have been identified. Several elk behavioral patterns have been documented and related to habitat requirements. The results provide an information base for the development of comprehensive elk-habitat guidelines providing forest managers with positive prescriptions for maintaining and enhancing elk habitat within timber management programs.

258. Lyon, L. Jack. 1983. Road density models describing habitat effectiveness for elk. *Journal of Forestry* 81(9): 592-595.

Graphical models of habitat effectiveness (five of normal use) vs. road density (miles of road per square mile of habitat) are discussed with reference to published and unpublished data on elk use at varying distances from forest roads in Washington, Montana, and Idaho. Differences in calculation method can lead to substantial differences in predictions. A composite model is presented which shows reasonable agreement with actual elk use at road densities up to 6 miles per square mile.

259. Lyon, L. Jack. 1984. Field tests of elk/timber coordination guidelines. Res. Pap. INT-325. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 11 p.

During field tests on 11 study areas in Montana and northern Idaho in the summers of 1980 and 1981, elk pellet distribution was compared with evaluations of habitat based on different combinations of cover/forage and road models. Elk response to variations in habitat quality was primarily determined by road density.

260. Lyon, L. Jack; Jensen, Chester E. 1980. Management implications of elk and deer use of clear-cuts in Montana. *Journal of Wildlife Management* 44(2): 352-362.

Elk, mule deer, and white-tailed deer pellet-group densities were counted in and adjacent to 87 clearcuts of different sizes and ages in eastern and western Montana. Pellet distributions suggest animals enter clearcut openings in search of better quality or greater quantities of forage. The willingness of animals to enter an opening, however, is influenced by a requirement for security during the feeding period and is locally modified by the past experiences of animals in the available environment. Both elk and deer preferred clearcuts with cover in the opening except where such cover inhibited forage growth. Both preferred openings in which logging slash was not a barrier to movement. Elk preferred smaller openings than did deer but were more tolerant of large openings, particularly where natural openings were already present in the environment. Elk use of clearcuts was severely depressed by the presence of open roads and inadequate cover at the edge of the opening.

261. Lyon, L. Jack; Lonner, Terry N.; Weigand, John P. [and others]. 1985. Coordinating elk and timber management. [Place of publication unknown]: [Publisher unknown]; final report of the Montana cooperative elk-logging study 1970-1985. 53 p.

Interagency cooperative research on the relationships between elk and logging activities in western Montana was initiated in 1970. This research produced a series of recommendations directed toward influencing the design and conduct of timber sales to minimize adverse effects on elk populations. The initial recommendations have been modified and supplemented and are described in this publication. The recommendations are intended primarily to influence habitat quality for elk.

262. Lyon, L. Jack; Mueggler, Walter F. 1968. Herbicide treatment of north Idaho browse evaluated six years later. *Journal of Wildlife Management* 32(3): 538-541.

Five species of north Idaho browse plants that were treated in 1960 were reexamined to evaluate long-term response to herbicides. We found some lag in plant mortality of undesirable species coupled with generally poor persistence of sprouting and relatively quick recovery from crown dieback in the desirable species. *Redstem ceanothus*, the most desirable browse plant tested, was killed by all treatments.

263. Mackie, Richard J. 1970. Range ecology and relations of mule deer, elk, and cattle in the Missouri River Breaks, Montana. Wildl. Monogr. 20. Washington, DC: The Wildlife Society. 79 p.

A study of food habits, range use, and interspecific relations of mule deer, elk, and cattle was conducted during 1960-64 on a 75,000-acre area in the Missouri River breaks to provide criteria for management of ponderosa pine-juniper and related vegetation types.

264. Marcum, C. Les. 1975. Summer-fall habitat selection and use by a western Montana elk herd. Missoula, MT: University of Montana. 203 p. Ph.D. dissertation.

Summer-fall habitat selection and use by a western Montana elk herd were investigated from 1971 through 1973. Objectives were to evaluate the interrelations between elk and various biological and physical habitat factors. Habitat use was determined by obtaining locations of radio-tagged elk. Habitat selection was determined by testing for statistically significant difference between the use of various environmental situations by elk and the availability of those situations by elk and the availability of those situations within the study area. Habitat factors generally used by elk in excess of the availability of those factors were identified as (1) *Pseudotsuga menziesii/Calamagrostis rubescens* and *Abies lasiocarpa/Galium triflorum* habitat types; (2) slopes on southwest and south aspects; (3) gentle (0-15%) slopes; (4) drainage bottoms and upper slopes; (5) elevations of 5,350 to 6,349 feet from an available range of 3,850 to 7,900 feet; (6) an overstory canopy cover of 26-75%; and (7) areas within 150 yards of water. Also, when in openings, elk preferred areas near timber, but lands within 100 yards of ecotones were used in excess of availability only during 1973. Use of areas on or within 550 yards of open system roads and clearcuts by elk was significantly less than the availability of those areas. Elk were displaced by logging activities at higher elevations on their summer-fall range and from roads open to vehicular traffic during hunting seasons. Much of the displacement of elk from open roads during hunting seasons was more than 1 mile. They also made greater use of heavily forested areas during hunting seasons.

265. Marcum, C. Les. 1976. Habitat selection and use during summer and fall months by a western Montana elk herd. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 91-96.

Summer and fall habitat selection and use by a western Montana elk herd was investigated from 1971 through 1973. Objectives were to evaluate the interrelations between elk and various biological and physical habitat factors in an area which included roads and logging. Elk within the study area demonstrated a great tolerance for various environmental situations available to them. Plant communities near water,

however, are probably the most critical areas on the summer-fall range in terms of their potential influence on elk productivity. No measurable benefits accrued to elk as a result of logging on higher elevation ranges. Areas where roads were closed to vehicular traffic received greater elk use than areas where roads remained open, especially during hunting seasons.

266. Marcum, C. Les. 1979. Summer-fall food habits and forage preferences of a western Montana elk herd. In: Boyce, Mark S.; Hayden-Wing, Larry D., eds. North American elk ecology, behavior and management: Proceedings of a symposium; 1978 April 3-5; Laramie, WY. Laramie, WY: University of Wyoming: 54-62.

Forage use by Rocky Mountain elk was examined during fall 1971 and 1972 and summer 1972 in the Sapphire Mountain Range of western Montana. Forbs were the most important summer elk forage (51% use), followed by browse (36% use) and graminoids (13% use). Graminoids were the dominant forage during fall months, comprising approximately 1/2 or more of the total diet. Percentage fall browse use was similar to percentage browse use during summer, but forb use declined in the fall by more than 50%. Findings of dietary variations within both seasons and of preferences by elk for specific plant species are presented. Forage use by elk during this study occurred predominantly within forested areas.

267. Martinka, C.J. 1968. Habitat relationships of white-tailed and mule deer in northern Montana. *Journal of Wildlife Management* 32(3): 558-565.

A study was conducted from June 1965 through March 1967 in the Bear Paw Mountains of north-central Montana to obtain quantitative data on range use and food habits of mule deer and white-tailed deer on areas of cohabitation. Mule deer used the bunchgrass habitat type more consistently than other types. Use was less during summer when increased use was made of willow-meadow and alfalfa types. Alfalfa reached maximum importance during fall. White-tailed deer showed a more distinct preference than mule deer for alfalfa and woody, deciduous-leaved habitat types. They used principally bunchgrass, aspen, and alfalfa types during spring and willow-meadow and alfalfa types during summer. Use of the aspen type increased during fall; it received nearly three-fourths of the recorded winter use. Relative use of forage classes by season was comparable for the two species with some minor differences. Many species of browse, forbs, and to a lesser extent grass, were eaten by both species during spring, summer, and fall. During winter, when forage was least available, browse formed the largest portion of the diets. White-tailed deer fed mostly on western serviceberry (*Amelanchier alnifolia*) and quaking aspen (*Populus tremuloides*). Mule deer used these species plus creeping juniper (*Juniperus horizontalis*). Differences in range or forage use during most seasons precluded competition between the two deer species. There was potential competition for western serviceberry on the shrub type during mild winters and on the bunchgrass, pine-bunchgrass, and shrub types during more severe winters.

268. McCorquodale, Scott M. 1987. Fall-winter habitat use by elk in the shrub-steppe of Washington. *Northwest Science* 61(3): 171-173.

Fall-winter habitat-use patterns of radio-collared Rocky Mountain elk were studied on the Arid Lands Ecology Reserve in the shrub-steppe of Washington from October 1985 to March 1986. Collared elk showed activity-dependent habitat selection. *Artemisia tridentata*/*Poa sandbergii* areas were preferred by bedded (resting or ruminating) elk while *Poa sandbergii* and *Bromus tectorum* areas without sagebrush were preferred for foraging. Foraging elk tended to use fewer vegetation types than did bedded elk, thereby indicating they were more selective of foraging habitats than bedding habitats. Grass biomass was about 2/3 less in *Poa* areas with sagebrush than in *Poa* areas without sagebrush. Foraging elk selected areas without sagebrush because of the higher availability of forage relative to sagebrush-dominated areas. This study demonstrated the importance of considering animal activity in studies that seek to characterize habitat selection for a species.

269. McCorquodale, Scott M.; Eberhardt, L. Lee; Eberhardt, Lester E. 1988. Dynamics of a colonizing elk population. *Journal of Wildlife Management* 52(2): 309-313.

The estimated rate of increase (r) for a naturally colonizing elk population in the shrub-steppe region of south-central Washington was 0.20 for 1975-86 (2-13 years postcolonization). From 1982 to 1986, r was 0.30. Survival of all age classes was high. During 1982-86, 0.76 calves/female were weaned if 2-year-olds were included, or 0.91 calves/female if 2-year-olds were excluded. Age-specific pregnancy and survival rates were combined in a model to evaluate the impact of various parameter values on rates of increase. Observations and simulation results suggest that the high rate of increase observed was due to high first-year survival and probably substantial reproductive output from 2-year-old females.

270. McCorquodale, Scott M.; Raedeke, Kenneth J.; Taber, Richard D. 1986. Elk habitat use patterns in the shrub-steppe of Washington. *Journal of Wildlife Management* 50(4): 664-669.

Spatial and temporal habitat-use patterns of elk in the shrub-steppe of Washington were studied from March through October 1983 and 1984. Four male and four female radio-collared elk were relocated a total of 782 times. Female elk preferred low elevation sagebrush associations during spring, late summer, and fall and riparian areas during the calving period and late summer months. Sagebrush stands were important bedding areas, particularly during late summer. Male elk selected sagebrush types during spring, summer, and fall. Elk preferred low elevation topographic zones. The distribution of natural springs was an important determinant of habitat use patterns for lactating female elk, but bull elk habitat use was less constrained by free water. Elk were active nocturnally. In the absence of extensive thermal cover, elk decreased thermoregulatory costs by bedding in sagebrush stands and by limiting major diurnal foraging bouts. The behavior of this population suggested that elk can be successful with limited cover under conditions of infrequent disturbance and adequate forage.

271. McCorquodale, Scott M.; Raedeke, Kenneth J.; Taber, Richard D. 1989. Home ranges of elk in an arid environment. *Northwest Science* 63(1): 29-34.

Home ranges of elk inhabiting montane and coastal forests have been previously documented, but few estimates have been reported for elk occupying nonforested habitats. We analyzed the home ranges of elk inhabiting the treeless shrub-steppe of Washington by using 782 relocations of eight radio-collared individuals during 1983 and 1984. Annual minimum convex polygon estimates averaged 161.4 square km for female elk and 163.1 square km for male elk. Annual 95% confidence ellipses averaged 305.1 square km for female elk and 284.5 square km for male elk. Seasonal home ranges of female elk decreased significantly each season from spring through fall. Large home ranges of elk in the shrub-steppe relative to elk in more mesic environments are hypothesized to be a strategy to compensate for low forage density in the arid shrub-steppe. These elk maintained large home ranges yet were reproductively successful, indicating that large home ranges can be an effective strategy for large herbivores faced with low food densities. We hypothesize that the success of these elk was mediated by the quantity rather than the quality of foraging areas in a prairie-like environment. Home range shapes appeared to be related to the availability of disturbance-free areas. A review of the literature suggested annual precipitation may be a relatively good predictor of home range sizes for elk.

272. McCulloch, Clay Y., Jr. 1955. Utilization of winter browse on wilderness big game range. *Journal of Wildlife Management* 19(2): 206-215.

During the 1930s, attention was focused on a big game problem in northern Idaho's upper Selway River drainage. Since 1910, there occurred a severe decline in the mule deer population, a great build-up of elk numbers, and the beginnings of destructive use of parts of the winter range, which eventually spread to the entire winter range. Just preceding or contemporary with these phenomena were vast forest fires resulting in large areas of new browse forage, and restriction of legal hunting, decline of tooth and hide hunting, active predator control work, establishment of large wilderness game refuges, and the inaccessibility of the area to quick hunting trips. The present study investigated browse forage conditions of the winter range during the winter of 1951-52. Of the 10 most abundant available shrub species, 6 were heavily used, and the other 4 were scarcely touched. This is presumed to be primarily elk use, because the combined mule and white-tailed deer population is estimated at less than one-third of the elk numbers on the area. Despite a decrease in elk numbers since the middle 1930s, the upper Selway winter range in its present condition is still inadequate for the numbers of elk using it during the winter of 1951-52.

273. McCullough, Dale R. 1964. Relationship of weather to migratory movements of black-tailed deer. *Ecology* 45(2): 249-256.

A study of the influence of weather factors on the migrations of a herd of black-tailed deer in the west-central Cascade Range of Oregon showed that periods of migration, as indicated by night spotlight samples, were closely correlated with seasonal changes in minimal relative humidity. Both spring and fall migrations, and possibly an atypical summer movement, occurred during ranges of 40-60% minimal relative humidity. Snowstorms, rainfall, absolute humidity, and temperature were not so closely correlated. The migrations could not be attributed to habitat factors such as food, water, or escape cover.

274. McCullough, Dale Richard. 1960. An ecological study of the Columbian black-tailed deer in a logged environment. Corvallis, OR: Oregon State University. 63 p. M.S. thesis.

A study of the effects of old-growth Douglas-fir logging upon the Columbian black-tailed deer was conducted from January 8 to December 30, 1958, in the H.J. Andrews Experimental Forest near Blue River, Oregon. Objectives of the study were to obtain information about the activities, behavior, movements, migrations, and general ecology of the black-tailed deer in a logged environment. Prelogging records indicated that few deer used the area before initial logging in 1950. Deer numbers increased, however, in the excellent browse conditions of brushy successional stages of vegetation after the removal of the virgin timber. A sex ratio of 1 buck per 3.24 does and an age ratio of 4.19 adults per yearling were derived. Fawning occurred mainly during June, and a ratio of 1.4 to 1.5 fawns per does was determined. Weather conditions, especially temperature, appeared to affect the daily activities of deer. Deer were distributed nearly evenly between north and south slopes until June when a movement to the north slope occurred. This aspect was slightly favored by deer through the remainder of the summer. On the north slope, units below 2,500 feet in elevation were preferred, although deer showed a tendency to move upward during midsummer. In August this trend was reversed when a sharp downward movement occurred. The spring migration into the H.J. Andrews Experimental Forest occurred as a gradual upward drift in March, and by early May, most of the population had arrived. Many deer were returned to their home ranges of the previous summer. The downward fall migration occurred in September, long before the advent of inclement weather.

275. McLean, L. Scott. 1972. Movements and migrations of the Lochsa elk herd. Moscow, ID: University of Idaho. 65 p. M.S. thesis.

Movement and migration patterns of the Lochsa elk herd during the 1971 study were based on 848 observations of 28 radio-collared cow elk. Instrumented and marked elk in the lower portion of the drainage demonstrated lateral seasonal movements to the river. These movements were elevational changes. Instrumented elk in the mid-Lochsa drainage exhibited a combination of parallel and lateral movements between seasonal ranges. Those wintering in large brushfields bordering timbered areas farther upriver made parallel movements in early May to spring areas in these timbered areas. Elevational increases were not noticeable during this movement. Movement

and migrations during the fall were reverse patterns to those in the spring. No intermediate area was used. The fall movements were short and steady, lasting from 4 to 6 weeks, in comparison with the spring movement which lasted from 2 to 9 weeks. Fall migrations were made primarily in response to increasing snow depth. Movements of elk in winter areas were influenced by snow depth, snow condition, temperature, aspect, and food availability. Movements in summer areas appeared to be slow and directed toward a general use of the area and newly available plant growth. Hunting pressure did not appear to influence elk movements unless an actual hunter-elk encounter occurred. Elk showed preference for different seasonal habitats. Large brushfields were preferred during late winter and early spring, decreasing toward summer and fall. Timbered areas increased in preference from spring to a peak in early fall. During this study most elk showed little seasonal preference for logged areas, but three elk used new growth in the previous year's burn.

276. McNay, R. Scott. 1984. Forest crowns, snow interception, and management of black-tailed deer winter habitat. Vancouver, BC: University of British Columbia. 111 p. M.S. thesis.

Snow interception by forest stands is examined. Interception relationships extracted from literature are evaluated for their applicability to the silvicultural and climatic conditions of south coastal British Columbia. Hypotheses tested address (1) the prediction of snow interception, (2) comparisons of heterogeneity in snow interception between second-growth and old-growth forests, and (3) how interception and interception efficiency vary depending on forest crown completeness and storm size. Particular reference is made to the effect of interception on energetics costs of locomotion for black-tailed deer. Management of coastal forests for the interception of snow should focus on maximizing crown completeness and crown surface area. Further research is required concerning the relationships used in the simulation models. Emphasis should be placed on deer response to snowpacks, the influence of melt on snowpack development, and the influence of canopy closure on spatial distribution of snowpacks.

277. Mereszczak, Ihor M.; Krueger, William C.; Vavra, Martin. 1981. Effects of range improvement on Roosevelt elk winter nutrition. *Journal of Range Management* 34(3): 184-187.

Three pasture types dominate the Beneke Creek Wildlife Management Area on this Roosevelt elk winter range in northwestern Oregon. In winter, elk showed a strong preference for perennial ryegrass pastures that were hayed the previous summer and fall fertilized over bentgrass pastures also hayed and fertilized or unmanaged bentgrass pastures. These perennial ryegrass pastures provided forage that met minimal requirements for digestible protein and digestible energy all winter while both bentgrass pasture types were deficient in these nutrients through winter. Improvement of bentgrass pastures by conversion to ryegrass should result in higher rates of elk reproduction and better survival of offspring.

278. Merrill, E.H.; Raedeke, K.; Knutson, K.; Taber, R. 1986. Elk recolonization and population dynamics in the northwest portion of the Mount St. Helens blast zone. In: Keller, S.A.C., ed. Mount St. Helens five years later: Symposium proceedings; 1985 May 16-18; Cheney, WA. Cheney, WA: Eastern Washington University Press: 359-368.

The May 18, 1980, eruption of Mount St. Helens killed an estimated 1,600 Roosevelt elk. The distribution, movement patterns, and population dynamics of the elk population recolonizing the northwest portion of the blast zone during the 5 years after the eruption are described. Aerial and ground observations of elk herds indicated a 12% and 27% increase in the spatial distribution of elk within the blast zone in 1982-83 and 1982-84, respectively. Distances between activity centers of annual home ranges of elk moving into the blast zone averaged 4.2 km. Most of the annual use, however, remained within 5 km of the blast-zone edge. The effects of topography, vegetation, and hunting pressure on elk distribution and movements are discussed. Adult cows comprised the largest proportion of elk observed in the area. Pregnancy rates of yearling and adult cow elk averaged 0.31 and 0.84, respectively, from 1982 to 1984. The proportion of branch-antlered bulls doubled under no-hunting and restricted-hunting regimes. Immigration into the area averaged 46% of the observed population growth if natural mortality was not significant. Yearlings constituted the majority of immigrating animals after 1982. Projections of population growth of the elk herds under recent harvest levels indicate that the numbers of elk would stabilize or increase over the next 5 years if natural mortality of adult animals remains below 10%.

279. Merrill, Evelyn Hunter. 1987. Population dynamics and habitat ecology of elk in the Mount St. Helens blast zone. Seattle, WA: University of Washington. 264 p. Ph.D. dissertation.

Population dynamics and habitat ecology of elk recolonizing the northwest portion of the Mount St. Helens blast zone were studied from 1982 to 1985. A combination of rapid vegetation regrowth, mild winters, and low harvest have allowed a rapid re-invasion and recovery of the elk population to preeruption population levels in the 5 years since the eruption. The observed rate of population growth was 0.34 which approaches the maximum recorded for an elk population. Immigration accounted for a large proportion of the observed growth in the initial years, but early age of maturity and high pregnancy rates were also important. Summer-fall diets were generally higher in forbs during the summer and grasses in the fall than diets of most west coast elk populations. Elk altered their foraging behavior in response to declining forage resources. In November, elk decreased activity time as they approached a negative energy balance and allocated more time to rumination. Elk selection of plant communities was positively correlated with the abundance of the preferred forage class, thereby indicating that forage resources are the major determinant of habitat selection during the summer-fall period. Thermal modeling of the heat flux between an elk and the environment suggests that elk could maintain body temperatures despite high radiative heat gain because of their high sweating ability, large body size, and an increase in wind velocities during the midday. They did not move to forest cover during periods of high temperature but did switch to a nocturnal feeding pattern.

280. Miller, Frank L. 1968. Observed use of forage and plant communities by black-tailed deer. *Journal of Wildlife Management* 32(1): 142-148.

During 1964, 6,746 observations were made of known numbers of black-tailed deer within an enclosure within the Tillamook burn, Oregon. These observations provide insight into the deer's use of vegetation within the enclosure. Indices of preference by deer showed a spatial and seasonal nonrandom distribution of deer. Red huckleberry was the principal browse plant; vine maple and red alder were unimportant as browse. Browsing of Douglas-fir began with the first snow. Sightings of deer in the vine maple community were high every month. Deer presence in the huckleberry community increased in later winter, peaked in May, and declined the rest of the year. In the big-leaf maple community, deer sightings increased in late winter, declined in March and April, increased during the summer, and peaked in October. Relatively few deer were observed in the bracken fern and thimbleberry communities. Occurrence of deer in the alder community was highest in spring and fall.

281. Miller, Frank L. 1970. Distribution patterns of black-tailed deer (*Odocoileus hemionus columbianus*) in relation to environment. *Journal of Mammalogy* 51(2): 248-260.

During 1964, 1,410 hours of observation yielded 6,746 sightings of black-tailed deer within the Cedar Creek study enclosure on the Tillamook burn, Oregon. Deer activity was influenced by age, sex, reproductive phase, extremes or sharp changes in temperature, minimum relative humidity, and precipitation. Deer sought cover by midmorning from mid-May to November when weekly extreme temperatures exceeded 60 °F. Their activity was sharply reduced by heavy summer rainfall but was not influenced by winter rains. Monthly and annual home ranges were related to age and sex and varied with changes in the reproductive cycle and forage availability. Annual home ranges varied from 1/8 to 1/2 square mile.

282. Miller, Richard F.; Krueger, William C.; Vavra, Martin. 1981. Deer and elk use of foothill rangelands in northeastern Oregon. *Journal of Range Management* 34(3): 201-204.

Forested foothills of the Willowa Mountains in northeastern Oregon provide spring and early summer range for deer and elk. Deer and elk use varied both between plant communities and seasonally within plant communities. Plant species composition of big game diets also varied with season. Bunchgrass and logged communities collectively occupying 57% of the land area studied provided 90% of the big game diet during spring and early summer. Grasses made up 52% of the diet, forbs 38%, and browse 10%. Timothy and western goatsbeard were the two most important species consumed by big game. Pellet groups did not reliably estimate the value of various communities to deer and elk for forage use.

283. Miller, Richard F.; Vavra, Martin. 1982. Deer, elk and cattle diets on northeastern Oregon rangelands. In: Peek, J.M.; Dalke, P.D., eds. Wildlife-livestock relationships symposium; 1982 April 20-22; Moscow, ID. Moscow, ID: University of Idaho: 500-508.

This paper summarizes diet information of mule deer, Rocky Mountain elk and cattle from four studies in the Blue Mountains and Wallowa Mountains in northeastern Oregon. Plant species composition in the diets of deer and elk are discussed for winter, spring, and summer. Cattle diets are covered from late June until early October. Open pine-bunchgrass south slopes, seeded clearcuts, and forb and browse consumption in forested pastures appear to be areas with the greatest potential for competition to occur. Management alternatives for reducing competition are discussed.

284. Moir, Bruce C. 1976. Movement and range use patterns of mule deer in the Pahsimeroi Valley, Idaho. Moscow, ID: University of Idaho. 89 p. M.S. thesis.

A mule deer telemetry study was conducted from June 1973 to July 1974 and for brief intervals in November 1974 and January 1975 to determine seasonal home range sizes, movement and range-use patterns, and whether changes in ecological relationships have occurred since two previous studies on the same area. Considerable variation in individual home range size and movement patterns was apparent for both sexes within and between seasons. Home ranges were large in summer, averaging 3.87 and 1.62 square miles for males and females, respectively, and small in winter, averaging about 0.7 square miles for both sexes. Summer home range sizes differed not only within geographic areas but also between them. Home ranges were scattered over a larger area in summer but were concentrated on a smaller area in winter. About 70% of the deer migrated to summer ranges between May 22 and June 10 and traveled from 2 to 17 air miles in southeast or north directions. Fall migrations occurred between the third week in September and mid-November. Douglas-fir and big sagebrush cover types were most important and equally important to deer throughout the year. Activity times during daylight hours in later winter were about equally divided between bedding activities and nonbedding activities. In general, deer were active within 4-hour periods beginning 2 hours after sunrise. Data compiled from 135 feeding sites revealed that feeding occurred on 75 plant species. Collectively, browse, forbs, and grasses contributed 62, 20, and 18%, respectively, to the annual diet. Overall herd composition for bucks, does, and fawns was 19, 45, and 35%, respectively, with a fawn:doe ratio of 80:100.

285. Morris, Melvin S.; Schwartz, John E. 1957. Mule deer and elk food habits on the National Bison Range. *Journal of Wildlife Management* 21(2): 189-193.

The relative food habits of mule deer and elk were studied on a game range that consists mainly of grassland and forest with a grass understory. Weather records indicated a fairly normal period for the study except for an unusually dry fall in 1952 which limited fall growth of grasses and forbs. Snow and the low winter temperatures were important factors in conditioning the availability and use of forage in the winter. Grasses were the principal forage material in the yearlong diet of the elk. Mule deer made unexpected use of grass as indicated by the November and December 1951 samples. The degree of use of grass in the spring was as anticipated. Forbs were dominant in the samples from May to November 1952. Douglas-fir was the principal constituent in the January samples.

286. Morrison, John A.; Trainer, Charles E.; Wright, Philip L. 1959. Breeding season in elk as determined from known-age embryos. *Journal of Wildlife Management* 23(1): 27-34.

Eight known-age elk embryos were obtained from cow elk bred under observation. The embryo ages were 25, 30, 37, 43, 59, 90, 123, and 182 days. One term calf was obtained; its gestation period was 247 days. The embryos were measured, weighted, and their morphology described. A growth curve was constructed from crown-rump or forehead-rump length, depending on the stage of development, to be used for aging embryos from wild cow elk and thus computing the average conception date and average calving date. The average conception date in 18 free-ranging Bison Range elk was estimated to be October 3 by use of the embryonic growth curve. In 22 Yellowstone National Park elk, the average conception date was estimated to be October 6. Gravid uteri were not markedly enlarged until after the 30th day of gestation. The placental cotyledons and chorionic villi appear to develop at a rate similar to that found in some cattle.

287. Mueggler, Walter F. 1966. Herbicide treatment of browse on a big-game winter range in northern Idaho. *Journal of Wildlife Management* 30(1): 141-151.

The chemicals 2,4-D, 2,4,5-T, and a mixture of these two chemicals were tested for effectiveness in lowering the live crown and increasing the basal sprouting of browse grown beyond the reach of elk and deer. Concentrations of 3/4, 1-1/2, and 3 lb acid equivalent per acre were applied by helicopter in late June. The mixture of 3 lb per acre was most effective in killing aerial crowns. Rocky Mountain maple was relatively resistant to these sprays; Scouler willow, Saskatoon serviceberry, creambush rockspirea, and bitter cherry were moderately sensitive; redstem ceanothus and Lewis mockorange were very sensitive. Willow sprouted prolifically; rockspirea and maple sprouted moderately; ceanothus and mockorange sprouted poorly. Species differed considerably in reaction to date of spraying. Early summer and late summer spraying were usually more effective than midsummer spraying; however, the study revealed no seasonal pattern that could be used as a general guide for spraying to achieve optimum effectiveness in browse rehabilitation.

288. Nellis, Carl H.; Ross, Robert L. 1969. Changes in mule deer food habits associated with herd reduction. *Journal of Wildlife Management* 33(1): 191-195.

Food habits of mule deer on the National Bison Range, Montana, were determined from 48 rumen samples taken from November 1962 to January 1964. Forbs and shrubs each accounted for a third of the total diet, grass, 21%, and conifers, 13%. These data are compared with similar information from 1952. A large increase in the use of shrubs and a smaller increase in conifer use occurred from 1952 to 1963. A compensatory decrease in use of grass in spring and winter and of forbs in summer and fall occurred during this period. These changes in food habits were associated with a reduction in mule deer by 1963 to about 1/3 of their 1952 levels. Range condition declined from 1952 to 1963.

289. Nyberg, J.B.; Bunnell, F.L.; Janz, D.W.; Ellis, R.M. 1986. Managing young forests as black-tailed deer winter ranges. Land Mgt. Rep. 37. Victoria, BC: British Columbia Ministry of Forests. 49 p.

During snowy winters, black-tailed deer in coastal British Columbia appear to survive best in old-growth forests. Reserving these forests from logging forever would mean losing important economic benefits, so alternatives for ensuring deer survival have been suggested. Of these, the use of specialized silvicultural treatments of young Douglas-fir and western hemlock stands appears most promising. To serve as winter ranges, young forests will need to be patchier than most intensively managed stands, and in some patches, tree densities will need to be lower than normal. Initial prescriptions for creating winter ranges should aim to produce a 60/40 ratio of cover to forage-producing areas. By selecting suitable stands, planning treatment regimes carefully, and beginning treatments early, managers can probably provide suitable winter ranges in 40- to 80-year-old stands. These ranges may be poorer than prime old-growth winter ranges, but by managing larger areas, managers can compensate for lower quality with greater quantity under most winter conditions.

290. Nyberg, J. Brian. 1987. Man-made forests for deer: challenge or dilemma? Forestry Chronicle 63(3): 150-154.

As young forests in many areas of Canada enter the middle and later stages of their rotations, new concerns are arising about the future of deer populations. Analysis of silvicultural impacts on deer habitat requirements indicates that the food, cover, and water needs of deer can be met in young forests but that most uniformly treated stands will be lacking in one or more components. Mosaics of young stands, each 20-40 ha in area and at different stages of management, will provide good habitat in many areas. In areas with snowy winters, however, deer need to find all habitat components much more closely interspersed.

291. Nyberg, J. Brian; McNay, R. Scott; Kirchhoff, Matthew D. [and others]. 1989. Integrated management of timber and deer: coastal forests of British Columbia and Alaska. Gen. Tech. Rep. PNW-226. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 65 p.

Current techniques for integrating timber and deer management in coastal British Columbia and Alaska are reviewed and evaluated. Integration can be improved by setting objectives for deer habitat and timber, improving managers' knowledge of interactions, and providing planning tools to analyze alternative programs of forest management. A handbook designed to summarize relevant knowledge and assist planning in coastal British Columbia is described, and examples of its contents are included.

292. Nyquist, Maurice Otto. 1973. Deer and elk utilization of successional forest stages in northern Idaho. Pullman, WA: Washington State University. 95 p. Ph.D. dissertation.

Clearcut and burned stands in the *Tsuga heterophylla/Pachistima myrsinites* habitat type of northern Idaho were studied to document plant succession, browse production, and deer and elk use of clearcuts. Fifteen clearcut and burned stands of different ages (1-20 years) and three mature stands were sampled. Plant communities on clearcut and burned sites were distinctly two-layered. Although species diversity was reduced on these seral sites, 56% of the shrubs and 61.5% of the herbs were the same as those in climax communities. Revegetation of clearcut and burned sites was rapid, with 100% ground cover being achieved by the end of the second growing season. Natural tree regeneration, however, was slow because relatively few coniferous tree seedlings became established, and tall shrubs dominated the sites for the first 20 years. Means of the total available stems per acre increased commensurately with age of the clearcut, but stem production for individual browse species varied greatly. Production of preferred browse species was greater in clearcuts and along clearcut roads than in mature stands. Production of preferred browse also increased with age (1-20 years). *Ceanothus sanguineus* was the most preferred browse species, and it was the most abundant browse species in clearcuts. Deer and elk used more browse in clearcuts and along clearcut roads than in mature stands. Deer and elk use generally increased with age of the clearcuts. Increased use of older clearcuts (10-20 years) was probably related to increased availability of highly preferred browse species.

293. O'Neil, Thomas A. 1981. Validation testing of elk management guidelines. Missoula, MT: University of Montana. 91 p. M.S. thesis.

A basic concept for management of elk habitat assumes that management actions, specifically timber harvest, can be manipulated to provide an optimum balance between cover and forage areas. The optimum ratio proposed was 40% cover and 60% foraging area. Currently, guidelines are widely used although neither the underlying assumptions nor the methods of application have been standardized and appropriately tested. Validation testing of elk management guidelines was undertaken with the hypothesis that individual segments of habitat equally available to the same elk will be used by elk at levels predicted by the guidelines. Five areas in western Montana were studied. Deviation from optimum habitat was referred to as an area's effectiveness and was defined as the proportion of the habitat actually available to elk after reductions related to road density and the amount of thermal and hiding cover. The cover/forage ratio was measured for effectiveness by using a single curve that had 100% effectiveness at 40% cover and multicurves in which effectiveness varied by habitat-type group. The effects of roads were measured with models developed by Perry and Overlay, and Lyon. Consequently, by using different methods and models, 12 area-effectiveness percentages were calculated for each subunit. Elk management guidelines were tested to determine which model and method came the closest to the elk's preference. This study fails to reject the hypothesis, but in doing so, these models and methods were favored: to obtain a cover/forage ratio, use the percent in cover by photo interpretation (P.I.) of increase type of the tree/shrub breakdown; to test for cover/forage effectiveness use the single curve; to evaluate road effects, use the Perry and Overly model.

294. Pac, David F.; Mackie, Richard J.; Jorgensen, Henry E. 1984. Relationships between mule deer and forest in southwestern Montana—some precautionary observations. In: Meehan, William R.; Merrell, Theodore R., Jr.; Hanley, Thomas A., eds. Fish and wildlife relationships in old-growth forests: Proceedings of a symposium; 1982 April 12-15; Juneau, AK. [Place of publication unknown]: American Institute of Fishery Research Biologists: 321-328.

Results of a 10-year study in the Bridger Range, Montana, provide insight of the role and importance of forest vegetation in the population ecology and management of mule deer on mountain/foothill habitat in the northern Rocky Mountains. General distributional data together with specific information on distribution, movements, and population characteristics of deer in two important population units supported a hypothesis that the forest zone constitutes core habitat for production of mule deer in the Bridger Range. Although analysis of relations to specific forest communities have not been completed, late mature and "old-growth" stands of Douglas-fir and subalpine fir at intermediate elevations appeared important in sustaining high deer densities. Logging and application of present intensive silvicultural practices in forest lands in the Bridger Range can be expected to reduce the capacity of this important deer habitat to support and produce animals for future harvest and other recreational uses.

295. Pac, Helga Ihsle; Kasworm, Wayne F.; Irby, Lynn R. [and others]. 1988. Ecology of the mule deer, *Odocoileus hemionus*, along the east front of the Rocky Mountains, Montana. *Canadian Field-Naturalist* 102(2): 227-236.

Mule deer wintering along the east slope of the Rocky Mountains from Sun River to Birch Creek in north-central Montana represented seven herd units. Distribution and movement patterns of deer in each herd unit were influenced by the topography and vegetation on winter ranges and in the mountains west of winter ranges. Each herd unit consisted of deer that were yearlong residents on or near winter ranges, deer that summered in valleys near the winter range, and deer that moved 20 or more km to mountain summer ranges. Movement patterns and apparent vulnerability to hunting varied among segments. Degradation of mountain front winter ranges through intensive oil and gas development could significantly reduce mule deer numbers in large areas of the Rocky Mountains.

296. Pedersen, Richard J. 1976. Pre-logging elk habitat use. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 85-87.

The Bobsled elk study, in the Umatilla National Forest of Oregon, has documented elk habitat use in an undisturbed forest situation. Our study indicated that elk use specific habitat types and that significant differences in use patterns exist by month, sex, and age class of elk.

297. Pedersen, Richard J.; Adams, A.W.; Skovlin, Jon. 1979. Elk management in Blue Mountain habitats. Portland, OR: Oregon Department of Fish and Wildlife. 27 p.

From the Bobsled Ridge cooperative elk study, information is provided on elk habitat requirements, elk habitat management, and elk relationship with roads.

298. Pedersen, Richard J.; Adams, A.W.; Skovlin, Jon M. 1980. Elk habitat use in an unlogged and logged forest environment. Wildl. Res. Rep. 9. Corvallis, OR: Oregon Department of Fish and Wildlife. 121 p.

Seral plant communities which develop after fire, domestic stock grazing, or logging are more conducive to forage production than dense stands of climax or subclimax forest. Recent fire-suppression programs have reduced one of the natural processes responsible for maintaining elk habitat. Logging activities are the most important land management activity affecting plant communities. In response to a need for documentation of the direct effect of timber harvest, road construction, and human disturbance on elk, this cooperative study defines the relationship between elk and their habitat before, during, and after road construction and timber harvest.

299. Pedersen, Richard Jerome. 1985. Elk habitat use of an unlogged and logged forested environment. Moscow, ID: University of Idaho. 154 p. Ph.D. dissertation.

The influence of forest management on elk habitat use was determined from 6,875 telemetry data points obtained from 149 tagged animals in the northeast Oregon summer range from 1973 to 1978. Approximately 55% of the study area was conifer forest and 45% natural grassland or shrub/grassland. Elk consistently selected Land Types 2 (old-growth white fir), 13 (north-south complex) and 15 (riparian forest). Land Types 3 (derived forest), 7 (upland grassland), and 11 (south slope grassland) were selected against. The riparian forest supported the greatest elk use during August and September in 4 of the 5 years. Elk selected against areas within 250 m of roads during construction and logging; the animals did not become accustomed to roads. Logged units were selected against for 3 years. Month, sex, age class, year, weather, and plant phenology affected elk habitat-use patterns.

300. Peek, James M.; Scott, Michael D.; Nelson, Louis J. [and others]. 1982. Role of cover in habitat management for big game in Northwestern United States. In: Sabol, Kenneth, ed. Transactions of the 47th North American wildlife and natural resources conference; 1982 March 26-31; Portland, OR. Washington, DC: Wildlife Management Institute: 363-373.

Conifer and deciduous overstories, or cover, are a significant component of the habitat of big game in the Northwestern U.S. The spatial and temporal distribution of cover is affected by natural processes such as plant growth, plant succession, disease, pests, and fire. Big game animals have evolved under this regime and are presumed to be well adapted for existence under these conditions. Humans, however, are not significantly influencing the dynamics of cover with logging, fire, and pest control. The impact of these changes on big game populations depends on their ability to adapt to rapid changes in habitat. This paper reviews studies of cover-use patterns of big game and discusses the relationship between cover preference and requirement.

301. Perry, Charles; Overly, Robert. 1976. Impact of roads on big game distribution in portions of the Blue Mountains of Washington. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 62-68.

Roads were grouped into three classifications based on their character and corresponding use. Big game distribution was measured by pellet-groups analysis and stratified by topographic and vegetative features of the landscape. Generally, roads reduce big game use of adjacent habitat located from road edge to more than 1/2 mile away. This impact was greatest along main roads and through open vegetation types, and diminished with reduced road quality and increasing vegetation density.

302. Peterson, Gary Edward. 1983. Structural and vegetative components of deer summer range in the Klamath Mountains. Davis, CA: University of California. 44 p. M.S. thesis.

Vegetative and structural components of the summer ranges of 16 radio-collared, black-tailed deer were evaluated for factors affecting summer habitat use. The study area in Trinity County, California, is characterized by steep topography and a complex pattern of forest and shrub communities. Complex structural and plant species information was stratified into four groups of discriminating variables. Each group of discriminating variables was subjected to discriminant analysis and evaluated as to its ability to discriminate between low and high deer-use habitats. Deer use of subalpine/upper montane habitats was best described by browse species in the shrub layer: *Angelica arguta*, *Ceanothus velutinus*, and *Vaccinium* spp. Deer use of mid-montane habitats affected by various logging intensities was best described by shrub and herbaceous layer species. Deer use in an area repeatedly disturbed by logging and characterized by large seral brushfields and relatively high deer use was best described by shrub-layer species. Deer use in an area less affected by logging and characterized by mature forest and relatively low deer use was best described by herbaceous-layer species. Discriminating species at both midmontane sites were indicators of microhabitats attractive to deer. Resident deer habitats at lower elevations were best characterized by important browse species in the shrub layer: *Quercus kelloggii* and *Ceanothus lemmonii*. Herbaceous- and shrub-layer species were the most important sets of discriminating variables, which implies that forage resources are the major influence on deer habitat selection and activity.

303. Picton, Harold D. 1960. Migration patterns of the Sun River elk herd, Montana. *Journal of Wildlife Management* 24(3): 279-290.

A study of summer use of vegetative types and migration of the Sun River elk herd in Montana was conducted during 1957 and 1958. Of a total of 190 elk tagged and marked, 68 were relocated 1 to 3 times. Discussion of the usage of vegetative types was based upon observations of 2,544 elk seen during the summers of 1957 and 1958. Five vegetative types and three subtypes were recognized in the study area. During June, the grassland areas were the most heavily used type. Movement through the forest types to the subalpine barrens was noted in June and July. The forb subtype was most heavily used in the subalpine barrens, followed by the mixed

subtype. The beargrass subtype, covering half of a study area in the barrens, was little used. In late summer, elk moved downward into the forest types. Groups seen in open areas and in forest types averaged 7.2 and 2.5 elk, respectively. Migration from the winter range to the North Fork of the Sun River occurred in April and May. The grassland areas of the lower North Fork drainage were used as a calving ground.

304. Pollard, R.H. 1982. Deer and elk habitat preferences in southeastern Washington. Pullman, WA: Washington State University. 82 p. M.S. thesis.

To determine specific preferences by elk and deer for various habitat components, the pellet-group count technique was used on a portion of the Wooten Wildlife Recreation Area in the Blue Mountains of southeastern Washington. Elk use was greatest on the upper third and tops of slopes. Deer use was not significantly correlated with position on slope. Elk exhibited a preference for the grassland vegetation type and for the *Agropyron spicatum/Poa secunda* habitat type. Deer showed a preference for the conifer type series and for the *Pinus ponderosa/Symphoricarpos albus* and *Pseudotsuga menziesii/Physocarpus malvaceus* habitat types. Elk use was greatest (1) on elevations of 944-1,220 m, (2) on southwest and southeast exposures, (3) at 901-1,200 m from the road, and (4) in the 0-50% thermal cover class. Deer use was greatest (1) on elevations of 671-808 m and 1,083-1,220 m, (2) on northern exposures, (3) at 0-300 m from the road, and (4) in the 51-100% thermal-cover class. Slope percent had no major influence on elk and deer distribution. The hypothesis that deer seemed to defer use of a given habitat when elk preferred this habitat (and vice versa) was tested and found to be significant at $P > 0.05$.

305. Raedeke, Kenneth J.; Merrill, Evelyn H.; McCorquodale, Scott M. 1986. Estimates of intrinsic growth rates in three elk populations in Washington. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 235-244.

Population growth rates during the initial phase of irruption in three elk populations in Washington state were compared. Two of the elk populations experienced irruptive growth after introduction into new geographic areas (Rocky Mountain elk), while the other grew exponentially during recolonization of the Mount St. Helens blast zone (Roosevelt elk). Maximum observed growth rates in the three populations differed, depending on degree of hunting mortality and immigration. The growth rate of the Mount St. Helens population exceeded "intrinsic growth rate" (that is "r-max") due to reproduction alone. Immigration was believed to be a significant contribution to growth. The Cedar River Watershed elk population was below "r-max" because elk were lost to illegal hunting mortality and emigration. The Arid Lands Ecology Reserve elk population, in sagebrush-steppe of central Washington most closely approached maximum "r-max" because emigration and mortality were minimal. Immigration was not a significant factor. The comparisons indicate potential effects of the different mortality, reproduction, immigration, and emigration levels. The results also indicate that potential elk population growth rates vary under different environmental conditions.

306. Raedeke, Kenneth J.; Taber, Richard D.; Paige, Dwayne K. 1988. Ecology of large mammals in riparian systems of Pacific Northwest forests. In: Raedeke, Kenneth J., ed. Streamside management: riparian wildlife and forestry interactions: Proceedings of a symposium; 1987 February 11-13; Seattle, WA. Contrib. 59. Seattle, WA: University of Washington, College of Forest Resources: 113-132.

The literature is reviewed relating to the ecological needs of large, free-living mammals to the riparian environment to determine these species' degrees of need and the particular habitat characteristics important in meeting their ecological requirements. Species covered are Virginia opossum, snowshoe hare, Nuttall's and eastern cottontail, mountain beaver, beaver, muskrat, nutria, red fox, grey fox, fisher, mink, striped skunk, western spotted skunk, river otter, bobcat, elk, mule and black-tailed deer, white-tailed deer, and moose. Native species considered dependent on riparian areas or that find optimum habitat there are beaver, muskrat, raccoon, mink, river otter, elk, and mule deer. Native species more abundant in riparian areas than in adjacent uplands are snowshoe hare, grizzly bear, western spotted skunk, white-tailed deer, and moose. The other species listed use riparian areas but are as abundant in other habitats. The significant features of riparian systems were abundance of prey species; productivity of the shrub/herb layer; early spring phenological development of food plants; reduced snow accumulations; aquatic habitat, and lineal continuity of habitat.

307. Rieck, Carroll Adelbert. 1952. Black-tailed deer investigations on a closed area in western Oregon. Corvallis, OR: Oregon State College. 74 p. M.S. thesis.

This paper investigates Columbian black-tailed deer in the Coast Range in western Oregon from September 1950 to December 1951. The specific problem was to determine population densities and distribution on diversified types of habitat and to add life-history data to a long-term study being conducted by the Oregon Cooperative Wildlife Research Unit. The study area included about 40,000 acres which were closed in August 1950 to test the possibility of increasing deer numbers by protection on burned areas where browse was plentiful. The closed area consisted of three regions: a lowland agricultural area; a central district which contained a marginal winter area; and a western district on a high, flat, logged and burned plateau. The western area was frequently covered by snow in the winter, which may have caused deer kill and seasonal movement to the central winter area. Observations on winter habits, life history, voice, family groups, antler rot, enemies, and rutting are given. The relative deer density was determined in the late summers of 1950 and 1951. The areas of good and fair deer abundance were found to be located on the margin of the plateau where it bordered the central district in two large drainage basins which contained a variety of natural foods. General food preferences were established. A nutritional analysis of some important winter deer foods indicated that the ranges were deficient in food value. An evident drift of the deer to the agricultural district was probably caused by a combination of deer snow conditions in the west and an effort to meet nutrient requirements. As a result, deer did some damage to crops in the farming area.

308. Riley, Shawn J.; Dood, Arnold R. 1984. Summer movements, home range, habitat use, and behavior of mule deer fawns. *Journal of Wildlife Management* 48(4): 1302-1310.

Radio telemetry was used to determine movements, home range, behavior, and habitat use of 77 mule deer fawns in the Missouri River Breaks of north-central Montana. Average distance between successive radio locations was 0.78 km. Among individuals, movements were highly variable, but fawns were capable of extensive movements at any age; 77% made movements greater than 1 km before 1 month of age. Average home range size was 185 ha. Home range sizes decreased with increased population size but did not overlap until peak population was attained. Fawns increased their activity and spent more time with does as they grew older. Maternal does were intolerant of other deer until their fawns were at least 1 month old. Regular spacing of adjacent home ranges and solitary behavior exhibited by does suggested that a social pattern that resembled territorial organization occurred. Fawns selected habitat types with dense vegetative cover and typically used the mid- and lower 1/3 of slopes. Seasonal shifts in habitat use were correlated with desiccation of herbaceous cover and associated diet changes by does. Findings are also discussed in relation to mule deer behavior, coyote predation, variation in vegetation production, and weather.

309. Rochelle, James Arthur. 1980. Mature forests, litterfall and patterns of forage quality as factors in the nutrition of black-tailed deer on northern Vancouver Island. Vancouver, BC: University of British Columbia. 296 p. Ph.D. dissertation.

The relative availability and quantities of black-tailed deer forage supplied by litterfall and understory vegetation during winter were assessed in selected mature conifer stands in the Nimpkish Valley of northern Vancouver Island. Composition and rates of litterfall and its use by deer were determined as were yearlong food habits of deer using mature conifer stands and logged areas. Amounts of litterfall suitable for forage equal or exceed year-round quantities of available rooted vegetation in some mature conifer stands. Lichens made up 86% of forage litterfall. Monthly litterfall rates varied in response to weather conditions. Litterfall provides a relatively small but continuous source of forage during the winter. Forbs and shrubs were of major and equal importance in the annual diet of deer. *Epilobium angustifolium* was the most heavily used species during the spring to fall period; use of conifers and lichens was greatest in winter.

310. Rouse, Ralph A. 1957. Elk food habits, range use and movements, Gravelly Mountains, Montana. Bozeman, MT: Montana State University. 29 p. M.S. thesis.

An elk food-habits, range-use and movements study was conducted in the southern portion of the Gravelly Mountains, southeast of Dillon, Montana. Field work was conducted in the summer of 1956 and the winter of 1956-57. Food habits were determined by analyses of 14 elk rumen samples [with at least 1 sample occurring in each month of the year] and by feeding site examinations totaling 14,578 instances of

plant use. Six vegetative types were described. The number of elk, the time of year observed, and the vegetative type they were using while being observed indicated range use. Fifteen elk calves were tagged with plastic ribbons from May 28 to June 12. Ten relocations of six marked calves were obtained during the summer. Overlap of area use by elk and livestock was determined by observations.

311. Scharpf, Raymond W.; Kuttel, Mike P.; Anderson, Robert J. [and others]. 1986. A forage-based model for evaluating elk habitat potential. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 101-116.

A forage-based model for evaluating habitat effectiveness of elk was developed for winter range in the Gifford Pinchot National Forest, Washington. The model differs from others because it uses environmental stress to determine the desired forage/cover relationship. It can be modified to reflect stress conditions during winter and summer. It effectively evaluates silvicultural options by rotation patterns that yield the highest habitat potential over time.

312. Schoen, John Warren. 1977. The ecological distribution and biology of wapiti (*Cervus elaphus nelsoni*) in the Cedar River watershed, Washington. Seattle, WA: University of Washington. 423 p. Ph.D. dissertation.

The objectives included developing a database for the population characteristics and seasonal biology of the Cedar River herd, testing the hypothesis that wapiti use the landscape selectively and developing a word model describing the ecological distribution of migratory wapiti inhabiting the managed forests of western Washington. Throughout the year wapiti selectively used the landscape within the study site. During the active growing season (calving, summer, and rut), wapiti used the landscape within their respective seasonal home ranges in a highly selective manner; this was termed the accumulation period. During the remainder of the year, they used their seasonal home ranges less selectively; this corresponded to the period of conservation. The elevational distribution varied annually, as well as seasonally, corresponding to fluctuations in snow accumulation. Increasing slope appeared to affect wapiti most by making travel more difficult. They preferred slopes of 0% year-round. Throughout the summer and rut, wapiti preferred northern aspects where new succulent forage was available. Beginning in late fall through winter, spring, and calving, they preferred southerly aspects which had comparatively less snow and greater forage availability. Throughout the year, they preferred regions with 1,300 feet of free water. They use low traffic roads as travel lanes but avoid intensively used roads. Throughout fall, winter, and spring wapiti preferred low elevation second-growth deciduous and hemlock clearcuts 5-15 years postharvest and riparian and meadow communities.

313. Schuerholz, G.; McNamee, P.; Massie, M.R.C. 1988. Estimation of the effect of intensive logging on ungulates (cervids) in the White River drainage. Info. Rep. BC-X-303. Victoria, BC: Canadian Forestry Service, Pacific Forestry Centre. 35 p.

A generalized ungulate population model was developed to estimate sustainable populations of elk, moose, and deer before and after salvage logging of beetle-damaged

lodgepole pine in the White River area of the east Kootenays, British Columbia. Ecosystem classification schemes were used to describe the biogeoclimatic zones and subzones for the study area as a basis for the discussion of habitat requirements by corresponding cervid species. The results show that salvage logging will significantly enhance winter ranges for elk, deer, and moose.

314. Schwartz, John E., II; Mitchell, Glen E. 1945. The Roosevelt elk of the Olympic Peninsula, Washington. *Journal of Wildlife Management* 9(4): 295-319.

Reports on a 3-year study (1935-38) of the Roosevelt elk with information on the number of elk, their seasonal distribution, reproduction, migrations, food habits, mortality, and damage to range and soil resources.

315. Scott, Michael D. 1978. Elk habitat selection and use on an undisturbed summer range in western Montana. Missoula, MT: University of Montana. 98 p. M.S. thesis.

Elk habitat selection and use of an undisturbed, forested summer range was studied during the summers of 1976 and 1977 in the Chamberlain Creek drainage of western Montana. Virtually all available habitats are used by elk at one time or another. While no environmental situation is preferred over all seasons, some situations are consistently avoided. Use is always lower than availability on slopes over 30 degrees, primary upper slopes and ridgetops, dense stands of small lodgepole pine, and areas farther than 450 yards from water. Seasonal habitat-use patterns appear to be based primarily upon a combination of weather and vegetation composition, structure, and phenology. During spring, the most preferred sites were clearings, either bunchgrass meadows on dry west-facing slopes at lower elevations or wet meadows or seeps. During the summer, elk use shifted to more closed overstory canopies, primarily into stands of medium to large size lodgepole pine on west and northerly aspects. Fall and winter elk use was less well defined but clearly shifted away from the lodgepole pine and spruce-fir types to open Douglas-fir-larch types on southwest and west aspects at lower elevations. The most preferred sites were the most exposed ones, clearings or stands of scattered large Douglas-fir on secondary upper slopes and ridgetops. In addition to seasonal shifts in habitat use, yearly shifts were also evident in response to weather conditions. Elk appeared to respond to the drier conditions of 1977 by moving earlier than usual into the upper Chamberlain Creek drainage from the drainage to the north and west. Chamberlain Creek drainage is especially important for elk in dry years.

316. Singleton, J. 1976. Food habits of wild ungulates in British Columbia. [Victoria, BC]: Department of the Environment, Environment and Land Use Committee Secretariat, and Department of Recreation and Travel Industry, Fish and Wildlife Branch. 51 p.

Presents a bibliography of food habit studies on moose, deer, elk, mountain goat, bighorn sheep, and caribou in British Columbia and in other northwest states and provinces. Also included is a plant synopsis that shows the forage preference indicated by a relative value of various plant species eaten by wild ungulates. Both the bibliography and plant synopsis are arranged according to the animal species or subspecies.

317. Skovlin, Jon; Vavra, Martin. 1979. Winter diets of elk and deer in the Blue Mountains, Oregon. Res. Pap. PNW-260. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 21 p.

Dietary contents of pellet droppings from elk and deer were analyzed from collections on five winter-range units throughout the Blue Mountains during early and late winter of 1973-74. Botanical intake was identified by species to establish levels of elk and deer competition for food. Elk consumption of grasses during early and late winter was slightly over 1/2 and 3/4 of their total intake, and deer use of grass early and late winter was about 1/3 and 1/2 of their intake. Forb use by both elk and deer was insignificant. Elk diets contained less than 25% shrubs. Shrubs are apparently not as important to elk and deer in the Blue Mountains as they are on other winter ranges of the mountain west. Conifer use by deer, especially, was high on two winter range units when snow was in excess of 1 foot and temperatures near zero. Idaho fescue was the most often selected species by both animals. Competition for available forage species was not acute under the moderately severe winter conditions that prevailed.

318. Skovlin, Jon M.; Edgerton, Paul J.; Harris, Robert M. 1968. The influence of cattle management on deer and elk. In: Trefethen, James B., ed. Transactions of the 33d North American wildlife and natural resources conference; 1968 March 11-13; Houston, TX. Washington, DC: Wildlife Management Institute: 169-181.

Forage use relationships of deer, elk, and cattle were studied on a ponderosa pine-bunchgrass summer range in the central Blue Mountains of northeastern Oregon. Long-term deer use averaged 2.8 days per acre, elk use averaged 1.5 days per acre, and overall cattle use averaged 3.8 days per acre. Big game annual use depended on the accumulation of snow which determined the length of the grazing season into winter months. Deer consistently preferred the forested areas over grassland openings, but elk showed no special preference. Elk use decreased as rate of cattle stocking increased; rate of stocking had little influence on use by deer. Deer, however, tended to use grasslands more as the rate of stocking increased. Deer preferred deferred-rotation ranges somewhat more than season-long ranges, but neither system had much effect on use by elk. Based on animal requirements, big game consume about 25% of the total forage removed. Based on forage use, however, cattle were estimated to remove at least 10 times more of the principal plants than were deer and elk. There was no evidence of direct competition between big game and cattle for any particular food plants on the study area.

319. Skovlin, Jon M.; Edgerton, Paul J.; McConnell, Burt R. 1983. Elk use of winter range as affected by cattle grazing, fertilizing, and burning in southeastern Washington. *Journal of Range Management* 36(2): 184-189.

A study of ways to increase winter use by elk of Pacific bunchgrass foothill range in southeastern Washington employed fertilizing and rangeland burning with and without spring cattle grazing. First-year response of elk to fertilizer applied in fall (56 kg N/ha) was a 49% increase in use; however, no significant carry-over effect was noted in

subsequent years. Fall burning to remove dead standing litter and enhance forage palatability provided no increase in elk use in winter. Intensive cattle grazing in spring to promote regrowth did not increase elk use. Cattle grazing decreased winter elk use by 28% in 1 of the 3 years studied. The cost effectiveness of increasing elk use by fertilizing appeared marginal except perhaps in special situations.

320. Smith, Cary S. 1978. Summer-fall movements, migrations, seasonal ranges, and habitat selection of the Middle Fork elk herd. Missoula, MT: University of Montana. 91 p. M.S. thesis.

Elk that winter along the Middle Fork of the Flathead River were investigated from May through November 1977. Five cow elk were fitted with radio transmitters; 87 locations were accumulated during 18 tracking flights; 71 locations were made on the ground. Migrations to the summer range were 9 to 15 miles in north and easterly directions. The return to winter range was more gradual and followed similar routes. Range size varied greatly, seasonally and among individual elk. During May, the elk moved from relatively mesic sites, associated with the winter range, to more hydric habitats. June was characterized by continued use of hydric, late seral habitats near the heads of small tributaries where areas of dense shrubs were interspersed with wet sedge meadows. Use shifted to more open areas at higher elevations during July and August. Elk returned to densely forested midelevation habitats during September and October. Use of early seral stages increased as elk approached their winter range. Areas disturbed by clearcuts and logging roads were significantly avoided throughout the study period. Soil samples taken from a frequently used mineral lick showed sodium, potassium, calcium, and magnesium in high concentrations. Vegetative cover at each site sampled on the ground was used to construct an ordination of environmental factors influencing each radio location. Gradual changes in habitat preference were thus quantitatively represented.

321. Smith, Ian Donaldson. 1968. The effects of hunting and seral succession upon Vancouver Island black-tailed deer. Vancouver, BC: University of British Columbia. 140 p. M.S. thesis.

The role of seral succession and hunting in the regulation of Vancouver Island black-tailed deer populations was studied from comparison of observed changes in the Northwest Bay herd over the period 1954-1966 with those predicted from a computer simulation of population processes of such a herd. Northwest Bay was chosen because there were accurate logging records since the first cut was made in 1939 and accurate kill records since hunters were first allowed into the area in 1954. Previous studies had shown that deer populations increase rapidly after fire and logging but tend to return to former levels 15 to 20 years later. From 1956 to 1966, the Northwest Bay area deer population decreased while hunting pressure increased. Two independent indices suggested that the decrease in deer numbers over this period was correlated with a decline in the condition of the younger age-classes of males. Average weights of the lower age-classes of females followed similar patterns, but the decreases in weight were not significant. These changes supported the hypothesis that seral succession is the most important long-range determinant of deer

numbers, but one expected change the development of an older average age—was not found. Hunting was the greatest cause of mortality, with winter weather being a second major cause. It was concluded that seral succession had been the indirect cause of the decline in number over the period 1954-1966 but that numbers of animals in any year during the period 1954-1961 were dependent upon the severity of the winter; in later years, the population levels were dependent primarily on the effects of hunting.

322. Smith, Jack L. 1980. Reproductive rates, age structure and management of Roosevelt elk in Washington's Olympic Mountains. In: Macgregor, W., ed. Proceedings of the Western States elk workshop; 1980 February 27-28; Cranbrook, BC. [Victoria, BC]: British Columbia Fish and Wildlife: 67-111.

This report summarizes 4 years of research by the Washington Game Department concerning population characteristics and effects of human use of elk populations. Habitat is discussed as it relates to population characteristics brought about by interactions of human use of elk populations. Objectives of the studies were (1) to determine sex and age composition; (2) to determine age-specific productivity of females; (3) to analyze the elk harvest for temporal distribution, composition. Hunted elk populations outside the Olympic National Park were more productive than unhunted elk within the Olympic National Park even with significantly more large bulls in the park population than outside. Female age structure indicated the Olympic herd to be a very "old" female population, rivaling some completely protected herds. A definite and significant decrease in female productivity was noted after 13 years of age. A high correlation between fewer branched-antlered bulls in the breeding population and lower pregnancy rates in adult cows was observed with sex ratios prevailing outside the Olympic National Park. Management objectives designed to increase productivity by lowering female age structure and providing increased bull escapement were established and discussed.

323. Smith, Winston Paul. 1982. Status and habitat use of Columbian white-tailed deer in Douglas County, Oregon. Corvallis, OR: Oregon State University. 285 p. Ph.D. dissertation.

A study conducted May 1978-December 1980 determined that the present geographic range of Columbian white-tailed deer in Douglas County encompassed 1,119 square km. The area was predominately a *Quercus* woodland community. The highest densities of deer occurred along the North Umpqua River between Glide and Wilbur. Ten habitats are described. The deer exhibited a preference for grass-shrub, oak-savanna, open oak, closed oak, riparian and conifer habitats while selecting the remaining habitats less frequently than was expected from corresponding availabilities. Grassland use increased proportionally with biomass production of grasses and forbs during the spring and with mean monthly precipitation in the fall. Fawns used woodland and brushland habitat more frequently than did yearlings and adults; yearlings used grasslands more often and grass-shrub habitats less frequently than adults. Adult males occurred less frequently in grass-shrub and more often in conifer habitats than adult females, particularly in summer. The population estimates for the 2,745-ha study area were 628 and 740, representing an average density of 22.9 and 27.0 per square km, respectively. Malnutrition and vehicle-inflicted injuries accounted

for the largest proportion of known mortality. The ultimate cause of mortality was associated with reproduction; these activities were more demanding on males. Convex polygon estimates of home range size for females and males averaged 21.1 ha and 32.8 ha, respectively. Elliptical home range estimates were larger, 44.5 and 47.1 ha for females and males, respectively.

324. Smith, Winston Paul. 1987. Dispersion and habitat use by sympatric Columbian white-tailed deer and Columbian black-tailed deer. *Journal of Mammalogy* 68(2): 337-347.

Sympatric Columbian white-tailed deer and Columbian black-tailed deer maintained a local geographic and habitat segregation within the interior valleys of the Umpqua River Basin, Oregon, during May 1978 through December 1980. White-tailed deer occurred more often in portions of the study area within 1 km of the North Umpqua River than black-tailed deer. Distributional patterns indicated that at least one species demonstrated interspecific avoidance. Densities of white-tailed and black-tailed deer were inversely correlated throughout their sympatric range. Highest densities of white-tailed deer occurred in portions of the study area with greater than 50% woodland cover, and they used lowland *Quercus* associations more often and grassland associations less often than black-tailed deer. Black-tailed deer used lowland habitats more often in comparable environments supporting few or no white-tailed deer. High densities of white-tailed deer may preclude the use of corresponding habitats by black-tailed deer.

325. Starkey, E.E.; DeCalesta, D.S.; Witmer, G.W. 1982. Management of Roosevelt elk habitat and harvest. In: Sabol, Kenneth, ed. *Transactions of the 47th North American wildlife and natural resources conference*; 1982 March 26-31; Portland, OR. Washington, DC: Wildlife Management Institute: 353-362.

Postulates probable primeval Roosevelt elk habitat relationships, describes contemporary elk habitats and impacts of forest management on elk, and discusses areas of compromise and cooperation between wildlife and forest management.

326. Stehn, Thomas V. 1973. Daily movements and activity of cow elk in the Sapphire Mountains of western Montana during summer and fall. Missoula, MT: University of Montana. 66 p. M.S. thesis.

During summer and fall 1972, radio-collared elk were located 799 times, mostly at 3-hour intervals. By using a pulse-height, detector-Rustrak recorder system, 45,817 minutes of elk activities were classified as either active or bedded. Intrarange movements of one cow elk were documented throughout the study period. Repetitive, daily movement patterns were uncommon; the same areas were rarely used on consecutive days. Movement peaks occurred during the 3 hours following sunrise and sunset. The daily activity rhythm was highly variable from day-to-day. Cow elk were active 68.2% of the time during summer and 59.0% during fall. These differences held for both diurnal and nocturnal periods. Elk spent approximately equal percentages of time active during day and night. Major active peaks occurred at sunrise and sunset. Times of the greatest amount of bedding were less pronounced and occurred at midday and 1.5 hours before sunrise. There were 12 alternative bedding and feeding

periods per 24 hours. The longest feeding bouts were at sunrise and sunset, averaging 184 and 217 minutes in length, respectively. During both day and night, feeding and bedding bouts were similar in length and averaged between 94 and 103 minutes. Long, daytime or nocturnal bedding periods were not observed.

327. Steigers, William D., Jr.; Flinders, Jerran T. 1980. Mortality and movements of mule deer fawns in Washington. *Journal of Wildlife Management* 44(2): 381-388.

Thirty-nine mule deer fawns were captured in south-central Washington in 1977. The fawns were 1-24 days old and weighted 2.9-9.7 kg. The average age at capture was 6.9 days. Fawns were located daily May through August, and monthly through December. Average distance traveled by fawns from the previous day's location during an approximate 24-hour period for the first 3 months of life was highly variable and averaged 438 m. The mean home range was 257 ha for fawns approximately 60 days old or older. Total mortality was 14 out of 26 radio-instrumented fawns. Predation by coyotes accounted for 10 of the losses. Drowning caused three deaths, and circulatory collapse accounted for one death. Combined fawn mortality was 54%. High variability in average daily distance traveled by individual fawns indicates that age is not reliable as the sole factor for predicting fawn movements. Intensive coyote removal on the study area probably would not substantially reduce total mortality in the fawn population.

328. Stevens, David R. 1966. Range relationships of elk and livestock, Crow Creek drainage, Montana. *Journal of Wildlife Management* 30(2): 349-363.

A study of range relationships between elk, cattle, and sheep was made in 1963-64 on 100,000 acres of the Crow Creek drainage, Elkhorn Mountains, Montana. Use by elk of the fescue-wheatgrass, Douglas-fir, and spruce-fir zones was determined from 4,939 observations of elk. The fescue-wheatgrass zone received almost 100% of the elk use from January through March and about 90% in April and May. Each zone received considerable use in June, and the spruce-fir zone received most of the use in July and August. Elk food habits were determined by examining 94 feeding sites and analyzing the contents of eight elk rumens. The spring diet consisted of 77% grasses and 23% forbs, and the summer diet consisted of 76% forbs and only 16% grasses. Data from fall rumen samples indicated a progressive shift to grasses during the period. In the spruce-fir and Douglas-fir zones grazed in spring, summer, and fall by elk and in summer and fall by cattle, interspecific competition was not considered significant. In the fescue-wheatgrass zone grazed in spring, fall, and winter by elk and summer and fall by cattle, competition was not considered serious, but the data indicated a potential for conflict on areas used by elk in winter. A potential for competition in summer was indicated between sheep and elk, but the degree existing on the study area was not considered excessive.

329. Stevens, Marschall Calvin. 1965. A preliminary study on the movement, distribution, abundance, and sex and age composition of the Roosevelt elk in and adjacent to the Prairie Creek Redwoods State Park. Arcata, CA: Humboldt State College. 122 p. M.S. thesis.

A study of the Roosevelt elk in and adjacent to the Prairie Creek Redwoods State Park was undertaken April 1963-64. The relationship of the elk and the various

vegetative conditions existing in the region was examined. The movement and distribution of elk was also studied, and elk throughout the area were classified as to sex and age for comparative herd composition data. Plots for vegetative analysis were established in the coastal brushlands, the virgin redwood timber, and cutovers of various ages. Results revealed that the density of browse species was essentially the same in the virgin redwood forest and the coastal brushlands. After logging operations, the density of browse species decreased, after which it began rising again sharply. The total average density was found to be greatest in the 22-year-old cut-over area. Browsing intensity was low in the virgin forest. An initial sharp decline of browsing intensity followed logging. Within 6 years, the browsing had increased greatly, peaking at 11 years, then declining rapidly to a low level in the 22-year-old cutover area. Coastal brushlands and the 11-year-old cutover were the most important regions used by elk. Virgin redwood timber, newly logged areas, and very old cutovers are of relatively minor importance as elk habitat. The elk situation is continuously changing because of logging activity and regrowth. The distribution and density of elk in and adjacent to the study area will greatly decrease within a decade or two, as present cutover areas mature.

330. Stevenson, Susan K.; Rochelle, James A. 1984. Lichen litterfall—its availability and utilization by black-tailed deer. In: Meehan, William R.; Merrell, Theodore R., Jr.; Hanley, Thomas A., eds. Fish and wildlife relationships in old-growth forests: Proceedings of a symposium; 1982 April 12-15; Juneau, AK. [Place of publication unknown]: American Institute of Fishery Research Biologists: 391-396.

Amounts of forage available from litterfall and amounts used by black-tailed deer were measured in mature conifer forests on northern Vancouver Island. Litterfall forage, including lichens and green conifer foliage, exceeded understory forage on three of five sites studied. The beard lichens *Alectoria sarmentosa* and *Bryoria* spp. constituted 26% by volume of the rumen contents of deer wintering in timber. Quantities of these lichens present in litterfall ranged from 2 to 151 kg/ha in 180 days. Use of litterfall was measured by comparing accumulation inside and outside 3-m-high deer exclosures. Significantly more beard lichen litter accumulated inside than outside exclosures; use ranged from 37 to 53% of available quantities. Because beard lichens are abundant in old-growth forests but sparse in immature stands, the harvesting of mature forests reduces this source of winter forage for black-tailed deer.

331. Stevenson, Susan Kingsbury. 1978. Distribution and abundance of arboreal lichens and their use as forage by blacktailed deer. Vancouver, BC: University of British Columbia. 148 p. M.S. thesis.

Biomass of arboreal lichens used as winter food by black-tailed deer was studied. Three methods were used to assess abundance of *Alectoria sarmentosa* and *Bryoria* spp. Biomass of *Alectoria* on the 14 plots studied ranged from 21 to 1,528 kg/ha. Physical and vegetative characteristics of the plots were measured and related to lichen abundance. Taken together, slope, aspect, and elevation accounted for 82% of the variation in lichen abundance. Forest productivity was negatively related to lichen abundance. Within the range of sites studied, *Alectoria* was most abundant on moderate to steep south-facing slopes, at elevations above 500 m, where tree growth

was poor. To assess availability of lichens and their use by deer, litterfall was measured inside and outside exclosures on three sites where levels of deer use in winter were known. The relationships between litter deposition rates and weather were examined. Quantities of *Alectoria* litter were 69.9 kg/ha/180 days in a severe winter range area; 151.2 kg/ha/180 days in a mild winter range area; and 31.9 kg/ha/180 days in a poor winter range area. On all three sites, significantly more *Alectoria* litter was present inside than outside exclosures. Use of *Alectoria* was 37, 53, and 52% of available qualities on the three sites, respectively. The relationship between lichen abundance and selection of winter habitat by black-tailed deer was assessed. Areas selected by deer as winter range tended to be moderate or high in lichen abundance.

332. Sullivan, Thomas P.; Sullivan, Druscilla S. 1979. The effects of glyphosate herbicide on food preference and consumption in black-tailed deer. *Canadian Journal of Zoology* 57(7): 1406-1412.

The use of herbicides is an important part of forestry management practices in the Pacific Northwest because the regeneration of coastal forests is hampered by many species of deciduous shrubs and weeds. The herbicide glyphosate is used to control these undesirable species. Some effects of glyphosate on black-tailed deer have been investigated by analyzing food preference and consumption under simulated field conditions. Deer given a choice of control or glyphosate-treated alder and alfalfa browse showed no preference or ate more of the treated foliage. The ingestion of treated browse did not affect the consumption of laboratory chow by the deer. These results indicate that spraying with the herbicide glyphosate should not prevent deer from feeding on foliage in the affected area.

333. Suring, Lowell H.; Vohs, Paul A., Jr. 1979. Habitat use by Columbian white-tailed deer. *Journal of Wildlife Management* 43(3): 610-619.

Columbian white-tailed deer were studied to provide information for management of habitat essential to this endangered subspecies. Vegetation was assigned to major community groupings of rush, thistle, grass, horsetail, and forest. Coverage of 85% of the 790-ha study area provided information concerning use of the plant communities by these animals that have adopted a diurnal activity pattern. Communities providing both cover and forage were more heavily used than were communities providing cover or forage alone. Communities providing forage alone were used most near adjacent cover. Canada thistle (*Cirsium arvense*) provided cover in summer and allowed deer to use previously unused areas. Browse was not used. Green forage was available throughout the year. Restricting visitors to periphery roads allows continuance of the diurnal activity pattern of the deer and aids public enjoyment. Establishment of patches of permanent woody cover where absent would aid in dispersion of the population throughout the refuge.

334. Suring, Lowell Howard. 1974. Habitat use and activity patterns of the Columbian white-tailed deer along the lower Columbia River. Corvallis, OR: Oregon State University. 59 p. M.S. thesis.

A study of the life history, population dynamics, and ecological relationships of the Columbian white-tailed deer was conducted on the Columbian White-tailed Deer National Refuge during 1972-73 to provide information for management of this endangered subspecies. Vegetation on the study area was categorized into five major community groupings of rush, thistle, grass, horsetail, and forest. Deer were observed most often in those communities that provided both cover and forage. Communities providing forage without cover were most used where cover was adjacent. The population on the study area during the winter was estimated between 200 and 230 deer or 1 deer per 8.5-9.8 acres. A buck:doe:fawn ratio of 34:100:35 was calculated for November. Average group size of deer while grazing was 2.2 animals. The major classification of group size through the year was of single deer. Numbers of individuals within groups were highest during winter. Overt aggression between individuals was observed infrequently. Frequency of aggressive behavior was greatest during cold weather. Bucks were always dominant over does and fawns, and does were always dominant over fawns. Grazing was numerically the major activity observed. Deer grazed more and rested less in summer than during winter. Copulations may occur primarily at night. Home ranges of bucks were larger than those of does, and home ranges of yearlings were larger than those of adults. Average home range size was smaller than that reported for other subspecies of deer. Deer avoided association with cattle and used areas where cattle were not present.

335. Swanson, Donald Oscar. 1970. Roosevelt elk-forest relationships in the Douglas-fir region of the southern Oregon Coast Range. Ann Arbor, MI: University of Michigan. 173 p. Ph.D. dissertation.

Objectives were to study elk use of forage plants, elk use of cutovers, and effects of elk damage to Douglas-fir regeneration. Plant succession and influences of elk on vegetation were determined through vegetation analyses of permanent plots in clearcuts and elk exclosures. Case histories of marked trees in plantations, direct seedings, and exclosures showed the impact of elk on regeneration. Forage plants most used by big game were found to be trailing blackberry, red huckleberry, salal, western swordfern, and false dandelion. Douglas-fir ranked eighth year-round and fifth in winter. Time spent by elk in cutovers was influenced primarily by stage of plant succession. Greatest use occurred in clearcuts 5 to 9 years after logging, though burning and heavy soil disturbance delayed development of brush and prolonged the optimum stage for elk. Elk use patterns were modified by physical factors affecting comfort and mobility. The warmer west- and south-west facing slopes had heaviest use, except in summer. Gentle terrain received heavier use than steep slopes. Elk preferred tractor-logged settings over high-lead settings because of easier travel along skid trails. Patterns of big game damage to regeneration resembled elk use patterns. Most damage to Douglas-fir occurred on sites having high herbaceous and relatively low woody plant coverage. Before their first growing season, 30% of a sample of 1,400 planted Douglas-fir seedlings had been injured (including 10% killed) by big game. By the fifth year, 70% of the original sample (including 27% killed) had been damaged by big game.

336. Taber, Richard D. 1973. Effects of even-age forest management on big game. In: Hermann, Richard K.; Lavender, Denis P., eds. Even-age management: Proceedings of a symposium; 1972 August 1; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 59-74.

Reviews the effects of even-aged management (caused by clearcutting) in Pacific Northwest forests on black-tailed deer and elk. Discusses response of forage plants, response of ungulates with regard to movement, relations of ungulates to forest seedlings, and the human cultural elements that affect the silviculture-ungulate relationship.

337. Taber, Richard D.; Hanley, Thomas A. 1979. The black-tailed deer and forest succession in the Pacific Northwest. In: Wallmo, Olof C.; Schoen, John W., eds. Sitka black-tailed deer: Proceedings of a conference; 1978 February 22-24; Juneau, AK. Ser. No. R10-48. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region: 33-52.

In the range of the black-tailed deer in the Pacific Northwest, the value of timber generally far exceeds the values of other natural resources, and consequently logging is the dominant activity affecting deer habitat and deer populations. Almost any forestry practice can be a powerful tool for enhancing or reducing the quality of habitat. The interaction of timing, location, juxtaposition of cuttings, and harvest methods employed can result in widely differing effects on deer habitat quality. The land manager should think in terms of habitat type, the kind and amount of vegetation that a given land area is capable of producing. Winter range is the limiting factor for the majority of black-tailed deer populations, and this is becoming especially critical as clearcutting moves to higher elevations and winter ranges at lower elevations are becoming older, dense second-growth coniferous forests. Patches of land not suitable for timber production (for example power or pipeline rights-of-way, riparian communities, roadsides) and areas of low site quality may be more valuable in providing cover for deer than in providing timber.

338. Taber, Richard D.; Raedeke, Kenneth J. 1980. Black-tailed deer of the Olympic National Forest. Seattle, WA: University of Washington, College of Forest Resources, Wildlife Science Group; final report; contract R6-79-237. 90 p.

Discusses the Columbian black-tailed deer of the Olympic National Forest and adjacent lands, and the relations between forest management patterns and deer population response. Summarizes the ecological requirements of the deer and how these are met or affected by forest management practices. Describes the affected environment. This historical pattern of land use and tenure are considered in the context of their influence on deer numbers and distribution. The biological environment, the climate and vegetation, are described, particularly as they affect deer requirements. Deer population characteristics, population trends, harvest rates, and mortality factors are analyzed, on the basis of information available from the Washington State Game Department Big Game Status Reports and historical literature accounts. Finally, an evaluation is made of how alternative forest management practices could meet different habitat management goals that might be established by the Forest Service.

339. Taber, Richard D.; Raedeke, Kenneth J. 1980. Roosevelt elk of the Olympic National Forest. Seattle, WA: University of Washington, College of Forest Resources, Wildlife Science Group; final report; contract R6-79-237. 107 p.

Discusses the Roosevelt elk of the Olympic National Forest and adjacent lands and the relations between forest management patterns and elk population response. Summarizes the ecological requirements of the elk and how these are met or affected by forest management practices. Describes the affected environment. The historical patterns of land use and tenure are considered in the context of their influence on elk numbers and distribution. The biological environment, climate, and vegetation are described, particularly as they affect elk requirements. Elk population characteristics, population trends, harvest rates, and mortality factors are analyzed on the basis of the information available from the Washington State Game Department annual Big Game Status Report and historical literature accounts. Finally, alternative forest management practices that could meet different habitat management goals are evaluated.

340. Taylor, A. Doug. 1986. Roosevelt elk calf ratios from grassland versus forestland, N.W. Oregon. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 245-247.

Elk herd classification observed on the northwest coast of Oregon indicates that the availability of domestic grass increases calf production an average of 33%. Ten years of data indicate that herds that find access to grasslands consistently outproduce similar herds that are found over 1-1/2 miles away from such grass forage.

341. Thiessen, J.L. 1976. Some relations of elk to logging, roading and hunting in Idaho's game management unit 39. In: Hieb, Susan R., ed. Proceedings of the elk-logging-roads symposium; 1975 December 16-17; Moscow, ID. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 3-5.

Since 1960, intensive forest management practices including timber harvest and road-building have been applied extensively in west-central Idaho. Elk populations have declined significantly since 1964 in this area. In 1973, approximately 75% of all elk harvested in the Boise River area were taken from roadless and undisturbed areas, which comprise about 25% of the timbered portions of this drainage.

342. Thomas, Donald Charles. 1970. The ovary, reproduction, and productivity of Columbian black-tailed deer. Vancouver, BC: University of British Columbia. Ph.D. dissertation.

Ovarian changes, patterns of reproduction, and age-specific productivity of female Columbian black-tailed deer on Vancouver Island were elucidated largely by examination of serial, stained sections of ovaries from 444 females. Well-defined, 8- or 9-day, follicular cycles occur during the breeding season in November and early December. The changes in ovarian structures during the breeding season were ascertained in 12 females, whose follicles and corpora lutea were dated by the cleavage stage of fertilized ova. These provided criteria for estimating ovulation dates in other females. In each cycle, about 50% of the adult females ovulated within 8-days. The

mean date of first ovulation in each of the 5 years was approximately November 16; the second ovulation followed after a remarkably short period of 8-9 days. About 96% of the females conceived at second ovulation and 4% conceived on subsequent ovulations. A high proportion of "silent heats" accompany first ovulation, as indicated by lack of sperm on 4 of 6 ova. Growth curves, based on fetuses conceived at second ovulation, provided the conception dates of two late conceivers. Females may cycle at least five times if pregnancy does not occur. The average number of viable fetuses per doe increased progressively from 0.91 in yearlings to 1.81 in the 5.5 to 6.5 age-classes, and thereafter decreased. These changes in fertility with age were mirrored by changes in weight and girth. The relative contribution of fawns by each age-class in the population progressively decreased with age. One hundred females of reproductive age produced about 137 fawns.

343. Thomas, Jack Ward; Leckenby, Donavin A.; Erickson, Leonard J. [and others]. 1986. Wildlife habitats by design: National Forest in the Blue Mountains of Oregon and Washington. In: McCabe, Richard E., ed. Transactions of the 51st North American wildlife and natural resources conference; 1986 March 21-26; Reno, NV. Washington, DC: Wildlife Management Institute: 203-214.

The Forest Service is required by numerous laws to consider wildlife habitat as well as forest management in the National Forests. Managers now have 10 years experience in the Blue Mountains of northeastern Oregon. The experience includes developing, testing and modifying criteria for considering wildlife habitat in planning and management; developing techniques to evaluate and prescribe wildlife habitats; evolving technical skills for inventorying and monitoring habitats; and fostering the concept that habitats are a product of management forests. A model of elk habitat effectiveness has been developed and refined and is being used to produce both elk and timber from managed forests.

344. Thomas, Jack Ward; Leckenby, Donavin A.; Henjum, Mark [and others]. 1988. Habitat-effectiveness index for elk on Blue Mountain winter ranges. Gen. Tech. Rep. PNW-218. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 28 p.

An elk-habitat evaluation procedure for winter ranges in the Blue Mountains of eastern Oregon and Washington is described. The index is based on an interaction of size and spacing of cover and forage areas, roads open to traffic per unit of area, cover quality, and quantity and quality of forage.

345. Thomas, Jack Ward; Leckenby, Donavin A.; Lyon, L. Jack [and others]. 1988. Integrated management of timber-elk-cattle: interior forests of western North America. Gen. Tech. Rep. PNW-225. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 12 p.

The need for and the evaluation of elk habitat evaluation models are reviewed, and a state-of-the-art example is presented that incorporates distribution of elk-habitat use related to distance from cover/forage edges, distance from roads, cover quality, and forage quantity and quality.

346. Thomas, Jack Ward; Miller, Rodney J.; Black, Hugh [and others]. 1976. Guidelines for maintaining and enhancing wildlife habitat in forest management in the Blue Mountains of Oregon and Washington. In: Sabol, Kenneth, ed. Transactions, 41st North American wildlife and natural resources conference; 1976 March 21-25; Washington, DC. Washington, DC: Wildlife Management Institute: 452-476.

In response to the requirements of the National Environmental Policy Act, forest managers need to be able to predict effects, over time, of forest management activities on wildlife populations. This publication is a conceptual framework, specific to the Blue Mountains of Oregon and Washington. It discusses the relationship of resident vertebrates to forest communities and their successional stages. Elk is used as an example to show how particular species can be emphasized in a relationship. Special and unique habitats not specific to a plant community or successional stage (snags, talus) are also discussed.

347. Trainer, Charles E. 1986. Breeding season of elk in Oregon. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 217-234.

Conception dates were estimated from embryos recovered from uteri of Rocky Mountain elk and Roosevelt elk cows harvested during November-January hunting seasons in Oregon, 1983-85. Differences in time of breeding were evident between cows from some areas. Median dates of conception by area varied from 25 September to 13 October. There was no indication that disturbance from hunting seasons interrupted the rutting period. No clear relationship was apparent between postseason bull ratios and conception dates. Other factors possibly influencing the time of breeding are discussed.

348. Trainer, Charles E.; Lemos, James C.; Kistner, T.P. [and others]. 1981. Mortality of mule deer fawns in southeastern Oregon, 1968-1979. Wildl. Res. Rep. 10. Portland, OR: Oregon Department of Fish and Wildlife, Research and Development Section. 113 p.

A study was conducted on Steens Mountain to identify causes for the low crops of fawns in this herd of mule deer. Examination of 216 does collected annually February-May revealed a 93% pregnancy rate and a fetal rate of 1.62 viable fetuses per doe. Despite the level of fertility, periodic herd composition counts indicated that low recruitment to the population resulted from heavy mortality of fawns during their initial 9 months of life. A total of 163 mortalities of instrumented fawns was documented by cause. Accidents, disease, and starvation, occurring mostly during the summer, accounted for 16% of the total mortality. Coyotes accounted for 49% of all fawn mortalities, bobcats 11%, and golden eagles about 1%. The cause of death was not determined for 24% of the fawns that died, primarily because the remains found were too incomplete to identify cause of death. A coyote removal program was conducted to measure the effect of coyote control on fawn losses. Coyote removal was effective in reducing fawn mortality but was probably not of sufficient intensity to allow the deer herd to increase.

349. Trainer, Charles E.; Lightfoot, Wm C. 1970. The fertility of yearling male Roosevelt elk (*Cervus canadensis roosevelti*) in Oregon. In: Proceedings of the 50th annual conference of Western Association of State Game and Fish Commissioners; 1970 July 13-16; Victoria, BC. [Place of publication not available]: 311-317.

To determine the breeding potential of yearling bulls (spikes), breeding trials were conducted with a captive population of Roosevelt elk by using only yearling males as sires. During the first season of study (1967-68), a minimum of 2 calves was born in the experimental herd consisting of 10 adult cows and 3 yearling bulls. In the following reproductive season (1968-69), a minimum of 5 calves was produced by the herd, which contained 11 adult females and 2 yearling males. Because the lower natality observed during 1967-68 was believed related to stresses experienced by the initial period of confinement, the birth rate of approximately 45% recorded in 1968-69 was considered the most accurate estimate of the fertility of yearling males obtained in the two seasons of study. Comparison of natality recorded in 1968-69 as a result of spike service, with the 50% rate of pregnancy observed in adult female Roosevelt elk killed in adjacent areas during November and January, 1964-68, suggests that yearling bulls have approximately the same potential for breeding as is apparent in herds containing adult bulls.

350. Trainer, Charles Edward. 1971. The relationship of physical condition and fertility of female Roosevelt elk (*Cervus canadensis roosevelti*) in Oregon. Corvallis, OR: Oregon State University. 93 p. M.S. thesis.

The ratio of calves to cows observed annually during winters of 1950-69 indicated that about 20% fewer calves were seen than in similar inventories for Rocky Mountain elk. To determine if fertility was an important cause of the comparatively low percentage of calves, factors affecting reproduction were investigated. Examination of 264 uteri of adult elk collected during 1964-68 revealed that 50% were pregnant. By contrast, a pregnancy rate of 88% was evident for 90 adult Rocky Mountain elk harvested in northeast Oregon. A mean calf:cow ratio of 41% was observed 13 months later, indicating that the number of calves was largely determined by fertility rather than postnatal survival. None of 14 nonpregnant yearling elk sampled had ovulated. Tests for diseases harmful to reproduction indicated that pathological factors were not affecting fertility. Measurements of kidney fat indicated a significant difference in physical condition between pregnant and nonpregnant cows, which probably indicates that environmental factors, probably related to nutrition, were the underlying cause of the low reproductive rates. The stress of lactation was identified as the main physiological process affecting energy reserves of the cow to the detriment of fertility. Data were not available to determine whether reproduction was limited because of qualitative or quantitative deficiencies in forage.

351. Tucker, R.E.; Majak, W.; Parkinson, P.D.; McLean, A. 1976. Palatability of Douglas-fir foliage to mule deer in relation to chemical and spatial factors. *Journal of Range Management* 29(6): 486-489.

Relative preference of Douglas-fir needles from eight environmental conditions was determined in a feeding trial with penned tame deer of mixed age and sex. Relative

reference varied between 0 and 74%, with significant differences between open (16%) and gully (9%) sites, between old (20%) and young (4%) trees, and between tops (16%) and bottoms (8%) of trees. Shading was found to be responsible for some difference in palatability, unshaded being preferred (22%) over shaded needles (4%). Relative preference was found to be correlated with moisture content. Relative preference was also found to be correlated with chlorogenic acid, a naturally occurring phenolic ester which was quantified by fluorometric scanning after being observed in a thin layer chromatography screening experiment. Crude protein was not significantly correlated with preference.

352. Uresk, Daniel W.; Uresk, Virginia A. 1982. Diets and habitats of mule deer in south-central Washington. *Northwest Science* 56(2): 138-147.

Forty-four food items were identified in the fecal pellets of the mule deer on three areas of the Hanford site in south-central Washington. Microscopic analysis of plant fragments indicated that bitterbrush (*Purshia tridentata*) was the most common species occurring in the diets of deer from the B-C Cribs area. Russian thistle (*Salsola kali*) and goldenrod (*Solidago* sp.) were the most abundant plants found in the fecal pellets collected from B Pond and Gable Mountain Pond habitats, respectively. The similarity in diets among the habitats was low, ranging from 10 to 16%. Preference indices of forage plants among sites were not similar (7 to 19%), thereby indicating that deer are selecting different food plants at each site, although many plants are common to all three sites.

353. Wambolt, Carl L.; McNeal, Allen F. 1987. Selection of foraging sites by elk and mule deer. *Journal of Environmental Management* 25(3): 285-291.

Environmental factors that influence the selection of winter foraging areas by elk and mule deer were evaluated on the Gardiner winter range in south-western Montana. Twenty-eight vegetation and landform variables were assessed. Five site variables entering a step-wise regression analysis accounted for 71% of the variation in elk pellet-counts by site, and eight site variables accounted for 82% of the variation in mule deer pellet counts. Elk apparently selected feeding sites on the winter range where the relationship of food intake to energy expenditure was optimized. Deer selected feeding sites where forage availability, security, and thermal cover were optimized on this exposed winter range. Optimum models for prediction of elk and mule deer selection of foraging areas are suggested.

354. White, Keith L. 1960. Differential range use by mule deer in the spruce-fir zone. *Northwest Science* 34(4): 118-126.

This paper reports on the results of two summers' study of Rocky Mountain mule deer in the spruce-fir zone of western Montana, in the Rattlesnake Creek drainage of the Missoula Hills. The study area supported two habitat types, *Picea-Abies/Xerophyllum* and *Picea-Abies/Menziesia*, and had never been grazed or logged. Range use by mule deer was influenced most by the combination of vegetation and

topography. Observations substantiated the results of rumen analyses and pellet-group distribution—deer range use was greatest on the warm south slopes of the *Xerophyllus/Vaccinium* habitat subtype. The natural separation of merchantable timberland and mule deer range suggests that any future logging in this high country should result in small adverse effect on the mule deer population.

355. Wickstrom, Mark L.; Robbins, Charles T.; Hanley, Thomas A. [and others]. 1984. Food intake and foraging energetics of elk and mule deer. *Journal of Wildlife Management* 48(4): 1285-1301.

The energetic cost of grazing was measured by using indirect calorimetry with a tracheotomized elk. The cost of eating herbaceous forage averaged 0.32 kcal/kg body weight/hour, an energetic increment of 26% over standing costs. Forage intake was quantified using esophageal fistulated elk and mule deer. Dry matter consumption rate and mean bite size increased curvilinearly as functions of forage biomass for both species. Assymptotic grass intake rates were 2.2 and 14.04 g dry matter/minute for deer and elk, respectively. Consumption rate and bite size were greater in shrub-forb communities than on grass pastures of comparable biomass. Biting rate ranged from about 15 to 60 bites/minute and was inversely related to bite size. Rate of travel during foraging decreased exponentially with increasing forage availability. A computer model was constructed to evaluate the interaction of time and energy constraints on foraging ungulates. The effects of variation in forage quality, forage abundance, and snow cover on the ability to meet daily energy requirements are discussed.

356. Wilkins, Bruce T. 1957. Range use, food habits, and agricultural relationships of the mule deer, Bridger Mountains, Montana. *Journal of Wildlife Management* 21(2): 159-169.

The range use, food habits, and agricultural relationships of the Rocky Mountain mule deer were investigated from June 16, 1955 to May 7, 1956. Four vegetative types—mountain meadow, montane forest, sagebrush-bitterbrush, and bunchgrass prairie—were recognized and described. Intraseasonal and interseasonal differences in use of vegetative types is described. During the summer, forbs were the most important group, followed by browse and grass. The data from the fall indicate a reversal in importance of browse and forbs. During the winter, the relative positions of the groups were retained. Big sagebrush replaced bitterbrush as the most abundant species. In the spring, forbs and grass were of equal importance.

357. Willms, W.; McLean, A.; Ritcey, R. 1976. Feeding habits of mule deer on fall, winter, and spring ranges near Kamloops, British Columbia. *Canadian Journal of Animal Science* 56(3): 531-542.

Diets of mule deer were studied in the Kamloops area from September to April. The forages of 67 rumen samples were sorted to grass, tree, shrub, and forb species and the percent oven-dry weights calculated for each. Polynomial regressions (to the third degree) were used to describe the use of each plant-growth form over time, as well

as to determine the influence of snow depth on plant species consumption. Douglas-fir formed most of the tree component of the diet of the deer. Consumption of this species was highest in December and January. Grass consumption was less than 10% until early spring when it increased to almost 100%. More forbs were consumed in fall than in winter, and shrubs were consumed more in early fall and late winter than in late fall. Species composition of each plant growth-form generally varied with season. Increasing snow depth altered the proportion of both small and large plants in the diet. As snow depth increased, fewer small plants but more large plants were consumed.

358. Wisdom, Michael J. 1986. Development of a model for Roosevelt elk habitat in western Oregon. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 159-170.

Describes the framework of a model that was developed to evaluate habitat for Roosevelt elk and illustrates some potential uses.

359. Wisdom, Michael J.; Bright, Larry R.; Carey, Christopher G. [and others]. 1986. A model to evaluate elk habitat in western Oregon. Publ. R6-F&WL-216-1986. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 36 p.

This model provides a systematic way to evaluate and monitor elk habitat; it is a planning tool that identifies impacts, provides options for mitigation, and allows managers to set objectives. It is not, however, a panacea for such functions and must be considered a "first attempt" in the development of standard evaluation methods for elk habitat in western Oregon. As research continues, new evaluation methods will evolve to modify or substitute for earlier methods. Over time, this ongoing process will improve knowledge and capability to manage elk and elk habitat.

360. Witmer, G.W.; deCalesta, D.S. 1983. Habitat use by female Roosevelt elk in the Oregon Coast Range. *Journal of Wildlife Management* 47(4): 933-939.

Based on 3,710 relocations, six radio-collared female Roosevelt elk preferred old-growth forest and hardwood stands in managed forest land of the Oregon Coast Range in 1978-79. Mixed forest and sapling-pole stands were used less than expected. Brushy clearcuts were used more than new clearcuts for foraging. Elk preferred southern aspects yearlong and did not venture far from forest-clearcut edges. Elk spent more time in cover and used lower-elevation areas closer to water during calving season than the rest of the year. Elk appeared unaffected by inclement weather during the mild winter of the study and sought cover during warmer periods of the day during all seasons. Cover use increased during the hunting season. Elk typically foraged in brushy clearcuts during early and late daylight hours and spent the midday bedded or loafing in old-growth stands. Integration of management for Roosevelt elk and other forest resources is recommended.

361. Witmer, Gary; Wisdom, Michael. 1986. Some important elk-forest habitat relationships for western Oregon and Washington. In: Eastman, Dan L., ed. Proceedings of the 1986 Western States and Provinces elk workshop; 1986 March 17-19; Coos Bay, OR. Portland, OR: Oregon Department of Fish and Wildlife: 149-157.

Reviews some basic relationships of Roosevelt elk habitat: space and water, forage areas, cover areas, an interspersed component, and the roading/disturbance component.

362. Witmer, Gary W.; deCalesta, David S. 1985. Effect of forest roads on habitat use by Roosevelt elk. *Northwest Science* 59(2): 122-125.

Movements of six female Roosevelt elk were monitored for 12 months by radio telemetry in Alder Creek Basin in the Oregon Coast Range. Frequency distributions of elk from paved and spur (dirt) roads were compared with distributions about such roads of 200 randomly located points. Elk use was approximately 50% of that expected within a 500-m band surrounding paved roads. Distribution of elk was less affected by spur roads, though significantly fewer elk were monitored in a 125-m band along spur roads open to vehicles. No differences between expected and observed distributions of elk were found around spur roads closed to traffic. It is concluded that human activity on forest roads alters the distribution of Roosevelt elk habitat use.

363. Witmer, Gary W.; Wisdom, Mike; Harshman, Edmund P. [and others]. 1985. Deer and elk. In: Brown, E. Reade, ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. Publ. R6-F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region: 231-258.

This chapter discusses the relationships of black-tailed deer and Roosevelt elk with forest habitats, especially as influenced by silvicultural practices. Practices for habitat improvement are discussed and a procedure outlined for use in developing forest management plans that consider the needs of elk. Some forest management options that reflect the needs of deer and elk are provided for the forest manager to consider when implementing silvicultural practices.

364. Witmer, Gary William. 1981. Roosevelt elk habitat use in the Oregon Coast Range. Corvallis, OR: Oregon State University. 111 p. Ph.D. dissertation.

Daily and seasonal habitat use by Roosevelt elk was investigated in the Oregon Coast Range on managed, public forest land. Over 3,700 locations of 6 radio-collared cow elk were recorded during 12 consecutive months. Two elk formed part of a north band and four elk were part of a south band. Home ranges for elk bands were mutually exclusive and enclosed areas of 400 ha or less each season. Heavily used central cores of activity comprised a small portion of the total home range. Seasonal home ranges of a given band overlapped substantially and were largest in calving and summer seasons. Cow elk of a given band were most often associated with one another during spring, rut, and, winter seasons and were otherwise more dispersed. Elk exhibited preferences for old-growth forest and hardwood stands over mixed forest and dense, young conifer stands. Brushy clearcuts were used more

than new clearcuts for foraging. Use of new clearcuts increased in winter. Elk preferred southerly aspects throughout the year, avoided roads, and did not venture far from forest-clearcut edges. A consistent daily pattern of habitat use was for elk to forage on brushy clearcuts during early and late daylight hours and to retreat to an old-growth stand to bed and loaf through the midday. The pattern of several hours of activity followed by several hours of inactivity appeared to extend through the night. Despite variability in seasonal and individual elk habitat use, discriminant analyses suggested that cover types, adjacent cover types, and aspects were the most promising of the parameters measured for the prediction of habitat-use patterns.

365. Zahn, Helmut Max. 1985. Use of thermal cover by elk (*Cervus elaphus*) on a western Washington summer range. Seattle, WA: University of Washington. 185 p. Ph.D. dissertation.

Microclimatic parameters were recorded in different habitat types on the Cedar River watershed in western Washington. The results of these measurements were applied to an elk model to assess the magnitude of various sources of thermal energy, as well as avenues of heat loss available to free-ranging elk. Habitat use and activity patterns by radio-tagged elk were related to the amount of solar radiation the animals were exposed to. Analysis of the data suggests that, given the availability of suitable microclimates, elk generally do not use thermal capacitance to remain in stressful environments but opt for using habitat types that offer shade. In relatively open clearcut habitat types, elk activity declined in direct relationship to the amount of solar radiation experienced that day. In cover-limited clearcuts, elk showed a clear preference for patches of advanced regeneration as bedding sites. Compared to various age clearcuts, elk activity in remaining old-growth stands was high, suggesting that the favorable microclimate within such stands allowed for periodic foraging activity.

366. Zalunardo, Raymond A. 1965. The seasonal distribution of a migratory mule deer herd. *Journal of Wildlife Management* 29(2): 345-351.

Rocky Mountain mule deer were trapped, marked, and released on the Silver Lake winter range in south-central Oregon, and their subsequent movements were observed from June 1960 through October 1963 to determine ranging habits. A total of 752 deer were marked on 4 areas of the winter range, and an estimated 497 were later observed on the summer range. The summer range of marked animals encircled the winter range, however, no animals summered in areas northeast of the winter range because of lack of suitable habitat. The largest percentage of animals summered in areas south, southwest, and west, and within 30 miles of the winter range. Deer from any one of the four trapping areas did not move to a particular part of the summer range but were found throughout the area. The average size of the summer range for individual mule deer of the Silver Lake herd was approximately 1 square mile. Individual movement on the winter range was determined by retrapping. The mean movement of animals on the winter range was less than 1/4 mile from the point of original capture. Individual deer returned to the same area of the winter range each year.

367. Zalunardo, Raymond Alfred. 1962. The range and movements of mule deer in a central Oregon herd. Corvallis, OR: Oregon State University. 32 p. M.S. thesis.

The summer and winter movements of marked mule deer on the South Silver Lake winter range, Oregon, were studied during 1960 and 1961. The study was designed to determine (1) the summer range of deer using the South Silver Lake winter range; (2) the extent of the area used by individual deer on the summer and the winter ranges, and (3) whether animals from four areas of the winter range tended to use separate parts of the summer range. In order to accomplish these objectives, deer were trapped and marked, and information on their subsequent movement was obtained from all possible sources.

368. Zwickel, Fred; Jones, Gardiner; Brent, Homer. 1953. Movement of Columbian black-tailed deer in the Willapa Hills area, Washington. *Murrelet* 34(3): 41-46.

On the Clemons Tree Farm of western Washington, 639 fawns have been tagged. Tag returns and observations show that 85% of the fawn and yearling deer were seen or killed within 1 mile of the location of tagging while only 3% were seen or killed over 4 miles from the location of tagging. Six returns from 2-1/2-year-old does show that none were killed over 1.25 miles from the tagging site. Eight returns from 2-1/2-year-old bucks show movements ranging from 0 to 16 miles, with four of the eight bucks being killed over 4 miles from the site of tagging. It is believed that this differential movement by the bucks in this age class is primarily a result of the rutting period though population pressures or intraspecific strife may also be in operation.

369. Allan, G.G.; Gustafson, D.I.; Mikels, R.A. [and others]. 1984. Reduction of deer browsing of Douglas-fir (*Pseudotsuga menziesii*) seedlings by quadrivalent selenium. *Forest Ecology and Management* 7(3): 163-181.

The feasibility of using selenite ion as a systemic deer repellent for the protection of Douglas-fir seedlings is evaluated. When applied to the soil, the selenite ion is absorbed by the seedling roots, transported to the foliage, and thereafter volatilized. Acute phytotoxicity is observed only when selenium foliar concentrations exceed 100 parts per million, and animal repellency is demonstrated at concentrations as low as 1-2 p/m. The design of a slow release device, based on a sparingly soluble salt of selenious acid, is reported, and its evaluation in a series of field trials is described. Preliminary results indicate that statistically significant reduction of browse damage can be achieved.

370. Anthony, R. Michael. 1982. Protecting ponderosa pine from mule deer with plastic tubes. *Tree Planters' Notes* 33(3): 22-26.

Ponderosa pine seedlings in a plantation in Oregon, some of which had been damaged by deer browsing in winter 1974, were enclosed by 5-cm diameter plastic protectors in 1975, and damage, survival, and height growth were recorded in spring and autumn 1975-80. Survival was 92-98% in protected seedlings and 44-100% for unprotected controls. Seedlings were not browsed when enclosed by protectors, but 20% were damaged in 1980 when protectors began to disintegrate. Of surviving

unprotected seedlings, 77% were damaged by deer. In autumn 1980, protected seedlings were more than twice as tall as unprotected seedlings, although in many cases, the main shoots were bent or growing spirally where they had become caught in the plastic mesh.

371. Besser, Jerome F.; Welch, Jack F. 1959. Chemical repellents for the control of mammal damage to plants. In: Trefethen, James B., ed. Transactions of the 24th North American wildlife conference; 1959 March 2-4; New York. Washington, DC: Wildlife Management Institute: 166-173.

Describes trials of three commercially available repellents whose active ingredients are trinitrobenzene-aniline (TNB-A), zinc dimethyl dithio carbamate cyclohexylamine complex (ZAC), and tetramethyl thiuram disulfide (TMTD). Tests were done throughout the U.S. to determine effectiveness against browsing by rabbits and hares, deer, and other wild mammals and livestock.

372. Boyd, R.J. 1987. Vegetation management and animal damage. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 55-58.

Vegetation associated with forest trees can be managed so as to prevent the formation of plant communities which encourage animal populations which damage tree regeneration. Techniques are also available to treat existing vegetation to reduce animal populations and the attendant damage. Vegetation management aimed at enhancing tree performance by reducing competition should consider the possibility that such treatment may be counterproductive in that resident animals, robbed of their major food supply, may cause severe damage to the trees. Where animal damage and competition can both be controlled with vegetation manipulation, tree response results can be spectacular.

373. Browning, Bruce M.; Lauppe, Earl M. 1964. A deer study in a redwood-Douglas-fir forest type. California Fish and Game 50(3): 132-146.

A two-phased study was made of the relationship between black-tailed deer and the reproduction of the principal timber trees in the coastal redwood-Douglas-fir forests of California. Two deer-proof exclosures were constructed and 328 trees tagged and measured annually. Stomach contents were collected from hunters and special out-of-season collection and used to gather data on reproduction, age, condition, disease, and parasites. Young conifers outside of the exclosures averaged 2.7 inches growth per year and made a 166% growth increase over the 4-year period. Protected trees averaged 8.0 inches per year and made a 410% growth increase to an average height of 39.8 inches. A young conifer is able to escape deer damage at a height of about 3 to 4 feet, but unprotected trees may require as long as 20 years to reach the escape height. Stomach analyses indicated a definite seasonal pattern in feeding habits. The greatest pressure on the conifers comes during a rather limited period in the spring, generally coinciding with the trees' growing period. Deer need to be controlled in reforestation areas of the coastal redwood-Douglas-fir forests.

374. Campbell, D.L.; Evans, J. 1977. Guidelines for field evaluations of repellents to control deer damage to reforestation. In: Jackson, W.B.; Marsh, R.E., eds. Test methods for vertebrate pest control and management materials: a symposium; 1976 March 8; Monterey, CA. ASTM Spec. Tech. Publ. 625. Philadelphia, PA: American Society for Testing and Materials: 145-150.

A repellent evaluation process used by the U.S. Fish and Wildlife Service in a research program directed at reducing browsing damage to regenerating Douglas-fir by black-tailed deer in the Pacific Northwest is reviewed. Several methods of repellent testing to control deer damage to commercially valuable trees are being used in the United States. Our procedures to assess deer damage and efficacy of candidate repellents could be used in most of these evaluations to provide uniform data for comparisons of materials and aid in registration of deer repellents needed by land managers.

375. Campbell, Dan L. 1969. Plastic fabric to protect seedlings from animal damage. In: Black, Hugh C., ed. Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 87-88.

Tests of methods to prevent browsing damage in summer to actively growing Douglas-fir seedlings by black-tailed deer and to prevent clipping damage to dormant seedlings by snowshoe hares were conducted in enclosures at Olympia, Washington. Field tests with the most promising device, inexpensive tubes of polypropylene plastic netting placed on individual seedlings, are being completed in western Washington. Both repellent-treated and untreated netting appear to greatly reduce or prevent damage to new growth by deer and to both old and new growth by hares.

376. Campbell, Dan L. 1974. Establishing preferred browse to reduce damage to Douglas-fir seedlings by deer and elk. In: Black, Hugh C., ed. Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium; 1973 September 11-12; Corvallis, OR. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University: 187-192.

Propagation of palatable forbs on new Douglas-fir plantations was investigated as a means of reducing summer browsing on Douglas-fir seedlings by deer and elk in western Washington. Four species were tested: candyflower, catsear, a hybrid fleabane, and oxeye daisy. Seed was collected, tested for germination in the laboratory, and fall-seeded in field plots paired with unseeded controls. Seeding or rescarification of candyflower on two previously scarified plantations did not greatly increase or prolong stands of this species, and all stands of candyflower had greatly decreased 2 years after the original scarification. The other three species were seeded as a mixture on seven burned or scarified plantations. Despite losses of seeds and seedlings of 80-95%, all had produced stands of plants by the following June. Catsear appeared particularly adaptable to seeding, with foliage coverage averaging 10% on seeded plots. The establishment of preferred forbs as browse for big game appears feasible, although the test plots were too small to determine usage by deer and elk.

377. Campbell, Dan L.; Bullard, Roger W. 1972. A preference-testing system for evaluating repellents for black-tailed deer. In: March, Rex E., ed. Proceedings, 5th vertebrate pest conference; 1972 March 7-9; Fresno, CA. Davis, CA: University of California: 56-63.

In a program to evaluate repellents for protecting Douglas-fir seedlings from browsing by black-tailed deer, a preference-testing system was developed to supplement preliminary pen tests. The system uses an apparatus that presents individual test deer with a choice between two foods (usually feed pellets treated with a candidate repellent or a marginally palatable standard). The two foods are presented, in alternative positions, only long enough for the deer to make a choice; results are recorded in terms of percentage choices made for the candidate repellent, or percentage consumption. Tests thus far with a number of candidate repellents, including several chemical fractions derived from putrefied fish, have generally given clearcut results, and the system appears very promising for this kind of evaluation.

378. Campbell, Dan L.; Evans, James. 1975. Improving wildlife habitat in young Douglas-fir plantations. In: Sabol, Kenneth, ed. Transactions, 40th North American wildlife and natural resources conference; 1975 March 16-19; Pittsburgh, PA. Washington, DC: Wildlife Management Institute: 202-208.

Browsing damage to Douglas-fir seedlings by black-tailed deer and elk is a major problem in western Washington and Oregon. If damage to seedlings can be minimized for the first 3 or 4 years after stocking, browsing is usually no longer a limiting factor. Instead of physical barriers or repellents, the prompt introduction and establishment of native forbs to serve as browse is suggested. This hypothesis is based on observations made in plantations that for some reason have had a rapid, natural increase in preferred forbs and have experienced only negligible damage. This has not yet been demonstrated experimentally, but long-term studies are underway.

379. Campbell, Dan L.; Evans, James. 1975. Vexar seedling protectors to reduce wildlife damage to Douglas-fir. Wildl. Leaf. 508. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 11 p.

Describes uses of "Vexar" seedling protectors to reduce clipping and browsing damage to regenerating Douglas-fir by snowshoe hares, rabbits, black-tailed deer, and Roosevelt elk. The information was collected from 1968 through 1974 in a cooperative study with DuPont, Inc., to develop and evaluate "Vexar" as a conifer seedling protector in western Washington and Oregon. "Vexar" protectors are an inexpensive method of reducing clipping and browsing. They are made of photo-degradable material; designed so seedling height growth and form are not impaired; and nonhazardous to the forest ecosystem, domestic animals, or man.

380. Campbell, Dan L.; Evans, James. 1978. Establishing native forbs to reduce black-tailed deer browsing damage to Douglas-fir. In: Howard, Walter E., ed. Proceedings, 8th vertebrate pest conference; 1978 March 7-9; Sacramento, CA. Davis, CA: University of California: 145-151.

Principal methods being used to alleviate browsing damage to Douglas-fir seedlings by black-tailed deer in the Pacific Northwest are animal repellents applied to foliage and plastic mesh cylinders around individual seedlings. As an alternate method, we demonstrated that prompt establishment of highly palatable native forbs reduced summer browsing on planted seedlings to the point that black-tailed deer were no longer a factor limiting Douglas-fir regeneration. We believe that establishing native forbs is a sound ecological approach to deer-reforestation problems; furthermore, it should have wide use because it integrates forest and wildlife management objectives by promoting prompt regeneration of conifers and enhancing wildlife habitat.

381. Campbell, Dan L.; Evans, James; Engeman, Richard. 1987. Deer repelled from Douglas-fir new growth using BGR-P and aversive conditioning. DNR Note 46. Olympia, WA: Washington Department of Natural Resources. 7 p.

In 1986, a test was conducted on Capitol Forest near Olympia, Washington, to improve the effectiveness of Big Game Repellent-Powder (BGR-P) by conditioning black-tailed deer to avoid browsing BGR-P treated Douglas-fir seedlings fitted with flagging and other plastic materials. All materials were placed around or over terminals before bud burst and before applying the repellent. Treatments with standard blue plastic flagging and other plastic materials significantly reduced browsing damage during the 1986 growing season. As a result, it was found that the visually aversive stimuli used in this study eliminates the need to apply BGR-P to new growth immediately after bud burst and also eliminates repeatedly applying repellents during a particular damage season.

382. Campbell, Dan L.; Evans, James; Hartman, George B. 1988. Evaluation of seedling protection materials in western Oregon. Tech. Note OR-5. Portland, OR: U.S. Department of the Interior, Bureau of Land Management. 14 p.

A 3-year comparison was made for six materials to protect Douglas-fir seedling from damage by wildlife. No treatment materials were maintained after the initial application. Materials included a nested plastic mesh tube, a split plastic mesh tube, a paper bud cap, a plastic mesh tube cap, BGR spray and BGR powder Big Game Repellent. Nested plastic mesh tubes provided the most protection and significantly better growth than other treatments. Split, small-diameter plastic mesh tubes protected seedlings better and generally provided more growth than bud caps or repellents. Bud caps and repellents provided some protection and growth depending on type of damage and season of damage. Costs and comparisons of seedling growth for different materials are reported. Damage was primarily caused by mountain beaver, elk, and black-tailed deer.

383. Connolly, Guy E.; Ellison, Barbara O.; Fleming, John W. [and others]. 1980. Deer browsing of Douglas-fir trees in relation to volatile terpene composition and in vitro fermentability. *Forest Science* 26(2): 179-193.

The compositions of the volatile terpenes in steam-distilled oils from new growth and year-old needles of browsed and unbrowsed Douglas-fir trees were compared by gas chromatographic analysis. Levels of specific compounds did not differ significantly between browsed and unbrowsed trees in the young growth at bud burst, but differences appeared as the young growth matured. Browsed trees had higher levels of microbial promoters and lower levels of inhibitors of rumen fermentation processes than the unbrowsed trees, but they did not differ in vitro fermentability by deer rumen microbes, or in nitrogen, crude fiber, crude fat, total sugar, sucrose, or moisture content. Significant variations among pairs of trees were noted for a few terpene components, in vitro fermentability, and crude fat.

384. Crouch, Glenn L. 1965. Major factors influencing seedling browsing by deer under known herd densities. In: Proceedings, 1964 annual meeting of western reforestation coordinating committee; 1964 November 30-December 1; Spokane, WA. Portland, OR: Western Forestry and Conservation Association: 46-47.

From a study in the Tillamook Burn of northwest Oregon, interrelationships among deer numbers, weather conditions, and forage preference and availability are briefly described.

385. Crouch, Glenn L. 1966. Effects of simulated deer browsing on Douglas-fir seedlings. *Journal of Forestry* 64(5): 323-326.

Douglas-fir seedlings were planted on four different microsites in the Tillamook Burn of northwest Oregon and clipped to simulate browsing by deer. Survival of seedlings after one field growing season was significantly greater on a recently disturbed site with relatively sparse vegetative cover than on sites dominated by stands of *Cac-cinium parvifolium*, *Rubus parviflorus*, and *Acer circinatum*. Survival was also correlated with the amount of clipping. Height growth of unclipped seedlings was poorest on the more shaded site. Light to moderate browsing during the first winter field season did not adversely affect survival.

386. Crouch, Glenn L. 1966. Preferences of black-tailed deer for native forage and Douglas-fir seedlings. *Journal of Wildlife Management* 30(3): 471-475.

Studies of forage preferences of black-tailed deer were conducted during the winters of 1962 and 1963 in a 3-acre enclosure in the Tillamook Burn on northwest Oregon. Two deer were allowed to forage on native vegetation and planted Douglas-fir seedlings while periodic inspections were made of availability and use of trailing blackberry leaves, twigs of woody species, and the conifer seedlings. Blackberry leaves were the most highly preferred forage during the trial periods. Leaves of salal ranked high, but plants were relatively scarce in the enclosure. Red huckleberry and cascara were preferred woody plants, but other common species including red alder, hazel, and vine maple were used only when leafy forage was unavailable. Douglas-fir

ranked higher in preference than most common woody plants. Winter-active herbaceous forage was qualitatively determined to be highly preferred winter and early spring food. Douglas-fir and woody plant browsing appeared to be closely related to weather during the winter.

387. Crouch, Glenn L. 1968. Forage availability in relation to browsing of Douglas-fir seedlings by black-tailed deer. *Journal of Wildlife Management* 32(3): 542-553.

Relationships between forage availability and browsing of planted Douglas-fir by black-tailed deer were studied between June 1961 and February 1964 in a 340-acre enclosure occupied by known numbers of deer. The study area, in the Tillamook Burn of northwest Oregon, was burned by three wildfires between 1933 and 1945. Since 1945, much of the enclosure has been disturbed by salvage logging and subsequent erosion, and vegetation consists mainly of seral species of six plant communities. Overstory plant cover averaged 12% and understory cover 77% in the summer of 1963. Green weights of summer forage averaged about 2,600 lb/acre, and forage available for the following winter averaged about 640 lb/acre at the end of the growing season. By midwinter, weathering losses and deer use had greatly reduced this amount. Winter growth of herbaceous forage produced about 90 lb/acre of green feed in March, and by May, forage was again abundant. Leaves of trailing blackberry were highly preferred forage during winter. Salal ranked high but was limited in distribution and abundance. Red huckleberry and cascara were preferred among common woody plants, but red alder, hazel, and vine maple were browsed only when green herbage was unavailable. Green herbage was highly important in winter and early spring. Leaves of forbs and woody plants supplied most summer forage and were used in all seasons when available. Planted Douglas-fir seedlings ranked higher in preference than most common woody species. Browsing on Douglas-fir began with the first snowfall and continued through the winter. It is evident that browsing of Douglas-fir will continue until seedlings grow out of reach of deer.

388. Crouch, Glenn L. 1968. Spring-season deer browsing of Douglas-fir on the Capital Forest in western Washington. Res. Note PNW-84. Portland, OR: U.S. Department of Agriculture. Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Deer started browsing Douglas-fir shortly after bud burst began and continued browsing for about 1 month. Douglas-fir was eaten despite abundant new growth on many plant species that deer prefer in late spring and early summer. The beginning and ending of tree browsing did not seem to be related to any visual growth-stage characteristic except bud burst. Leaders were growing rapidly when browsing began and ended. Availability of other vegetation in similar stages of development also appeared unrelated to Douglas-fir browsing.

389. Crouch, Glenn L. 1969. Deer and reforestation in the Pacific Northwest. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium*; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 63-66.

Reviews the present knowledge of deer-reforestation interactions and problems in the Pacific Northwest. The occurrence and seasonal distribution of browsing on seedlings by deer are described and factors that influence browsing are considered. Available and potential browsing effects and methods for controlling browsing are also discussed.

390. Crouch, Glenn L. 1976. Deer and reforestation in the Pacific Northwest. In: Siebe, Charles C., ed. *Proceedings, 7th vertebrate pest conference*; 1976 March 9-11; Monterey, CA. Davis, CA: University of California: 298-301.

Deer and reforestation interact mainly during regeneration after wildfire or logging. In interior forests, browsing by mule deer often damages conifer seedlings planted on winter or transitional ranges. In the Douglas-fir region, numbers of black-tailed deer increase dramatically after forests are logged or burned, in response to improved forage supplies. Here, browsing on planted stock in clearcuts lowers forest productivity by reducing growth rates and occasionally contributes to plantation failures. Browsing damage can be controlled by fences or cages, but costs are prohibitive. Amelioration of damage by black-tailed deer could be achieved through long-range planning for concurrent deer and timber harvests, with hunting pressure directed to areas where logging promotes more deer. Thus, more deer can be made available to hunters and browsing damage to reforestation lessened. Such programs would require complete cooperation among resource managers and an intensive, well-planned effort to sell them to both customers and critics.

391. Crouch, Glenn L. 1980. Postseason hunting to reduce deer damage to Douglas-fir in western Oregon. Res. Note PNW-349. Portland, OR: U.S. Department of Agriculture, Pacific Northwest Forest and Range Experiment Station. 6 p.

Effects of two successive postseason deer hunts on deer browsing of Douglas-fir seedlings in the Coast Ranges in western Oregon were evaluated. Terminal browsing was significantly lower on the area subjected to more hunting compared with other areas.

392. Crouch, Glenn L.; Paulson, Neil R. 1968. Effects of protection from deer on survival and growth of Douglas-fir seedlings. Res. Note PNW-94. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.

Protection from deer had little effect on survival of planted and natural Douglas-fir seedlings after eight growing seasons. Protected trees were slightly taller than unprotected trees. Trees from natural seedfall were taller than planted trees. Unprotected planted stock was shorter than its protected counterpart and showed no sign of "catching up." This difference should be of little consequence after a cutting cycle.

393. Crouch, Glenn L.; Radwan, M.A. 1981. Effects of nitrogen and phosphorus fertilizers on deer browsing and growth of young Douglas-fir. Res. Note PNW-368. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

Nitrogen and phosphorus fertilizers were applied in March 1968 singly or in combination at a rate equivalent to 200 lb/acre of N or P to young trees (2-5 feet tall) in Oregon and Washington. Trees were examined and measured for up to 4 years. In the first year after treatment, trees given the nitrogen-only fertilizer in Washington were more heavily browsed by black-tailed deer, but this effect did not occur in the second year. Height growth was increased by nitrogen-only treatment in taller trees in Oregon after 1 and 2 years, but the effect had ceased after 4 years. Total nitrogen content was significantly increased by the nitrogen and nitrogen + phosphorus treatments in the first year, but this effect also ceased after 2 years. The amounts of moisture, ash, calcium and phosphorus, and diameter growth were not affected by any treatments.

394. Crouch, Glenn Leroy. 1964. Forage production and utilization in relation to deer browsing of Douglas-fir seedlings in the Tillamook Burn, Oregon. Corvallis, OR: Oregon State University. 176 p. Ph.D. dissertation.

The main objective of this investigation was to evaluate the relationship between the production and use of forage and deer browsing of planted Douglas-fir seedlings. A second purpose was to study some effects of selected physical and biological site factors on the survival and growth of fir seedlings. Present vegetation consists mainly of seral species which have been classified into six plant communities. Vegetation studies showed that overstory plant cover averaged about 12% and understory cover 77% in the summer of 1963. Blackberry leaves were the most highly preferred forage during the winter season. Salal ranked high but was limited in distribution. Huckleberry and cascara were preferred woody plants, whereas alder, hazel, and vine maple were used only when herbaceous forage was unavailable. Planted Douglas-fir occupied a prominent place on the food preference list, ranking higher than most common woody plants. Winter-active herbaceous forage was highly important in winter and early spring diets. Browsing of Douglas-fir seedlings began at lower elevations when the enclosure was first covered with snow. Later it occurred at all levels but was concentrated on lower areas. The incidence of Douglas-fir browsing was found to be significantly related to several physical and biological site variables. It was concluded the Douglas-fir browsing will continue unless or until seedlings are completely protected from deer by physical or physiological (chemical) isolation because fir seedlings are an important source of forage during the winter.

395. DeYoe, David R.; deCalesta, David S.; Schaap, Wieger. 1985. Understanding and controlling deer damage in young plantations. Ext. Circ. 1201. Corvallis, OR: Oregon State University, Extension Service. 15 p.

Familiarizes private woodland owners with methods for minimizing or preventing damage caused by black-tailed and mule deer in young plantations. Information is provided on deer habitat requirements, the impact of deer damage, and specific control methods that can be used.

396. Dimock, Edward J., II. 1970. Ten-year height growth of Douglas-fir damaged by hare and deer. *Journal of Forestry* 68(5): 285-288.

The development of Douglas-fir seedlings, planted under dense bracken on an old cutover in Washington's coastal zone, was closely charted for 10 years. Varying amounts of damage to all seedlings were caused through clipping by snowshoe hare and browsing by black-tailed deer. Despite obviously severe pressure by deer in later years, nearly all animal-caused losses were attributed to earlier damage by hares.

397. Dimock, Edward J., II. 1971. Influence of Douglas-fir seedling height on browsing by black-tailed deer. *Northwest Science* 45(2): 80-86.

To discover if Douglas-fir seedlings from widely separated provenances might evoke varying feeding responses in deer under controlled conditions, an exploratory trial was made during the winter of 1965-66 with planting stock from five seed sources in western Washington. Preliminary results revealed that feeding preference differed markedly among the races tested. Further testing and analysis showed the preferences were strongly linked to small variations in seedling height, independent of seed origin. Ascribing demonstrated preferences solely to height is probably an oversimplification. The close correlation between source-related seedling heights and preferences shown does not preclude the possibility that qualitative variations also affected deer browsing. The case is convincing, however, that height at planting functions independently as a determinant of feeding preference by deer among seedlings less than 25 cm tall.

398. Dimock, Edward J., II. 1974. Animal-resistant Douglas-fir: how likely and how soon? In: Black, Hugh C., ed. *Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium; 1973 September 11-12; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 95-101.*

Summarizes more than 6 years of effort to exploit genetic variation in Douglas-fir to combat damage in young plantations caused by two problem animals—snowshoe hare and black-tailed deer. Traces developmental phases of experimentation that include verification that animals will discriminate in feeding on foliage, based upon a tree's genotype; determination that resistant traits within the tree are inherited and under strong genetic control; corroboration that effective reduction of damage may be achieved under experimental field conditions; and speculation that resistant genotypes will become an operationally viable tool for mitigating future damage problems.

399. Dimock, Edward J., II; Silen, Roy R.; Allen, Virgil E. 1976. Genetic resistance in Douglas-fir to damage by snowshoe hare and black-tailed deer. *Forest Science* 22(2): 106-121.

Genotype of Douglas-fir significantly affected feeding selection for foliage by both snowshoe hare and black-tailed deer in pen tests with captive animals. Nine clones were rated independently for each animal species. Genotypes preferred by deer and hare ranged up to 64 and 178% more attractive, respectively, than those least preferred. Genetic analysis suggests that resistance to animals based on nonpreference is strongly inherited and chiefly additive.

400. Driscoll, Richard S. 1963. Repellents reduce deer browsing on ponderosa pine seedlings. Res. Note 5. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Deer browsing of ponderosa pine seedlings can be reduced by spraying with 10% solutions of either zinc dimethyl dithio carbamate cyclohexylamine complex (ZAC), tetramethylthiuram disulfide (TMTD), or copper omadine, each mixed with 10% acrylic resin adhesive (Rhoplex AC-33), 0.2% Methocel (a thickening agent), and 0.6% Hexadecanol-ethanol (a defoaming agent). Covering with brush also reduces browsing. The spray treatment provides the most effective protection year-round. The treatment must be applied each year to provide protection to yearly growth. This should be done in the fall after current growth is completed and before deer concentrate in plantation areas. The number of years spray treatments must be carried out was not determined.

401. Edgerton, Paul J. 1971. The effects of cattle and big game grazing on a ponderosa pine plantation. Res. Note PNW-172. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Mixed conifer stands that have been clearcut, planted with trees, and seeded to grass are a potential source of summer forage for livestock and wildlife. Heights of planted trees in portions of a clearcut that had been ungrazed, grazed only by deer and elk, and by deer, elk, and cattle were compared. After five growing seasons, grazing had neither greatly harmed nor benefited growth and survival of the trees in the plantation.

402. Gauditz, Illo. 1977. Bioassay methods guiding the development of a big game repellent. In: Jackson, W.B.; Marsh, R.E., eds. Test methods for vertebrate pest control and management materials: A symposium; 1976 March 8; Monterey, CA. ASTM Spec. Tech. Publ. 625. Philadelphia, PA: American Society for Testing and Materials: 34-46.

This paper describes bioassay techniques found useful to support the development of big game repellents and discusses the criteria for matching these techniques to specific tasks. The latter range from the preliminary screening of large numbers of potential repellents to the final selection of a small number of candidates which in repeated tests exceeded all established repellents and other candidates in degree and persistence of repellency. From this small number of candidates, the new, improved big game repellent is selected through field bioassays with the help of statistical analysis of their results. The bioassay techniques described here use a herd of wild deer held captive in a large pen under near natural conditions. They are simple multiple-choice tests of preference, and no statistical methods are used for data analysis. Tests using the pen bioassay techniques for rapid screening of products are evaluated by gross ranking of browse counts; extended tests of promising candidates are evaluated via browse curves which show the increase in browsing with time. Established repellents are used as a reference standard against which the performance of each product is compared.

403. Gillingham, Michael P.; Speyer, Menno R.; Northway, Steve; McLaughlin, Ron. 1987. Feeding preferences and its relation to herbivore repellent studies. *Canadian Journal of Forest Research* 17(2): 146-149.

Solids emitting gaseous selenium compounds were attached to Douglas-fir seedlings, and their effectiveness in reducing browsing damage by black-tailed deer in British Columbia was tested by using two procedures: pen bioassay trials with simultaneous access to all treatments; and tests with controlled access to only one treatment at a time. The two procedures yielded different results. Bioassay trials indicated that there was a significant difference in damage between treated and untreated seedlings, and there was no difference in browsing damage when all seedlings in the enclosure were identically treated.

404. Harmon, Mark E.; Franklin, Jerry F. 1983. Age distribution of western hemlock and its relation to Roosevelt elk populations in the South Fork Hoh River valley, Washington. *Northwest Science* 57(4): 249-255.

Breast height cores were taken from western hemlock (d.b.h 5-90 cm) on a 2-ha plot on each of the upper and lower terraces in the valley. Total age of the trees was estimated. The age structure of western hemlock on terraces did not correspond well with estimated elk populations. Periods of heavy establishment of western hemlock did not occur when elk declined. The results did not support the hypothesis that elk browsing is so severe that hemlock can establish only when elk populations are small.

405. Harper, James A. 1969. Relationship of elk to reforestation in the Pacific Northwest. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium*; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 67-71.

Based on studies of Roosevelt elk on cutover areas in southwestern Oregon, discusses preferences of habitat and occurrence of browsing damage to Douglas-fir seedlings. Elk, in relation to the damage they cause, are influenced by the time since logging, treatment of slash, method of logging, type of habitat, and proximity to cover. Elk grazing on cutover areas, as demonstrated by our observation of elk feeding and by distribution of pellet groups, is light the year after timber removal, peaks from 6 to 8 years after logging, and becomes light within 11 to 12 years. Soil disturbance during logging and slash burning after logging extend forage production and elk grazing. The effect of burning is influenced, however, by the type of vegetation. Our observations of feeding elk indicate that grazing on cutover land decreases as the distance from standing timber increases. Also, elk grazing is reduced by the removal of adjacent timber stands. The relations between elk and deer are considered, and findings from studies of enclosures indicate that half the browsing on Douglas-fir may be from deer.

406. Harris, Mark T.; Palmer, William L.; George, John L. 1983. Preliminary screening of white-tailed deer repellents. *Journal of Wildlife Management* 47(2): 516-519.

Compares the effectiveness of 14 commonly used deer repellents under pen conditions. Repellents tested include: feather meal, mothballs, creosote, hot sauce, hair, blood meal, meat meal (all home remedies); Big Game Repellent, Magic Circle, Spotrete F flowable fungicide; Hinder; Gustafson 42-S, Chaperone, Nott Chew-Not (all registered deer repellents). Five repellents (mothballs, creosote, human hair, Magic Circle, and blood meal) were not as effective as the others. The others show promise and should be investigated further. Chew-Not, Chaperone, Gustafson 42-S, and Spotrete-F all contain thiram as the active ingredient. In the future, one thiram repellent should be selected for use as a representative of all thiram repellents.

407. Hartwell, Harry D. 1973. Effect of deer browsing on height growth of Douglas-fir trees. DNR Note 5. Olympia, WA: Washington Department of Natural Resources. 5 p.

Study plots were established in Capitol Forest and Satsop River areas of Grays Harbor County and in the Yacolt Burn area of Clark County for the specific purpose of measuring the approximate impact of spring deer browsing on early height growth of outplanted Douglas-fir trees. Each plot contained 110 trees, and every tenth tree was protected from wildlife by a stabilized cage of chicken wire. Tree heights and wildlife feeding injuries were recorded up to the end of the sixth growing season. The uncaged trees on each plot sustained moderate to high rates of deer browsing annually as long as the terminals remained in reach of deer. On the assumption that the data is unbiased, wildlife feeding injuries (predominantly spring deer browsing) retarded potential height growth of the uncaged trees by 41.5% on Capitol Forest, 21.8% on Satsop River, and 31.2% on the Yacolt Burn, during the 6-year study period.

408. Hartwell, Harry D. 1973. Putrefied fish—a promising repellent for reducing spring deer browsing on Douglas-fir trees. DNR Note 4. Olympia, WA: Washington Department of Natural Resources. 10 p.

Summarizes exploratory field evaluations during 1969 of five candidate materials for reducing spring deer browsing. The materials tested were (1) putrefied fish, derived from decomposed salmon; (2) Herbivore Repellent, an experimental deer repellent; (3) ZIP, a commercial deer repellent, active ingredient, zinc dimethyl dithio carbamate cyclohexylamine complex; (4) benzene hexachloride, a well known insecticide; and (5) moth balls, active ingredient, naphthalene. Putrefied fish was considered the most promising material tested.

409. Hartwell, Harry D. 1975. Investigation of spatial repellency for protecting Douglas-fir seedlings from spring deer browsing. DNR Rep. 34. Olympia: Washington Department of Natural Resources. 12 p.

Describes a field test to determine efficacy of four candidate repellents derived from animal and plant materials for reducing spring deer browsing on the growing terminal

shoots of Douglas-fir seedlings. Seedlings among 11 treatments showed reductions in browsing between 41.4 and 94.2% and increases in annual height growth between 7.3 and 43.4%, compared to untreated seedlings. Three of the materials were tested for short distance spatial repellency (aversion to odor), and one of these reduced damage significantly when applied nearly 1 month before browsing started. Spatial repellents may have important logistic advantages over contact repellents; prospects for developing spatial repellents for operations use are discussed.

410. Hartwell, Harry D.; Johnson, Larry E. 1983. Survival and height of large and small Douglas-fir seedlings in relation to animal damage six years after planting. DNR Note 38. Olympia, WA: Washington Department of Natural Resources. 20 p.

Douglas-fir 2+0 and 3+0 nursery seedlings averaging about 1 and 3 feet in height, respectively, were evaluated for field performance in five separate potential animal damage areas in western Washington over a period of six growing seasons. Results indicate that the trees were subject to moderate or severe hare clipping damage on three of the areas and to severe mountain beaver clipping damage on another area. Trees on all areas were subject to persistent, moderate, or severe spring-summer deer browsing damage. The 3+0 trees showed much greater resistance to mortality caused by hare clipping and substantially greater resistance to growth delay caused by hare clipping and spring-summer deer browsing. Both classes of tree, however, were highly vulnerable to mortality caused by mountain beaver clipping. An economic projection revealed that the 3+0 seedlings would be a better investment on the three hare-deer damage sites and that both classes of seedling would result in stands of suboptimum wood volume on the mountain beaver-deer damage site. Observations concerning the influence of vegetation competition on growth and survival of trees are discussed.

411. Hines, William W. 1963. Relationship of black-tailed deer density to conifer survival. In: Proceedings of the 43d annual conference of Western Association of State Game and Fish Commissioners; 1963 June 10-12; Tucson, AZ; [Place of publication not available]: 188-192.

An investigation designed to study the interrelationships between black-tailed deer and their environment in the Tillamook Burn of Oregon was initiated in 1958. One winter's tree damage experience with a deer density of 81 deer per square mile revealed that 45% of newly-planted trees were damaged between February and April. A subsequent reduction to 28 deer per square mile drastically reduced damage to 2% in new plantings for the 1959-60 and 1960-61 winters. Overall damage to all plantings was 5 and 7%, respectively. Differential damage rates among the five yearly plantings were attributed to the deer's preference for taller trees and the browsing of taller seedlings at times when snow covered the younger plantings. Winter weather, as well as population density, seems influential in determining the extent of damage. During the mild winter of 1962-63, damage was 43% less than it had been the previous year, even though the population density remained the same.

412. Hines, William W. 1971. Physical versus chemical means of deterring browsing of Douglas-fir by black-tailed deer. *Tree Planters' Notes* 22(2): 9-13.

The purpose of the investigation was to compare the efficiency of the best of three terminal leader envelopes (fiberglass window screen, 2 mm Saran plastic, and 5 mm translucent polyethylene sheeting) with the commercially prepared contact repellent tetramethylthiuram disulfide (TMTD) in discouraging browsing of terminal leaders on 2+0 Douglas-fir plantations during the winter of outplanting. Results showed that TMTD foliar repellent was effective in discouraging winter rodent use on Douglas-fir terminal leaders for at least 2 months after outplanting. Polyethylene envelopes proved ineffective in deterring rodent browsing, but they were highly effective in preventing browsing of terminal leaders by deer. It is suggested that a combination of TMTD and polyethylene envelopes should be used where rodent and deer use will be significant. The method of applying polyethylene envelopes is expensive, but costs can be greatly reduced if the resource manager will apply remedial measures in those areas only where their need is forecast.

413. Hines, William W.; Land, Charles E. 1974. Black-tailed deer and Douglas-fir fir regeneration in the Coast Range of Oregon. In: Black, Hugh C., ed. *Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium; 1973 September 11-12; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 121-132.

We studied the occurrence and seasonal distribution of browsing of Douglas-fir by a regulated herd of black-tailed deer within a 340-acre fenced enclosure at Cedar Creek, in the Tillamook Burn in western Oregon. We describe the influence of plant community, site, deer density, availability of forage, seedling height, and other factors on severity of browsing. We also discuss distribution and timing of seedling mortality and the effect of browsing on Douglas-fir growth, based on field observations and simulated browsing studies. Two levels of deer-herd control are considered as management alternatives. We evaluated the impact of intensive forest management on carrying capacity and deer densities in the future and forecast future trends in deer damage to Douglas-fir regeneration.

414. Hines, William W.; Smith, Carl W. 1962. An account of the relationship of black-tail deer to the propagation of Douglas-fir seedlings. *Bull.* 9(17): 3,6,8. Portland, OR: Oregon State Game Commission.

In the Cedar Creek deer study on the Tillamook Burn, 43 deer in an enclosure of 344 acres damaged 45.2% of the planted Douglas-fir trees by February of the first winter. Damage ranged in severity from trees being killed outright (11%) to light lateral branch cropping. The majority of damage was in the severe classification, which meant that the terminal stem and over 50% of the lateral branches had been browsed. The following year, with 15 deer in the enclosure, only 5.2% of the planted trees were browsed. The third year, again with 15 deer in the enclosure, damage

was again light (6.9%). The fourth year, an intermediate deer density (33 animals) browsed 40.5% of the trees. Thus, an interesting trend is emerging in the relationship between deer densities and damage rates. The amount of deer damage on conifers is not in direct proportion to animal densities. The abrupt beginning to tree usage suggests that deer are not browsing trees until other forage is scarce. Further studies have been initiated to evaluate food preference, forage availability, and plant usage. In addition, plantations were browsed more intensively the second year than the first year after planting, but first year damage tended to be more severe. Damage rates are greater on low versus high elevations, south versus north exposures, and flat versus steep slopes.

415. Horton, Alan J. 1987. Animal damage prediction models in conifer plantations. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 29-36.

Forest Service districts in south-central Oregon have implemented site-specific models for predicting damage by pocket gophers, big game, and livestock. Prediction models are based upon habitat, history and experience, population cycles, weather and disturbance factors (big game), use patterns and travel routes (big game and livestock), and available controls. Plantation establishment costs have declined significantly; however, the models have failed to accurately predict damage on a few plantations. Ongoing refinement of the models is necessary, particularly in separating "high risk" from "moderate risk" conclusions. Samples of the models are included.

416. Kosco, Barbara H.; Bartolome, James W. 1983. Effects of cattle and deer on regenerating mixed conifer clearcuts. *Journal of Range Management* 36(2): 265-268.

In a study near Georgetown, California, cattle grazed the study area from June 1 until September 20 each year. Deer are primarily migratory, passing through the study area in March and April and again in October and November each year. The results of treatments on two clearcuts indicate cattle do not harm tree regeneration. Browsing on trees occurred, but no significantly higher numbers of trees were browsed by cattle and deer than by deer alone. White fir seedlings were browsed the most heavily. No trampling damage occurred. Browsing has made no difference in overall tree seedling height or basal diameter between treatments. Brush cover was significantly reduced on grazed treatments on both clearcuts. The reduction in brush cover has had no effect on tree seedling heights or basal diameters yet. Results from this study indicate that proper cattle grazing does not harm tree regeneration on young mixed conifer plantations, and, furthermore, cattle grazing may be used as a vegetation management tool in reducing brush on these clearcuts.

417. Lightfoot, W.C.; Hines, W.W. 1960. Factors associated with the measurement of animal damage to Douglas-fir plantation. In: Proceedings of the 40th annual conference of the Western Association of State Game and Fish Commissioners; 1960 June 20-22; Salt Lake City, UT. [Place of publication not available]: 211-216.

Deer population control measures have been undertaken in an enclosure on the Tillamook Burn area of northwestern Oregon. Deer influence on Douglas-fir plantings was then studied by dividing the enclosure into 11 25-acre planting units and then further dividing each into 5-acre subunits. It was planned that each year for 5 years, 1 subunit in each of the 11 units would be stocked with a standard planting of Douglas-fir 2+0 trees. Deer damage to young Douglas-fir trees was measured on sample plots. Damage is seasonal in nature, occurring primarily from December to April. Future manipulations of deer numbers within the enclosure should reveal the density of deer that can be maintained without serious conflict with reforestation programs. Other objectives of this ongoing study are to develop better tools for inventorying the species and to test repellents and other practices that may be employed to reduce animal damage to tree plantations.

418. Mealey, Robert H. 1969. Nylon fencing to protect forest plantations from deer and elk. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium*; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 89-90.

An expansion of productive habitat for deer after extensive clearcutting on the Siuslaw National Forest and a corresponding increase in black-tailed deer and Roosevelt elk has created animal damage problems on forest plantations. Effective protection of plantations subjected to big game browsing has been provided by fencing with nylon netting. Experience with nylon fencing on the forest is described. Materials needed and construction and maintenance costs are listed. Procedures for installation of nylon fences are outlined and problems encountered are discussed. Wire cages and Crylde bird barrier to protect coniferous seedlings exposed to big game damage also are considered. Fencing, because of high costs and other disadvantages, is only recommended for demonstrated problem areas that cannot be protected by alternative methods.

419. Melchior, M. Anthony; Leslie, Charles A. 1985. Effectiveness of predator fecal odors as black-tailed deer repellents. *Journal of Wildlife Management* 49(2): 358-362.

Pen bioassays were conducted to evaluate the effectiveness of predator fecal odors as deer repellents. Aqueous extracts from predator feces were more effective than BGR (4.9% egg solids) and as effective as BGR-P (36% egg solids). In Test I, browsing reductions for the predator feces tested were: bobcat—51%; mountain lion—27%; wolf—17%; and coyote—8%. The efficacy of fecal extracts in Test I correlated with the concentration of predator feces in initial formulations (5, 10, and 20% by weight). In Test II, increasing the concentration of feces to 30% for bobcat and mountain lion did not increase their repellency. Fecal odors of predators significantly suppressed the feeding activities of black-tailed deer; however, additional laboratory and field work are needed before predator odors can be used operationally.

420. Mitchell, K.J. 1964. Height growth losses due to animal feeding in Douglas-fir plantations, Vancouver Island, BC. *Forestry Chronicle* 40(3): 298-307.

Douglas-fir plantations on the east coast of Vancouver Island were examined to determine the effect of animal feeding upon height growth. Length of internodes and evidence of past leader damage were recorded and cumulative average height-age growth curves compared for undamaged trees and for trees suffering various intensities of damage. The average reduction in tree height attributable to animal feeding in heavily browsed plantations varied from 1/2 foot to 2 feet over a period of 8 to 10 years. It is unlikely that either tree volume or quality at rotation age would be seriously affected. Exposed trees were browsed more heavily than those protected by vegetation or logging slash.

421. Palmer, William L.; Wingard, Robert G.; George, John L. 1983. Evaluation of white-tailed deer repellents. *Wildlife Society Bulletin* 11(2): 164-166.

Repellents tested were Hinder, Hot Sauce, Big Game Repellent, Spotrete-F (commercially-produced, registered repellents), Feather Meal and Meat Meal. Flowering dogwood seedlings, a highly-preferred native food of the deer, were used for testing the repellents. Only Big Game Repellent was consistent in reducing deer feeding, but it still requires further evaluation under field conditions.

422. Radwan, M.A. 1972. Differences between Douglas-fir genotypes in relation to browsing preference by black-tailed deer. *Canadian Journal of Forest Research* 2(3): 250-255.

Tissue digestibility, essential oils, and levels of several chemical constituents were compared in foliage of Douglas-fir. Genotypes with different susceptibilities to deer browsing were used, and foliage was collected during the dormant season. In general, clones resistant to deer browsing had lower dry-matter and cellulose digestibilities, essential oils with greater inhibitory action on rumen microbial activity, higher content of fats, total phenols, flavanols, and leucoanthocyanins, and lower levels of chlorogenic acid. Results suggest that these resistance characteristics, especially the chlorogenic acid content, might be used instead of conventional bioassays with captive deer, to screen Douglas-fir breeding stock for resistance to deer browsing.

423. Radwan, M.A. 1978. Foliar essential oils and deer browsing of Douglas-fir genotypes. Res. Note PNW-324. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.

Yield and composition of essential oils were compared in foliage of Douglas-fir. Five clones with different susceptibilities to deer browsing were used; foliage was collected during the dormant season. There were no qualitative differences among the oils of the different clones, but the oils differed quantitatively in all variables measured. Eight variables appeared useful in separating resistant from susceptible clones. Only one compound, however, an unidentified chemical, seemed capable of distinguishing between all three deer browsing preference classes.

424. Radwan, M.A.; Crouch, G.L. 1974. Plant characteristics related to feeding preferences by black-tailed deer. *Journal of Wildlife Management* 38(1): 32-41.

Six plant species of known preference by black-tailed deer were used to evaluate several factors thought to influence preference. Factors studied included chemical composition, *in vitro* fermentation of dry matter and cellulose, and effects of essential oils and water and methanol extracts on rumen microbial activity *in vitro*. Chemical analyses revealed considerable differences among species in all constituents but, with the exception of moisture which was generally higher in the more preferred species, tissue components did not show any consistent relationship to preferences. Fermentations of cellulose but not of dry matter were more closely related to preference than chemical composition and provided a good general indication of species preference. Similarly, the overall effects of oils and extracts on rumen activity suggested different preference ratings for the species, but results of the water extracts most closely approximated the established preference order.

425. Radwan, M.A.; Crouch, G.L. 1978. Selected chemical constituents and deer browsing preference of Douglas-fir. *Journal of Chemical Ecology* 4(6): 675-683.

Douglas-fir foliage from eight full-sib F1 families was analyzed for chlorogenic acid and essential oils and ranked according to browsing preference of penned black-tailed deer. Foliage was obtained during the dormant season, and tissues for both the preference test and chemical analyses were collected from the same trees. Deer ranked the different families, and chlorogenic acid content was correlated with preference order. Families varied significantly in yield and composition of essential oils, but differences were not related to preference. Results may have application in selections for Douglas-fir resistant to browsing.

426. Radwan, M.A.; Ellis, W.D.; Crouch, G.L. 1978. Chemical composition and deer browsing of red alder foliage. Res. Pap. PNW-246. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.

Chemical factors suspected of influencing seasonal change in deer preference for red alder leaves were investigated. There were many differences in the leaves between seasons. It is postulated, however, that changes in contents of crude fat and total phenols were the important factors in increasing deer preference for the species from June to September.

427. Rochelle, James A.; Gauditz, Illo; Oita, Katashi; Oh, John H.K. 1974. New developments in big game repellents. In: Black, Hugh C., ed. *Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium; 1973 September 11-12; Corvallis, OR*. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University: 103-112.

Reviews the potential of essential oils from unpalatable plants, pheromones of black-tailed deer, and extracts from putrefied animal matter as big game repellents.

Research efforts leading to the development of an effective repellent to protect conifer seedlings from big game browsing damage are outlined. Bioassay procedures for evaluating the effectiveness of candidate repellent materials are described. Data presented indicate that a repellent derived from fermented whole chicken eggs reduced frequency of big game browsing on conifer seedlings, in semioperational trials, by an average of about 80% of that received on untreated seedlings. This level of protection exceeds that provided by commercially available repellents. Weather factors that limit effectiveness of field treatments with the egg-derived repellent also are discussed.

428. Roy, D.F. 1960. Deer browsing and Douglas-fir seedling growth in northwestern California. *Journal of Forestry* 58(7): 518-522.

Damage to conifer seedlings by deer browsing in northwestern California varies from place to place. The severity of browsing damage appears to be related to the amount of preferred browse species growing on an area. Browsing, although generally not fatal to conifer seedlings, seriously reduced height growth when repeated year after year. Deer populations seem to reach maximum densities in areas where vegetation is disturbed, and logging is one of the principal influences which increases the carrying capacity of forest land. When browse high on the palatability scale is scanty or lacking, the land manager attempting to regenerate a stand of trees is faced with a problem of damage caused by browsing deer.

429. Schaap, Wieger; DeYoe, David. 1986. Seedling protectors for preventing deer browse. Res. Bull. 54. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University. 12 p.

The study compares the efficacy of eight protectors for minimizing deer browse: Vexar tubes, heavy netting, light netting, Remay sleeves, paper bud caps, Reemay budcaps, leader tubes, and No Nibbles. Data were collected on browse damage, survival, terminal restriction, protector loss, and height growth. All protectors were effective in preventing browse damage. None of the protectors consistently reduced survival or height growth. On a high-elevation site facing southwest, however, seedlings inside Reemay sleeves survived poorly compared to controls following a week of daytime temperatures above 100° F. Restricted or bent seedling terminals and protector loss occurred with certain protectors on some sites; however, these problems could be decreased by proper or modified installation with stakes or stapling, respectively. Only "No Nibbles" caused abortion of terminal bud flushes. The study demonstrates that alternatives to Vexar tubes are available that cost less and exhibit comparable effectiveness.

430. Silen, Roy R.; Dimock, Edward J., II. 1978. Modeling feeding preferences by hare and deer among Douglas-fir genotypes. *Forest Science* 24(2): 57-64.

Data on deer and hare preference for Douglas-fir genotypes in eight pen and two field trials were compared to data generated from a mathematical model. The model

predicted sequential preference changes from the products of two probabilities that accounted for a changing availability (P_a) and an assumed constant palatability (P_p) for each of several, simultaneously tested plant types. In all 10 experiments, data were closely mimicked by the model. In only one experiment did the predicted feeding sequence deviate significantly from actual data. High correlations were achieved among P_p values calculated independently for duplicate tests of identical genotypes. Since P_p is a mathematical estimate of palatability—itsself a qualitative phenomenon—the concept may prove useful for aiding interpretations of other studies expressing animal preference as an integration of plant availability and palatability.

431. Silen, Roy R.; Randall, William K.; Mandel, Nancy L. 1986. Estimates of genetic parameters for deer browsing of Douglas-fir. *Forest Science* 32(1): 178-184.

A total of 5,416 cuttings were collected in mid-January 1982 from 10-year-old progeny of a mating of 6 trees as females crossed with 11 trees as males. Open-pollinated progeny and cuttings from parent trees were included in the study. Six black-tailed deer were allowed to browse the cuttings and natural food. An average of 46% of the cuttings were browsed after 38 days, ranging from 39 to 69% among seed families. Of the total genetic variation, 65% was additive. Reciprocal, maternal, and specific combining ability components were not significant. Family heritability was estimated at 0.73. Gain per generation, based on selecting 10% of the most resistant families, was estimated to be 11%.

432. Staebler, George R.; Lauterbach, Paul; Moore, A.W. 1954. Effect of animal damage on a young coniferous plantation in southwestern Washington. *Journal of Forestry* 52(10): 730-733.

An experiment was begun in 1947 to trace the effects of deer, mountain beaver, rabbits, and cattle on a young plantation of Douglas-fir, Port-Orford cedar, and western hemlock established in an area of high animal populations in western Washington. The experiment was exploratory and based on only one area. The plantation was successful in an area where mountain beaver and deer populations were high. It also withstood heavy rabbit damage. The extensive damage caused a high percentage of deformed trees and severe reduction of height growth but did not lessen survival appreciably. Rabbit populations built up extremely fast and were not included in the original study plan. Damage from mountain beavers was negligible. Douglas-fir was the most damaged species but was superior to the others in survival and height growth. Areas with heavy bracken seem to have been the poorest risk for a plantation, partly due to competition and partly due to the concentration of rabbits in this cover type.

433. Sullivan, Thomas P.; Nordstrom, Lance O.; Sullivan, Druscilla S. 1985. The use of predator odors as repellents to reduce feeding damage by herbivores. II. Black-tailed deer (*Odocoileus hemionus columbianus*). *Journal of Chemical Ecology* 11(7): 921-935.

The effectiveness of predator odors (fecal and urine) in suppressing feeding damage by black-tailed deer was investigated in pen bioassays. Eight bioassay trials tested the effects of these odors on deer consumption of salal leaves and coniferous seedlings. Cougar, coyote, and wolf feces as well as coyote, wolf, fox, wolverine, lynx,

and bobcat urines provided the most effective suppression of deer feeding damage. Novel odors of ammonia and human urine did not reduce feeding. Predator fecal odor formulations in direct foliar application, adhesive application and in plastic vials were all effective in suppressing deer feeding. Of all urines tested, coyote provided the most consistent suppression of deer browsing on salal. Deer consumed significantly more untreated Douglas-fir and western red cedar seedlings than those protected by coyote urine odor. The active repellent components of predator odors, which suppress deer feeding, may be suitable for encapsulation in controlled release device which could provide long-term protection for forest and agricultural crops.

Mountain Beaver

General

434. Feldhamer, George A.; Rochelle, James A. 1982. Mountain beaver (*Aplodontia rufa*). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 167-175.

Reviews distribution, description, physiology, genetics, reproduction, ecology, food habits, behavior, mortality, economic status, and management of *Aplodontia rufa*.

435. Godin, Alfred J. 1964. A review of the literature on the mountain beaver. Spec. Sci. Rep.—Wildl. 78. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife. 52 p.

Summarizes current knowledge about the evolution, distribution, races, range, description, reproduction, habits, activity, enemies, ecology, economic significance, and control of mountain beaver and lists 260 literature references.

436. Hooven, Edward F. 1977. The mountain beaver in Oregon: its life history and control. Res. Pap. 30. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University. 20 p.

Aplodontia rufa, the single living species of the family Aplodontidae, inhabits the humid coast region of the Pacific Northwest. Population densities of 0 to 1.4 animals per ha may increase to 15 to 20 per ha as logged or burned lands revert to brush. These burrowing animals prefer moist, deep, well-drained soil dominated by hardwood brush species with an overstory of sword fern. They are medium-sized rodents that are monoestrus having 2 to 4 per litter in early spring. Young of the year disperse in early May. Food consists of a variety of plant species, including conifer seedlings. To reduce animal damage to seedlings on reforested lands, mountain beaver can be controlled by baiting, trapping, site preparation, or a combination of these. Where necessary, a physical barrier, such as Vexar tubing, may be used around the individual seedling.

437. Scheffer, Theo H. 1929. Mountain beavers in the Pacific Northwest: their habits, economic status, and control. Farm. Bull. 1598. Washington, DC: U.S. Department of Agriculture. 18 p.

Discusses the habitat, food habits, social habits, wintering, breeding, economic value, injurious habits, and control by trapping or poisoning.

438. Crouch, Glenn L. 1968. Clipping of woody plants by mountain beaver. *Journal of Mammalogy* 49(1): 151-152.

To determine preferences of mountain beaver for woody species, trees and shrubs were examined on 110 plots of 1,500 square feet each in the 340-acre deer enclosure in the Tillamook Burn area of northwestern Oregon. Examined were 900 trees and shrubs for evidence of clipping. Of the total, 22% exhibited signs of use by mountain beaver. Vine maple was the most frequently clipped plant, red huckleberry was the second, and red alder was the third most used species. Rose, cherry, currant, and redstem ceanothus were not clipped at all. Cascara, big leaf maple, and willow comprised a small percentage of the plant composition and received minor clipping. Hazel was relatively abundant in the enclosure, but few plants were clipped. Clipping by mountain beaver is a major factor influencing woody plant cover; those areas occupied by large numbers of mountain beaver are kept relatively free of shrub overstory. On the other hand, plant composition and distribution may influence distribution and abundance of mountain beaver. These relationships are not clear and need further investigation.

439. Goslow, George E., Jr. 1964. The mountain beaver—*Aplodontia rufa*. Arcata, CA: Humboldt State College. 74 p. M.A. thesis.

A behavioral study of the mountain beaver was conducted during the winter and spring of 1963 in Humboldt County, California. Initially, field studies of wild mountain beaver were supplemented by the observation of captive animals. Finally, certain physiological experiments were carried out on the animals to supplement the information gained by observation. Observations are reported on habitat, communication, and mannerisms. Experiments were done on water consumption and metabolic changes as related to body temperature.

440. Hooven, Edward F. 1973. Effects of vegetational changes on small forest mammals. In: Hermann, Richard K.; Lavender, Denis P., eds. Even-age management: Proceedings of a symposium; 1972 August 1; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 75-97.

Certain physical and biotic changes that occur relative to clearcutting can affect small mammal populations. Soil moisture and soil temperature may increase for the first few years but decrease as revegetation occurs. These factors affect the small mammal populations through their influence on food availability, shelter, and habitat. Although habitat preferences were readily observable by changes in species density, most of the small mammals were found on all units. Different small mammal populations result from different cutting systems, but regardless of the treatment, the small mammals exert an influence on regeneration whether by seed or seedlings. After clearcutting, regardless of the change of species, composition, and densities, the small mammal biomass remains comparable to that of the uncut forest and exerts the same detrimental effect upon regeneration.

441. Ingles, Lloyd G. 1959. A quantitative study of mountain beaver activity. *American Midland Naturalist* 61(2): 419-423.

Mountain beavers may be active and out of their burrows at all hours of the day or night. At night, they are more active and wander farther from their underground runways, which, even during the day, lead them to an abundance of protected feeding places. There are six or seven activity periods that occur with considerable regularity each 24 hours. These activity periods vary in length up to 2 hours and 45 minutes. They average 22 minutes longer at night. The activity periods of a captive animal grouped themselves about four activity peaks; the two periods at night being the largest. There is no explanation for the mountain beaver being more nocturnal than diurnal in summer since an abundance of food is safely available at all times.

442. Johnson, Sheldon Robert. 1971. The thermal regulation, microclimate, and distribution of the mountain beaver, *Aplodontia rufa pacifica* Merriam. Corvallis, OR: Oregon State University. 164 p. Ph.D. dissertation.

As a result of the present study and the evolutionary history of the aplodontids, it is surmised that *Aplodontia* has had a long association with a cool and moist environment. The burrow systems of these rodents have provided protection from predators and climatic extremes. A moist environment has insured an ample supply of succulent vegetation for maintaining water balance, and the cool environment has been a prerequisite because of their lack of adequate mechanisms to thermoregulate at high ambient temperatures.

443. Lovejoy, Bill P.; Black, Hugh C. 1974. Growth and weight of the mountain beaver, *Aplodontia rufa pacifica*. *Journal of Mammalogy* 55(2): 364-369.

Growth and weight of *Aplodontia rufa pacifica* from 2 months of age to maturity, from 181 specimens, are described. Males outnumbered females in the trapped sample 61.9% to 38.1%, but the sex ratio of 72 young from three successive breeding seasons was 1:1. Our earliest dates of capture of young mountain beavers were 3 and 15 June. These juveniles were estimated to be from 8 to 10 weeks old and weaned. Adult females were seen lactating from 8 April to 27 May. Young grew rapidly during the first 4 months after birth, but the growth rate diminished in June and July, and became asymptotic in August. This period of retarded growth was maintained at 69% of the adult mean weight. Yearlings gained weight rapidly in spring of their second year, and mean weight in June was 92% of the adult mean weight. Adults averaged 806 g. Sexual dimorphism in size was pronounced only among adults, with the males consistently heavier than females. Mean weights of both males and females were at a minimum in spring after the breeding season, and at a maximum in July.

444. Lovejoy, Bill P.; Black, Hugh C. 1979. Movements and home range of the Pacific mountain beaver, *Aplodontia rufa pacifica*. *American Midland Naturalist* 101(2): 393-402.

The home range and movement patterns of the mountain beaver were studied in the Coast Range of western Oregon. By using a mark-release-and-recapture method

with a rotation system of livetrapping on a 5.5-ha grid, 181 mountain beavers (109 adults, 72 juveniles) were captured 872 times during 5,144 trap nights, or 17.0 captures per 100 trap nights. Trapping success, which correlated with population size, was highest in summer and lowest in autumn and winter. Movements were analyzed in terms of average distance between captures (D), maximum distance between captures (M), and home range area. Only the movements of adult males and females differed significantly. The D and M averaged 44 m and 79 m for males and 32 m and 46 m for females. Sizes of the irregularly shaped home ranges were calculated by multiplying the range length times the range width. The average home range of adult males (0.32 ha) was nearly twice that of adult females (0.17 ha), considerably larger than previously reported. Home ranges of juveniles averaged 0.13 ha. Home ranges sometimes shifted and overlapped between sexes and between juveniles and adults.

445. Lovejoy, Bill P.; Black, Hugh C. 1979. Population analysis of the mountain beaver, *Aplodontia rufa pacifica*, in western Oregon. Northwest Science 53(2): 82-89.

A rotational system of live-trapping Pacific mountain beaver on a weekly basis was conducted on a 5.5-ha grid from July 1965 to August 1967. A total of 5,144 trap nights over an 88-week period resulted in a catch of 181 mountain beavers. Of this total, 109 were adults and 72 were juveniles; males outnumbered females by a ratio of 1.62:1. The sex ratio of juveniles was 1:1. Population estimates on the grid ranged from a low of 41 in November to a high of 54 in July of the same year. Transients made up a large part of the catch. Conservative estimates of density on the grid plus a boundary strip of 40 m ranged from 4.2 to 5.4 animals per ha. Survival rate of animals tagged in August 1965 was 64% after 1 year. Eleven of the 45 animals, or 24%, were still alive after 2 years. Some of the animals were sexually mature (2 years old or older) when first captured and were at least 4-1/2 years old when last taken in 1967.

446. Lovejoy, Bill P.; Black, Hugh C.; Hooven, Edward F. 1978. Reproduction, growth, and development of the mountain beaver (*Aplodontia rufa pacifica*). Northwest Science 52(4): 323-328.

Presents a summary of observations of the growth, development, and behavior of two mountain beavers born in captivity and raised for 68 days. Initial growth was rapid, and the mean weight of the young increased from 19.8 g at two days to 364 g at 60 days, or 43% of adult mean weight. The most rapid growth was during weeks seven and eight, coincident with weaning. Death was attributed to a bacterial infection.

447. Lovejoy, Bill Pertl. 1972. A capture-recapture analysis of a mountain beaver population in western Oregon. Corvallis, OR: Oregon State University. 105 p. Ph.D. dissertation.

This report summarizes a 25-month field study of a mountain beaver population in the Coast Range of western Oregon. The primary objectives of the study were three-fold: (1) to analyze the growth and development of the young within the population;

(2) to determine the composition and size of the population; and (3) to determine home ranges and movement patterns of individuals. In addition, a secondary objective involved the sampling of various environmental factors in order to ascertain what influence they might have on the population.

448. Martin, Paul. 1971. Movements and activities of the mountain beaver (*Aplodontia rufa*). *Journal of Mammalogy* 52(4): 717-723.

In western Washington, the movements of 16 adult and 11 subadult mountain beaver, fitted with miniature collar-type transmitters, were recorded by using a radio-tracking system. During radio-tracking periods of 3 to 19 months, 447 adult animal locations were obtained and used in home-range calculations. Average home-range size was 0.3 acre. Maximum recorded movement from a nest site was 160 feet. Approximately 90% of all locations occurred within 80 feet of nest sites. The animals used these sites for long periods. Nest construction, foraging activities, and nest sites are described. Extensive intermittent linear movements in burrows and on the ground surface appeared to be typical of dispersing subadults before nest establishment.

449. Motobu, Di Anne. 1978. Effects of controlled slash burning on the mountain beaver (*Aplodontia rufa rufa*). *Northwest Science* 52(2): 92-99.

A study was done on the effects of controlled slash burning on mountain beaver populations and movements. Results indicated that the fire, which removed most of the vegetation and left little, if any, slash accumulations remaining within the unit, substantially reduced the mountain beaver population within the unit. The fire left a large unburned part within the unit (20% unburned). Of the estimated population, 80% survived; most of these animals were captured in the unburned part of the unit after the fire. The fire did not cause animals captured after the burn to move out of their home ranges, although an animal tended to move to an unburned area if the area was located within the animal's home range. Predator activity within the units increased after the fire, probably because of the presence of carcasses of animals which had been killed by the fire.

450. Neal, Fred D.; Borrecco, John E. 1981. Distribution and relationship of mountain beaver to openings in sapling stands. *Northwest Science* 55(2): 79-86.

Mountain beaver was usually associated with treeless openings in sapling stands of Douglas-fir (age 18 years, d.b.h 102 mm) at two sites in Washington. Damage to saplings usually occurred in the border area around the openings. Amount of damage was related to stand characteristics, that is age, size, and density of trees, and was greatest on trees 9-12 years old (coinciding with canopy closure). The distribution of animals, their use of vegetation and the patterns of damage suggest that, as the canopy closes, understory vegetation is suppressed and mountain beavers are forced to rely on Douglas-fir for food. It is concluded that stands should be managed to reduce the number of openings and thus to reduce beaver damage.

451. O'Brien, James P. 1981. Summer food habits of the mountain beaver in northeastern California. *Murrelet* 62(3): 86-87.

This study presents data on species and mass of plants present in the summer food caches of mountain beaver in northeastern California. Food caches accumulated by at least two mountain beaver, inhabiting a seepage slope covered with alder (*Alnus tenuifolia*) at 1,660 m in Sierra County, California, were collected each day before sunrise between June 25 and August 7, 1980. Tall larkspur (*Delphinium glaucum*) was the most frequent food item, accounting for 58.3% of the mass of all caches. Mountain alder (*Alnus tenuifolia*) accounted for a higher percentage of the total mass than corydalis (*Corydalis caseana*) but occurred in relatively fewer caches. Corn lily (*Veratrum californicum*) and other plants (grasses, sedges, and ferns) occurred in fewer caches than the above and in smaller amounts. There was no relationship between frequency of occurrence in caches or total mass in caches and the occurrence of plants in the vicinity.

452. Pfeiffer, E.W. 1958. The reproductive cycle of the female mountain beaver. *Journal of Mammalogy* 39(2): 223-235.

Aplodontia has a low reproductive rate because it usually does not bear young until it is 2 years old, produces only one litter per year, and has few young per litter. Conception occurs during only a few weeks in the year because of the very short estrous period. All females that ovulate in a given population do so at about the same time each year so that there is a very sharply defined and extremely limited breeding season within a population.

453. Pfeiffer, Egbert Wheeler. 1956. The male reproductive tract of a primitive rodent, *Aplodontia rufa*. *Anatomical Record* 124(4): 629-635.

The male reproductive tract of *Aplodontia* consists of a penis with a baculum, testes encircled with longitudinal, parallel blood vessels, and the following accessory organs: two small, relatively little branched seminal glands that are almost invisible macroscopically in the immature or nonbreeding individual; an aseptate, compact, highly compound, tubuloalveolar prostate gland opening into the urethra by a single pair of primary ducts at the colliculus with the ejaculatory ducts and utriculus masculinus; a pair of large, compound tubuloalveolar bulbo-urethral glands that are greatly expanded during the breeding season by an opaque, colorless secretion. A pair of ducts from these glands leads into a urethral diverticulum, the bulbar gland. This structure connects with the urethra by a single, midventral slit. The testes and accessory sex organs of adult males fluctuate seasonally with maximum size attained in midwinter, but most first-year males show no hypertrophy of the reproductive tract. The male accessory sex organs of *Aplodontia* resemble those of certain sciurids as does the arrangement of testicular blood vessels. The occurrence of a bulbar gland is of particular taxonomic significance in view of the speculation about the phylogenetic relationships of the *Aplodontia*. This gland has been reported previously only in the Sciuridae, and its presence in *Aplodontia* indicates sciurid relationships.

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454. Raedeke, Kenneth J.; Taber, Richard D.; Paige, Dwayne K. 1988. Ecology of large mammals in riparian systems of Pacific Northwest forests. In: Raedeke, Kenneth J., ed. Streamside management: riparian wildlife and forestry interactions: Proceedings of a symposium; 1987 February 11-13; Seattle, WA. Contrib. 59. Seattle, WA: University of Washington, College of Forest Resources: 113-132.

The literature is reviewed relating to the ecological needs of large, free-living mammals to the riparian environment to determine these species' degrees of need and the particular habitat characteristics important in meeting their ecological requirements. Species covered are Virginia opossum, snowshoe hare, Nuttall's and eastern cottontail, mountain beaver, beaver, muskrat, nutria, red fox, grey fox, fisher, mink, striped skunk, western spotted skunk, river otter, bobcat, elk, mule and black-tailed deer, white-tailed deer, and moose. Native species considered dependent on riparian areas or that find optimum habitat there are beaver, muskrat, raccoon, mink, river otter, elk and mule deer. Native species more abundant in riparian areas than in adjacent uplands are snowshoe hare, grizzly bear, western spotted skunk, white-tailed deer, and moose. The other species listed use riparian areas but are as abundant in other habitats. The significant features of riparian systems were abundance of prey species; productivity of the shrub/herb layer; early spring phenological development of food plants; reduced snow accumulations; aquatic habitat, and lineal continuity of habitat.

455. Voth, Elver Howard. 1968. Food habits of the Pacific mountain beaver, *Aplodontia rufa pacifica* Merriam. Corvallis, OR: Oregon State University. 263 p. Ph.D. dissertation.

Two features of the mountain beaver diet are rather striking: its controlled succulence and its primitiveness. First, it has been suggested that the animal controls its water intake by adjusting the total water content of its food intake to a level of perhaps 60 to 70% through wilting part of the plant reserves. Second, the high proportion of ferns in the diet corresponds favorably with the "primitiveness" of the animal. Here is a primitive rodent eating a primitive plant diet in an uncontested food niche. Primitive plants have more tissue boundaries and hence are more easily masticated and presumably digested than others. Two ferns, *Polystichum* and *Pteridium* contribute 82% of the animal's diet.

Damage and Management

456. Anonymous. 1980. Multi-million threat to reforestation—control of mountain 'boomer' needed. Forest Log 49(9): 4-5.

The mountain 'boomer' (beaver) is a serious pest of Douglas-fir and hemlock seedlings in Oregon. Control measures include removing habitat, encasing seedlings in plastic net tubes, trapping, and encouraging natural predators such as bobcats and coyotes.

457. Borrecco, J.E.; Anderson, H.W.; Black, H.C. [and others]. 1979. Survey of mountain beaver damage to forests in the Pacific Northwest, 1977. DNR Note 26. Olympia, WA: Washington Department of Natural Resources. 16 p.

Results of a questionnaire sent to forest land managers throughout western Oregon, western Washington, and northern California on the nature and extent of problems caused by the mountain beaver and control methods in current use. Damage reported was primarily in Oregon and Washington, mostly in Douglas-fir stands.

458. Borrecco, John E.; Anderson, Robert J. 1980. Mountain beaver problems in the forests of California, Oregon, and Washington. In: Clark, Jerry P., ed. Proceedings, 9th vertebrate pest conference; 1980 March 4-6; Fresno, CA. Davis, CA: University of California: 135-142.

Mountain beavers cause considerable damage to forest trees in the Pacific Northwest. Feeding injuries result in mortality, growth losses, deformity of trees, and understocked plantations. Losses are most severe in new plantations with significant damage problems also occurring in sapling stands. Trapping and placing physical barriers around individual trees are the most common methods of control. Both methods are costly but effective in reducing damage.

459. Campbell, Dan L.; Evans, James. 1988. Recent approaches to controlling mountain beavers (*Aplodontia rufa*) in Pacific Northwest forests. In: Crabb, A. Charles; Marsh, Rex E., eds. Proceedings, 13th vertebrate pest conference; 1988 March 1-3; Monterey, CA. Davis, CA: University of California: 183-187.

Biologists at the Denver Wildlife Research Center are currently investigating ways of managing mountain beaver populations and are developing methods for alleviating mountain beaver damage to conifer trees being grown for timber in the Pacific Northwest. Studies initiated in 1986 indicated that aversive conditioning with Big Game Repellent powder (BGR-P) dusted on cull Douglas-fir seedlings placed in burrows significantly reduced mountain beaver damage to planted seedlings treated with BGR-P and to untreated seedlings. Trials also showed that strychnine-sword fern baits prepared with a 4.9% (active) strychnine paste concentrate are very effective and selective for mountain beaver control. Other subjects discussed included results of several probes with toxic baits and phosphine gas, trials with a drug and a wetting agent to induce hypothermia, destruction of underground nests to prevent reinvasion, and mountain beaver behavior associated with controlling damage.

460. Campbell, Dan L.; Evans, James; Hartman, George B. 1988. Evaluation of seedling protection materials in western Oregon. Tech. Note OR-5. Portland, OR: U.S. Department of the Interior, Bureau of Land Management. 14 p.

A 3-year comparison was made for six materials to protect Douglas-fir seedling from damage by wildlife. No treatment materials were maintained after the initial application. Materials included a nested plastic mesh tube, a split plastic mesh tube, a

paper bud cap, a plastic mesh tube cap, BGR spray, and BGR powder Big Game Repellent. Nested plastic mesh tubes provided the most protection and significantly better growth than other treatments. Split, small-diameter plastic mesh tubes protected seedlings better and generally provided more growth than bud caps or repellents. Bud caps and repellents provided some protection and growth depending on type of damage and season of damage. Costs and comparisons of seedling growth for different materials are reported. Damage was primarily caused by mountain beaver, elk, and black-tailed deer.

461. Evans, James. 1987. Mountain beaver damage and management. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 73-74.

There is a critical need to develop and evaluate methods and materials to alleviate mountain beaver reforestation damage problems. At present, there are no repellents registered for mountain beaver, and only a Special Local Needs registration of a pelleted strychnine bait exist in Oregon.

462. Hartwell, Harry D.; Johnson, Larry E. 1983. Survival and height of large and small Douglas-fir seedlings in relation to animal damage six years after planting. DNR Note 38. Olympia, WA: State of Washington, Department of Natural Resources. 20 p.

Douglas-fir 2+0 and 3+0 nursery seedlings averaging about 1 and 3 feet in height, respectively, were evaluated for field performance in five separate potential animal damage areas in western Washington over a period of six growing seasons. Results indicate that the trees were subject to moderate or severe hare clipping damage on three of the areas and to severe mountain beaver clipping damage on another area. Trees on all areas were subject to persistent, moderate, or severe spring-summer deer browsing damage. The 3+0 trees showed much greater resistance to mortality caused by hare clipping and substantially greater resistance to growth delay caused by hare clipping and spring-summer deer browsing. Both classes of tree, however, were highly vulnerable to mortality caused by mountain beaver clipping. An economic projection revealed that the 3+0 seedlings would be a better investment on the three hare-deer damage sites and that both classes of seedling would result in stands of suboptimum wood volume on the mountain beaver-deer damage site. Observations concerning the influence of vegetation competition on growth and survival of trees are discussed.

463. Hoyer, Gerald E.; Anderson, Norman; Riley, Ralph. 1979. A case study of six years of mountain beaver damage on Clallam Bay western hemlock plots. DNR Note 28. Olympia, WA: Washington Department of Natural Resources. 5 p.

The Clallam Bay western hemlock study plots were installed in 1971 to measure the influence of various initial spacing regimes in a 13-year-old stand. Spacing was accomplished by felling trees on the plots, leaving desirable trees at specified average

distances apart. The results showed that the number of trees damaged by mountain beaver can be high (43%) in stands of western hemlock, even with diameters averaging 2.8 inches and larger.

464. Motobu, DiAnne; Jones, Marvin. 1977. Trapping guidelines for mountain beaver. [Centralia, WA]: Weyerhaeuser Company; Forestry Research Technical Report 042-4101/77/20. 28 p.

Contains guidelines for organizing a mountain beaver trapping program. Organization of trapping crews, procedures in setting a trap, and techniques for evaluating crew performance are discussed.

465. Scheffer, Theo H. 1952. Spring incidence of damage to forest trees by certain mammals. *Murrelet* 33(3): 38-41.

Describes the damage caused by three mammals in the second-growth forests of the Puget Sound area. Western gray squirrels girdle tree tops in the spring when the sap is rising and the bark is looser. Mountain beaver prune seedlings and sometimes slender saplings, to a height of 10 feet or more, leaving stubs of severed branches as a ladder. The black bear strips the bark from boles of trees to get at the cambium layer soon after the animals come out of hibernation. It appears that damage by bears has increased in recent years.

466. Anderson, Robert J.; Barnes, Victor G., Jr.; Bruce, Anna M. 1976. A bibliography of pocket gophers: family geomyidae. Weyerhaeuser For. Pap. 16. Centralia, WA: Forestry Research Center, Weyerhaeuser Co. 50 p.

Brings together a comprehensive and varied set of literature references on pocket gophers which emphasizes, but is not restricted to, forest relationships. Citations are arranged alphabetically, by author, within subject categories.

467. Barnes, V.G., Jr.; Black, H.C.; Capp, J.C. [and others]. 1975. Survey of pocket-gopher research in the Western United States. [Place of publication unknown]: Northwest Forest Pocket Gopher Committee, Oregon-Washington Silvicultural Council, Western Forestry and Conservation Association. 6 p.

A questionnaire was sent to 173 colleges and universities to assemble information on current or planned research work on pocket gophers. This publication lists the titles of 33 research projects in progress, the researcher involved, and his affiliation.

468. Chase, Janis D.; Howard, Walter E.; Roseberry, James T. 1982. Pocket gophers (geomyidae). In: Chapman, Joseph A.; Feldhamer, George A., eds. *Wild mammals of North America: biology, management, and economics*. Baltimore, MD: Johns Hopkins University Press: 239-255.

Reviews distribution, description, physiology, genetics, reproduction, population dynamics, ecology, food habits, behavior, mortality, economic status and management of the various *Thomomys* and *Geomys* species.

Pocket Gophers

General

469. Teipner, Cynthia Lea; Garton, Edward O.; Nelson, Lewis, Jr. 1983. Pocket gophers in forest ecosystems. Gen. Tech. Rep. INT-154. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 53 p.

A state-of-knowledge report on available information on gopher biology, ecology, damage, and control. Habits and related problems are reviewed for gopher species throughout the U.S., but attention is focused on pocket gophers in northwestern forest environments. A bibliography containing over 1,000 literature citations is included.

Ecology

470. Andersen, Douglas C.; MacMahon, James A. 1985. Plant succession following the Mount St. Helens volcanic eruption: facilitation by a burrowing rodent, *Thomomys talpoides*. *American Midland Naturalist* 114(1): 62-69.

The May 18, 1980, eruption of Mount St. Helens initiated plant succession over a broad region. Northern pocket gophers *Thomomys talpoides* survived in widespread subalpine and montane sites where up to 25 cm of tephra had buried dormant or only recently snow-free vegetation. Burrowing and consequent construction of mounds by this herbivorous rodent has both modified the physical structure of the tephra and led to the placement of preeruption soil material on the tephra surface. We compared the composition of the plant community and the pattern of seedling establishment on and off gopher mounds. More plant species and individuals survived burial on mounds than at off-mound sites. Seedlings are also most diverse on mounds. We conclude that pocket gophers, through their soil-disturbing activities, can strongly affect plant population dynamics in volcanically disturbed areas, and thus may be an important agent in determining the pathway of succession. Limited observations suggest that differential herbivory may further affect plant community composition. Possible mechanisms that enhance plant survivorship and seedling establishment on mounds are discussed.

471. Anderson, Robert John. 1976. Relation of the northern pocket gopher to forest habitats in south-central Oregon. Corvallis, OR: Oregon State University. 46 p. M.S. thesis.

The purpose of the study was to determine the factors that influence the local distribution of the northern pocket gopher in a forested region of south-central Oregon. Specific objectives were to determine the factors important to pocket gopher occurrence and to determine the relationship of the indexes to gopher density to variations in the habitat. The activity level and the number of animals captured per acre increased with increasing elevation and slope and tended towards more mesic timber types. The habitat preference was greater for an area with more site disturbance and greater forb cover. The assumption that forest management activities improve pocket gopher habitat is supported by the results of this study. A reduction in the amount of site disturbance, forb cover, or both, is suggested to decrease the probability of gopher occurrence and the associated gopher-caused tree damage.

472. Black, H.C.; Hooven, E.F. 1974. Response of small mammal communities to habitat changes in western Oregon. In: Black, Hugh C., ed. *Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium; 1973 September 11-12; Corvallis, OR.* Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University: 177-186.

Habitat changes after wildfire, clearcutting, or herbicide application profoundly affect species composition of small mammal communities. Small mammals responded to habitat changes after disturbances according to their habitat preferences. Shrews, voles, and Townsend's chipmunks were few or absent on Douglas-fir clearcuts after wildfire, but shrews and voles were abundant in early successional stages of unburned Douglas-fir clearcuttings. Red-backed voles rarely were found on clearcuts, even in the shrub stage of succession. Golden-mantled ground squirrels and Great Basin pocket mice were abundant on clearcuts in the mixed conifer region, although they were not found on uncut stands. After herbicide treatments of Douglas-fir clearcuts, vagrant shrews, Pacific jumping mice, and Oregon voles were less abundant on treated areas, but small mammal habitat recovered markedly within 2 years after herbicide treatment of clearcuts in the grass-shrub stage of succession. In southwestern Oregon, small mammal communities were less affected by herbicide-induced habitat changes because microtines and other species associated with grassy habitats were only minor components of the community. On areas with complete vegetation control, however, abundance of pocket gophers was reduced greatly 1 year after treatment.

473. Burton, Douglas H.; Black, Hugh C. 1978. Feeding habits of Mazama pocket gophers in south-central Oregon. *Journal of Wildlife Management* 42(2): 383-390.

The annual diet of 110 Mazama pocket gophers collected in the pine region of south-central Oregon during 1973-74 consisted mainly of the aboveground parts of forbs (40%), grasses (32%), and woody plants (4%); plant roots comprised 24% of the diet. Food availability was an important determinant of diet. Vegetation on the study area was about 1/3 grasses and 2/3 forbs; annual forbs comprised 87% of the total forb cover. The diets of gophers collected during the growing season, July to September, did not differ significantly, but diets during other sampling periods did. Succulent forbs were preferred to all other plants, but they were not abundant enough to provide a dependable food supply. Grasses were consumed most heavily during the dormant season when annual forbs were not available. Woody plants, including ponderosa pine, were eaten in winter, but they constituted only a minor portion of the diet.

474. Burton, Douglas Harlow. 1977. The feeding habits of the Mazama pocket gopher in the pine region of south-central Oregon. Corvallis, OR: Oregon State University. 64 p. M.S. thesis.

Pocket gophers were collected on alternate months from July 1973 through September 1974. Species of plants eaten were identified by comparing fragments of epithelial tissue in the stomach contents to a reference collection that had previously been collected and mounted on microscope slides. Shrubs, common mullein, and ponderosa pine seedlings also were examined in the field monthly for evidence of aboveground feeding by gophers. Forbs comprised 55% of the vegetative cover in July

1973 and 61% in July 1974. They constituted 40% of the annual diet and were eaten most heavily during the growing season. Grasses comprised 41% of the cover in July 1973 and 30% in July 1974. They constituted 32% of the annual diet and were eaten extensively during the dormant season. Woody plants were eaten during the dormant season, but they constituted only a small part of the annual diet. Ponderosa pine was the most heavily eaten woody plant. Evidence of gophers feeding aboveground on woody plants was found only from December through April. Perennial forbs were the preferred food, but grasses were the most important food in winter. Results indicated that vegetative alteration, an indirect method of controlling pocket gopher damage to conifers, should be directed at controlling grasses without stimulating the establishment of perennial herbs.

475. Cummins, Eric Boyd. 1975. Pocket gopher feeding preferences for ponderosa pine strains. Moscow, ID: University of Idaho. 51 p. M.S. thesis.

Feeding preferences of northern pocket gophers for seedlings grown from 20 geographic seed sources of ponderosa pine were studied from December 1972 to August 1974. Two laboratory procedures and one field test were developed and applied to test feeding preferences for seedlings. Pocket gophers did not preferentially select any particular source of ponderosa pine when presented with a set of seedlings from six different sources. Pocket gophers exhibited significant preferences for seedling from particular sources in terms of amounts consumed of each strain. The preferred parts of a ponderosa pine seedling, in order of decreasing preference, were the stem, roots, needles, and the terminal bud. The proportion of a seedling eaten varied inversely with seedling size. Individual pocket gophers ate significantly greater amounts of all seedlings than did other gophers. Field tests did not indicate any selective feeding preferences. Pocket gophers damaged more seedlings in early spring and late fall than during summer.

476. Dalquest, W.W.; Scheffer, V.B. 1944. Distribution and variation in pocket gophers, *Thomomys talpoides*, in the State of Washington. *American Naturalist* 78(777): 308-333 and 78(778): 423-450.

In a monographic treatment, the development of the population since the Pleistocene from a relic and an immigrant group of subspecies is first outlined. Present day ecological habits of each group allow the post Pleistocene changes in distribution to be correlated with geologic variation. The habits of pocket gophers enable them to survive long periods in the isolated patches of inhabitable territory provided by the diverse topographical conditions. Thus the tendency to form microgeographic races is pronounced and is strikingly exemplified by a mutant type with an internasal bone found in one of them. In an exhaustive analysis of gopher populations from seven prairies in the Puget Sound area, definite correlations are established between body size and depth of soil. Studies of hair color and pattern types have shown greater genetic differences between the immigrant and relic groups of subspecies than between the subspecies of each group. The authors present an annotated catalog of 17 subspecies, including notes on range, color, and photographs of skulls of each.

477. Hungerford, Kenneth E. 1976. Food preferences and food locations by pocket gophers in Idaho. In: Siebe, Charles C., ed. Proceedings, 7th vertebrate pest conference; 1976 March 9-11; Monterey, CA. Davis, CA: University of California: 131-138.

Pocket gophers in environmental systems adapted readily to laboratory conditions. The laboratory equipment is described in this paper. Results are reported, including data on food consumption as it varies with the activity patterns of the gopher and the variation between individual gophers. One gopher used an average of 52 g of food per day for a 131-day period, but during an extremely active 17-day period, the gopher consumed approximately its own weight in food each day (75 g). The experimental setup is described for food location experiments, and results indicate that gophers locate their food primarily by odor. Test animals react very quickly (in seconds or minutes) to odor stimuli if the gopher's food cache is depleted and the animal is hungry.

478. Huntly, Nancy; Inouye, Richard. 1988. Pocket gophers in ecosystems: patterns and mechanisms. *BioScience* 38(11): 786-793.

Pocket gophers have large effects on soil fertility. Because of this, gophers change the resource environment of plants and have major indirect effects on plant communities. Gophers increase spatial variation in the availability of soil nitrogen. The relationships between total soil nitrogen and available soil nitrogen and between soil nitrogen and available light are looser when gophers are present. These effects cause development of a plant community that is more diverse and that differs in species composition from what would otherwise occur. Gophers also have direct effects on plant populations. Their aboveground and belowground consumption is selective and favors ungrazed plants over those that are preferentially consumed. The changes that gophers cause in the physical environment and in vegetation affect the herbivore food web, and gophers and other small herbivores provide the major food source of many carnivores. Thus, the activities of pocket gophers cascade through the entire trophic web.

479. Maser, Chris; Trappe, James M.; Nussbaum, Ronald A. 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. *Ecology* 59(4): 799-809.

Most higher plants have evolved with an obligatory symbiotic relationship with mycorrhizal fungi. Epigeous mycorrhiza formers have their spores dispersed by air currents, but hypogeous mycorrhizal fungi are dependent upon small mammals as primary vectors of spore dissemination. Mammalian mycophagists defecate within the coniferous forest ecosystem, spreading the viable spores necessary for survival and health of the conifers. As one unravels and begins to understand the interrelationships between small mammal mycophagists and mycorrhizal fungi, it becomes apparent that the various roles of small mammals in the coniferous forest ecosystem needs to be reevaluated. One can no longer accept such simplistic solutions to timber management as poisoning forest rodents to enhance tree survival. One must consider the

direct as well as the indirect costs and benefits of timber management decisions if one is to maintain balanced, healthy coniferous forests.

480. Moore, A.W.; Reid, Elbert H. 1951. The Dalles pocket gopher and its influence on forage production of Oregon mountain meadows. Circ. 884. Washington, DC: U.S. Department of Agriculture. 36 p.

To develop a basis for judging the need for pocket gopher control and the results to be expected from it, a cooperative study was carried out in the Blue Mountains of eastern Oregon from 1931 through 1948. The following observations on the life history of the Dalles pocket gopher were obtained from the study: (1) It prefers open areas and is most abundant in mountain meadow. It avoids dense forests but gradually spreads into them as the canopies are thinned by logging. (2) Although it is active throughout the year, its activities are more easily observed in the fall. Control measures are, therefore, applied more easily at that time. (3) It feeds mainly on roots and underground stems and on surface vegetation in the immediate vicinity of its opened side runways. It prefers the common broad-leaved herbs but also feeds on grasses, young pine, quaking aspen, and other trees. Results of studies on range improvement indicated that gopher control is necessary as a range improvement practice to obtain satisfactory improvement of infested mountain meadows that are in poor range condition. However, where pocket gophers infest mountain meadows in fair range condition, their control may not be necessary. In such a situation, the main value of control is either to make available to livestock or game the forage the gopher would use or destroy or to permit more rapid restoration of the range.

481. Scrivner, Jerry H.; Smith, H. Duane. 1981. Pocket gophers (*Thomomys talpoides*) in successional stages of spruce-fir forest in Idaho. Great Basin Naturalist 41(3): 362-367.

This study examined the relative abundance of the pocket gopher in four successive stages (1-10, 11-39, 40-79 and 80+ years following disturbance) of spruce-fir forest, the relationship between the number of gopher signs (mounds and earth plugs) to gopher density, and a method of sampling pocket gopher populations by using a 500- by 4-m strip transect. The number of gopher mounds was significantly correlated with the number of earth plugs. Data were pooled and a categorical log linear analysis used to test for significant differences in pocket gopher signs between the four successive stages. The 1-10- and the 80+-year-old sites had significantly more gopher signs than the 11-39- and 40-79-year-old sites. No significant differences were found between the 11-39- and 40-79-year-old sites or between the 1-10- and the 80+-year-old sites. The difference in population densities may be due to understory vegetation differences between the successional stages. A significant correlation between amount of gopher signs and gophers caught in each of the study sites indicates that counts of pocket gopher signs may be used to estimate pocket gopher density. The strip transect is recommended as the most appropriate method when sampling heterogeneous habitats or when there is cause to suspect that gopher populations are aggregated within the area rather than spaced randomly or regularly.

482. Tevis, Lloyd, Jr. 1956. Pocket gophers and seedlings of red fir. *Ecology* 37(2): 379-381.

A high ridge between the New and Trinity Rivers in northwestern California originally was covered with a turf of Idaho fescue (*Festuca idahoensis*) which prevented the spread of conifers. Around the turn of the century, overgrazing by livestock resulted in gradual destruction of the turf and multiplication of deep-rooted and bulbous plants. Then pocket gophers, responding to a new supply of food, increased in numbers. Their burrowing accelerated deterioration of the range. Removal of vegetation and churning of ground by gophers produced an ideal seed bed for conifers. In 1951, red fir set a bumper crop of cones. In the following spring, enormous numbers of seedlings sprouted. Mortality was high. After 2 years, abundant survivors were found only on bare ground not visited by the rodents. In brushfields and forest, young trees died because of shade and competition from other plants. After 2 years, seedlings that had survived on bare ground were sufficiently numerous to indicate that much of the range is destined to become forest. A reversal of this present trend in ecological succession will require reduction in numbers of livestock and gophers and seeding of bare areas with grass.

483. Volland, Leonard A. 1974. Relation of pocket gophers to plant communities in the pine region of central Oregon. In: Black, Hugh C., ed. *Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium*; 1973 September 11-12; Corvallis, OR. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University: 149-166.

Presents preliminary results from a vegetation site inventory of 1.8 million acres of the central Oregon pumice region. Twenty-three communities were identified within the ponderosa pine and lodgepole pine types. Tree productivity data are given for 19 communities. A vegetation site key is provided for field identification. Describes the preferences of pocket gophers for certain identifiable habitats and suggests procedures for minimizing gopher damage, based on field identification of preferred habitats.

484. Walker, Kenneth Merriam. 1955. *Distribution and taxonomy of the small pocket gophers of northwestern Oregon*. Corvallis, OR: Oregon State College. 94 p. Ph.D. dissertation.

Members of the genus *Thomomys* are abundant over the entire Western United States. Five species (and numerous subspecies) are currently recognized as ranging within the boundaries of Oregon: *T. bulbivorous*, *T. townsendii*, *T. bottae*, *T. talpoides*, and *T. monticola*. This investigation is concerned with the distribution and taxonomic interrelationships between the races *T. monticola* as they occur in northwestern Oregon. The objectives of the study were (1) to find out what forms of gophers occur in northwestern Oregon; (2) to ascertain the geographic range of each; (3) to determine and catalog the variation in each form; (4) to compile descriptions by means of which accurate identifications and comparisons are possible; and (5) to provide brief information on habits and habitats as gleaned in the pursuit of the above.

485. Alsager, D.E. 1977. Impact of pocket gophers (*Thomomys talpoides*) on the quantitative productivity of rangeland vegetation in southern Alberta: a damage assessment tool. In: Jackson, W.B.; Marsh, R.E., eds. Test methods for vertebrate pest control and management materials: A symposium; 1976 March 8; Monterey, CA. ASTM Spec. Tech. Publ. 625. Philadelphia, PA: American Society for Testing and Materials: 47-57.

A quantitative assessment of impact by pocket gophers on vegetative production of rangeland in southwestern Alberta was obtained. The technique described outlines a method of experimental plot selection, design, treatment, and evaluation over 3 months, which is relatively simple and has potential for application in other types of rodent damage assessments. The experimental design is particularly useful in that it allows the researcher to correlate the presence of rodents to measurable changes in net vegetation production. In this study, forage production increased 16% during the final 60 days of the 3-month study on plots where pocket gophers were removed completely. Plots treated with a machine application of rodenticide showed a 4 and 5% increase in forage production, respectively. During the same period, forage yields on untreated control plots (where pocket gophers were not removed) declined 18%.

486. Anthony, R. Michael; Lindsey, Gerald D.; Evans, James. 1984. Hazards to golden-mantled ground squirrels and associated secondary hazard potential from strychnine for forest pocket gophers. In: Clark, Dell O., ed. Proceedings, 11th vertebrate pest conference; 1984 March 6-8; Sacramento, CA. Davis, CA: University of California: 25-31.

Radio telemetry and capture-recapture techniques were used to evaluate the hazards to golden-mantled squirrels from hand baiting with 0.5% strychnine-treated oats for western pocket gophers on conifer plantations in eastern Oregon. Toxicology data were collected on field-killed and caged ground squirrels and on caged mink, great horned owls, and red-tailed hawks. Ground squirrel populations were reduced 50% to 75% following underground baiting for pocket gophers. Maximum amount of strychnine alkaloid found in cheek pouches and carcass of a field-killed golden-mantled ground squirrel was 2.88 mg. Mean amount of strychnine in carcasses was 0.35 mg; almost all occurred in the gut. The estimated LD₅₀ for mink was 0.6 mg/kg. The lowest lethal dose for great horned owls and red-tailed hawks was 7.7 mg/kg and 10.2 mg/kg, respectively. The LD₅₀ for owls and hawks was not determined. Long-term effects on golden-mantled ground squirrel populations and secondary hazard potential to owls and hawks were judged to be minimal. Wild mustelids as large as mink could be adversely affected by consuming the gut content of strychnine-killed golden-mantled ground squirrels.

487. Anthony, Richard A.; Barnes, Victor G., Jr.; Evans, James. 1978. Vexar plastic netting to reduce pocket gopher depredation of conifer seedlings. In: Howard, Walter E., ed. Proceedings, 8th vertebrate pest conference; 1978 March 7-9; Sacramento, CA. Davis, CA: University of California: 138-144.

In 1976, we began a comprehensive evaluation of "Vexar" seedling protectors as a means of reducing damage to conifer seedlings by pocket gophers. The evaluation is being conducted on four national forests in three Western States. Lodgepole pine, ponderosa pine, and Shasta red fir are being studied. After two growing seasons,

gophers have caused only 5% mortality among Vexar-enclosed seedlings compared to 20% mortality among unprotected seedlings. In addition, stocking and heights of protected seedlings are better than those of unprotected seedlings. Problems associated with the use of Vexar included compression of the protectors by snow, breakage of the plastic during subfreezing temperatures, and protrusion of seedling terminals through mesh openings; however, these problems have been minor thus far. Information on long-term effectiveness and cost efficiency is still needed before we can recommend operational use of Vexar protectors for pocket gopher damage control.

488. Anthony, Richard M.; Barnes, Victor G., Jr. 1983. Plot occupancy for indicating pocket gopher abundance and conifer damage. In: Kaukeinen, D.E., ed. Vertebrate pest control and management materials: Fourth symposium. ASTM STP 817. Philadelphia, PA: American Society for Testing and Materials: 247-255.

Pocket gopher (*Thomomys mazama*) sign (mounds and earth plugs) was inventoried at 48-hour and 1-month intervals in study areas in central and south-central Oregon. Similar counts of 48-hour and 3-month accumulations of sign made by *Thomomys mazama* and *T. talpoides* were taken in California, Idaho, and Oregon. Plot occupancy—the frequency at which sign occurred on circular, 81-square-m plots—was strongly correlated with counts of individual signs and gopher depredation of planted conifer seedlings. For one area, we also determined that plot occupancy was significantly related to gopher density. We recommend the 48-hour plot occupancy count—done in late summer or early fall, when gophers are most actively producing mounds—as the most useful index for forest management.

489. Barnes, V.G., Jr.; Black, H.C.; Capp, J.C. [and others]. 1976. Survey of pocket gopher damage to conifers in the Pacific Northwest, 1975. [Place of publication unknown]: Northwest Forest Pocket Gopher Committee, Oregon-Washington Silvicultural Council, Western Forestry and Conservation Association. 7 p.

Summarizes results of a questionnaire sent to 168 managers of federal, state and private forest lands in Washington, Oregon, Idaho, and northern California. Eighty replies (48%) were received, and 46 (57%) reported that pocket gophers were not a problem. From the 34 respondents who indicated that pocket gophers were a problem, it was determined that (1) damage is most extensive and is receiving greatest attention on National Forests and a few private industry ownerships; (2) damage occurs primarily east of the Cascade crest and is causing reforestation loss or delay on at least 200,000 acres; (3) most land managers expect the affected acreage to remain constant or increase in the next 10 years and; (4) present control is ineffective or partially effective and is applied to less than 1/10 of the acres incurring damage.

490. Barnes, Victor G., Jr. 1973. Pocket gophers and reforestation: a problem analysis. Spec. Sci. Rep. Wildl. 155. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 18 p.

Reviews pocket gopher problems in the Northwest, summarizes present knowledge of gopher biology, outlines current control methods, and suggests future research needs.

491. Barnes, Victor G., Jr. 1974. Response of pocket gopher populations to silvicultural practices in central Oregon. In: Black, Hugh C., ed. *Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium*; 1973 September 11-12; Corvallis, OR. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University: 167-175.

Discusses the response of pocket gopher populations to different methods of timber harvesting and site preparation, and to animal control practices used by forest managers in central Oregon. Preliminary results of studies in various habitat types are presented. The major conclusion is that many instances of gopher damage could be avoided or modified through early recognition of the animals' probable response to habitat changes and by prompt application of direct or indirect control measures.

492. Barnes, Victor G., Jr. 1978. Survival and growth of ponderosa pine seedlings injured by pocket gophers. *Tree Planters' Notes* 29(2): 20-23.

Gophers can influence regeneration for 10 or more years, but most seedling mortality occurs the first 2 years after planting. This report quantifies survival and growth of ponderosa pine injured by gophers 2-1/2 to 3 years after planting. Pocket gophers caused 2/3 of the damage and almost all mortality of sample trees. Nearly all of the gopher damage occurred from fall 1970 to spring 1971, when seedlings were at a mean height of 42 cm. The injuries inflicted by gophers caused 52% mortality and, in the most heavily damaged plantation, left sizable areas unstocked. Virtually all gopher damage was done by animals burrowing through snow, and with one exception, the damage was by clipping of the lateral branches and gnawing on the main stem. Fifty-six percent of the injured seedlings were debarked around more than half the stem circumference. Of these seedlings 89% died. In contrast, mortality was only 11% when less than half the stem perimeter was affected. Mortality also was high (80%) when length of injury exceeded 25% of seedling height. The impact of gopher depredation becomes less severe as pine seedlings grow larger; more feeding must occur before fatal injury is sustained. Height increment of surviving trees is similar to undamaged trees, probably because terminal injury is less common than lower stem gnawing.

493. Barnes, Victor G., Jr.; Anthony, Richard M.; Lindsey, Gerald D. 1982. Evaluation of zinc phosphide bait for pocket gopher control on forest land. In: Marsh, Rex E., ed. *Proceedings, 10th vertebrate pest conference*; 1982 February 23-25; Monterey, CA. Davis, CA: University of California: 219-225.

Laboratory bioassays and field test were conducted to determine if zinc phosphide baits would control pocket gophers in forest plantations. Zinc phosphide baits generally were less effective than the strychnine alkaloid-oat bait commonly used by forest managers to control gophers. However, a carrot bait with 0.75% zinc phosphide showed potential as a substitute for strychnine. Size of carrot bait and grooming activity of gophers were identified as important factors affecting efficacy of baits.

494. Barnes, Victor G., Jr.; Martin, Paul; Tietjen, Howard P. 1970. Pocket gopher control on Oregon ponderosa pine plantations. *Journal of Forestry* 68(7): 433-435.

After a series of laboratory bioassays, control of pocket gophers was evaluated on two ponderosa pine plantations in Oregon. The forest land burrow-builder (a bait-dispensing machine) operated satisfactorily in difficult terrain and better than 90% control was attained with baits of strychnine alkaloid and Gophacide.

495. Canutt, Paul R. 1969. Development and operation of the forestland burrow builder. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR.* Corvallis, OR: Oregon State University, School of Forestry: 77-79.

Problems caused by pocket gophers in pine plantations in Oregon and inadequacy of hand baiting prompted search for more effective means of controlling gopher damage. The U.S. Department of Agriculture, Forest Service has developed an artificial burrow builder for machine-baiting of gophers, adapted from burrow builders designed for use on agricultural lands. Operation of the machine is explained and operational factors that affect field use are listed, such as slope, obstructions, soil texture, and soil moisture. Effectiveness of machine baiting is based on preliminary evaluation, which showed 91 to 96% of gophers eliminated on test plots.

496. Canutt, Paul R. 1970. Pocket gopher problems and control practices on national forest lands in the Pacific Northwest region. In: Dana, Richard H., ed. *Proceedings, 4th vertebrate pest conference; 1970 March 3-5; West Sacramento, CA.* Davis, CA: University of California: 120-125.

Reviews damage by pocket gophers and control techniques by hand baiting or mechanical baiting with the burrow builder.

497. Capp, John C. 1976. Increasing pocket gopher problems in reforestation. In: Siebe, Charles C., ed. *Proceedings, 7th vertebrate pest conference; 1976 March 9-11; Monterey, CA.* Davis, CA: University of California: 221-228.

Concern over pocket gopher damage to conifer seedlings is increasing rapidly in the Northwestern U.S. The evolution of the pocket gopher has resulted in an animal that occurs throughout northwest forested areas and responds to site disturbances by increasing numbers and distribution. Pocket gophers kill or slow growth of conifer seedlings. More extensive logging, wildfire, and insect epidemics are resulting in more damage problem areas; this will continue. Current damage control is judged poor. Juvenile dispersal, high natural mortality rate, need for intensive treatment on entire damaged areas, current dependency on pesticides for control, increasing wood product values, and decreasing tolerance for reforestation delays are causing this increased concern. Integrated control appears necessary for the future.

498. Crouch, Glenn L. 1971. Susceptibility of ponderosa, Jeffrey, and lodgepole pines to pocket gophers. *Northwest Science* 45(4): 252-256.

Some foresters working in south-central Oregon observed that ponderosa pines seemed to be more heavily damaged by gophers than were Jeffrey pine or lodgepole

pinus. If these observations could be substantiated, then the less-susceptible species might be planted in gopher-infested areas where the ecological requirements of the tree were met. The purpose of this study was to determine relative preferences of gophers for the three pine species on one area where damage by gophers was known to occur. Results showed that planting one pine species instead of another did not reduce gopher predation. The findings also clearly demonstrated that gophers damaged conifers predominantly during the winter, which suggests that efforts to control damage by reducing gopher numbers should be scheduled just before winter. Finally, the loss rate to gophers over the 3-year study confirms the prediction by others that unless trees are protected from these animals, plantations infested with them are probably doomed.

499. Crouch, Glenn L. 1982. Pocket gophers and reforestation on western forests. *Journal of Forestry* 80(10): 662-665.

Pocket gophers damage conifer regeneration after logging or wildfires on western forests. Poisoning is the usual control method, but nonlethal techniques are currently being tested. Silvicultural practices that minimize habitat conditions favorable to gophers may be the most practical solution for avoiding damage.

500. Crouch, Glenn L. 1986. Pocket gopher damage to conifers in western forests: a historical and current perspective on the problem and its control. In: Salmon, Terrell P., ed. Proceedings, 12th vertebrate pest conference; 1986 March 4-6; San Diego, CA. Davis, CA: University of California: 196-198.

Pocket gophers damage or destroy regeneration on hundreds of thousands of acres of forest land in the Western United States each year. Despite years of research, poisoning the offending animals--a technique developed around the turn of the century on agricultural land--is still the most prevalent practice for controlling damage on western forests.

501. Crouch, Glenn L.; Frank, Larry R. 1979. Poisoning and trapping pocket gophers to protect conifers in northeastern Oregon. Res. Pap. PNW-261. Portland, OR: U.S. Department of Agriculture. Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Poisoning or trapping pocket gophers was employed on mixed conifer plantations in northeastern Oregon to reduce the rodent's damage to young trees. Single treatment of either procedure was ineffective, but two applications, about 2 weeks apart, resulted in significant reductions in mound building and damage to trees.

502. Dingle, Richard Wm. 1956. Pocket gophers as a cause of mortality in eastern Washington pine plantations. *Journal of Forestry* 54(12): 832-835.

An experiment in the artificial regeneration of ponderosa pine in eastern Washington revealed that several species of wild animals were associated with reductions in plantation survival. Pocket gophers were particularly important causes of mortality in several locations. Gopher control by baiting tunnel systems with pieces of strychnine-treated carrot was quite effective in reducing populations of gophers and increasing survival of planted trees.

503. Evans, James. 1987. Efficacy and hazards of strychnine baiting for forest pocket gophers. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 81-83.

Underground baiting with 0.5% strychnine alkaloid oat bait is commonly used to control pocket gophers in coniferous forests. This paper gives some background on baiting and reviews some of the efficacy and hazards of strychnine baiting for forest pocket gophers.

504. Fagerstone, Kathleen A.; Barnes, Victor G., Jr.; Anthony, R. [and others]. 1980. Hazards to small mammals associated with underground strychnine baiting for pocket gophers. In: Clark, Jerry P., ed. Proceedings, 9th vertebrate pest conference; 1980 March 4-6; Fresno, CA. Davis, CA: University of California: 105-109.

To control gopher populations and reduce damage, the U.S. Department of Agriculture, Forest Service annually treats thousands of hectares with strychnine alkaloid bait. Because an underground application of strychnine bait could pose a threat to other species, we monitored small mammal populations before and after a baiting operation. Although two deer mice recovered within baited areas were killed by strychnine, live-trapping revealed no differences in small mammal populations before and after baiting. Thirty yellow pine chipmunks and one northern flying squirrel were fitted with radio transmitters before treatment. Twenty-four of the chipmunks, and the flying squirrel, survived to the end of the study. Transmitter signals were lost on three chipmunks before treatment, and they were unaccounted for. Two chipmunks died during the study and contained strychnine residues in body tissues. The remaining chipmunk appeared to have been killed by a predator.

505. Gross, Rob; Laacke, Robert J. 1984. Pocket gophers girdle large true firs in northeastern California. *Tree Planters' Notes* 35(2): 28-30.

Serious damage to trees by pocket gophers had been thought to be limited to trees less than 5 inches in d.b.h. Excavation of a sample of 20 trees (mostly *Abies magnifica* with some *A. concolor* and *Pinus contorta*) d.b.h 5.8-36.9 inches showed that the phloem was missing in 5-100% of the excavated areas. An extensive burrow system with burrows next to recently gnawed roots, bark strips in burrows, and marks typical of gopher teeth on the stripped roots indicated that the damage was caused by gophers.

506. Hermann, Richard K.; Thomas, Harold A. 1963. Observations on the occurrence of pocket gophers in southern Oregon pine plantations. *Journal of Forestry* 61(7): 527-529.

Gophers were controlled effectively by baiting during the first year, when drought caused 75% loss after establishing a plantation of ponderosa pine in 1951 in southern Oregon, but caused such damage in succeeding years that only 0.9% of seedlings planted were alive after 11 years. Most damage was during winters. Control of gophers appears necessary until the crowns close. Eradication probably is undesirable because their burrowing improves some unfavorable ground.

507. Hooven, Edward F. 1971. Pocket gopher damage on ponderosa pine plantations in southwestern Oregon. *Journal of Wildlife Management* 35(2): 346-353.

Pocket gophers often make regeneration of ponderosa pine difficult in Oregon, because, after logging, the gophers increase in substantial numbers. Efforts to reforest with ponderosa pine can be nullified if many pocket gophers are present, and in such localities control efforts must be constant. This study showed seedling survival of 87% in areas free of pocket gophers in contrast to 12% in areas occupied by pocket gophers. The conditions that create a suitable pocket gopher habitat are unknown, but they are apparently influenced by the species of trees present before logging, various vegetative responses after logging, elevation, and soil characteristics.

508. Hoppe, J.P. 1977. Manipulating vegetation to control pocket gopher numbers and gopher-caused seedling mortality. [Centralia, WA]: Weyerhaeuser Company; Forestry Research Technical Report 042-4102/77/34. 6 p.

The effects of vegetation management on gopher numbers and damage to seedlings have been investigated by several researchers. Their findings indicate that a reduction in vegetation results in a reduction in gopher numbers which reduces damage to seedlings; but this is not a linear relationship. By using data available in the literature, the relationships between vegetation management and gopher damage to seedlings were defined. Utilization of these relationships as the basis for the development of an operational pocket gopher control program is outlined in this report.

509. Horton, Alan J. 1987. Animal damage prediction models in conifer plantations. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. *Animal damage management in Pacific Northwest forests*; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 29-36.

Forest Service districts in south-central Oregon have implemented site-specific models for predicting damage by pocket gophers, big game, and livestock. Prediction models are based upon habitat, history/experience, population cycles, weather and disturbance factors (big game), use patterns and travel routes (big game and livestock), and available controls. Plantation establishment costs have declined significantly, however, the models have failed to accurately predict damage on a few plantations. Ongoing refinement of the models is necessary, particularly in separating "high risk" from "moderate risk" conclusions. Samples of the models are included.

510. Hull, A.C., Jr. 1971. Effect of spraying with 2,4-D upon abundance of pocket gophers in Franklin Basin, Idaho. *Journal of Range Management* 24(3): 230-232.

Four 50- by 50-foot plots were sprayed with 2 lb/acre 2,4-D in 1959, 1960, 1965, and 1969 to kill fleshy-rooted, spring-growing plants and annuals. These plants are the major source of food for pocket gophers. Averaging the 10-year period, 1960-69, spraying reduced gopher mounds by 93% and winter casts by 95% when compared to the unsprayed areas.

511. Kingery, James L.; Graham, Russell T.; White, Jeffrey S. 1987. Damage to first-year conifers under three livestock grazing intensities in Idaho. Res. Pap. INT-376. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 8 p.

Three study areas with a high potential for both forage and timber production were planted with 2+0 seedlings of ponderosa pine with Douglas-fir (one area) or with white pine (two areas). Within each area, uniform sites were located to represent light, medium, and heavy intensities of livestock grazing. Frequent observations were made after planting to define and quantify causes of seedling damage and mortality. The intensity of livestock use and livestock management practices appeared to influence damage associated with livestock, big game, pocket gophers, other rodents, and nonanimal factors. Considering all sites together, livestock caused little direct damage. Rotation grazing appeared to reduce damage and mortality to seedlings. Pocket gophers caused most damage, with the greatest damage occurring on sites with the least livestock grazing.

512. Lee, Ling Ling. 1986. Laboratory and field studies of behavioral and population responses of pocket gophers (*Thomomys* spp.) to durable baits. Davis, CA: University of California. 124 p. Ph.D. dissertation.

Behavioral and population responses of pocket gophers to durable baits designed to last a long time were studied both in laboratory and field to improve control of pocket gophers, especially in forest situations. Durable baits were made either by heat-sealing the grain in plastic bags (bag baits) or by mixing the grain with melted paraffin (paraffin baits) to protect loose grain from moisture in gopher burrows. They were designed to prolong the duration of effective control and to increase the chance of each baiting reaching those gophers whose systems had been missed. Thirty-four types of durable baits were tested for the durability in simulated underground burrows. Twenty types of nontoxic baits were tested for their attractiveness to Botta pocket gophers (*T. bottae*). Concentrations of 0.5% and 1% strychnine alkaloid durable baits were tested in the laboratory and in the field. The results showed that bag baits remained toxic and acceptable in burrow systems longer than paraffin baits. They were also favored in the laboratory tests; however, in the field tests, bag baits were sometimes pushed out of tunnels unopened, whereas paraffin baits were rarely pushed aboveground. This study also tested and discusses the importance of preventive control; that is, how control before logging, when usually few gophers are present, can help keep gopher populations from increasing rapidly after logging. Another finding was that some test gophers developed a tolerance for strychnine alkaloid baits and were able to exist on an exclusive diet of these baits.

513. Lindsey, Gerald D.; Evans, James. 1983. Evaluation of zinc phosphide for control of pocket gophers on Christmas tree plantations. *Tree Planters' Notes* 34(2): 11-14.

In laboratory tests, pocket gophers were offered five kinds of treated bait, including 1% zinc phosphide in oats, 0.75% zinc phosphide in fresh carrots, and 0.5% strychnine in rolled oats (three mixtures). The carrot bait was as effective for killing gophers as the strychnine mixtures. Plots in a 4-year-old Douglas-fir and white pine plantation

in Washington, with occupied gopher burrows, were baited with the carrot or one of the strychnine mixtures in November 1981. Both baits produced only a 63% reduction in gopher activity, possibly because of the availability of abundant alternative vegetative food. It was estimated that tree mortality due to root pruning by gophers was 10% on this site. It is recommended that the carrot/zinc phosphide bait be registered for special local needs where safety to wildlife and domestic animals is important.

514. Marsh, Rex E. 1987. The role of anticoagulant rodenticides in pocket gopher control. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 87-92.

The use of anticoagulants for pocket gopher control began in the early 1960s, but generally their use has been very limited, and little research has been conducted on current formulations or the potential use of second-generation anticoagulant baits for pocket gophers. Studies using second generation anticoagulants suggest they give superior control when compared with first-generation anticoagulants.

515. Moore, A.W. 1943. The pocket gopher in relation to yellow pine reproduction. *Journal of Mammalogy* 24(2): 271-272.

On Ochoco National Forest in Oregon, it was noted that grazing and the presence of pocket gophers are responsible for the lack of reproduction of ponderosa pine. When pressed for food, livestock will consume most growing green vegetation within reach, which greatly reduced the natural reproduction of ponderosa pine. Pocket gophers consumed a variety of vegetation including roots, tops, and bark of pines, but not pine seed. Use of pocket gopher runways by white-footed mice is the primary cause of the lack of pine reproduction in areas inhabited by gophers. When gophers are removed from an area, the tunnels collapse and do not afford shelter to the mice, and as a result, pine seeds are gleaned less thoroughly by the seed-eating mice.

516. Plesse, Lloyd F. 1984. An innovative approach to pocket gopher fumigation. In: Clark, Dell O., ed. Proceedings, 11th vertebrate pest conference; 1984 March 6-8; Sacramento, CA. Davis, CA: University of California: 24.

Describes a method of gassing gophers with carbon monoxide fumes by using a cartridge made by the U.S. Fish and Wildlife Service.

517. Radwan, M.A.; Crouch, G.L.; Harrington, C.A.; Ellis, W.D. 1982. Terpenes of ponderosa pine and feeding preferences by pocket gophers. *Journal of Chemical Ecology* 8(1): 241-253.

Yield and composition of essential oils were compared in foliage, stems, and roots of ponderosa pine seedlings, and preferences for the trees by pocket gophers were determined. Test seedlings represented nine widely separated provenances in the Western U.S. Seed source of the trees influenced gopher feeding preferences and resulted in varied tree damage. The damage ranged from 0 to 31%, suggesting that some sources might possess sufficient natural resistance to give tree practical protection from gophers in the field. There were no morphological differences among

sources to explain differential tree damage. All sources contained essential oils in all tissues examined, but oil yield varied among and within tissue types. Oils were predominantly composed of monoterpene hydrocarbons. Oil composition varied by source, and different tissue types varied greatly in the yield and composition of their oils. Neither yield nor constituents of foliage oils were significantly correlated with gopher damage (or preference). In contrast, some components of stem and root oils were strongly related to preference. Results of correlation and discriminant analyses showed that some oil constituents could serve as indicators of resistance (or susceptibility) to gopher damage. Such important chemical variables, when verified, could be used in selections for ponderosa pine resistant to gophers.

518. Ray, Vic. 1978. Response of pocket gopher (*Thomomys mazama*) to baiting with strychnine oats plus attractant in polyethylene bags. [Centralia, WA]: Weyerhaeuser Company; Forestry Research Tech. Rep. 042-4102/78/84. 5 p.

In 1977, a field trial was established to determine the effect of strychnine-treated oats bagged in polyethylene on reducing gopher numbers and gopher-caused seedling damage. Twelve months after treatment, both standard (loose) and bagged baits significantly reduced seedling damage by gophers and animal activity. Currently, there are no significant differences in activity levels or tree damage between the standard and bagged-bait treatments. Although tree damage in both treatment areas has reached unacceptable levels with activity levels increasing, an additional observation in spring, 1979, is needed to more fully evaluate the long-term effectiveness of bagged baits.

519. Sullivan, T.P. 1987. Understanding the resiliency of small mammals to population reduction: poison or population dynamics? In: Richards, C.G.J.; Ku, T.Y., eds. Control of mammal pests. London, UK: Taylor and Francis Ltd.: 69-82.

Populations of wilderness rodents and lagomorphs inflict damage upon forests and agricultural crops wherever these small mammals coincide with land development. The main method of control involves the use of rodenticides and related poisons. This approach seldom considers the importance of resiliency in maintaining small mammal populations. The repopulation of experimentally depopulated areas by five species of small mammals shows that poison cannot effectively suppress these populations for long, at least in limited areas. Alternative control strategies based on population dynamics, behavioral and feeding ecology, and predator odor repellents offer more effective and long-term control than is currently achieved by using standard methods. Small mammal species studied include the deer mouse, montane vole, northern pocket gopher, snowshoe hare, and Columbian ground squirrel.

520. Sullivan, Thomas P.; Crump, Douglas R.; Sullivan, Druscilla S. 1988. Use of predator odors as repellents to reduce feeding damage by herbivores. IV. Northern pocket gophers (*Thomomys talpoides*). *Journal of Chemical Ecology* 14(1): 379-389.

This study investigated the influence of the major anal gland compounds from the stoat and ferret in generating an avoidance response by northern pocket gophers in tree fruit orchards in the Okanagan Valley of British Columbia. A secondary objective assessed the impact of additional predator odors on gopher avoidance behavior in laboratory bioassays. In field bioassays, a 1:1 mixture of 2-propylthietane

and 3-propyl-1,2-dithiolane, as well as 3,3-dimethyl-1,2-dithiolane placed in gopher burrows did not reduce the number of gophers colonizing treatment versus control grids in orchard blocks. These predator odors, however, did dramatically alter the distribution of gophers. Significantly more gophers were captured at perimeter than nonperimeter trap stations on treatment versus control grids in two of three orchards. In all orchards, significantly more gophers were captured at perimeter stations after the predator odors had been placed in burrows than before the start of the experiment. Gophers clearly avoided 2,5-dihydro-2,4,5-trimethylthiazoline, a component of fox feces, but did not avoid 2,2-dimethylthietane from the mink or 3-methyl-3-butenyl methyl sulfide from fox urine in laboratory bioassays. Poor avoidance was also recorded for 3,3-dimethyl-1,2-dithiolane, although this may be because of the state of polymerization of this compound. An improved formulation is required to disperse these semiochemicals in controlled-release devices within orchards and other forest-agricultural areas.

521. Tunberg, Allen D.; Howard, Walter E.; Marsh, Rex E. 1984. A new concept in pocket gopher control. In: Clark, Dell O., ed. Proceedings, 11th vertebrate pest conference; March 6-8; Sacramento, CA. Davis, CA: University of California: 7-16.

A new concept in pocket gopher control is advanced which relies on two behavioral traits common to pocket gopher: (1) gophers are quick to invade unoccupied burrow systems when the previous occupant has been killed by a rodenticide; and (2) the invading animal will use existing food stores (that is, baits) left by the previous gopher. With long-lasting (that is, durable) baits containing sufficient toxicant, several pocket gophers can be controlled by a single baiting. This new approach assists in improving gopher control, for control is extended beyond the initial baiting results. Pocket gophers missed in the original treatment or gophers invading from outside areas will continue to be killed for some time after the baiting program. Laboratory and field studies provide supportive evidence concerning the feasibility and practicality of this new concept.

522. Ward, A. Lorin; Hansen, Richard M. 1960. The burrow-builder and its use for control of pocket gophers. Spec. Sci. Rep.—Wildl. 47. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service.

A new approach for controlling pocket gophers has been developed, by using a machine called a "burrow-builder." This equipment, attached to a tractor, constructs artificial gopher runways at controlled depths below the surface of the ground and mechanically places bait in the runways. Tests in Colorado have shown the high potential this approach has in controlling both the plains pocket gopher and the mountain pocket gopher.

523. Ward, A. Lorin; Hansen, Richard M. 1962. Pocket gopher control with the burrow-builder in forest nurseries and plantations. *Journal of Forestry* 60(1): 42-44.

Discusses the development and use of the burrow-builder, a machine which constructs artificial gopher runways and places bait in them. Good control has been obtained in agricultural areas, and the procedure may be equally useful in certain forest nurseries and plantations.

Porcupine

General

524. Dodge, Wendell E. 1982. Porcupine (*Erethizon dorsatum*). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 355-366.

Reviews distribution, description, reproduction, ecology, food habits, behavior, mortality, economic status, and management of *Erethizon dorsatum*.

525. Dodge, Wendell E.; Barnes, Victor G., Jr. 1975. Movements, home range, and control of porcupines in western Washington. Leaflet 507. Washington, DC: U.S. Fish and Wildlife Service. 7 p.

Radio telemetry was used to monitor the movements of 18 porcupines in typical west Cascade habitat near Mount St. Helens, Washington. Average linear movement ranged from 249 m in 24 hours to 1585 m for periods of more than 30 days. The greatest linear movement was 31.1 km in 66 days. Average home range of animals tracked for 10 months or more was 83.5 ha; the average range of males (106.6 ha) exceeded that of females (81.2 ha). Concentration of animals at densities was not observed. Hunting porcupines with dogs is probably the most effective control measure.

526. Evans, James. 1987. The porcupine in the Pacific Northwest. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 75-78.

Presents information on porcupine biology, behavior, tree damage, and control in the Pacific Northwest.

527. Hooven, Edward F. 1971. The porcupine in Oregon: its life history and control. Res. Pap. 10. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University. 22 p.

Reviews information on life history of the porcupine and discusses control methods that can be used where the porcupine has become a pest and is causing damage to future crop trees.

Ecology

528. Craig, Erica H.; Keller, Barry L. 1986. Movements and home range of porcupines, *Erethizon dorsatum*, in Idaho shrub desert. Canadian Field-Naturalist 100(2): 167-173.

Biotelemetry and direct observation were used to study movements and home range size of porcupines in a desert-shrub environment in southeastern Idaho. Winter movements were found to be significantly less than those in spring and summer, probably as a result of seasonal food availability and weather. Home range size (modified minimum area method) averaged 0.07 ha for two porcupines monitored from January through March 1976. Spring and summer home range size averaged 23.1 ha for seven females and was 81.7 ha for one male. Movements and home range size generally were smaller than those reported in forested habitats in the Western United States.

529. Gill, Don; Cordes, Lawrence D. 1972. Winter habitat preference of porcupines in the southern Alberta foothills. *Canadian Field-Naturalist* 86(4): 349-355.

Isolated stands of limber pine on windswept ridge crests in the southern Alberta foothills create islands of winter habitat for porcupines. The dwarfed and stunted growth form of this tree provides cover, and the high nutrient content of its bark makes it a preferred source of winter food. Reduction in predators during the past half-century has enabled porcupine numbers to increase to the extent of threatening the existence of limber pine. These trees occur at an unusual low-elevation krummholz and may thus have value as an aesthetic resource; if these limber pine stands are to survive, control of porcupine numbers may have to be initiated.

530. Harder, Lawrence D. 1977. Winter food habits of porcupines (*Erethizon dorsatum*) and their relationship to habitat use in montane forests of southwestern Alberta. Edmonton, Alberta: University of Alberta. 157 p. M.S. thesis.

The physical characteristics of conifers that had been fed upon by porcupines and of unused conifers were examined on two areas. Three vegetation types were examined: (1) a windward community of limber pine and Douglas-fir; (2) a leeward forest of Douglas-fir with scattered spruce; and (3) a leeward community of limber pine and Douglas-fir which appeared to be seral to the Douglas-fir forest. Of the factors considered, exposure and age were most influential in determining the size and form of trees, although density was also important in leeward forests. The superior growth rates of leeward trees and the associated differences in phloem production probably account for the preference of porcupines for leeward trees. The trees used by porcupines commonly had extensive crowns and were larger and more vigorous than unused trees, so that they probably provided greater access to more abundant, better quality food. This type of tree occurred most frequently in low density stands of the leeward forest. Use of both areas by porcupines peaked and declined in relation to the ages of the forests, suggesting that trees may become too large to be climbed and the declining growth rates of trees are associated with a reduction in the quality of inner bark. During winters of porcupine abundance, the use of poor quality stands increased. Although the actual mechanisms of tree selection are unknown, stand density and the physical characteristics of individual trees, particularly trunk diameter and crown size, are correlated with porcupine preference. Winter food and habitat selection by porcupines appear to be interdependent.

531. Harder, Lawrence D. 1979. Winter feeding by porcupines in montane forests of southwestern Alberta. *Canadian Field-Naturalist* 93(4): 405-410.

Past feeding on the inner bark of Douglas-fir and limber pine by porcupines was examined on two areas of southwestern Alberta. Measurements of annual growth from increment cores were used to estimate the previous sizes of trees. In conjunction with the ages of feeding scars, these estimates provided a means of determining the physical characteristics of the trees used by porcupines over a 20-year period. Of the three community types available to porcupines, pure stands of Douglas-fir in leeward situations were preferred. Although porcupines fed in the larger, faster growing trees within this community on both study areas, the average diameter of the boles of used trees differed between study areas. This may be related to a possible relaxation of the preference for larger trees on the more extensively used area.

532. Harder, Lawrence D. 1980. Winter use of montane forests by porcupines in southwestern Alberta: preferences, density effects, and temporal changes. *Canadian Journal of Zoology* 58(1): 13-19.

The pattern of winter use of montane forest by porcupines during a 40-year period was examined on two areas in southwestern Alberta. Of the three available coniferous communities, porcupines fed in relatively more trees in pure stands of Douglas-fir in leeward situations. Douglas-fir, limber pine, and hybrid spruce were used with equivalent frequency when found in the same community. The number of porcupines that used both areas peaked and declined in relation to the average ages of the forests. Trees in low density stands (trees/100 square m) were fed during more years than those in denser stands, and the use of dense stands was more frequent during years when porcupines were most abundant. Differences between the study areas in repeated feeding in leeward Douglas-fir and in the relative proportions of trees used in low and high density stands are attributed to differences in the abundance of porcupines.

533. Smith, Graham W. 1977. Population characteristics of the porcupine in north-eastern Oregon. *Journal of Mammalogy* 58(4): 674-676.

In the Umatilla National Forest, south of Heppner, Oregon, 168 porcupines were captured and immobilized, and then age and sex was determined. A sex ratio of 100 males to 118 females was found among the 168 porcupines. Porcupines were born from May through August in the study area; the breeding season is calculated to be from October through December. Birth of a single young is common; multiple births have not been documented. A 259-ha area was intensively censused during the winter, and a density of 32.5 porcupines per square mile was determined, similar to that reported in other studies. Density is undoubtedly related to vegetation, availability of food, and predator activity.

534. Smith, Graham W. 1979. Movements and home range of the porcupine in north-eastern Oregon. *Northwest Science* 53(4): 277-282.

Capture-recapture techniques and radio telemetry were used in an investigation of porcupine movements and home range in a ponderosa pine and Douglas-fir forest in northeastern Oregon. Significantly shorter movements in December to February as compared with April to July were related to seasonal changes in weather and vegetation. An average yearly home range size of 70.1 ha was found for two female porcupines radio-tracked from February through August. The maximum distance between recaptures was 525 m to 1,156 m, which compares closely to the length of home range areas for porcupines radio-tracked during the study.

535. Smith, Graham W. 1982. Habitat use by porcupines in a ponderosa pine/Douglas-fir forest in northeastern Oregon. *Northwest Science* 56(3): 236-240.

Porcupine preferred large trees within ponderosa pine or Douglas-fir-dominated sub-units of a mixed conifer/pinegrass, residual soil community for daytime resting in the study area in the Umatilla National Forest. There was significant avoidance of a ponderosa pine/Douglas-fir/elk sedge community. The preferred stands offered protection

from winter weather and an abundance of young trees on which to feed. During spring and summer, porcupines fed nocturnally within meadows.

536. Smith, Graham Worthington. 1975. An ecological study of the porcupine (*Erethizon dorsatum*) in the Umatilla National Forest, northeastern Oregon. Pullman, WA: Washington State University. 110 p. M.S. thesis.

This investigation on porcupine ecology in a ponderosa pine forest focused on movements, habitat use, and population characteristics. Capture-recapture techniques and radio-tracking were the primary research methods. The maximum distance between recaptures along the trend route was 3,000 to 4,000 feet and compares closely to the length of home range areas for radio-tracked porcupines. An average home range size of 201.3 acres was found for radio-tracked porcupines. Porcupine movements are probably controlled by seasonal availability of food. Herbaceous vegetation is the major component of the diet in the spring, summer, and early fall. Movements are extensive and meandering as animal forage widely. Herbaceous vegetation ceases by late fall, and porcupines feed until spring upon ponderosa pine and Douglas-fir trees. Trees are fed upon throughout the year, but their use varies relative to the availability of ground forage. Porcupines preferentially fed upon 4-10-inch d.b.h. ponderosa pine and caused extensive damage to these d.b.h. classes. Top girdling was the most common injury and occurred in over 50% of the trees damaged. Porcupines appeared to prefer a dense ponderosa pine stand type for resting locations and appeared to avoid open low stocked areas. A density of 32.5 animals per square mile was found within the study area. A sex ratio of 100 males to 118 females was found for 168 animals. Biological control through fisher predation should be part of the management plan. Summer night hunting appears to be the best method of artificial control.

537. Yocom, Charles F. 1971. Invasion of Humboldt and Del Norte Counties of northwestern California by porcupines. *Murrelet* 52(1): 1-6.

Porcupines have moved west in the 1920s from Siskiyou County into Del Norte County and in the early 1900s from Trinity or Mendocino Counties into southern and southeastern Humboldt County. The mass cutting of Douglas-fir forests triggered population increases and caused migration of porcupines into all of Humboldt and Del Norte Counties in the late 1950s and during the 1960s. Also, the carrying capacity of the land in the two counties must have been increased through succession. Stands of old-growth redwood and Douglas-fir have little food for porcupines, but an abundance of food is created by the plant succession that follows logging.

538. Anthony, R. Michael; Evans, James; Lindsey, Gerald D. 1986. Strychnine-salt blocks for controlling porcupines in pine forests: efficacy and hazards. In: Salmon, Terrell P., ed. Proceedings, 12th vertebrate pest conference; 1986 March 4-6; San Diego, CA. Davis, CA: University of California: 191-195.

Strychnine-salt blocks were evaluated for effectiveness in killing porcupines in pine forests in Oregon and California. Radio-collared porcupines were exposed to strychnine-salt bait located on trees and on the ground in covered bait stations called "cubbies." Bait blocks placed in trees and in cubbies were poorly accepted by porcupines. Only 4 of 32 marked porcupines exposed to bait were poisoned. Two died

at cubbies and two died at trees. Other wildlife found poisoned at cubbies were seven unmarked porcupines, seven yellow-pine chipmunks, five Nuttall's cottontails, four deer mice, three golden-mantled ground squirrels, and one Douglas squirrel. Fewer nontarget animals—two unmarked porcupines, two yellow-pine chipmunks, and one northern flying squirrel—died at tree sets. Bioassays with caged porcupines further indicated that strychnine alkaloid is an ineffective toxicant for porcupines.

539. Curtis, James D.; Wilson, Alvin K. 1953. Porcupine feeding on ponderosa pine in central Idaho. *Journal of Forestry* 51(5): 339-341.

Porcupine damage was analyzed on five randomly selected subplots from each of seven noncontiguous 10-acre cutting plots. Results indicate that (1) the denser the pole stand, the greater the percentage of stems fed on; (2) there appears to be a relationship between the number of instances of feeding in the first log-length and the total number of feedings in both the first log and higher portions of the trees; (3) the occurrence of trees fed on once is independent of the number of trees fed on more than once; (4) there is evidence that the occurrence of porcupine-caused crook, fork, and spike-top defects is related to the total number of feedings occurring; and (5) when data are grouped by crown classes there is significant relationship between number of poles fed on and the total number of poles present in each crown class.

540. Dodge, Wendell E.; Canutt, Paul R. 1969. A review of the status of the porcupine (*Erethizon dorsatum epixanthum*) in western Oregon. Olympia, WA: U.S. Bureau of Sport Fisheries and Wildlife, and Portland, OR: U.S. Department of Agriculture, Forest Service. 25 p.

Reports the results of a survey of federal, state and private timber managers about the severity and location of stands damaged by porcupines in western Oregon. Maps show locations of damage and where porcupines have been killed.

541. Gabrielson, Ira N. 1928. Notes on the habits and behavior of the porcupine in Oregon. *Journal of Mammalogy* 9(1): 33-38.

By cutting off smaller limbs and by girdling, porcupine sometimes seriously damage forest trees, particularly yellow pine.

542. Gabrielson, Ira N.; Horn, E.E.; Garlough, F.E. 1938. Porcupine control in the Western States. Leaflet 60. Washington, DC: U.S. Department of Agriculture. 8 p.

Reviews food habits, movements and migrations, and control by hunting and poisoning. A strychnine-salt bait can be placed in suitable rock formations near feeding grounds or in tree stations known to be favorite rest trees of porcupines.

543. Lawrence, William H. 1957. Porcupine control: a problem analysis. For. Res. Note 16. Centralia, WA: Weyerhaeuser Company. 43 p.

Reviews the type of damage caused by porcupine in the ponderosa pine region. Discusses the life history and ecology of the species, methods of control, and proposed research on control.

544. Neitro, William A. 1969. Aluminum shelters for baiting porcupines. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University. 86 p.

An aluminum station for poisoning porcupines was developed to increase the durability and safety of bait stations. It has provided excellent kill results. And, initially, the cost was comparable to that of the hardboard station (\$3.75 and \$2.83). Some problems are significant, however. Recent increases in the price of aluminum may preclude its widespread use. Also, the visibility of aluminum has contributed to vandalism.

545. Neitro, William A. 1970. A permanent type poison station for porcupine control. In: Dana, Richard H., ed. *Proceedings, 4th vertebrate pest conference; 1970 March 3-5; West Sacramento, CA.* Davis, CA: University of California. 4: 98-100.

A method has been devised to protect the poison strychnine-salt blocks used in controlling porcupines from the weather, killing of nontarget animals and vandalism. An aluminum poison bait station has been developed that is light weight, durable, camouflaged, and safe. These structures are easily constructed and are relatively inexpensive when longevity is considered. Porcupines are controlled effectively and economically by using this method.

546. Storm, G.L.; Halvorson, C.H. 1967. Effect of injury by porcupines on radial growth of ponderosa pine. *Journal of Forestry* 65(10): 740-743.

Radial growth was reduced in ponderosa pines growing in a plantation in Lolo National Forest, Montana, and injured by porcupines. The most significant reduction in radial growth occurred in completely girdled trees. Reductions in radial growth in scarred trees were most pronounced during the first and second years after scarring, but the mean difference in radial growth between scarred and unscarred trees was not significant the fifth year after scarring.

547. Sullivan, Thomas P.; Jackson, William T.; Pojar, James; Banner, Allen. 1986. Impact of feeding damage by the porcupine on western hemlock-Sitka spruce forests of north-coastal British Columbia. *Canadian Journal of Forest Research* 16(3): 642-647.

Damage by porcupine was studied in March 1985 on 69 plots in 4 transects in second-growth western hemlock/Sitka spruce forest regenerated naturally after logging in 1947 and 1954 near Prince Rupert, British Columbia. Western hemlock, comprising 67% of the stands, was the most severely attacked, with a total incidence of damage of 52.7% of which 5.1% was newly attacked trees. Damage to Sitka spruce was minor (7.8%). Pacific silver fir and western redcedar were not attacked. A total of 30.9% of hemlocks were girdled, including 55.9% of stems 27.4-cm d.b.h. Stems 12.5-cm d.b.h. had little (3.7%) damage. Most wounds occurred on the middle and upper third of hemlock stems. Dominant and codominant hemlocks were preferred. A sanitation spacing trial should be conducted in these stands, favoring Sitka spruce, Pacific silver fir, and western redcedar as crop trees.

Rabbits and Hares

General

548. Bittner, Steven L.; Rongstad, Orrin J. 1982. Snowshoe hare and allies (*Lepus americanus* and allies). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 146-163.

Reviews distribution, description, physiology, reproduction, ecology, food habits, habitat, behavior, mortality, economic status, and management of *Lepus americanus* and subspecies.

549. Chapman, Joseph A.; Hockman, J. Gregory; Edwards, William R. 1982. Cottontails (*Sylvilagus floridanus* and allies). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 83-123.

Reviews description, physiology, genetics, reproduction, ecology, food habits, habitat, behavior, mortality, and management of the various *Sylvilagus* species, including *S. bachmani* and *S. nuttallii*.

550. Dunn, John P.; Chapman, Joseph A.; Marsh, Rex E. 1982. Jackrabbits (*Lepus californicus* and allies). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 124-145.

Reviews distribution, description, physiology, genetics, reproduction, ecology, food habits, habitat, behavior, mortality, economic status, and management of *Lepus californicus* and related species.

Ecology

551. Adams, Lowell. 1959. An analysis of a population of snowshoe hares in northwestern Montana. *Ecological Monographs* 29(2): 141-170.

A field study of an isolated population of snowshoe hares was conducted over an 18-month period on Bull Island in Flathead Lake, Montana. The three main objectives were (1) to develop techniques for population censusing; (2) to analyze environmental factors affecting abundance and distribution of the hares, and (3) to study the general life history of the hares in comparison with similar studies elsewhere. The census technique involved estimations of pellet numbers which were calibrated to hare numbers. Three kinds of environmental factors were analyzed in their relation to hare distribution and abundance—the food-cover-predator complex, cover density, and physical obstacles. The breeding season extended from late February to early July in males and from mid-March to early July in females. Lactation was practically continuous from late April to late September. Litter size averaged 2.85 per female, with an average of 2.6 young per litter in 1953 and 3.0 in 1954. At birth the hares weighed an average of 40 g; at maturity the average weight was 1,000 to 1,100 g. The sex ratio did not differ significantly from 1:1 in either adults or young. Home ranges of individuals was largest for adult males (25 acres), second largest for adult females (19 acres) and smallest for juveniles (14 acres). There was much overlapping of home ranges. Dispersal movements outside the home range occurred in males only. Twenty-one species of plants used as food are listed by relative amounts eaten, season of use, and parts eaten.

552. Barash, David P. 1973. Territorial and foraging behavior of pika (*Ochotona princeps*) in Montana. *American Midland Naturalist* 89(1): 202-207.

In studies of the individual and social behaviors of pika in Glacier National Park, Montana, the animals were socially intolerant and territorial, with intolerance increasing steadily after mating in late spring. The young exhibit adult social behavior within a few weeks after emergence. Auditory communication, haying and feeding behavior, and patterns of daily activity are described. Correlation between pika social organization and ecology is discussed.

553. Bates, Richard D. 1969. Ecology of the pika (*Ochotona princeps uinta*) in the Uinta Mountains, Utah. Provo, UT: Brigham Young University. 54 p. M.S. thesis.

Pikas were observed for 10 months at four study areas, Shady Dell East (8,000 feet), Shady Dell West (8,000 feet), Steiner (10,300 feet), and Murdock Mountain (11,000 feet). The first two study areas were in an aspen-lodgepole pine forest, the third in a spruce-fir forest, and the fourth in the alpine-tundra. Comparisons were made among the members of these four colonies in regard to population density, daily and seasonal activity patterns, haying behavior, and home ranges and territoriality. In addition, food consumption and behavior were observed in a captive colony throughout the winter. Population densities were greater at the lower elevation study areas and ranged from 0.0107 pikas per square m to 0.0019 per square m. Pikas at lower elevations were most active from just before sunrise until about 10:00 a.m. and from about 5:00 p.m. until dark. There was little, if any, pika activity at the higher elevation study areas until after sunrise and a sharp decrease in activity after sundown. Activity at all four study areas increased during the haying season in August and September and subsequently decreased in October and November. Only 38% of observed animals built haypiles. There was no apparent correlation between the altitude at which the pika lived and the size of the haypiles they constructed. Territories were set up around each animal's haypile and were defended by calling or chasing intruders. A combination of snow tunnels and the observed eating of lichens by pikas in November indicate that these animals may live off of or supplement the food stored in their haypiles by eating plants buried in the snow.

554. Beidleman, Richard G.; Weber, William A. 1958. Analysis of a pika hay pile. *Journal of Mammalogy* 39(4): 599-600.

Plants in a hay pile at 12,000 feet in Rocky Mountain National Park, Colorado, were counted and identified. Five thousand pieces, totaling 4 ounces in weight, consisted of 22 identified species. *Geum rossii* (Alpine avens) predominated with 69.7% of the pile. Casual observations suggest that pikas are opportunist, gathering what is most readily available rather than exhibiting specific preferences.

555. Black, Hugh Clark. 1965. An analysis of a population of snowshoe hares, *Lepus americanus washingtonii* Baird, in western Oregon. Corvallis, OR: Oregon State University. 258 p. Ph.D. dissertation.

The study was undertaken because of the need for additional knowledge of the snowshoe hare in the face of an expanded planting program and increased emphasis on

the rapid and complete regeneration of Douglas-fir in the Pacific Northwest. The ecology of the snowshoe hare needs to be better understood to effectively control damage to coniferous reproduction. The foremost objective of the study was to investigate as many aspects as possible of the ecology of a normal population of the snowshoe hare, as revealed by mark-and-recapture methods. Specific attention was given to those parameters of the hares' ecology, such as habitat preferences, feeding habits, and home range and movements that may be affected by changes in silvicultural methods.

556. Boutin, Stan. 1984. Effect of late winter food addition on numbers and movements of snowshoe hares. *Oecologia* 62(3): 393-400.

Peak (1980) and early decline (1981) populations of snowshoe hares were supplied with extra food in late winter to test the hypothesis that snowshoe hare populations are limited by food supply. Food supplemented populations increased through immigration in both years, but the response was more pronounced in the early decline population. Animals supplied with extra food lost less weight, had higher survival in some cases, and males began to breed earlier. Immigrants to the food addition area were of two types: those that established home ranges on or near the area and those that spent only a brief time there before returning to their initial range. The possibility that these latter individuals were prevented from remaining on the food grid by residents is discussed. Results indicate that food supply is one factor that can limit peak and declining populations of snowshoe hares, but the relation of spacing behavior to food supply and numbers must also be considered.

557. Boutin, Stanley Albert. 1983. An experimental analysis of juvenile survival and dispersal in snowshoe hares. Vancouver, BC: University of British Columbia. Ph.D. dissertation.

To test the hypothesis that spacing behavior limits survival and recruitment of juvenile snowshoe hares, I removed adults or first litter juveniles from two 8-ha trapping grids. Survival of juveniles on these areas was unchanged, but recruitment was higher relative to that on the control areas. This was due to higher immigration rather than increased recruitment of residents. Results support the hypothesis that spacing behavior limits immigration. To test the hypothesis that snowshoe hare populations are limited by late winter food supply, I added laboratory rabbit chow to an 8-ha study area during March 1980 and March-June 1981. Hares on the food addition area lost less weight and had higher survival than those without supplemental food. The number of males on the food addition grid increased slightly in 1980, and number of both males and females increased 3-fold in 1981. Results support the hypothesis that snowshoe hare populations are limited by food supply in late winter. I monitored dispersal of snowshoe hares during increase, peak, and early decline phases of a population cycle by means of a total removal area and by telemetry monitoring of marked individuals. Per capita rate of dispersal was not density-dependent, and dispersal accounted for only 11% of the losses of radio-collared animals during the decline. Dispersal could not account for the decline in numbers and snowshoe hares. Telemetry indicated that the removal grid overestimated the amount of dispersal that was occurring and did so to a greater extent during peak and early decline phases of the cycle.

558. Brandt, Charles Arnold. 1984. The evolution of sexual differences in natal dispersal: tests of three hypotheses. Durham, NC: Duke University. 258 p. Ph.D. dissertation.

This study is an investigation of the evolutionary basis for the predominant natal dispersal of female pika, studied in northeastern Oregon during the summers of 1980 to 1982. Three hypotheses which could account for the differences are (1) socially subordinate females may be forced to emigrate by more dominant males; (2) females may be polyandrous and may disperse so as to acquire more mates, or they may disperse in order to find males with preferred characteristics; (3) females and not males may disperse to find better nesting areas if males defend resources rather than the females themselves because females are not expected to be territorial and hence would have lower costs of dispersal. Juvenile males were found to be no larger than females of the same age, and they did not dominate juvenile females. More females dispersed than could be explained on the basis of sexual dominance relationships and secondary sex ratio. Females were not polyandrous, and they did not consistently mate with the larger, older, or less related of the males available. Female reproductive success was most influenced by the nest site rather than the characteristics of the males themselves. Adult males defended nest sites rather than females, and did not interfere with the movements of adult females during the mating period. Pikas thus appear to exhibit a resource-based mating system. After mating, both sexes defended territories of equal size, which is inconsistent with the third hypothesis. Dispersal patterns are suggested to be related to the likelihood of inbreeding in an animal's place of birth and the costs and benefits of dispersing.

559. Broadbooks, Harold E. 1965. Ecology and distribution of the pikas of Washington and Alaska. *American Midland Naturalist* 73(2): 299-335.

The main purpose of this study was to census the pikas and their haypiles, map their local distribution, and compare the behavior and ecology of the northern *Ochotona collaris* and the more southern *O. princeps*. The animals were observed during July and August of 1959, 1961, and 1962 at two localities in the Cascade Range of Washington, at three places in the Rocky Mountains and in Mount McKinley National Park, Alaska. Both Alaskan and Washington pikas are strongly territorial in summer, maintaining the boundaries by calling frequently and by chasing neighbors a few times a day. The home range and territories were about the same size in Alaska and Washington, up to 0.6 acre, 520 feet long by 120 feet wide, and overlapping each other. The defended territory was as much as 310 feet long and 120 feet wide, or 0.5 acre. The area from which plants were harvested was even smaller, only about 40% of the territory. The distance between haypiles along a large rock slide in Washington averaged 230 feet, and the population was 25 per mile, or 2.1 per acre. On small, isolated rock piles the animals were closer together, reaching a maximum density of 117 per mile, or 10 per acre. Even with an optimum of food and cover, about 50 feet is the nearest a neighbor is tolerated.

560. Bunnell, S. Dwight; Johnson, Donald R. 1974. Physical factors affecting pika density and dispersal. *Journal of Mammalogy* 55(4): 866-869.

Pikas are widely distributed in scattered colonies throughout the mountainous parts of the Western U.S. and Canada where they occupy rock slides, lava flows, and occasionally slab piles left by sawmill operations. Sometimes pikas are absent from what appears to be suitable habitat near existing colonies. To determine the effects of certain physical factors on pika density, we censused populations and measured four physical characteristics of nine small rockslides in Benewah County, Idaho. There is evidence that food accessibility on the periphery of a rockslide is an important factor in determining territories and hence population. Rock size may be a possible factor limiting colony size. Pikas require rocks of sufficient size to permit movements within the slide. Shallow slides support few pikas, probably because they offer less protection from predators and rigorous weather. The mean dispersal distance for pikas is not known, but individuals have been found several miles from the nearest suitable habitat, and a mean dispersal distance of 2 miles seems reasonable.

561. Bunnell, Stephen Dwight. 1970. Ecology of the pika (*Ochotona princeps*) in north Idaho. Moscow, ID: University of Idaho. 54 p. M.S. thesis.

A study of the ecology of the pika was conducted from October 1968 through March 1970 on St. Joe Baldy, Benewah County, Idaho. Objectives were to evaluate pika habitat requirements, investigate the bioenergetics of pikas, and observe the general ecology of northern Idaho pikas. Nine rock slides were chosen for habitat analysis. Altitude, summer surface temperature, area, perimeter, and pika population were measured on each slide. Pika population was designated as the dependent variable in a step-wise linear multiple-regression analysis. Perimeter alone accounted for 81% of the variation in population. The other variables (temperature, area, and altitude) added no information to the analysis. Since pikas forage in meadow areas adjacent to the slides, perimeter is an index of food accessibility. It is concluded that the size of pika territories, and thus the population of a slide, is influenced more by food accessibility than by the area of the slide. Based on microenvironmental temperature data collected and on data in the literature, a metabolic rate-temperature curve was constructed for the pika. It is estimated that an adult pika requires 49.3 kcal of energy during a typical summer day and 60.9 kcal during a typical winter day. Calculations show that a pika probably consumed 50% of the hay harvested annually, with the remainder used for nesting material, wasted, or consumed by other animals. Pikas that died in traps or enclosures were examined for reproductive data. Based on this small sample, litter sizes and numbers of litters per year were similar to those found in other populations.

562. Chapman, Joseph A.; Harman, Amy L. 1972. The breeding biology of a brush rabbit population. *Journal of Wildlife Management* 36(3): 816-823.

The breeding biology of the northernmost subspecies of the brush rabbit (*Sylvilagus bachmani ubercolor*) was studied between June 1967 and August 1969 near Corvallis, Oregon. Female brush rabbits were pregnant from mid-February to mid-August.

Sexually active males first appeared in the population in January, with no males sexually active after July. The breeding season in Oregon started about 45 days later than in California but appeared to be about the same in total length. The mean litter size was 2.67 in 1968 and 3.27 in 1969. Litter sizes were smaller in Oregon than in California. There appeared to be an inverse relationship between litter size and latitude. The mean ovulation rate for female brush rabbits in Oregon was 3.39. It was calculated that 16.3% of the ova failed to implant and that 15.5% of the embryos were resorbed. No evidence of juvenile breeding was found. Adult female brush rabbits were estimated to produce 15.18 young annually.

563. Chapman, Joseph Alan. 1970. Orientation and homing of the brush rabbit. Corvallis, OR: Oregon State University. 67 p. Ph.D. dissertation.

A study of orientation and homing in brush rabbits was conducted near Corvallis, Oregon. Sixty-seven individual rabbits were fitted with radiotransmitters and returned to the field. Home ranges were determined for 59 of these rabbits. Brush rabbits rarely left brushy cover. The home ranges of males were larger than those of females, and the home ranges of juvenile males were larger than those of adult males. Nineteen of the 59 brush rabbits whose home ranges were determined were displaced in 29 homing experiments. Brush rabbits homed successfully in 15 of 29 experiments. Homing success was not inversely related to distance displaced as has been reported for other small mammals. Rather, there was a distinct limit at about 600 feet beyond which no rabbit homed. Rabbits required as long as 36 days to complete a successful homing experiment. A direct correlation was found between homing time and distance displaced. This correlation was even higher when the size of the rabbit's standard home range was considered. It was concluded that brush rabbit homing ability was related to the size of the home range. With one exception brush rabbits chose clear nights to "home" indicating that sight was a primary mechanism involved in homing. They restricted their routes of travel to brushy cover while attempting to "home". Four factors interfered with homing: (1) interspecific aggressive behavior, (2) roads, (3) human and vehicular activity, and (4) predators.

564. Conner, Douglas A. 1983. Seasonal changes in activity patterns and the adaptive value of haying in pikas (*Ochotona princeps*). *Canadian Journal of Zoology* 61(2): 411-416.

Seasonal changes in the performance of four behaviors: perching, haying, feeding, and surface activity were studied in two populations of pikas living in Colorado. During late summer and early fall (July-September), haying, the gathering of meadow vegetation followed by storing it in their talus territories, made up almost 55% of the pikas' surface activity. After haying ceased, pikas continued to feed in the meadows until snowpack, cold temperatures, and the absence of surface vegetation made this impossible. Beginning in February, individuals remained under the snowpack feeding on vegetation from their hay piles and on lichens available below the snow. Surface activity was not seen again until May when spring vegetation began to appear. Haying appears to be an adaptive response to environmental unpredictability. Hay piles most likely become critical for survival when harsh weather prevents surface foraging or delays the emergence of new vegetation growth in the spring or early

summer. It is suggested that the evolution of territoriality in pikas is related to the need to gather sufficient vegetation to serve as a potential winter food supply during years when the winter season is unusually harsh or prolonged.

565. Elliott, Charles L. 1980. Quantitative analysis of pika (*Ochotona princeps*) hay piles in central Idaho. Northwest Science 54(3): 207-209.

Eleven haypiles of a pika colony in central Idaho were quantitatively examined. Twenty-six plant species were identified: *Smilacina stellata*, *Apocynum androsaemifolium*, and *Fragaria virginiana* comprised 88% of the total weight of all haypiles.

566. Frazier, Nancy A. Ewen. 1977. A behavioral study of a small group of pikas, (*Ochotona princeps*) on Mt. Hood, Oregon. Portland, OR: Portland State University. 30 p. M.S. thesis.

Observations of a small group of pikas occupying a southwest facing roadfill (1,518 m) on Mount Hood, Oregon were made during fall 1976. Territorial sizes of 305.5 square m for the dominant male and 121 square m for one of the other males were determined based on territorial displays. These territories were compared with those observed in other studies. The mean distance to the nearest neighbor was 15.1 m. A pair relationship between two of the pikas and a dominance order are discussed. The seasonal progression of the haypiles and the reactions of the pikas to other animals are also noted.

567. French, Norman R.; McBride, Ray; Detmer, Jack. 1965. Fertility and population density of the black-tailed jackrabbit. Journal of Wildlife Management 29(1): 14-26.

Data on reproduction of the black-tailed jackrabbit in southeastern Idaho, and data on movements and longevity, obtained by marking and releasing live animals, show that, as the population increased, the length of the breeding season decreased, and there was a decline of population reproduction. In a population decline, the opposite occurred. Thus, reproduction of the jackrabbit population is controlled in density-dependent fashion through frequency of pregnancy of females and to some extent through litter size. Litter size and frequency of pregnancy seemed to vary independently. Litter size in 1956-60 was maximum in May, and this timing appears to be innate. Frequency of pregnancy among females generally was maximum at least 1 month earlier. During the 1957 and 1960 seasons, when the onset of breeding was delayed, maximum frequency of pregnancy coincided with maximum litter size, resulting in apparent compensation for the late start. Marked hares were seldom retrieved at a distance greater than 1/4 miles from the release point, thereby indicating a home range of less than 40 acres. Dispersal movements to greater distances are estimated to affect approximately 18% of the population. The greatest distance moved by an animal was 28 miles in 17-weeks. Seasonal movements involved short distances but might result in dense local concentrations. Over one year, approximately 3.5% of a marked cohort remained.

568. Gashwiler, Jay S. 1970. Plant and animal changes on a clearcut in west-central Oregon. *Ecology* 51(6): 1018-1026.

Plant composition and coverage and small mammal populations were compared in virgin forest and clearcut areas from April 1954 to October 1956. Changes in ground cover vegetation were modest on the forest but marked on the clearcut. Ground plant coverage was less than 23% in the virgin forest; one year after the clearcut was burned, the cover was 2%; and by 10 years it was above 53%. Woody plant coverage was slightly more abundant the first 2 years after burning. Herbaceous species then became dominant for 3 years, after which woody plants gradually gained dominance. Deer mice increased on the clearcut soon after the burn. The populations varied from an estimated 0.9 to 12.8 animals per acre and fluctuated widely and irregularly. Townsend's chipmunk, Oregon vole, and snowshoe hare populations also increased on the area at different periods after the burn. Trowbridge's shrews, vagrant shrews, and ermine were present on both areas in relatively low numbers. Redback voles, Douglas squirrels, and northern flying squirrels were not found on the clearcut. California ground squirrels migrated to the clearcut and established a modest population. Richardson's voles, jumping mice, bushy-tailed woodrats, and a pika were visitors.

569. Hooven, Edward F. 1973. Effects of vegetational changes on small forest mammals. In: Hermann, Richard K.; Lavender, Denis P., eds. *Even-age management: Proceedings of a symposium; 1972 August 1; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 75-97.

Certain physical and biotic changes that occur relative to clearcutting can affect small mammal populations. Soil moisture and soil temperature may increase for the first few years but decrease as revegetation occurs. These factors affect the small mammal populations through their influence on food availability, shelter, and habitat. Although habitat preferences were readily observable by changes in species density, most of the small mammals were found on all units. Different small mammal populations result from different cutting systems, but regardless of the treatment, the small mammals exert an influence on regeneration, whether by seed or seedlings. After clearcutting, regardless of the change of species, composition, and densities, the small mammal biomass remains comparable to that of the uncut forest and exerts the same detrimental effect upon regeneration.

570. Hundertmark, Kris Joseph. 1982. Food selection and juvenile survival in Nuttall's cottontails in central Oregon. Corvallis, OR: Oregon State University. 50 p. M.S. thesis.

A population of Nuttall's cottontails in Deschutes County, Oregon, decreased from 166 individuals in August 1978 to 76 individuals in August 1979. Survival rates of four annual litter groups in 1978 were 0.74, 0.35, 0.72, and 0.93; survival rates for the same litter groups, respectively, in 1979 were 0.12, 0.28, 0.07, and 0.18. Population density and juvenile survival decreased between the 2 years, possibly because of alterations in forage quality and quantity caused by precipitation. Numbers of cottontails on the study area on August 30 were related significantly to initial breeding

density and to precipitation falling during the breeding season (February to July). Vegetative abundance at the end of the growing season (September) decreased by approximately 30% between the 2 years; the decline corresponded with a 45% decrease in crop-year (September to June) precipitation. Succulence of grasses, forbs, and shrubs was greatest in spring, declined in summer, and increased slightly in late summer. Forbs consistently were the most succulent group, except in September when shrubs were most succulent. Grasses exhibited the greatest variation in succulence in response to precipitation; shrubs exhibited the least. Cottontails seemingly selected forage groups in relation to their relative succulence, within limits. Juveniles selected forbs in significantly greater proportions than adults, possibly to acquire additional moisture for growth. Breeding females selected forbs in significantly greater proportions than males, possibly because of moisture demands associated with reproduction and lactation.

571. Huntly, Nancy J.; Smith, Andrew T.; Ivins, Barbara L. 1986. Foraging behavior of the pika (*Ochotona princeps*), with comparisons of grazing versus haying. *Journal of Mammalogy* 67(1): 139-148.

Pikas inhabit areas with talus and forage on surrounding vegetation. Their foraging behavior was consistent with several predictions of central place foraging theory. Intensity of foraging decreased with distance from talus, whereas selectivity increased. Plant abundance and species richness increased with distance from talus. Differences between grazing (direct consumption of plants) and haying (harvesting and caching plants) behaviors appear to reflect differences in costs and benefits between these activities. Higher proportions of forbs and tall grasses were hayed than grazed. When haying, pikas traveled significantly farther into the meadow from the talus border than when grazing. Pikas grazed year-round but hayed only during a restricted time (July through September) when plant biomass had peaked.

572. Johnson, Donald R. 1967. Diet and reproduction of Colorado pikas. *Journal of Mammalogy* 48(2): 311-315.

Pikas from 12 sites at elevations from 8,500 to 12,500 feet in southwestern Colorado were collected. Stomach contents were analyzed by season; forbs and shrubs comprised most of the food ingested throughout the year. Plant species gathered into haypiles included grasses, ferns, sedges, willow, mountain ash, Douglas-fir, serviceberry, currant, snowberry, and various herbs. Frequency of pregnancy and lactation was summarized for the 6 pregnant females collected in this study and for 78 females described in other studies. Pregnancy and lactation decreases progressively from a peak of 94% in May to 85% in June, 48% in July, and 11% in August. Little data is available for March and April, the early part of the reproductive season. Mean litter size was 2.9; litters per year averaged 1.5.

573. Johnson, Donald R.; Maxell, Marvin H. 1966. Energy dynamics of Colorado pikas. *Ecology* 47(6): 1059-1061.

Like other lagomorphs, pikas reingest fecal matter which is high in protein content and energy value. The plant food stored in haypiles is low in caloric content, but some populations used energy-rich aspen bark during the winter and spring months. The daily energy intake of a nongravid, nonlactating adult pika (171 g) is estimated at

54.8 kcal of which 68% is assimilated. Food intake, and perhaps feces reingestion, is increased during pregnancy and lactation.

574. Johnson, Randal D.; Anderson, Jay E. 1984. Diets of black-tailed jack rabbits in relation to population density and vegetation. *Journal of Range Management* 37(1): 79-83.

Diets of black-tailed jack rabbits and composition of plant communities were compared among habitats that supported different densities of jack rabbits in sagebrush (*Artemisia tridentata*)/perennial grass communities on the Idaho National Engineering Laboratory in southeastern Idaho. Diets were more similar than vegetation among areas, indicating that jack rabbits feed selectively; winterfat (*Ceratoides lanata*) and perennial grasses were staple foods, comprising about 80% of the diet in all areas. Jack rabbit densities were higher in areas having higher proportions of grass cover. Similarity between diet and vegetation was positively correlated with jack rabbit density and with the amount of grass cover in the habitat. Jack rabbits selected grass-dominated areas for feeding at night and then fed as generalists on the grass species present.

575. Kawamichi, Takeo. 1976. Hay territory and dominance rank of pikas (*Ochotona princeps*). *Journal of Mammalogy* 57(1): 133-148.

Field observations of 31 pikas were made during the autumn harvesting season in Colorado. Sizes of home ranges and territories were calculated. Lack of overlap in home ranges was the result of social interactions. Each occupant was thought to possess territorial motivation centering around its haypiles. The narrow boundary between two neighboring territories was well recognized by both occupants. Most invaders will recognize the existence of territories before invasion. Males invaded territories of others more frequently than females. Territorial defense was not successful against dominant invaders. Males were generally dominant to females and adults to juveniles. Body weights of dominants were heavier than those of subordinates. Dominants frequently invaded haypile areas of subordinates, whereas subordinates either did not invade the territories of dominants or their invasion avoided the haypile areas of dominants. Pairing situations involving juveniles were accepted. Mutual repulsion between females was apparent and appeared to be connected with sedentariness. Less favorable habitats were occupied by juveniles. The social organization of *O. princeps* as compared to three other species of *Ochotona* is unique in the possession of a territory centered around haypiles. Other basic social relationships are similar. The development of calling parallels the occurrence of harvesting behavior.

576. Keith, Lloyd B. 1964. Daily activity pattern of snowshoe hares. *Journal of Mammalogy* 45(4): 626-627.

The daily activity pattern of snowshoe hares was measured in their frequently used "runways" by means of a treadle device which broke an electrical circuit attached to an continuously operating events recorder. The summary of hare activity over a 24-hour period indicates a nearly symmetrical curve peaking at 11:00 p.m. Less than 15% of the 3,325 recorded movements occurred between 3:30 a.m. and 5:30 p.m.; almost 60% occurred between 8:30 p.m. and 1:30 a.m.

577. Keith, Lloyd B. 1966. Habitat vacancy during a snowshoe hare decline. *Journal of Wildlife Management* 30(4): 828-831.

Changes in numbers and distribution of snowshoe hares on a square-mile study area at Rochester, Alberta, are described. Data spanned 2-years, 1962-64, during which the hare population was undergoing a cyclic decline. Analyses of survival, reproduction, and movement indicated that intrapopulation movements rather than differential survival or reproduction were primarily responsible for the observed changes in hare distribution which accompanied the population decrease.

578. Keith, Lloyd B.; Surrendi, Dennis C. 1971. Effects of fire on a snowshoe hare population. *Journal of Wildlife Management* 35(1): 16-26.

This paper examines the demographic effects of a spring fire on a snowshoe hare population near Rochester, Alberta. A major change in distribution of hares on the study area resulted from abandonment of severely burned sites. Reoccupation of the severe burn took place during the second summer after the fire, as brushy cover redeveloped through sprouting. There was no evidence of fire-induced mortality. Sex ratios of both adult and juvenile cohorts were unaffected, but the proportion of juveniles on the study area was reduced markedly. Pregnancy rates were also lowered after the fire. The investigators believe that egress of young hares was principally responsible for the aberrant summer age ratios and that such movements were probably a response to intensified social interaction resulting from the postfire concentration of population in remaining habitat.

579. Keith, Lloyd B.; Windberg, Lamar A. 1978. A demographic analysis of the snowshoe hare cycle. *Wildl. Monogr.* 58. Washington, DC: The Wildlife Society. 70 p. Supplement to *Journal of Wildlife Management* 42(2): 1978 April.

This paper summarizes 15 years of demographic changes in cyclic snowshoe hare populations near Rochester, Alberta, and relates such information to that from other sections of North America where the hare also exhibits an approximate 10-year cycle of abundance. The main demographic events associated with fluctuations at Rochester have also occurred in other cyclic hare populations. The sequencing of such variables is consistent with the hypothesis that winter food shortage provokes the initial population decline and thereby leads to higher rates of predation that extend it.

580. Lechleitner, R.R. 1959. Sex ratio, age classes and reproduction of the black-tailed jack rabbit. *Journal of Mammalogy* 40(1): 63-81.

At the Gray Lodge Waterfowl Management Area, Butte County, California, 453 black-tailed jackrabbits were collected and examined over 18 months. The sex ratio was 198 males to 191 females. The prenatal sex ratio was 26 males to 25 females. Mortality seems to be equally divided between sexes. The reproductive system of the male jackrabbit is similar to that of the domestic rabbit. In the Gray Lodge population there is a yearly cycle of testicular growth and production of spermatozoa reaching and maintaining a peak from January until late July. Sexually active males are present in all months. The reproductive system of the female resembles that of the domestic rabbit. The corpora lutea of a jackrabbit ovary, however, are much larger. There is a post-partum heat, and during the height of the breeding season, females

which are pregnant and nursing young are the rule rather than the exception. Pregnant females were present during every month but did not appear in large numbers until January. By February, all observed females were pregnant, and this condition continued until April when the young of early litters began to appear. Young jackrabbits are capable of breeding by the time they are 8 months old. The older female hares maintained 100% breeding activity from January through August. The rainfall pattern and the greening of the vegetation seem to be the main factors associated with the peak of breeding season. The average number of embryos per female is one in January, four in April, and one in August.

581. MacCracken, James G.; Hansen, Richard M. 1982. Herbaceous vegetation of habitat used by blacktail jackrabbits and Nuttall cottontails in southeastern Idaho. *American Midland Naturalist* 107(1): 180-184.

Abundance of blacktail jackrabbits and Nuttall cottontails as determined by fecal pellet accumulation was positively related to biomass of herbaceous vegetation on the Idaho National Engineering Laboratory site. These leporids were most abundant where biomass of herbaceous vegetation was greatest, but abundance of blacktail jackrabbits and Nuttall cottontails was related inversely. Blacktail jackrabbits occupied sites with a larger biomass of grasses than forbs, and Nuttall cottontails occupied areas with larger forb biomass and numerous rock outcrops. Both species were most abundant on portions of the study area not grazed by livestock.

582. MacCracken, James G.; Hansen, Richard M. 1984. Seasonal foods of blacktail jackrabbits and Nuttall cottontails in southeastern Idaho. *Journal of Range Management* 37(2): 256-259.

The diets of blacktail jackrabbits and Nuttall cottontails were estimated by examination of fecal pellet botanical composition. Cluster analysis combined leporid pellets into two distinct groups based on botanical composition, representing feeding during spring-summer and fall-winter periods. Generally, grasses and forbs were most abundant in blacktail jackrabbit and Nuttall cottontail pellets during the spring-summer period, whereas shrubs were most abundant during the fall-winter period. Diet similarity was greatest between blacktail jackrabbits and Nuttall cottontails during the same season. Diversity of forage consumed was greatest for both leporids during spring-summer periods. Habitat segregation minimizes competition for forage. Livestock grazing appears to limit leporid population density rather than alter leporid food habits.

583. Markham, O.D.; Whicker, F.W. 1973. Seasonal data on reproduction and body weights of pikas (*Ochotona princeps*). *Journal of Mammalogy* 54(2): 496-498.

Pikas were shot or live-trapped on Mount Evans, Clear Creek County, Colorado, at elevations from 3,590 to 4,265 m in May through September of 1968, 1970, and 1971. The mean litter size based on embryo counts for 53 pregnant females was 3.2. The mean litter size for placental scars was 3.6 for 33 females. The average size of the 21 litters born in captivity was 2.9. The breeding season apparently begins in late April and May as only 20% of the females collected during the first half of May were gravid as compared to 83% during the last half of May. The end of the breeding

period appeared to be the last of July. Pikas appear to have two litters per year. Mid-June was believed to be the average date for birth of the first litter and the conception of the second litter. Although the average adult male weighed more than the average adult female during every month except August, only the September average of 190 g for the males was significantly larger than the 170 g average for females.

584. Maser, Chris; Trappe, James M; Nussbaum, Ronald A. 1978. Fungal small-mammal interrelationships with emphasis on Oregon coniferous forests. *Ecology* 59(4): 799-809.

Most higher plants have evolved with an obligatory symbiotic relationship with mycorrhizal fungi. Epigeous mycorrhiza formers have their spores dispersed by air currents, but hypogeous mycorrhizal fungi are dependent upon small mammals as primary vectors of spore dissemination. Mammalian mycophagists defecate within the coniferous forest ecosystem, spreading the viable spores necessary for survival and health of the conifers. As one unravels and begins to understand the interrelationships between small mammal mycophagists and mycorrhizal fungi, it becomes apparent that the various roles of small mammals in the coniferous forest ecosystem need to be reevaluated. One can no longer accept such simplistic solutions to timber management as poisoning forest rodents to enhance tree survival. One must consider the direct as well as the indirect costs and benefits of timber management decisions if one is to maintain balanced, healthy coniferous forests.

585. McKay, Donald O.; Verts, B.J. 1978. Estimates of some attributes of a population of Nuttall's cottontails. *Journal of Wildlife Management* 42(1): 159-168.

Density, natality, and mortality of a population of Nuttall's cottontails in shrub-juniper scabland of central Oregon were monitored from August 1972 to March 1974. Monthly censuses indicated population density ranged from 6.6 to 254.4/100 ha. Densities declined 89 and 85% from August to December in 1972 and 1973, respectively; within these periods, greatest losses occurred at times of unusually low minimum daily temperatures. In 1972, four litters were produced (April-July) of which 10, 22, 68 and 80%, respectively, survived to August 30. In 1973, only three litters were produced (April-June) of which 25, 21, and 11% survived to August 30. The decline in production and survival of juvenile cottontails in summer 1973 was believed to be related to reduced precipitation during the reproductive period; precipitation was 64% less in 1973 than in 1972. Differential survival of litter groups indicated that drought had the greatest impact on younger cohorts, perhaps through reduction in succulent forage for weanlings.

586. McKay, Donald O.; Verts, B.J. 1978. Habitat preference and dispersion of Nuttall's cottontails. *Northwest Science* 52(4): 363-368.

Dispersion in a population of Nuttall's cottontails was ascertained by live-trapping and by direct observation of individuals flushed along 32 transect lines across an 84.9-ha study area in central Oregon. Dispersion of 457 captures in three habitat types based on vegetation, edaphic, and topographic substrates was significantly different from a

uniform distribution; however, dispersion of 86 cottontails flushed in the same habitats was not significantly different from a uniform distribution but was significantly different from the distribution of captures. Observed differences in dispersion were believed to be related to diel activity patterns of cottontails and to the physiographic and vegetative differences in habitats. Based on these conclusions, observed habitat preferences of cottontails on the study area were believed to be artifacts of the methods of quantification of dispersion of the population.

587. McKay, Donald Oren. 1975. Dynamics of a population of mountain cottontail rabbits in central Oregon. Corvallis, OR: Oregon State University. 63 p. M.S. thesis.

Data from 186 mountain cottontail rabbits captured 455 times by live-trapping and from 46 rabbits collected by shooting were evaluated to determine monthly densities, survival rates, extent of movements, dispersion in relation to habitat types, and criteria for determining ages of mountain cottontails. Estimates of density computed for each month ranged from a high of 102.9 per 100 acres in August 1972 to a low of 2.7 per 100 acres in November 1973. A 74% decline in numbers of cottontails occurred between August 1972 and August 1973. Calculated dates of conception indicated that four litter groups of juvenile cottontails were conceived during the breeding season in 1972, and three were conceived in 1973. Onset of drought periods that began in July 1972 and June 1973 were thought to be responsible for cessation of breeding of mountain cottontails. Survival of cottontails from August 1972 to April 1973 was 18%. Numbers of cottontails born in litter groups one through three that survived from birth through August 1972 were significantly different from numbers that survived from birth through August 1973. Poor survival of the third litter group and absence of production of a fourth litter group in 1973 were thought to be responsible for lower densities in 1973. Average distances between points of capture for mountain cottontails caught two or more times within a 30-day period ranged from 7.7 to 213.3 yards in 1972, and from 19.7 to 171.9 yards in 1973. Differences between diurnal and nocturnal dispersion of cottontails occurred because cottontails occurred more frequently in low flats at night and more frequently in transition areas during the day.

588. Meslow, E. Charles; Keith, Lloyd B. 1968. Demographic parameters of a snowshoe hare population. *Journal of Wildlife Management* 32(4): 812-834.

Snowshoe hare populations were studied near Rochester, Alberta, during 1961-67; this period encompassed a peak in hare numbers, the decline to a low, and the initial stages of population recovery. The estimated magnitude of change exhibited on a square-mile study area was from 622 adult hares in April 1962 to 3 by the summer of 1965; the June 1967 population was 24. Other study areas showed similar trends. The observed population trend was province-wide. Annual adult survival dropped from 22% in 1962-63 to 13% in 1963-64, and then improved progressively to 28% in 1966-67. Juvenile survival of about 3% (birth to spring) during 1962-63 and 1963-64 rose to 10% between 1964 and 1966 and improved again to about 24% in 1966-67. Changes in pregnancy rate, litter size, and the presence or absence of a fourth litter group, collectively determined the mean number of young born per adult female surviving the breeding season each year. This statistic decreased progressively from 15.3 in 1961 to 7.8 in 1963 and then increased to 18.6 by 1965; in 1966 and 1967,

17.9 and 17.1 young were born per adult female. The decline in the hare population resulted from a decrease in adult survival, a juvenile survival of only about 3%, and a halving of the reproductive rate. Recovery from the low was a function of doubled adult survival and reproductive rates and marked increases in juvenile survival. These immediate mechanisms controlling population growth were compared with findings in other studies.

589. Meslow, E. Charles; Keith, Lloyd B. 1971. A correlation analysis of weather versus snowshoe hare population parameters. *Journal of Wildlife Management* 35(1): 1-15.

Computer analysis was used to examine five snowshoe hare population parameters for correlations with 12 weather factors in a wide array of time periods. Intensity of illumination in midwinter, as measured by cloud cover, was highly significantly correlated with the date of onset of breeding the following spring. No significant correlations between weather and the date of testis regression were disclosed. Between-year differences in litter size were significantly correlated with temperatures and snow depth. The colder the temperatures in the 250 days preceding mid-February, and the deeper the winter's accumulation of snow, the larger the litters the next spring. Adult survival in the period January through April 25 was highly significantly correlated with both temperatures and snowfall; the critical periods were the 80 days preceding April 25, and January 5 to March 26, respectively. Colder temperatures and deeper snow in these periods correlated with poorer adult survival. Relative survival of first-litter young during their first 45 days of life was highly significantly enhanced by brighter days and warmer temperatures throughout the 45-day survival period. Relative survival of second-litter hares was highly significantly negatively correlated with rainfall. Both total rainfall and the number of days with rainfall throughout almost the entire 45-day survival period were involved. Relationships expressed by the correlations were compared with the findings of other investigators; possible biological mechanisms operative in the correlations were outlined.

590. Millar, John S. 1972. Determination of age, age structure and mortality of the pika, *Ochotona princeps* (Richardson). *Canadian Journal of Zoology* 50(2): 229-232.

Determination of age of pikas by counting adhesion lines in periosteal bone of the lower jaw is described. Pikas attain a maximum age of at least 7 years in Alberta and Colorado. Estimated yearly losses of adults did not differ significantly between sexes, years of the study, or among collection areas, and averaged 46%. Age-specific rates of mortality were greater in the 0-1- and 5-7-year age groups, and the general mortality pattern was similar to those reported for other mammals.

591. Millar, John S. 1972. Timing of breeding of pikas in southwestern Alberta. *Canadian Journal of Zoology* 50(5): 665-669.

Conception dates of pikas were determined from the age of embryos in 125 collected females. First litters were conceived as early as would allow nursing under favorable feeding conditions. Mean birth date of first litters (June 8) coincided with the mean date of initiation of growth of vegetation (June 9). Second litters were conceived immediately after birth of first litters. Although pikas in southwestern Alberta matured

later and conceived fewer litters per year than some other species of pikas, they matured earlier and conceived more litters per year than other subalpine and alpine mammals of similar size. This breeding pattern may, in part, be responsible for the success of pikas at high elevations.

592. Millar, John S. 1973. Evolution of litter-size in the pika, *Ochotona princeps* (Richardson). *Evolution* 27(1): 134-143.

Potential litter sizes, mortality of embryos and nestlings, maternal fat reserves during pregnancy and lactation, and population parameters of pikas in southwestern Alberta are documented and used to evaluate several hypotheses on the significance of litter size. Two, three, or sometimes four ova are shed at conception. Relatively heavy losses in litters of four occur during gestation. These losses are not likely caused by any nutritional stress on females and may be related to an evolutionary reduction in litter size by limiting the capacity of the uterus. Relatively heavy losses in litters of three between birth and weaning and low maternal fat reserves during lactation indicate that females produce as many offspring as they can support. Population appeared at or near saturation level, and the advantage in partitioning maternal resources into two rather than three or four smaller offspring may be that the better nourished offspring are more successful at competing for space.

593. Millar, John S.; Zwickel, Fred C. 1972. Characteristics and ecological significance of haypiles of pikas. *Mammalia* 36(4): 58-68.

Examination of haypiles of pikas in southwestern Alberta indicated that plants growing as shrubs or clumped herbs and those with high protein content were collected preferentially. Size of these winter stores varied with sex and age of the animal involved, with the amount of forage available on feeding meadows, and with distance vegetation had to be transported. Pikas appeared to collect as much vegetation as possible during the haying season, but very few collected enough to provide an exclusive source of food for winter; hence pikas probably forage year round. The exact function of these hay stores remains unknown. Their presence may help pikas avoid predators but more likely serves as a reserve source of food when foraging conditions are unfavorable.

594. Moore, Robin Lee Kistler. 1987. Daily and seasonal activity patterns of the pika in southwestern Montana. Bozeman, MT: Montana State University. 61 p. M.S. thesis.

Diurnal and nocturnal activity patterns of pikas were studied by visual observations and radio telemetry during summer and fall 1984 and winter 1985 in Gallatin Canyon, Montana. Inferences were made on the extent of meadow feeding and haypile feeding during the winter, and seasonal changes in behavioral patterns were related to winter survival strategies. Pika body temperature and ambient temperature were recorded during the fall. Total pika activity was significantly greater in fall than during winter; however, there were no significant differences between summer-fall and summer-winter activity. There were no significant differences in mean proportion of activity throughout the 24-hour periods, although pikas showed small, consistent peaks of

activity during the morning and later afternoon in all seasons. Throughout the seasons, pikas spent a major portion of their time inactive below the talus surface and feeding above the surface. The proportion of time spent meadow feeding did not vary significantly throughout the seasons. More time was spent in haypiling, perching, and social behavior during summer than during fall. The proportion of time spent feeding and inactive below the surface varied significantly with time of day during summer and fall but not in winter. During periods of inclement weather in the fall, nocturnal meadow feeding was significantly reduced. During winter nights with temperatures below -17 degrees C., there was a decrease in meadow foraging excursions and an increase in haypile usage, but these differences were not significant. During the winter the greatest amount of time was spent in inactivity below the surface.

595. Mossman, Archie S. 1955. Reproduction of the brush rabbit in California. *Journal of Wildlife Management* 19(2): 177-184.

Male brush rabbits capable of breeding may be encountered from November to June, and females from December to June inclusive. The peak of reproductive activity lasts from January through May in both sexes, the period of infertility coinciding with the dry season. The gestation period is deduced to be about 27 days, and females probably breed soon after giving birth. An adult female that lives through the entire breeding season could raise three or even four litters. The litter size ranges from two to six; each adult female is potentially capable of producing about 12 to 16 young per season.

596. Mozejko, Albert. 1972. A food habits study of the snowshoe hare, *Lepus americanus washingtonii* Baird, in western Oregon. Corvallis, OR: Oregon State University. 119 p. Ph.D. dissertation.

A food habits study of the snowshoe hare was conducted in the western Cascade Range of Oregon during 1962-65. The major objective of the study was to complete a histological-microtechnique analysis of a fecal pellet collection to determine the annual food habits of this mammal in the area studied. The study area was divided arbitrarily into three zones to facilitate selection of pellets for final analysis and to determine if hares used the zones, each different, interchangeably during feeding activities. Fecal pellets were collected from hares live-trapped at monthly intervals. Observations upon numerous trap-released hares verified use of 15 different plant species as food items. Captive hares were test fed plants in a predetermined manner. Hares ate some of each of 34 plant species offered and showed decided preferences. The diet of the hares was comprised mainly of herbaceous plants during warm seasons of the year. Woody plants, including buds, twigs, and bark of trees, were used heavily during colder seasons, especially when snow covered herbaceous foods. Grasses, sedges, and rushes were least eaten. Bracken-fern, *Pteridium aquilinum*, was used extensively from summer through winter. The most heavily browsed forbs were broad-leaved lupine, *Lupinus latifolius*, false dandelion, *Hypochaeris radicata*, white-flowered hawkweed, *Hieracium albiflorum*, and bear-grass, *Xerophyllum tenax*. Red huckleberry, *Vaccinium parvifolium*, was heavily used during winter. Coulter's willow, *Salix coulteri*, was extensively used during summer. Douglas-fir and western hemlock incurred greatest usage during winter, with the former being consumed more.

597. Paddock, Markley William. 1961. The food habits of the pika, *Ochtona princeps saxatilis* Bangs. Boulder, CO: University of Colorado. 81 p. M.A. thesis.

A population of pikas inhabiting a north-facing talus slope on Niwot Ridge was studied from June 1959 to August 1960 to obtain information about their food habits and the possible effects they had upon the vegetation adjacent to their rocky habitat. Many observations were made of the pikas and their activities. Their habit of collecting and storing vegetation in the late summer and early fall for winter use proved most interesting. Samples of this hay were collected and examined for comparisons with the cover values of the plants in the adjacent area. Some selectivity seemed to be exhibited by the animals in their selection of plants for storage and later from these stored plants for food. Pika fecal pellets were collected and mounted on slides for microscopic examination. By various techniques, it was possible to identify most of the plant epidermal fragments in the fecal material and therefore the plant species eaten by the pikas. The result of the fecal pellet slide analysis showed the *Kobresia* and *Carex* spp. comprised over 50% of the plant fragments identified, and *Geum* and *Trifolium dasyphyllum* were found in percentages lower than anticipated from previous data. These anomalous findings represented a differential destruction of plant epidermis in digestion. Evidence suggested that the grasses and sedges are more resistant to destruction in the pika's digestive system than are the softer dicotyledons. From observations and use of exclosures, the grazing effects pika have upon vegetation were studied. In some areas, the intensive clipping may produce and maintain "biotic climax" plant communities.

598. Pease, James L.; Vowles, Richard H.; Keith, Lloyd B. 1979. Interaction of snowshoe hares and woody vegetation. *Journal of Wildlife Management* 43(1): 43-60.

Winter feeding experiments with captive snowshoe hares indicated a mean daily requirement of about 300 g of woody browse having a maximum diameter of 3-4 mm. Food supplies were measured near Rochester, Alberta, during six consecutive winters. Food was insufficient for hare populations on two study areas during a cyclic peak and the following winter; food was still in short supply on a third study area two winters after the peak. Twenty hare exclosures and their control plots, established in 1968 and sampled in summer 1971 and 1972, showed that hares had reduced the total biomass of woody stems, 1.5 cm in diameter by more than 50%. Browsing-intensity surveys conducted in 1971, at the end of the peak winter, disclosed that almost 50% of the woody stems had been severely or heavily browsed; 2 years later, less than 2% were so intensively browsed. Marked changes occurred in nutrient levels of six common browse species monitored during 1969-74, but these appeared unrelated in any causal way to changes in hare population parameters. Mortality of malnourished captive hares was significantly related to ambient winter temperatures. Results of these field observations and feeding trials are discussed in relation to the hypothesis that cyclic declines of snowshoe hare populations are initiated by over-winter food shortage.

599. Powers, Roger A.; Verts, B.J. 1971. Reproduction in the mountain cottontail rabbit in Oregon. *Journal of Wildlife Management* 35(4): 605-613.

Reproductive tracts of 269 mountain cottontail rabbits collected in Deschutes and Jefferson Counties, Oregon, between May 28, 1968, and August 28, 1969, were excised and examined. Sex ratios of specimens collected by shooting, and of embryos more than 25 mm in length, were not significantly different from 1:1. Adult males appeared to be in breeding condition in the interval January-July. Juvenile males apparently did not attain breeding condition in the year of their birth. Adult females began to breed in late February and ceased to breed in early July in 1969. Most adult females probably produced four litters in 1969; some may have produced five litters. Thirty-one adult females shed an average of 5.0 ova per pregnancy, of which an average of 4.6 were implanted, and an average of 4.3 were viable embryos at the time of collection. Only one of 15 juveniles collected during the breeding season was pregnant. Productivity of the population of mountain cottontails in central Oregon was considerably less than reported for eastern cottontails (*Sylvilagus floridanus*) in Missouri or Oregon but apparently was considerably greater than heretofore thought possible for the species.

600. Radwan, M.A.; Campbell, D.L. 1968. Snowshoe hare preference for spotted catsear flowers in western Washington. *Journal of Wildlife Management* 32(1):104-108.

Relative preference by snowshoe hares for leaves, flower buds, and open flowers of spotted catsear (*Hypochoeris radicata*) was studied in western Washington. The hares demonstrated preference for open flowers, followed closely by flower buds. Leaves, alone or in presence of open flowers or flower buds, were the least preferred part of the plant. Sugar content was calculated on both a fresh- and dry-weight bases, and advantages of the former method are discussed. Based on fresh weights, levels of glucose and fructose—the principal sugars of catsear—appeared to be responsible for the observed order of preference, although other factors were not ruled out.

601. Raedeke, Kenneth J.; Taber, Richard D.; Paige, Dwayne K. 1988. Ecology of large mammals in riparian systems of Pacific Northwest forests. In: Raedeke, Kenneth J., ed. *Streamside management: riparian wildlife and forestry interactions: Proceedings of a symposium; 1987 February 11-13; Seattle, WA. Contrib. 59.* Seattle, WA: University of Washington, College of Forest Resources: 113-132.

The literature is reviewed relating to the ecological needs of large, free-living mammals to the riparian environment to determine these species' degrees of need and the particular habitat characteristics important in meeting their ecological requirements. Species covered are Virginia opossum, snowshoe hare, Nuttall's and eastern cottontail, mountain beaver, beaver, muskrat, nutria, red fox, grey fox, fisher, mink, striped skunk, western spotted skunk, river otter, bobcat, elk, mule and black-tailed deer, white-tailed deer, and moose. Native species considered dependent on riparian areas or that find optimum habitat there are beaver, muskrat, raccoon, mink, river otter, elk and mule deer. Native species more abundant in riparian areas than in

adjacent uplands are snowshoe hare, grizzly bear, western spotted skunk, white-tailed deer, and moose. The other species listed use riparian areas but are as abundant in other habitats. The significant features of riparian systems were abundance of prey species; productivity of the shrub/herb layer; early spring phenological development of food plants; reduced snow accumulations; aquatic habitat, and lineal continuity of habitat.

602. Roest, Aryan I. 1953. Notes on pikas from the Oregon Cascades. *Journal of Mammalogy* 34(1): 132-133.

Lists locations and elevations where pikas were found, some of which constitute range extensions. Parasites found on specimens are named.

603. Sharp, Peggy Lynn. 1973. Behavior of the pika (*Ochotona princeps*) in the Kananaskis region of Alberta. Edmonton, Alberta: University of Alberta. 118 p. M.S. thesis.

The behavior of the pika was studied in spring and summer of 1969 and 1970. General activity, individual oriented behavior (including comfort and maintenance behavior and food getting behavior), and territorial and social behavior (including spatial and temporal use of home range, vocalization, agonistic and related behavior, reproductive and maternal behavior, and scent marking) were studied. In summer, pikas avoided the hottest weather, and in early spring, they avoided the coldest weather. Pikas reingest cecal feces as they issue from the cloaca. Pelage maintenance acts increased gradually through the summer, and possible causes for this increase are discussed. Sitting activity occupied between 40 and 60% of the time pikas were seen. They groomed themselves, called, and interacted vocally while sitting. Feeding activity occupied between 20 and 30% of the time pikas were seen in spring and early summer, decreasing in males in July and in females and juveniles in August with the onset of haying activity, because pikas fed while haying. Haying occupied between 15 and 35% of the time pikas were seen in late summer. The significance of haypiles is discussed. Pikas lived in a paired arrangement. In the breeding season (April, May and June) pair members' core areas overlapped extensively and the majority of interactions occurred within pikas' core areas between males. In July, males had haypile oriented core areas and little overlap with their females. Agonistic interactions increased, occurring mainly outside of core areas.

604. Shields, Paul W. 1960. Movement patterns of brush rabbits in northwestern California. *Journal of Wildlife Management* 24(4): 381-386.

A brush rabbit population was intensively studied over a 16-month period. In all, 148 animals were captured, marked, and released. Subsequent observations revealed that the adult male range diameter was 278 feet, significantly larger than the 149 feet recorded for females. Sixty-seven and 96% of females recaptured were taken less than 100 feet and 300 feet from the original trapping points. The respective percentages for males were 24 and 75. Many males, but only one female, were taken further than 400 feet from the original capture points. Seven rabbits exhibited exceptional movement patterns, ranging from 562 to 1,156 feet. Brush rabbit mobility is affected by cover and food supply, breeding season, population density, and possibly weather.

605. Sinclair, A.R.E.; Krebs, C.J.; Smith, J.N.M. 1982. Diet quality and food limitation in herbivores: the case of the snowshoe hare. *Canadian Journal of Zoology* 60(5): 889-897.

Experiments with snowshoe hares in British Columbia (in captivity) show that hares maintain a relatively constant intake rate of food as quality (crude protein value) falls. This result allows us to use mean diet quality to predict whether animals can maintain body weight under natural conditions. The threshold diet quality below which weight loss occurred was 11% crude protein. There is a strong correlation between diet crude protein and fecal crude protein. By collecting fecal pellets in the field, one can monitor the diet of the population. If fecal crude protein falls below 7.5%, animals lose weight as a result of insufficient good food. Field data for 1977-80 show fecal protein for some animals dropping below this level in late winter of 1979 when the hare population was near its peak density.

606. Sinclair, A.R.E.; Smith, James N.M. 1984. Do plant secondary compounds determine feeding preferences of snowshoe hares. *Oecologia* 61(3): 403-410.

The food preferences of captive snowshoe hares were investigated in winter to test three hypotheses proposed to explain food choices by hares: that food choice is related to the protein content of twigs; that defensive chemicals present in twigs are negatively correlated, with hare food preferences; and that hares eat less-preferred but protein-rich twigs when their diet is buffered by large amounts of palatable food. Hares exhibited striking and consistent preferences for different species and, in general, preferred mature twigs to juvenile growth stages. Preference across species among mature twigs were not the same as preferences for juvenile growth stages across species. None of the three hypotheses adequately explained food choice by hares: hares did not select twigs that were high in protein content; they also did not consistently select twigs that were low in resins or phenols; and they generally ate less, not more of nonpreferred twigs in the presence of a protein and energy rich alternative food, commercial rabbit chow. Food preferences of hares must presumably have some chemical basis, but no simple theory has yet explained what this is. Hares may not be under severe dietary constraints imposed by chemical defenses in winter.

607. Smith, Andrew T. 1974. The distribution and dispersal of pikas: consequences of insular population structure. *Ecology* 55(5): 1112-1119.

The population structure of the pika was analyzed from demographic data and the observed spacing of populations on discrete islands of habitat in the Sierra Nevada of California. These islands of habitat varied in size and distance from one another. Not all of the islands were occupied, and most seemed to contain fewer individuals than they could hold. The populations apparently represent dynamic equilibria between extinction, which was directly related to island size, and recolonization, which was inversely related to interisland distance. Distances greater than 300 m appeared to pose difficult barriers to dispersing juveniles. The study site is near the

distributional boundary of pikas in this area. The birth rate is higher, adult death rate lower, and juvenile death rate higher than for other pika populations found near the center of the altitudinal or geographic range of the species. It appears that the probability of successful colonization decreases with progressively lower elevations, until ultimately colonization is unable to offset extinction, and the limit of the species range is determined.

608. Smith, Andrew T. 1974. The distribution and dispersal of pikas: influences of behavior and climate. *Ecology* 55(6): 1368-1376.

Daily and seasonal behavior in relation to local climate was analyzed for two populations of pikas, representing the extremes of the altitudinal range of the species in the Sierra Nevada of California. Pikas at the high altitude site (3,400 m) were active throughout the day, whereas at the warmer low altitude site (2,550 m) they concentrated their activity in the morning and late afternoon. Field experiments suggest that when pikas are deprived of the opportunity to retreat to favorable microclimates in rockslides, they are unable to tolerate the high diurnal temperatures found at lower elevations. Thus, high environmental temperatures apparently constitute a major stress on dispersing individuals at low altitudes. The onset of hay storage, vocalization, and parturition, three measures of seasonality, occurred about 6 weeks earlier at the low altitude site. Most juveniles at the low altitude site disperse during mid-summer when temperatures are high and their chance of success is low. Also, during dry years, most of the period suitable for gathering hay ends before a majority of juveniles can disperse. Temperature and seasonality apparently have little effect on the dispersal of pikas at high altitude. At high altitude the pikas are wider ranging than at low altitude, and they occupy a greater proportion of available sites.

609. Smith, Andrew T. 1978. Comparative demography of pikas (*Ochotona*): effect of spatial and temporal age-specific mortality. *Ecology* 59(1): 133-139.

The structure of four populations of the pika is examined to explore the causal mechanisms of evolution of life history features of the species. Litter size reflects potential and realized fecundity and is largest at Bodie (low latitude, low altitude) intermediate at Sierra and Colorado (low latitude, high altitude), and smallest at Alberta (high latitude). The age specificity of mortality largely determines the number of sites available for settlement by juveniles, which dictates the feedback to litter size. Populations are stable and habitats continuously saturated at Alberta; mortality of adults is predictable. The Sierra and Colorado sites possess unstable populations. At these sites, snowmelt in the spring (the harbinger of emergent vegetation and successful weaning) is relatively unpredictable compared to Alberta; adult mortality may be high in years of early or late snowmelt. The unpredictability also selects for asynchronous breeding such that more sites are available in any one year to offspring from certain successfully weaned litters. The habitat at Bodie is temporally and spatially unsaturated. Largely because of poor vagility of pikas, much of the habitat is vacant. Colonization is unable to completely offset extinction of populations on patches of habitat. Here, the selective factor determining litter size is juvenile production and not adult mortality.

610. Smith, Andrew T. 1980. Temporal changes in insular populations of the pika (*Ochotona princeps*). *Ecology* 61(1): 8-13.

Temporal change in size of populations of a small alpine mammal, the pika, at Bodie, California, was analyzed by comparing a 1972 census of the observed spacing of pikas on discrete islands of habitat to a similar 1977 census. The islands of habitat varied in size and distance from one another. Overall results from each census were strikingly similar. Not all of the islands were occupied, and most seemed to contain fewer individuals than they could hold. The populations apparently represent dynamic equilibria between extinction (which was inversely related to island size), and recolonization (which was inversely related to interisland distance). In spite of these similarities, the population size of individual islands changed dramatically. Eight previously unoccupied islands were colonized, and 11 island populations became extinct. Fifty-three percent of 77 islands compared changed their degree of saturation within the 5-year period. Changes in percentage saturation of available habitat on islands varied among island sizes and degrees of isolation. All cases of turnover (extinction or recolonization) occurred on small or medium-sized islands. Within these island size categories, turnover increased with isolation. Extinction of populations on islands close to a source of potential colonists was apparently minimized by recurrent colonization, a verification of the rescue effect.

611. Smith, Andrew Thomas. 1973. The distribution and dispersal of pikas (*Ochotona princeps*). Los Angeles, CA: University of California. 84 p. Ph.D. dissertation.

The population structure of the pika was analyzed by using demographic data and the observed spacing of populations on discrete islands of habitat in the Sierra Nevada of California. Not all of the islands were occupied, and most apparently contained fewer individuals than they could hold. The populations apparently represent dynamic equilibria between extinction, which was directly related to island size and recolonization, which was inversely related to interisland distance. Distances greater than 300 m appeared to pose difficult barriers to dispersing juveniles. It appears that the probability of successful colonization decreases as one goes to progressively lower elevations, until ultimately colonization is unable to offset extinction, and the limit of the species range is determined. Daily and seasonal behavior in relation to local climate was analyzed for two populations representing the extremes of the altitudinal range of the species. The goal was to determine the relationship of a propagule to its environment at the time of dispersal so as to evaluate the probability of successful colonization in different parts of the species range. Pikas at the high altitude site (3,400 m) were active throughout the day, but at the warmer low altitude site (2,500 m) they concentrated their activity in the morning and late afternoon. When pikas are deprived of the opportunity to retreat to favorable microclimates in rockslides, they are unable to tolerate the high diurnal temperatures found at lower elevations. Thus, high environmental temperatures apparently constitute a major stress on dispersing individuals at low altitudes.

612. Sullivan, T.P.; Sullivan, D.S. 1986. Resiliency of snowshoe hares to population reduction. *Journal of Applied Ecology* 23(3): 795-806.

This study tested the hypothesis that continuous removal of peak populations of snowshoe hares would result in successful population reduction. Intensive population monitoring and removal of hares conducted from August 1980 to August 1982 near Prince George, British Columbia, measured the resiliency and demographic responses of hares. Recovery ratios and a relative recruitment index clearly reflected high rates of dispersal or colonization for hares moving into the vacant habitat. A range of 25 to 58% recovery every 4 weeks was recorded during the winter of peak densities. Physical condition and body weights of dispersing hares were similar to those of control animals during the peak winter. In the decline phase, lightweight hares in poor conditions dominated the population colonizing the removal area. These results clearly indicate that periodic removal, at least on a local scale, does not effect a long-term reduction in populations of the snowshoe hare.

613. Sullivan, Thomas P.; Sullivan, Druscilla S. 1983. Use of index lines and damage assessments to estimate population densities of snowshoe hares. *Canadian Journal of Zoology* 61(1): 163-167.

This study reports on the use of index lines to estimate the abundance of snowshoe hares in lodgepole pine stands in central British Columbia. Density estimates and related demographic information from the index lines were compared with a standard set of lines superimposed on a 9-ha grid. During the summer of a peak year in abundance, index line trapping provided reasonably accurate estimates of hare densities on a grid system. There was little variation in the demographic variables of reproduction, body weight, and sex ratio between line- and grid-sampled populations. Hare abundance and barking damage (feeding injuries to trees) were greater in heavily stocked stands of lodgepole pine than in lightly stocked stands. Index lines provide a rapid and economical survey method for censusing snowshoe hares in lodgepole pine stands.

614. Uresk, Daniel W. 1978. Diets of the black-tailed hare in steppe vegetation. *Journal of Range Management* 31(6): 439-442.

Thirteen species of plants were identified in fecal pellets of black-tailed hares (jack-rabbits) collected from sagebrush and bitterbrush communities in south-central Washington. Microscopic analysis of plant fragments indicated that yarrow was the most common food item in the diet, making up 25% of the overall diet. Other food items in decreasing order of importance were turpentine cymopterus > hoary aster > needle-andthread > and Jim Hill mustard. Preference indices indicated that needleandthread was the most preferred plant in the sagebrush community, and yarrow was the most preferred plant in the bitterbrush community. Although the communities were not similar in plant species frequency of occurrence and cover, the hare diets were quite similar in both communities, thereby, indicating that hares were actively seeking preferred foods.

615. Van Daele, Lawrence J.; Hafer, Hilary A. 1978. Stability in pika density. *Murrelet* 59(3): 101.

Bunnell and Johnson censused pikas from 1969 to 1972 on nine small rockslides on St. Joe Baldy Mountain, Benewah County, Idaho. Pika populations at these slides were stable during the first 2 years of the study and their numbers declined in the 2 subsequent years. We had an opportunity to census pikas living in these same rockslides during the 1977 field season, 5 years after termination of their study. The total number present and counts for individual slides are nearly identical to those made in 1969 and 1970, before collection reduced the population.

616. Verts, B.J.; Gehman, Steven D.; Hundertmark, Kris J. 1984. *Sylvilagus nuttalli*: a semiariboreal lagomorph. *Journal of Mammalogy* 65(1): 131-135.

Lagomorphs generally are considered to be terrestrial mammals, but observations in central Oregon since 1968 revealed that some individuals climbed in western juniper up to 3 m above the ground. This activity is quantified and an explanation is provided, based on the population and feeding ecology of the species.

617. West, Edward Watson. 1980. Adaptive patterns in behavior of the Sierran pika, *Ochotona princeps*. Davis, CA: University of California. 112 p. Ph.D. dissertation.

The study consisted of three parts: (1) Food hoarding—To test the hypothesis that generalist herbivores show selective preference for food items based on nutrient quality, the foraging habits of the pika were examined. Haypiles were analyzed for species composition. Species in which the relative biomass in the haypile exceeded the relative biomass in the foraging area were designated as preferred species. Preferred and nonpreferred species were compared for caloric, protein, lipid, carbohydrate, and ash content. Preferred species showed significantly higher caloric, protein and lipid content. Nonpreferred species were higher in crude fiber content. No significant differences were noted for nitrogen-free extractive or ash; (2) The song—The structure and behavioral context of the pika song was studied to determine the functional role songs play in the species social system. Evidence suggests that the function of the pika song is to establish individual male identity for sexual advertisement; (3) The mating system—Pikas appear to be fundamentally polygynous as a result of ecological emancipation of males from parental care duties. The extent to which polygynous matings occur, however, is ecologically constrained by limited spatial and temporal distribution of food resources. The time and energy requirements of territorial maintenance precludes the formation of communal breeding groups, but multiple matings of dominant males may occur with two or more females in adjacent territories. Where food and space resources are evenly distributed, monogamous matings may predominate in a colony.

618. Windberg, Lamar A.; Keith, Lloyd B. 1976. Experimental analyses of dispersal in snowshoe hare populations. *Canadian Journal of Zoology* 54(12): 2061-2081.

Dispersal was investigated in snowshoe hare populations near Rochester, Alberta, from May 1970 to May 1974. Ingressing hares (dispersers) were removed every

3-4 weeks after removal of the initial resident population from an 11.3-ha study area. Dispersal into this vacant habitat occurred during all seasons of each year. The highest rates of ingress were recorded during the winter of peak population densities (1970-71). There was a higher proportion of yearlings among ingressing hares than among residents. During 2 winters of known food shortage (1970-71 and 1971-72) dispersing hares had lower body weights than residents. Lighter adrenals and a higher incidence of scarring were also found among ingressing hares during winter 1970-71. During winter 1971-72, the resident hare population was removed from another area. Comparable recapture rates between marked immigrants on this area and hares on unmanipulated study areas indicated that ingressing individuals had settled in the vacant habitat. Hare population response to sex-ratio imbalance, created by partial removal of each sex on different areas, was studied during 1970 and 1971. Pregnancy rates declined significantly only on the male-removal area. Movements by adults during the breeding season and by predominantly juveniles over winter tended toward rebalancing population sex ratios.

619. Windberg, Lamar A.; Keith, Lloyd B. 1976. Snowshoe hare population response to artificial high densities. *Journal of Mammalogy* 57(3): 523-553.

Demographic response of snowshoe hare populations to artificial high densities was studied during summer and autumn near Rochester, Alberta. Experimental populations were established by transplanting hares onto islands in lakes in May and June. High density populations on Dapp Island (15.4 ha) in 1970 and Birch Island (3.6 ha) in 1971 were adversely affected by food shortages. Rates of pregnancy and adult survival rates in these high density populations did not differ from unmanipulated natural populations nearby, but juvenile survival was markedly lower. In 1972, a fence was constructed across Birch Island to separate two introduced high density populations. One was supplementally fed commercial rabbit pellets *ad libitum*, and the other was forced to subsist on an insufficient quantity of native vegetation. Again, survival among adults was comparable in the fed and unfed high density island populations and unmanipulated populations at lower densities. Pregnancy rates were lower, and no young were found in the unfed island population. The high disappearance rate of juveniles from all high density populations with limited food appeared to have been directly linked to food scarcity which affected young more severely than adults. We could find no evidence that either parasitic or viral diseases, or social stresses, as indexed by incidence of scarring and adrenal weights, were acting as direct mortality factors in the food-limited, high density experimental populations.

620. Windberg, Lamar A.; Keith, Lloyd B. 1978. Snowshoe hare populations in woodlot habitat. *Canadian Journal of Zoology* 56(5): 1071-1080.

Snowshoe hare population dynamics were monitored on six woodlots totaling 33 ha in an agricultural area near Rochester, Alberta, from May 1970 to May 1974. Numerical trends in woodlot and nearby forest hare populations were similar, but densities were consistently lower in woodlot habitat until the final stages of a general population decline. Annual reproductive rates were greater in woodlot populations in 1971 and 1973 and similar to forest populations in 1970 and 1972. Consistently low rates

of first-year survival (4 to 7%) in woodlot hare populations resulted in lower annual population growth rates and hence lower population densities. Browsing-intensity surveys indicated that both forest and woodlot hare populations encountered over-winter food shortages. In addition, woodlot hare populations may have suffered higher rates of predation.

Damage and Management

621. Bell, Christina M.; Harestad, Alton S. 1987. Efficacy of pine oil as repellent to wildlife. *Journal of Chemical Ecology* 13(6): 1409-1417.

Pine oil, a by-product of the pulp industry, is a feeding repellent to snowshoe hares and voles. In pen trials with snowshoe hares and field trials with voles, when given a choice between food in a pine oil-treated bowl, two hares showed a reduced rate of food consumption, and one hare did not feed at all. Pine oil contains monoterpenes which may inhibit microbial symbionts in the digestive tracts of hares and voles. The repellent action of pine oil is likely based on this interference of digestive processes, and it is of adaptive advantage for cecal digestors to avoid it. Pine oil has potential as a commercial repellent for snowshoe hares and voles.

622. Besser, Jerome F.; Welch, Jack F. 1959. Chemical repellents for the control of mammal damage to plants. In: Trefethen, James B., ed. *Transactions of the 24th North American wildlife conference; 1959 March 2-4; New York. Washington, DC: Wildlife Management Institute: 166-173.*

Describes trials of three commercially available repellents whose active ingredients are trinitrobenzene-aniline (TNB-A), zinc dimethyl dithio carbamate cyclohexylamine complex (ZAC), and tetramethyl thiuram disulfide (TMTD). Tests were done throughout the U.S. to determine effectiveness against browsing by rabbits and hares, deer, livestock, and rodents.

623. Borrecco, John E. 1976. Controlling damage by forest rodents and lagomorphs through habitat manipulation. In: Siebe, Charles C., ed. *Proceedings, 7th vertebrate pest conference; 1976 March 9-11; Monterey, CA. California: University of California: 203-210.*

Damage to coniferous seedlings and trees by forest rodents, including forest lagomorphs, is a major factor limiting prompt regeneration and causing significant losses in young stands. Manipulating the vegetation to adversely influence food and cover thereby reducing animal numbers is proposed as an approach to alleviating damage. The adaptability, high reproductive potential, opportunistic feeding behavior, and mobility of forest rodents combined with the species diversity of rodent communities, rapid recovery of vegetation, and need for long-term protection make habitat manipulation for damage control a difficult approach. However, an example is presented where herbicide-induced reduction in vegetative cover and availability of summer foods resulted in a significant reduction of clipping damage to Douglas-fir seedlings by snowshoe hares.

624. Campbell, Dan L. 1969. Plastic fabric to protect seedlings from animal damage. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium*; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 87-88.

Tests of methods to prevent browsing damage in summer to actively growing Douglas-fir seedlings by black-tailed deer and to prevent clipping damage to dormant seedlings by snowshoe hares were conducted in enclosures at Olympia, Washington. Field tests with the most promising device, inexpensive tubes of polypropylene plastic netting placed on individual seedlings, are being completed in western Washington. Both repellent-treated and untreated netting appear to greatly reduce or prevent damage to new growth by deer and to both old and new growth by hares.

625. Campbell, Dan L.; Evans, James. 1975. Vexar seedling protectors to reduce wildlife damage to Douglas-fir. *Wildl. Leaf*. 508. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 11 p.

Describes uses of "Vexar" seedling protectors to reduce clipping and browsing damage to regenerating Douglas-fir by snowshoe hares, rabbits, black-tailed deer, and Roosevelt elk. The information was collected from 1968 through 1974 in a cooperative study with DuPont, Inc., to develop and evaluate Vexar as a conifer seedling protector in western Washington and Oregon. Vexar protectors are an inexpensive method of reducing clipping and browsing. They are made of photo-degradable material, are designed so seedling height growth and form are not impaired, and are nonhazardous to the forest ecosystem, domestic animals, or humans.

626. Crouch, Glenn L. 1973. Jackrabbits injure ponderosa pine seedlings. *Tree Planters' Notes* 24(3): 15-17.

Little quantitative information is available on mortality and height losses of conifer seedlings from browsing by jackrabbits. This note gives an account of injuries to an experimental planting of ponderosa pine in south-central Oregon. Jackrabbits clipped the main stems of 43% of the sample trees during the fall and early winter of the first year after planting. Of those clipped, 34% (15% of the number planted) subsequently died. Injuries ranged from severance of the stem near ground level to removal of 1 or 2 cm. of terminal growth. Clipped trees averaged only about half the height of unclipped trees and showed no signs of closing this gap. Delays like these in growth lengthen the time that rabbit-injured trees are highly susceptible to losses from pocket gophers. Thus, the indirect result of clipping by jackrabbits could contribute to the ultimate failure of plantations.

627. Dimock, Edward J., II. 1970. Ten-year height growth of Douglas-fir damaged by hare and deer. *Journal of Forestry* 68(5): 285-288.

The development of Douglas-fir seedlings, planted under dense bracken on an old cutover in Washington's coastal zone, was closely charted for 10 years. Varying

amounts of damage to all seedlings were caused through clipping by snowshoe hare and browsing by black-tailed deer. Despite obviously severe pressure by deer in later years, nearly all animal-caused losses were attributed to earlier damage by hares.

628. Dimock, Edward J., II. 1974. Animal-resistant Douglas-fir: how likely and how soon? In: Black, Hugh C., ed. *Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium; 1973 September 11-12; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 95-101.

Summarizes more than 6 years of effort to exploit genetic variation in Douglas-fir to combat damage in young plantations caused by two problem animals—snowshoe hare and black-tailed deer. Traces developmental phases of experiments that include: verification that animals will discriminate in feeding on foliage, based upon the genotype of a tree; determination that resistant traits within the tree are inherited and under strong genetic control; corroboration that effective reduction of damage may be achieved under experimental field conditions; and speculation that resistant genotypes will become an operationally viable tool for mitigating future damage problems.

629. Dimock, Edward J., II; Silen, Roy R.; Allen, Virgil E. 1976. Genetic resistance in Douglas-fir to damage by snowshoe hare and black-tailed deer. *Forest Science* 22(2): 106-121.

Genotype of Douglas-fir significantly affected feeding selection for foliage by both snowshoe hare and black-tailed deer in pen tests with captive animals. Nine clones were rated independently for each animal species. Genotypes preferred by deer and hare ranged up to 64 and 178% more attractive, respectively, than those least preferred. Genetic analysis suggests that resistance to animals based on nonpreference is strongly inherited and chiefly additive.

630. Duffield, John W.; Eide, Rex P. 1962. Application of rabbit repellent to coniferous planting stock in the Pacific Northwest. *Journal of Forestry* 60(2): 109-111.

Reviews the techniques used to apply repellents (ZAC and TMTD) to planting stock. Dipping tops of lifted seedlings or spraying stock after field planting have been tried but discontinued in favor of spraying planting stock before lifting in the nursery. Formulation, equipment, procedure, and costs are discussed.

631. Evans, James; Hegdal, Paul L.; Griffith, Richard E., Jr. 1970. Methods of controlling jackrabbits. In: Dana, Richard H., ed. *Proceedings, 4th vertebrate pest conference; 1970 March 3-5; West Sacramento, CA.* Davis, CA: University of California: 109-116.

Of the several approaches used to control jackrabbits, most biological methods (predation, habitat manipulation, disease and parasites, and chemosterilants) seem impractical. Mechanical control, except for fence barriers, usually has limited effectiveness. Currently, the most useful approach is still chemical control. Improved baiting techniques and several chemical control agents, including an experimental toxicant highly selective for jackrabbits, are described.

632. Hartwell, Harry D. 1969. Control of damage by snowshoe hares on forest plantations. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 80-81.

The primary objective of research on damage to conifers by snowshoe hares has been to find chemicals that will protect small seedlings. Seedlings require protection for several years until they are large enough to be unattractive to hares. Attempts to reduce hare populations by broadcasting apples treated with strychnine, by applying a strychnine-adhesive spray to seedlings and by treating seedlings with the systemic chemical tetramine have not met with success. They have either failed to give adequate protection to seedlings or have constituted a hazard for nontarget species. Strychnine salt blocks, which are attractive to hares and durable, show some promise as a control method, but they are considered hazardous if used extensively. Other chemical methods tried also have been unsatisfactory for protecting small seedlings. Planting large hare-resistant seedlings in one of the best control measures. Douglas-fir seedlings averaging 19 inches in height and initially treated with the repellent TMTD survived and grew well after outplanting in an area exposed to severe clipping by hares. Destruction of habitat seems to be another valuable control measurement.

633. Hartwell, Harry D.; Johnson, Larry E. 1983. Survival and height of large and small Douglas-fir seedlings in relation to animal damage six years after planting. DNR Note 38. Olympia, WA: Washington Department of Natural Resources. 20 p.

Douglas-fir 2+0 and 3+0 nursery seedlings averaging about 1 and 3 feet in height, respectively, were evaluated for field performance in five separate potential animal damage areas in western Washington over a period of six growing seasons. Results indicate that the trees were subject to moderate or severe hare clipping damage on three of the areas and to severe mountain beaver clipping damage on another area. Trees on all areas were subject to persistent, moderate, or severe spring-summer deer browsing damage. The 3+0 trees showed much greater resistance to mortality caused by hare clipping and substantially greater resistance to growth delay caused by hare clipping and spring-summer deer browsing. Both classes of tree, however, were highly vulnerable to mortality caused by mountain beaver clipping. An economic projection revealed that the 3+0 seedlings would be a better investment on the three hare-deer damage sites and that both classes of seedling would result in stands of suboptimum wood volume on the mountain beaver-deer damage site. Observations concerning the influence of vegetation competition on growth and survival of trees are discussed.

634. Hildreth, A.C.; Brown, G.B. 1955. Repellents to protect trees and shrubs from damage by rabbits. Tech. Bull. 1134. Washington, DC: U.S. Department of Agriculture. 31 p.

Reviews the results of 22 years of screening compounds for protection of trees from rabbits. Four materials have been shown to be satisfactory: nicotine, nicotine sulfate, tetramethylthiuram disulfide, and tetraethylthiuram monosulfide.

635. Hooven, Edward F. 1966. A test of thiram on two rabbit-infested areas of Oregon. *Tree Planters' Notes* 79: 1-3.

Douglas-fir seedlings treated with thiram were planted in two areas with a known density of animals (*Lepus americanus* on one plot and *Sylvilagus bachmanii* on the second). As a contact repellent applied to nursery seedlings, thiram gave excellent initial results for both species of rabbits. Treated trees were practically unmolested until new growth developed in summer. As summer progressed, damage intensified, especially on the untreated new growth. Snowshoe hares clipped the seedlings much more severely than did the brush rabbits. Protecting newly planted seedlings from rabbits (especially the snowshoe hare) is essential for successful regeneration in some areas, and experiments indicate that thiram repels the rabbits satisfactorily.

636. Hooven, Edward F. 1970. Animal damage to seed and seedlings. In: Hermann, R.K., ed. *Regeneration of ponderosa pine: Proceedings of a symposium; 1969 September 11-12; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 36-39.

Discusses rodents and birds that consume tree seed in the ponderosa pine area and reviews methods of seed protection.

637. Jones, Marvin. 1977. Preliminary report: pika, a new source of seedling damage in high elevation plantations. [Centralia, WA]: Weyerhaeuser Company; Forestry Research Tech. Rep. 042-4305/77/52. 3 p.

Observations show that the pika is responsible for clipping conifer seedlings on at least two west coast tree farms. To date, various repellent tests (including TMTD and BGR) have no effect in preventing damage. Physical barriers show nearly 100% protection, but they need more testing to determine their stability under heavy snow.

638. Radvanyi, A. 1987. Snowshoe hares and forest plantations: a literature review and problem analysis. Info. Rep. NOR-X-290. Edmonton, Alberta: Canadian Forestry Service, Northern Forestry Centre. 17 p.

Snowshoe hare damage to forest plantations, primarily in the Canadian prairie provinces, is studied through an extensive literature review. Interrelationships of habitat and snowshoe hare populations are examined. Eleven general methods of snowshoe hare damage control based on silvicultural treatments and population controls are presented and examined. Several avenues of research needed to improve snowshoe hare damage control procedures are suggested. A bibliography of 136 references is included.

639. Radwan, M.A. 1965. Determining minimum amounts of TMTD rabbit repellent needed to protect Douglas-fir planting stock. *Tree Planters' Notes* 70: 16-20.

Dip methods were used to determine the minimum amount of TMTD required to provide protection. Based on concentrations found effective in pen and field tests, weathering losses of the repellent (69%), and handling losses in the nursery

(26-64%), TMTD minimum requirements ranged from 11 to 22 mg. per seedling. However, nurseries use power spraying equipment and rates of application differ from dipping. Further studies have been initiated to determine minimum effective rates of spraying.

640. Radwan, M.A. 1969. TMTD wild mammal repellent: review and current status. *Forest Science* 15(4): 439-445.

TMTD properties, assay methods, and use as a repellent against wild mammals are reviewed. The reviews suggest that TMTD is a very useful animal repellent, although further research is needed.

641. Radwan, M.A.; Dodge, W.E.; Ward, H.S. 1967. Effect of storage on subsequent growth and repellency of Douglas-fir seedlings sprayed with TMTD. *Tree Planters' Notes* 18(4): 10-13.

The purpose of the study was to determine the effect of storage on subsequent growth and repellency of TMTD-sprayed and unsprayed 2+0 Douglas-fir seedlings. Repellency was evaluated both in the laboratory, by determining amounts of repellent on the seedlings, and in the pen against snowshoe hare. Survival, date of bud burst, needle appearance, and height growth were studied in the nursery after seedlings were outplanted. Results show that growth, survival, and repellency of TMTD-treated seedlings were affected by storing the treated seedling before outplanting. To obtain the best repellency, growth, and survival, seedlings should be sprayed with TMTD just before outplanting.

642. Radwan, M.A.; Dodge, Wendell E. 1965. Effective application rates of TMTD rabbit repellent to Douglas-fir seedlings in the nursery. *Tree Planters' Notes* 72: 7-9.

Formulations containing 10% TMTD have been effective in protecting Douglas-fir seedlings from damage by hares and rabbits. Rates of application of the repellent by power spraying, however, have not always been satisfactory. Minimum protective amounts of TMTD have ranged from 11 to 22 mg per seedling. This information was used in the present investigation to determine the minimum effective rate of spraying 2+0 Douglas-fir seedlings with 10% TMTD repellent. Results show that the application of about 9 gallons of repellent formulation per 1000 square feet of seedbed provides a TMTD coating of 12-19 mg per seedling and should afford protection throughout the dormant seedlings. Research is still needed on a better adhesive and on more efficient spray equipment.

643. Silen, Roy R.; Dimock, Edward J., II. 1978. Modeling feeding preferences by hare and deer among Douglas-fir genotypes. *Forest Science* 24(2): 57-64.

Data on deer and hare preference for Douglas-fir genotypes in eight pen and two field trials were compared to data generated from a mathematical model. The model predicted sequential preference changes from the products of two probabilities that accounted for a changing availability (Pa) and an assumed constant palatability (Pp)

for each of several, simultaneously tested plant types. In all 10 experiments, data were closely mimicked by the model. In only one experiment did the predicted feeding sequence deviate significantly from actual data. High correlations were achieved among Pp values calculated independently for duplicate tests of identical genotypes. Since Pp is a mathematical estimate of palatability—itsself a qualitative phenomenon—the concept may prove useful for aiding interpretations of other studies expressing animal preference as an integration of plant availability and palatability.

644. Staebler, George R.; Lauterbach, Paul; Moore, A.W. 1954. Effect of animal damage on a young coniferous plantation in southwestern Washington. *Journal of Forestry* 52(10): 730-733.

An experiment was begun in 1947 to trace the effects of deer, mountain beaver, rabbits, and cattle on a young plantation of Douglas-fir, Port-Orford cedar, and western hemlock established in an area of high animal populations in western Washington. The experiment was exploratory and based on only one area. The plantation was successful in an area where mountain beaver and deer populations were high. It also withstood heavy rabbit damage. The extensive damage caused a high percentage of deformed trees and severe reduction of height growth but did not lessen survival appreciably. Rabbit populations built up extremely fast and were not included in the original study plan. Damage from mountain beavers was negligible. Douglas-fir was the most damaged species but was superior to the others in survival and height growth. Areas with heavy bracken seem to have been the poorest risk for a plantation, partly due to competition and partly to the concentration of rabbits in this cover type.

645. Sullivan, T.P. 1987. Understanding the resiliency of small mammals to population reduction: poison or population dynamics? In: Richards, C.G.J.; Ku, T.Y., eds. *Control of mammal pests*. London, UK: Taylor and Francis Ltd: 69-82.

Populations of wilderness rodents and lagomorphs inflict damage upon forests and agricultural crops wherever these small mammals coincide with land development. The main method of control involves the use of rodenticides and related poisons. This approach seldom considers the importance of resiliency in maintaining small mammal populations. The repopulation of experimentally depopulated areas by five species of small mammals shows that poison cannot effectively suppress these populations for long, at least in limited areas. Alternative control strategies based on population dynamics, behavioral and feeding ecology, and predator odor repellents point the way to more effective and long-term control than is currently achieved by using standard methodology. Small mammal species studied include the deer mouse, montane vole, northern pocket gopher, snowshoe hare, and Columbian ground squirrel.

646. Sullivan, T.P.; Moses, R.A. 1986. Demographic and feeding responses of a snowshoe hare population to habitat alteration. *Journal of Applied Ecology* 23(1): 53-63.

This study tested the hypothesis that mechanical alteration of habitat would reduce peak populations of snowshoe hares and their feeding damage to coniferous seedlings. In the altered habitat, population density and residency of hares were dramatically reduced, juvenile and subadult hares dominated the age class structure, and

male hares were in consistently poor physical condition compared with those in the control habitat. Despite favorable demographic responses, seedling mortality from hare browsing reached 80% in the altered habitat. Complete scarification and application of herbicide would further reduce or eliminate vegetative food and cover and perhaps depress and maintain hare densities at levels below which damage (<5%) to seedlings could be tolerated.

647. Sullivan, Thomas P. 1984. Effects of snowshoe hare damage on juvenile lodgepole pine—implications for spacing natural stands. Res. Note 94. Victoria, BC: British Columbia Ministry of Forests. 27 p.

This study measured the impact of snowshoe hare feeding on lodgepole pine during the first 4 years after spacing. An 18-year-old stand was manually spaced (2 m x 2 m) in 1979. Hare feeding damage and populations were monitored from 1979 to 1983 in the spaced and on a nearby control (unspaced) stand. Negligible damage to crop trees was recorded in the first winter after spacing, as hares fed on the foliage from felled trees. Feeding attacks on spaced trees increased dramatically in the subsequent winter before declining during the third and fourth winters. In general, the frequency of attack and proportion of girdled and semigirdled trees were significantly greater among small (<60 mm d.b.h) than large trees. Trees larger than 60-80 mm diameter received little feeding damage from snowshoe hares. Several silvicultural recommendations are suggested to alleviate hare damage to spaced lodgepole pine.

648. Sullivan, Thomas P.; Crump, Douglas R. 1984. Influence of mustelid scent-gland compounds on suppression of feeding by snowshoe hares (*Lepus americanus*). Journal of Chemical Ecology 10(12): 1809-1821.

This study investigated the influence of mustelid anal-gland compounds in suppressing feeding by snowshoe hares on coniferous tree seedlings. Pen and field bioassays indicated that 3-propyl-1,2-dithiolane from the stoat, and secondarily, 2,2-dimethylthietane from the mink had a very negative effect on feeding behavior of hares. The major component of stoat anal gland secretions, 2-propylthietane, and the related compounds, thietane and 2-methylthietane, were not effective. From the least weasel and ferret 3,3-Dimethyl-1,2-dithiolane and di-n-propylsulfide (acyclic analog of 3-propyl-1,2-dithiolane) did not affect hare feeding. The compounds 3-propyl-1,2-dithiolane and 2,2-dimethylthietane may act as interspecific chemical signals which induce a fear or avoidance response in hares. Such compounds have outstanding potential as area repellents to reduce crop and livestock depredations.

649. Sullivan, Thomas P.; Crump, Douglas R. 1986. Feeding responses of snowshoe hares (*Lepus americanus*) to volatile constituents of red fox (*Vulpes vulpes*) urine. Journal of Chemical Ecology 12(3): 729-739.

This study investigated the influence of the volatile constituents of red fox urine in suppressing feeding by snowshoe hares on coniferous tree seedlings. Pen and field bioassays indicated that the odor of fox urine and its principal component, 3-methyl-3-butenyl methyl sulfide, had a negative effect on feeding behavior of hares. The other sulfur-containing compounds, 2-phenylethyl methyl sulfide and 3-methylbutyl

methyl sulfide, as well as six other constituents, were not effective. Synthetic urine mixtures composed of eight and nine volatile constituents, respectively, did not suppress feeding in pen bioassays. The mixture of eight compounds in a field bioassay, however, did result in significantly fewer seedlings being eaten by hares than in the control. The compound 3-methyl-3-butenyl methyl sulfide may act as an interspecific chemical signal which induces a fear or avoidance response in hares. Additional work is required to determine the optimum concentration and release system for 3-methyl-3-butenyl methyl sulfide to be used as a mammalian semiochemical in crop protection.

650. Sullivan, Thomas P.; Nordstrom, Lance O.; Sullivan, Druscilla S. 1985. The use of predator odors as repellents to reduce feeding damage by herbivores. I. Snowshoe hares (*Lepus americanus*). *Journal of Chemical Ecology* 11(7): 903-919.

The effectiveness of predator odors (fecal, urine, and anal scent gland) in suppressing feeding damage by snowshoe hares was investigated in pen bioassays at the University of British Columbia Research Forest. A total of 28 bioassay trials tested the effects of these odors on hare consumption of willow browse and coniferous seedlings. Lynx and bobcat feces, weasel anal gland secretion, and lynx, bobcat, wolf, coyote, fox, and wolverine urines resulted in the most effective suppression of hare feeding damage. Novel odors of domestic dog urine and 2-methylbutyric acid did not reduce feeding. A field bioassay with lodgepole pine seedlings and weasel scent provided significant results comparable to the pen bioassays. The short-term (up to 7 days) effectiveness of these treatments was more likely due to evaporative loss of the active repellent components of a given odor than habituation of hares to the stimulus. When encapsulated in weather-proof controlled release devices, these odors could provide long-term protection for forestry

651. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. Barking damage by snowshoe hares and red squirrels in lodgepole pine stands in central British Columbia. *Canadian Journal of Forest Research* 12(2): 443-448.

Barking damage by snowshoe hares and red squirrels is common in overstocked stands of juvenile lodgepole pine in central British Columbia. Average proportion of potential crop trees damaged by hares was 30% and by squirrels was 37.7%. Most hare feeding injuries occurred in heavily stocked (>20,000 stems/ha) stands, whereas squirrel damage was most common in less dense stands. Both animal species damaged trees in thinned stands, and hence may have a serious impact on stocking control programs in lodgepole pine.

652. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. Influence of fertilization on feeding attacks to lodgepole pine by snowshoe hares and red squirrels. *Forestry Chronicle* 58(6): 263-266.

Lodgepole pine shows favorable growth and yield responses to spacing and potentially to fertilization but is susceptible to feeding injuries by snowshoe hares and red squirrels. This study was designed to determine the incidence of animal damage to crop trees in a fertilized, spaced stand, compared with those in spaced only and

control (unspaced) stands. There was little variation in the percentage of crop trees (range 53.6% to 63.3%) damaged by hares in the three stands. Hares removed an average of 92.2 cubic cm of bark and associated vascular tissues per attack from fertilized stems compared with 46.2 cubic cm in the spaced only stand. This latter value was nearly double that recorded in the control stand (27.4 cubic cm). Squirrels damaged more fertilized trees (38.9%) than trees in the spaced (30.9%) or control (14.3%) stands. Squirrels removed the largest average amount of bark (66.9 cubic cm) per attack from fertilized stems with little difference between spaced (41.6 cubic cm) and control (42.3 cubic cm) stands. Hares and squirrels clearly prefer to feed on fertilized lodgepole pine stems over those in nonfertilized or unmanaged stands.

653. Sullivan, Thomas P.; Sullivan, Druscilla S. 1986. Impact of feeding damage by snowshoe hares on growth rates of juvenile lodgepole pine in central British Columbia. *Canadian Journal of Forest Research* 16(5): 1145-1149.

This study assessed the impact of snowshoe hare feeding injuries on diameter and height growth of juvenile lodgepole pine. Five-year growth increments of undamaged and damaged crop trees in control (unspaced) and spaced stands, 20 km east of Prince George, British Columbia, were compared by using analysis of variance. Semigirdling (sublethal) damage clearly suppressed diameter growth of small-diameter trees but had little effect on larger stems. Height increment was significantly reduced by semigirdling in all diameter classes except for the 61-80 mm class in the control. Surface area or amount of bark and vascular tissue removed had little effect on growth increments in the spaced stand. The recommendation to delay spacing until the average tree diameter is greater than 60 mm to avoid snowshoe hare damage is further supported for diameter but not necessarily for height growth.

654. Walters, J.; Soos, J. 1961. The relative efficiency of three hare-repellents in protecting Douglas-fir seedlings. *Forestry Chronicle* 37(1): 22-28.

Three repellents were tested on Douglas-fir plantations in the University of British Columbia Research Forest. The chemicals tested were (1) TN 2500—5%; a proprietary compound made by Panogen Inc., Ringwood, Illinois; (2) nicotine-asphalt emulsion, 3.63% nicotine; (3) tetramethylthiuram disulphide (TMTD)—asphalt emulsion, 7.27% active ingredient. The three repellents were of approximately equal efficiency in depressing the level of clipping, although the percentage decrease in seedlings clipped was greatest for seedlings treated with TMTD and least for seedlings treated with nicotine. The repellents provided complete protection only to that portion of the seedling covered by repellent. New growth, appearing after the repellent was applied, was clipped with increasing frequency as the repellent became weathered.

655. King, John A., ed. 1968. *Biology of Peromyscus* (Rodentia). Spec. Publ. 2. [Place of publication unknown]: American Society of Mammalogy. 593 p.

Seed-Eating Mammals

General

Includes information on palaeontology, classification, speciation, habitats and distribution, anatomy, ontogeny, parasites, endocrinology, genetics, home range and travels, population dynamics, behavior patterns, psychology, and activity of the genus.

656. Tomich, P. Quentin. 1982. Ground squirrels (*Spermophilus beecheyi* and allies). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 192-208.

Reviews distribution, description, annual cycle, reproduction, ecology, food habits, trapping and handling methods, captivity and breeding, economic status, and management of various species of *Spermophilus* and *Ammospermophilus*.

Ecology

657. Andrusiak, Lorraine A.; Harestad, Alton S. 1989. Feeding behaviour and distance from burrows of Columbian ground squirrels. Canadian Journal of Zoology 67(2): 381-384.

Percentage of cover of clover, a highly preferred forage of Columbian ground squirrels (*Spermophilus columbianus*), increased with increasing distance from burrows. Ground squirrels feeding far from burrows consumed more clover, and during the first 10 minutes of a feeding bout fed at greater rates than did ground squirrels feeding near burrows. Body weights did not differ between feeding locations. Because abundance of preferred forage as well as risk of predation increases with increasing distance from burrows, the feeding behavior of ground squirrels is mediated by time budgeting and differs with distance from burrows.

658. Anthony, R.G.; Forsman, E.D.; Green, G.A. [and others]. 1987. Small mammal populations in riparian zones of different-aged coniferous forests. Murrelet 68(3): 94-102.

Small-mammal populations inhabiting low-order riparian zones in three age classes of forests were compared and species composition and capture rates for streamside versus riparian fringe transects was contrasted. Small mammals were snap-trapped in young, mature, and old-growth forests. Deer mice were the most abundant species and made up 76 and 83% of the total captures during spring and summer, respectively. Total small-mammal abundance was greater in old-growth forests than in young and mature forests. *Microtus oregoni*, *Phenacomys albipes*, *Neotoma cinerea*, *Sorex palustris*, *S. monticolus*, and *Neurotrichus gibbsii* were captured only in old growth or mature forests. Six species of insectivorous mammals including five species of shrews were captured, which exemplifies the importance of riparian zones for this group. More species but fewer individuals were captured on the streamside transects in comparison to the riparian fringe transects. Additional studies with more intensive trapping designs are needed to define the specific habitat relationships of *Sorex palustris*, *S. bendirii*, *Phenacomys albipes*, *Neurotrichus gibbsii*, and *Microtus richardsoni*.

659. Anthony, Robert G.; Morrison, Michael L. 1985. Influence of glyphosate herbicide on small-mammal populations in western Oregon. Northwest Science 59(3): 159-168.

The effect of glyphosate application on vegetation and small-mammal populations in the Coast Range of western Oregon was investigated. Diversity, abundance, and biomass of small-mammal populations increased 1 year postspray on glyphosate-treated sites as compared to control sites. These changes were ephemeral, and the

above parameters were similar to prespray values 2 years after glyphosate application. The changes in diversity, abundance, and biomass were primarily a result of the increase in numbers of *Microtus oregoni* after an increase in grass and forb cover on treated grids 1 year postspray. The temporary effects of glyphosate treatment on vegetation had no detrimental effects on small-mammal populations.

660. Black, H.C.; Hooven, E.F. 1974. Response of small mammal communities to habitat changes in western Oregon. In: Black, Hugh C., ed. Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium; 1973 September 11-12; Corvallis, OR. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University: 177-186.

Habitat changes after wildfire, clearcutting, or herbicide application profoundly affect species composition of small-mammal communities. Small mammals responded to habitat changes after disturbances according to their habitat preferences. Shrews, voles, and Townsend's chipmunks were few or absent on Douglas-fir clearcuts after wildfire, but shrews and voles were abundant in early successional stages of unburned Douglas-fir clearcuttings. Red-backed voles rarely were found on clearcuts, even in the shrub stage of succession. Golden-mantled ground squirrels and Great Basin pocket mice were abundant on clearcuts in the mixed conifer region, although they were not found on uncut stands. After herbicide treatments of Douglas-fir clearcuts, vagrant shrews, Pacific jumping mice, and Oregon voles were less abundant on treated areas, but small-mammal habitat recovered markedly within 2 years after herbicide treatment of clearcuts in the grass-shrub stage of succession. In southwestern Oregon, small-mammal communities were less affected by herbicide-induced habitat changes because microtines and other species associated with grassy habitats were only minor components of the community. On areas with complete vegetation control, however, abundance of pocket gophers was reduced greatly 1 year after treatment.

661. Borrecco, John E.; Black, Hugh C.; Hooven, Edward F. 1979. Response of small mammals to herbicide-induced habitat changes. *Northwest Science* 53(2): 97-106.

In studies in western Oregon, half of each of three areas that had been logged and burned 8-12 years earlier were sprayed in spring 1970-71 with a combination of atrazine and 2,4-D. Dalapon and Silvex were included in 1970. The herbicides reduced the competition from other vegetation and provided a more favorable environment for survival and growth of Douglas-fir seedlings. The reduction in ground cover and numbers of species of grasses and herbs led to increases in numbers of *Peromyscus maniculatus* and *Sorex trowbridgii* and reductions in numbers of *S. vagrans*, *Microtus oregoni*, and *Zapus trinotatus*.

662. Borrecco, John Edward. 1972. The response of animals to herbicide-induced habitat changes. Corvallis, OR: Oregon State University. 92 p. M.S. thesis.

The objectives of this investigation were to examine the changes in vegetation resulting from application of herbicides, to study the effects of these vegetative changes on the abundance and composition of small-mammal populations, and to examine deer usage of treated and untreated plots. On three areas in Oregon, half of each

was treated with a combination of herbicides designed to control grasses and forbs without injuring Douglas-fir. Small mammals primarily associated with grass or meadow habitats decreased in abundance. The Oregon vole was the species most affected by the reduction in grassy vegetation. Species that find optimum habitat in brushy areas increased in abundance on treated plots. The deer mouse was the most common species to demonstrate a positive response on treated plots. Deer activity, as measured by pellet-group counts, was greater on treated plots during the growing seasons. No significant differences were found in the occurrence of browsing as a result of herbicide-induced habitat changes. Browsing was influenced by season. Herbicide treatments improved deer habitat during the growing season without significantly increasing the browsing of Douglas-fir seedlings.

663. Broadbooks, Harold E. 1958. Life history and ecology of the chipmunk, *Eutamias amoenus*, in eastern Washington. Misc. Publ. 103. Ann Arbor, MI: Museum of Zoology, University of Michigan. 49 p.

This study of the chipmunk is based on 11 months of field work in the Cascade Range in Yakima County, Washington, in 1946 and 1947. The study plot (42 acres) was in open, ponderosa pine forest at an altitude of 3,800 feet. The breeding cycles is as follows: mating occurs in April; the young are born in late May and early June; they first appear aboveground in June but do not reach breeding age until the following spring. There is only one litter per year. Two litters born in captivity consisted of four and six young. Seven females averaged 5.8 embryos each. About 84% of the adult females live-trapped in the spring were pregnant or lactating. The sex ratio was 50:50. Average weight at birth was 2.65 g. The daily increase in weight was 0.47 g, with a peak reached in about 90 days. Fourteen dens, all tunnels in the ground, were examined. The average length was 27 inches. The nest was at the end of the tunnel in a room about 6.5 inches wide. Favorite nest materials were grasses, pappi, and cotton from traps, and occasionally lichens and feathers. Winter food stores consisted mostly of seeds placed in the bottom of the nest. By mid-November most chipmunks are underground. During the winter, chipmunks probably alternate between sleeping and feeding from their food stores. Thirteen percent of the chipmunks caught in a retrapping check in 1950 were individuals marked in 1946 or 1947. Several of them were at least 5 years and 2 months old.

664. Broadbooks, Harold E. 1970. Home ranges and territorial behavior of the yellow-pine chipmunk, *Eutamias amoenus*. Journal of Mammalogy 51(2): 310-326.

About 600 chipmunks were live-trapped and observed on a study area of 42 acres of ponderosa pine forest in central Washington. Observation of dyed chipmunks showed that home ranges revealed by live-trapping are reasonably accurate. Evidence that male yellow-pine chipmunks are more active and have considerably larger home ranges than do females is consistent with studies of other mammals. Annual home ranges of adult males averaged 947 by 534 feet and covered 4.07 acres; those of adult females averaged 686 by 368 feet and had a mean area of 2.32 acres. Some ranges were elongated despite a relatively uniform habitat. Adult breeding females had an average of 6.4 neighboring females overlapping their home ranges, the mean area of overlap being 21.7% and number of captures 25.8%. Most chipmunks that were recaptured in the second and fifth years occupied their original home ranges. In 43 homing tests, 88% (15 of 17) of the chipmunks returned from points 430 to 1,500

feet from home; 57% (12 of 21) from half a mile, and 25% (1 of 4) from 1 mile. Seventy-seven percent of the males but only 25% of the females returned from half a mile. A shift of home range was accomplished by 7.8% of the females and 11.9% of the males recaptured the second year. Twenty-eight percent (13 of 46) of the young animals caught in June and July were recaptured in the autumn. Evidence from spacing of chipmunks and from observations of aggressive behavior near the den indicated that they are territorial.

665. Broadbooks, Harold E. 1970. Populations of the yellow-pine chipmunk, *Eutamias amoenus*. *American Midland Naturalist* 83(2): 472-488.

A population of about 600 yellow-pine chipmunks in the Cascade Range in central Washington was investigated for approximately 12 months in 3 different years. There was only one litter in May or June per year. From a base level of 1.54 per acre in May, the population rose with emergence of young in June to a peak of 3.13 per acre in July and August and then gradually declined to 1.64 per acre by September and October. By mid-November virtually all chipmunks were in winter burrows. New unmarked animals (most of them young that began appearing in early June) reached a high in July of about 35% of the population. By October 50% of the population were young of the year. By far the safest time for chipmunks was the 5-month hibernation period. Survival was nearly 100%. Highest mortality was among young chipmunks in their first weeks aboveground. One-year survival of July, August, and September groups averaged 29%. Ten percent of the chipmunks caught in mid-August 1947 were retaken in 1950.

666. Broadbooks, Harold Eugene. 1950. Life history, behavior and populations of the western chipmunk, *Eutamias amoenus affinis* (Allen). Ann Arbor, MI: University of Michigan. 317 p. Ph.D. dissertation.

This study was based on 11 months of field work in the Cascade Range in Yakima County, Washington, during the summers of 1946 and 1947. From live-trapping, home range size for females was 2.25 acres in 1946 and 2.36 in 1947; that of males was 3.80 in 1947. The average number of animals was 3.35 per acre in 1947. The seasonal cycle of populations is characterized by low spring numbers, followed by a rise to a peak in July or August and a gradual decline to zero in the fall when hibernation begins. The breeding cycle is as follows: copulation probably occurs in April, the young are born in late May and early June, first appear aboveground in June, but do not breed until the following spring. There is only one litter per year. Excavations of burrows showed that they averaged 27 inches long, with only one entrance to each borrow. Favorite nest materials were grasses, pappi, lichens, cotton from traps, and feathers. Winter stores consisted mostly of seeds of *Carex*, *Collinsia*, *Phacelia*, and *Pseudostuga*. Foods eaten most often were *Achillea millefolium*, *Cirsium lanceolatum*, *Deschampsia elongata*, *Gilia gracilis*, *Penstemon*, *Phacelia heterophylla*, *Polygonum*, *Pinus ponderosa*, and basidiomycetous tubers. Most chipmunks were underground by mid-November; during the winter, they probably alternate between sleeping and feeding from their food stores. Weights of 60 gm or more usually indicated pregnancy. Adult, nongravid females averaged about 50.0 gm, and adult males averaged 47.4 gm. Females had significantly greater weights than did males of comparable age.

667. Cameron, Duncan M., Jr. 1967. Gestation period of the golden-mantled ground squirrel. *Journal of Mammalogy* 48(3): 492-493.

In an experiment on a captive female, it was determined that maximum gestation period was 28 days, 5 hours, and minimum gestation was 26 days, 2 hours. A gestation period of 27-28 days is consistent with other investigations.

668. Cameron, Duncan MacLean, Jr. 1969. The population biology and interactions of two sciurid rodents (*Eutamias amoenus* and *Citellus lateralis*) in northeastern California. Davis, CA: University of California. 500 p. Ph.D. dissertation.

Population dynamics, movement phenomena, hibernation patterns, and interactions of the golden-mantled ground squirrel and the yellow-pine chipmunk have been examined in a ponderosa pine/Jeffrey pine forest community in northeastern California. Other workers have concluded that the two species occupy similar niches and compete very little, and therefore, coexist. Other studies of competition in mammals show that most often in a competitive relationship the superior competitor occupies a narrower niche. This study shows that there are niche differences, albeit great similarities as well, and that the golden-mantled ground squirrel occupies the narrower niche. An analysis of interaction showed that there was less interspecific interaction than intraspecific interaction when food resources were low. Golden-mantled ground squirrels were the better competitor on an historical basis, the occupance of a narrower niche, and by the indication that its numbers were maintained in the face of limited food resources, whereas the numbers of chipmunks were not maintained, particularly in the case of juvenile chipmunks where the rate of survival beyond weaning was very low. Apparently juvenile chipmunks were preyed upon by golden-mantled ground squirrels during the period of limited resources.

669. Dalquest, Walter W. 1941. Ecological relationships of four small mammals in western Washington. *Journal of Mammalogy* 22(2): 170-173.

Observations over a period of 4 years in a small damp ravine near Seattle, Washington, showed a definite relationship between the populations of the deer mouse, the shrew-mole (*Neurotrichus gibbsii*), the wandering shrew, and the trowbridge shrew. When the deer mouse population was removed, the insectivore population increased greatly. The complete removal of the deer mouse and the removal of the majority of the *Sorex vagrans* populations resulted in an increase in the *Neurotrichus* population. When *S. vagrans* occurs in a ravine, *S. trowbridgii* is rare there; when *S. trowbridgii* is common in a ravine, *S. vagrans* is usually absent. These two species compete, and *S. vagrans* dominates in damp areas. When *S. vagrans* was removed completely from the ravine just before the breeding season of *S. trowbridgii*, *S. trowbridgii* invaded the ravine and became common. It may be possible to regulate at will, through selective trapping, populations of small mammals.

670. Dunigan, P.F.X., Jr.; Lei, W.; Rickard, W.H. 1980. Pocket mouse population response to winter precipitation and drought. *Northwest Science* 54(4): 289-295.

A relationship between autumn-winter precipitation and population of *Perognathus parvus* in the arid shrub-steppe of south-central Washington is demonstrated. Captures are compared to phytomass and monthly precipitation for a drought year and an average year.

671. Elliott, Charles L.; Flinders, Jerran T. 1979. Seasonal home range of a colony of Columbian ground squirrels (*Spermophilus columbianus*) in the Idaho Primitive Area. *Journal of the Idaho Academy of Science* 15(2): 53-55.

Mean seasonal home range for a colony of Columbian ground squirrels was 1,532 square m. Density was 13 adult squirrels per ha.

672. Elliott, Charles L.; Flinders, Jerran T. 1980. Seasonal activity pattern of Columbian ground squirrels (*Spermophilus columbianus*) in the Idaho Primitive Area. *Great Basin Naturalist* 40(2): 175-177.

Data were gathered concerning the seasonal activity pattern of a population of Columbian ground squirrels in the Idaho Primitive Area. Adult females were significantly more active in June of all years than were adult males. A relationship between ground squirrel activity and temperature is postulated in which the squirrels alter their activity so as to avoid high temperatures and possible heat stress.

673. Elliott, Charles L.; Flinders, Jerran T. 1985. Food habits of the Columbian ground squirrel, *Spermophilus columbianus*, in south-central Idaho. *Canadian Field-Naturalist* 99(3): 327-330.

The food habits of two colonies of Columbian ground squirrels in the River of No Return Wilderness Area, Idaho, were determined. Clover (*Trifolium* spp.), alpine timothy (*Phleum alpinum*), and yarrow (*Achillea millefolium*) were the important species at the mountain meadow study site. Balsamorhiza (*Balsamorhiza sagittata*), blue-bunch wheatgrass (*Agropyron spicatum*), and silky lupine (*Lupinus sericeus*) were the major species consumed on the dry south-slope site.

674. Feldhamer, George A. 1979. Home range relationships of three rodent species in southeast Oregon. *Murrelet* 60(2): 50-57.

The purpose of this paper is to present home range values of least chipmunks (*Eutamias minimus*), deer mice (*Peromyscus maniculatus*), and Great Basin pocket mice (*Perognathus parvus*) in two shrub habitats of the high desert area of southeast Oregon and the effects of several habitat factors on the home ranges of these species. Least chipmunks had the largest mean home ranges of the three species. Deer mice generally had larger home ranges than did Great Basin pocket mice. Variation in the size of home ranges of the three species was related to differences index, habitat factors, reproductive condition, or population density.

675. Fordham, R.A. 1971. Field populations of deermice with supplemental food. *Ecology* 52(1): 138-146.

In a study in British Columbia from winter through fall, excess artificial food was provided in some areas with deer mice but not in others. Population size and production of young increased, and adult but not juvenile survival improved slightly with additional food; hence the hypothesis that no differences in breeding and survival would exist between experimental and control areas was rejected in part. The numbers of adult males in experimental and control situations were similar, suggesting that the male portion of the breeding population may be held relatively constant during breeding by behavioral mechanisms. Attention is drawn to the different numerical responses of males and females and the possibility of different regulating mechanisms for the sexes.

676. Gashwiler, Jay S. 1959. Small mammal study in west-central Oregon. *Journal of Mammalogy* 40(1): 128-139.

The estimated deer mouse population ranged from 0.0 to 2.5 animals per acre in old-growth Douglas-fir. There was an increase in the population after felling and logging. Burning caused many *Peromyscus* to go to the nearest green timber; after the fire they returned to their homes. Shortly after the fire, the density was 2 to 3 times that of the virgin timber population. The following year the deer mouse population was about twice its virgin timber level. *Peromyscus* regularly traveled between the clear-cut and the timber—some individuals ranged about 1/4 mile. It was estimated there were from 1.4 to 3.8 chipmunks per acre in the virgin timber. Logging caused a modest reduction in abundance on the experimental area. The first year after burning, it was estimated there were 0.5 animals per acre. Many chipmunks moved to the forest when the cutover was burned. They apparently ranged from the timber onto the burn the first season after the fire but did not reside there. Oregon voles, short-tailed weasels, Trowbridge shrews, vagrant shrews, bushy-tailed woodrat, and pika were captured on the clearcut after logging. Chickarees, flying squirrels, and snowshoe hares were neither captured nor observed on the area after logging.

677. Gashwiler, Jay S. 1965. Longevity and home range of a Townsend chipmunk. *Journal of Mammalogy* 46(4): 693.

In a study on the H.J. Andrews Experimental Forest in western Oregon, a chipmunk was captured 59 times. When he was first captured, he was estimated to be a juvenile approximately 3 months old. He was last captured nearly 7 years later and appeared to be in good health. From the location of the traps, it is estimated that the home range for the chipmunk was 1.7 acres for the life of the animal.

678. Gashwiler, Jay S. 1965. Tree seed abundance vs. deer mouse populations in Douglas-fir clearcuts. In: *Proceedings, Society of American Foresters meeting, 1965; 1965 October 24-28; Detroit, MI.* Washington, DC: Society of American Foresters: 219-222.

A comparison of the annual seed crop with deer mouse populations on the H.J. Andrews Experimental Forest over an 11-year period strongly suggests a

relationship between seed abundance and the following fall's deer mouse populations. This paper presents the data and interpretations.

679. Gashwiler, Jay S. 1969. Deer mouse repopulation of a poisoned Douglas-fir clearcut. *Journal of Forestry* 67(7): 494-497.

Repopulation by deer mice after baiting a clearcut with Compound 1080 was studied on the Mount Hood National Forest, Oregon, at an elevation of 2,000 feet. The poisoned clearcut and a similar untreated check clearcut nearby were live-trapped from November 1952 to December 1953. The December 1, 1952, poisoning appeared to be 100% effective on the resident deer mouse population. However, although the bait was effective at least 38 days, animals were infiltrating the area 15 to 19 days after baiting. Within 5 to 7 months the population had reached about the same relationship with the check area as it had before baiting. Dispersal was responsible for most of the December and January repopulation; subadults appeared to be the most active colonizers. The first immature mouse was trapped on the poisoned area in February. Postmortem examination revealed breeding deer mice in the vicinity every month except December 1953. The data suggested that more breeding occurred on the poisoned than on the check area.

680. Gashwiler, Jay S. 1970. Plant and animal changes on a clearcut in west-central Oregon. *Ecology* 51(6): 1018-1026.

Plant composition and coverage and small-mammal populations were compared in virgin forest and clearcut areas from April 1954 to October 1956. Changes in ground-cover vegetation were modest on the forest but marked on the clearcut. Ground plant coverage was less than 23% in the virgin forest; one year after the clearcut was burned, the cover was 2%; and by 10 years it was above 53%. Woody plant coverage was slightly more abundant the first 2 years after burning. Herbaceous species then became dominant for 3 years, after which woody plants gradually gained dominance. Deer mice increased on the clearcut soon after the burn. The populations varied from an estimated 0.9 to 12.8 animals per acre and fluctuated widely and irregularly. Townsend's chipmunk, Oregon vole, and snowshoe hare populations also increased on the area at different periods after the burn. Trowbridge's shrews, vargrant shrews, and ermine were present on both areas in relatively low numbers. Red-back voles, Douglas squirrels, and northern flying squirrels were not found on the clearcut. California ground squirrels migrated to the clearcut and established a modest population. Richardson's voles, jumping mice, bushy-tailed woodrats, and a pika were visitors.

681. Gashwiler, Jay S. 1971. Deer mouse movement in forest habitat. *Northwest Science* 45(3): 163-170.

Deer mouse movement in forest habitat is of importance in direct seeding operations. *Peromyscus* soon occupy underpopulated habitat, but specific data on their movement are scantily documented. In this study, on a 48-acre clearcut and adjacent forest, deer mice were live-trapped, marked, and recaptured. Twenty-four percent of the deer mice captured on the clearcut were also recaptured the same month in the timber. The greatest number (52%) was caught immediately after the clearcut was

burned; no monthly recapture pattern was apparent. Food resources and population densities may have influenced the mobility of deer mice. The number of animals recaptured per trap and the average travel data indicated that most of the deer mice traveled from about 450 to 700 feet between the clearcut and the timber. Forest deer mice living within this distance of clearcuts probably cause much of the repopulation problem in forest regeneration by direct seeding.

682. Gashwiler, Jay S. 1976. Biology of Townsend's chipmunk in western Oregon. *Murrelet* 57(2): 26-31.

A total of 215 Townsend's chipmunks was collected in western Oregon from 1952 to 1964. Adult males were caught aboveground from March to October and females from April to October. Juveniles were captured from July to December and were presumed active 1-2 months later than the adults. Fecund males were found from March to July and fecund females from April to September. Adult males had scrotal testes from March to July, and females lactated from June to September. Litter sizes ranged from 2-6, averaging 4.5 for corpora lutea, 4.2 for placental scars, and 4.0 for embryos. The data suggested only one litter per female per year. Adult females were significantly larger than adult males in all measurements taken. By October, head and body lengths of juvenile males were 94% and juvenile females 97% of the same measurement of the average adult male and female. The sex ratio for all animals captured was 51% males.

683. Gashwiler, Jay S. 1976. Notes on reproduction of Trowbridge shrew in western Oregon. *Murrelet* 57(3): 58-62.

Reproductive data were obtained from 463 carcasses of Trowbridge shrew trapped year-round in western Oregon from 1953 to 1965. Males comprised 46% of the total sample and formed the bulk from January to March each year. Males also were slightly more abundant than females in November samples. The fecundity period of both sexes extended from February to October. Breeding of females was 97% complete by the end of June. Corpora lutea, placental scars, and embryos per female ranged in number from 3 to 5 and averaged 3.94, 3.77, and 3.89, respectively. Post-partum pregnancies were found in 12% of the fecund females; the highest percentage occurred in the early part of the breeding season. Breeding shrews had an average weight of 5.02 g with the females heavier than the males, although not significantly so. Nonbreeding shrews had an average weight of 3.85 g, with the males being significantly heavier than the females.

684. Gashwiler, Jay S. 1979. Deer mouse reproduction and its relationship to the tree seed crop. *American Midland Naturalist* 102(1): 95-104.

Deer mice averaged 57% males in a sample of 3,833 collected in the Douglas-fir belt in western Oregon from 1952 to 1966. The percentage of mice captured in autumn and recaptured in spring was significantly greater in good (2.66 kg/ha or more) than in poor (0.45 kg/ha or less) Douglas-fir and western hemlock seed years. The autumn-spring population estimates for good and poor seed years, however, were not significantly different, but by the following autumn the good seed years had

significantly greater populations. There was a significantly larger number of young female deer mice (and by inference, male) deer mice in the population during the good seed years. On a seed-year basis, the average percentage of pregnancies was 2.9% greater for good years but was not significantly different. Average litter size was not significantly affected by the size of the seed fall. Calculated average number of litters per year was 2.9 for good seed years and 2.5 for poor, a significant difference. The positive factors contributed variously to higher populations during and following a good seed crop, at least by the following autumn.

685. Gordon, Kenneth. 1943. The natural history and behavior of the western chipmunk and the mantled ground squirrel. Studies in Zool. 5. Corvallis, OR: Oregon State University, Oregon State Monographs. 104 p.

This monograph is based on field research conducted by the author from 1935 through 1942 several sites, primarily in Oregon. Because of the similarity of their habits, the report does not differentiate between the various species and subspecies of *Eutamias*. Because the mantled ground squirrel is frequently found together in the same habitat with chipmunks, it is included in the discussion. Taxonomy, description, distribution, habitat, movements, food and water, reproduction, environmental factors, community organization, population, and behavior are reviewed. Results of experiments in modifiable behavior are described in detail.

686. Gunther, Pamela M.; Horn, Brenda S.; Babb, Geoffrey D. 1983. Small mammal populations and food selection in relation to timber harvest practices in the western Cascade mountains. Northwest Science 57(1): 32-44.

Small mammals were snap-trapped in a mature conifer forest, unburned clearcuts, and a burned clearcut in the western Cascade Range in central Washington. The largest populations were in unburned clearcuts, and the smallest overall population was in the forest. *Sorex trowbridgii* was the most abundant insectivore caught. *Clethrionomys gapperi* was the most abundant rodent caught in most clearcuts, and its population was the largest of any species in the study area. Other species caught include *Sorex monticolus*, *Neurotrichus gibbsii*, *Eutamias townsendii*, *Glaucomys sabrinus*, *Peromyscus maniculatus*, *Microtus townsendii*, and *Zapus trinotatus*. Vegetation and percent cover were analyzed in the study area, and small mammal stomach contents of all nine animal species were examined. In the forest and burned clearcut, small mammals ate more invertebrates than any other food type. In unburned clearcuts, fungi and epiphytic lichens, especially *Alectoria sarmentosa*, and conifer seeds, were the major foods eaten by rodents.

687. Hall, Gary L. 1969. Habitat and food habits of *Eutamias minimus scrutator* in the semi-desert regions of central Washington. Ellensburg, WA: Central Washington State College. 60 p. M.S. thesis.

A food-habit study was conducted from March 1968 through July 1968 in the Badger Pocket quadrangle, Kittitas County, Washington. The major objective of the study was to relate food availability within the local habitat to the food habits and overall biology of the least chipmunk. A total of 23 plants were used as food items from a total of 62 known species in the habitat. Forbs, grasses, and arthropods were the

most preferred food types and comprised the greatest portion of the diet. *Agoseris glauca* was the major plant food item in the diet of the least chipmunk. Preference for this plant did not appear to be governed entirely by availability within the habitat. The diets of all chipmunks regardless of sex or age were similar. In this habitat, it appeared that the most obvious influences on chipmunk food preferences were related to the physiology of the reproductive cycle, availability, or water balance.

688. Halvorson, Curtis H. 1982. Rodent occurrence, habitat disturbance, and seed fall in a larch-fir forest. *Ecology* 63(2): 423-433.

Small-mammal population changes were measured for 5 years by live-trapping on broadcast burned western larch/Douglas-fir clearcuts and in uncut timber on a north and a south slope in western Montana. Four species comprised 96% of the 1,324 animals caught: deer mice 42%; red-backed voles 27%; red-tailed chipmunks 22%; and long-tailed voles 5%. Deer mice and chipmunks were common on clearcut and timber plots. The voles were associated with moist sites but showed local allopatry. The red-backed vole were present only under tree canopy, and the long-tailed vole was found only in absence of tree canopy. A hard-burn effect was to eliminate most of the organic mantle and all small mammals except deer mice. A light burn which left duff intact was associated with retention of species diversity. Deer mice increased sharply on all plots the first fall after a heavy conifer seed crop. From these pattern observations, it is theorized that red-backed voles may dominate deer mice, but a heavy seed crop can temporarily enhance competitive standing of deer mice. An open, xeric, pioneering situation (hard burn) was conducive to persistently high deer mouse populations. Clearcutting appeared to be the principal determinant of total population size, but burn intensity seemed to influence species composition.

689. Hawes, Myrnl L. 1977. Home range, territoriality, and ecological separation in sympatric shrews, *Sorex vagrans* and *Sorex obscurus*. *Journal of Mammalogy* 58(3): 354-367.

Spatial and temporal analyses of home ranges of sympatric *Sorex vagrans* and *S. obscurus* are made by using an elliptical model. The occurrence of both intra-specific and interspecific territoriality is analyzed and discussed in context of competition and habitat preference. In both species, individual home range size increases significantly with the onset of reproductive activity, with males enlarging their home ranges to a greater extent than do females. Home range location tends to remain stationary throughout life, particularly in females. A territorial system is established among nonbreeding animals during their first summer but breaks down with the onset of reproductive activity the following year. The establishment of territories early in life ensures successful individuals sufficient food during the limiting winter months and acts as a density regulation mechanism at the population level.

690. Hooven, E.F.; Hoyer, R.F.; Storm, R.M. 1975. Notes on the vagrant shrew, *Sorex vagrans*, in the Willamette Valley of western Oregon. *Northwest Science* 49(3): 163-173.

Sorex vagrans is one of the commonest small mammals in the riparian zones of the Willamette Valley. Its habitat requirements are best met in heavily grassed, meadow-

like situations, where it is associated often with *Microtus canicaudus* and *M. townsendii*. Sexual maturation for the male vagrant shrew occurs in late January, and pregnant females were recorded in February. Two main reproductive periods occur in spring and fall. Postpartum pregnancies were noted in adult females, and 20% of the young of the year become sexually mature and reproductive by midsummer. Mean size of litter is six. The young weigh about 0.35 gm at birth, reach a top weight of 4 to 5 gm at 19 days, open their eyes at 21 days, are weaned at 24 to 25 days, and probably disperse at 4 to 5 weeks of age. Adult males are heavier than adult females; immature individuals are lighter, but only slightly smaller, than adults. The vagrant shrew eats about 8 gm of food per day, normally small invertebrates such as insects, larvae, and earthworms, plus some plant material. Principal known predators are the rubber boa, owls, and possibly garter snakes.

691. Hooven, Edward F. 1958. Deer mouse and reforestation in the Tillamook Burn. Res. Note 37. Corvallis, OR: Oregon Forest Lands Research Center. 31 p.

The white-footed deer mouse has an enormous capacity of coniferous tree seed, and this characteristic presents a serious problem in reforestation by natural or artificial seeding. The purpose of this study was to add information on the habits of the deer mouse so as to better cope with the problems it represents. Observations were taken on population levels and fluctuation throughout the year, home range, life span, and composition of the small-mammal community of the same area.

692. Hooven, Edward F. 1969. The influence of forest succession on populations of small animals in western Oregon. In: Black, Hugh C., ed. Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 30-34.

Reviews the influence on populations of small animals of logging, wildfire, and other factors that create abrupt vegetational changes. Studies at two locations in western Oregon demonstrated marked changes in composition and abundance of populations of small mammals after logging and wildfire. Small mammals were more abundant in a recently logged area than in a mature stand of Douglas-fir. Wildfire selectively reduced populations of small mammals, but recovery, particularly of deer mice, was rapid. This recovery primarily resulted from a reinvasion by the animals of habitat made favorable by the fire. The succession of important species of small mammals and seed-eating birds is related to vegetative succession and other changes in habitat.

693. Hooven, Edward F. 1973. Effects of vegetational changes on small forest mammals. In: Hermann, Richard K.; Lavender, Denis P., eds. Even-age management; Proceedings of a symposium; 1972 August 1; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 75-97.

Certain physical and biotic changes that occur relative to clearcutting can affect small-mammal populations. Soil moisture and soil temperature may increase for the first few years but decrease as revegetation occurs. These factors affect the small-mammal populations through their influence on food availability, shelter, and habitat. Although habitat preferences were readily observable by changes in species density,

most of the small mammals were found on all units. Different small-mammal populations result from different cutting systems, but regardless of the treatment, the small mammals exert an influence on regeneration whether by seed or seedlings. After clearcutting, regardless of the change of species, composition, and densities, the small-mammal biomass remains comparable to that of the uncut forest and exerts the same detrimental effect upon regeneration.

694. Hooven, Edward F. 1976. Changes in small-mammal populations related to abundance of Douglas-fir seed. Res. Note 57. Corvallis, OR: Oregon State University, School of Forestry, Forest Research Laboratory. 2 p.

Small-mammal populations were observed on study plots near the South Fork of the McKenzie River, Lane County, Oregon, from 1965 through 1975. Generally, a direct relation appeared between moderate-to-good cone crops and the high populations of small mammals that appeared the next year. A total of 21 species were caught overall during the 11 years of observations, but six species comprised 92% of all individuals caught: shrews (*Sorex trowbridgii*, *S. vagrans*), chipmunk (*Eutamias townsendii*), deer mouse (*Peromyscus maniculatus*, Oregon creeping vole (*Microtus oregoni*), and jumping mouse (*Zapus trinotatus*). Douglas-fir seed is only a small part of the diet of shrews, but the other species eat it more readily, and chipmunks have a tendency to cache the seeds. Because of the sharp increase of animals the summer after a good Douglas-fir cone crop, any control attempts would be quickly nullified by immigrating seedeaters from surrounding areas.

695. Hooven, Edward F.; Black, Hugh C. 1976. Effects of some clearcutting practices on small-mammal populations in western Oregon. Northwest Science 50(4): 189-208.

Changes in small-mammal populations and vegetation on two clearcuttings and one uncut stand of 125-year-old Douglas-fir in the foothills of the Cascade Range in western Oregon were noted from 1964 to 1970. Mark-release-recapture methods were followed each summer on a monthly basis. In all, more than 3,630 small mammals of 23 species were caught during 3 years of live-trapping from 1968 to 1970. Five species comprised more than 90% of the total catch. Logging and controlled slash burning profoundly affected habitats occupied by small mammals. Rapid changes in plant abundance occurred in the unburned unit, and vegetative recovery was dominated by herbaceous annuals 2 years after clearcutting. Shrews and chipmunks were affected adversely by logging. Conversely, populations of deer mice and Oregon creeping voles were affected favorably by both logging and slash burning and increased in abundance after treatment on both clearcuttings.

696. Hooven, Edward Frank. 1958. The relationship of the white-footed deer mouse to reforestation by direct seeding in the Tillamook Burn. Corvallis, OR: Oregon State College. 72 p. M.S. thesis.

The white-footed deer mouse, *Peromyscus maniculatus rubidus*, destroys more coniferous tree seed than any other small mammal in western Oregon. It has long been recognized that deer mice have a considerable influence on the restocking of forest lands, by natural or artificial seeding, but very little information is available

concerning the habits of the deer mouse. The purpose of this study is to add to the available information so that those concerned with reforestation may better cope with the problems this rodent presents. This report seeks answers to questions concerning population fluctuations, home range, and life span of the white-footed deer mouse.

697. Hooven, Edward Frank. 1972. Effects of clearcutting a Douglas-fir stand upon small animal populations in western Oregon. Corvallis, OR: Oregon State University. 202 p. Ph.D. dissertation.

An ecological study of small forest mammals was conducted from 1964 to 1970 in the west-central Cascade Range of Oregon. The objectives were to obtain chronological information relative to the effects of current logging practices on vegetational succession and small-mammal populations. The study areas were composed of a 125-year-old timbered control unit, a clearcut nonburned unit, and a clearcut slash-burned unit. Density and distribution of the small mammals were determined by live-trapping and release of marked animals. Reproductive information of some species was noted. Home range areas was computed for the more numerous species of rodents. More than 4,530 individual small mammals of 23 species were marked on the three areas during the 6 years of the study. Over 90% of the total animals caught consisted of five species: *Sorex* spp., *Eutamias townsendii*, *Peromyscus maniculatus*, and *Microtus oregoni*. The small-mammal densities varied from year to year. They were comparable between units on a monthly basis except for the unburned clearcut unit which differed for a year following logging. Shrews, abundant in the forest, were less on the unburned and sharply reduced on the slash-burned unit. Deer-mice, scarce in the closed forest, increased greatly in numbers on the clearcuts. Chipmunks were abundant in the forest, less on the slash-burned unit, and sharply reduced in numbers on the unburned unit. The results of this study suggest that more information is required relative to the diet of the small mammals, and the effects of vegetation manipulation should be examined.

698. Ingles, Lloyd G. 1960. A quantitative study on the activity of the dusky shrew (*Sorex vagrans obscurus*). *Ecology* 41(4): 656-660.

Analyzes the daily activity of the dusky shrew under summer conditions at 7,000 feet altitude in the Sierra Nevada Mountains, Fresno County, California. The daily activity rhythm is characterized by two major nocturnal peaks, a lower morning peak, and an afternoon depression. Light is the regulating factor responsible for changes in the 24-hour rhythm. Within the daily pattern is a "short-term rhythm" involving from 9 to 15 activity periods daily alternating with rest periods. This "short-term" activity is apparently caused by physiological requirements connected with nutrition.

699. Jameson, E.W., Jr. 1952. Food of deer mice, *Peromyscus maniculatus* and *P. boylei*, in the northern Sierra Nevada, California. *Journal of Mammalogy* 33(1): 50-60.

Peromyscus maniculatus and *P. boylei* were studied in Plumas County, California, on the western slope of the Sierra Nevada, at elevations of 3,500 to 5,000 feet, during 1949 and 1950. Percentages of seeds, fruits, arthropods, leaves, fungi, and miscellaneous food are listed for each species, by month, and from brushfields and from coniferous forests. Seeds from pine and Douglas-fir were important winter foods. In

both habitats, the mice ate a variety of arthropods. When deep snow covered the ground in brushfields, *P. maniculatus* climbed *Ceanothus cuneatus* and silktassel to browse on the leaves, but the mice seemed to take this food only under duress. In spring, seeds were consumed in smaller amounts, and in summer, the mice ate the seeds of both forbs and grasses. There is little question that deer mice dig up conifer seeds which have been placed by foresters in seed spots. Despite this trouble they cause to seed spots, they do a great good by destroying cutworms and other harmful insects. It remains for foresters to learn means for preventing rodents from robbing seed spots without hindering their destruction of insects.

700. Jameson, E.W., Jr. 1953. Reproduction of deer mice (*Peromyscus maniculatus* and *P. boylei*) in the Sierra Nevada, California. *Journal of Mammalogy* 34(1): 44-58.

Data taken from 1,546 *P. maniculatus* and 830 *P. boylei* trapped at various seasons in Plumas County, California, shows the similarities and differences in the reproduction of the two species. *Peromyscus boylei* are found almost exclusively in the brushfields, and *P. maniculatus* was sometimes common in both brushfields and coniferous forests. The two species were not equally abundant. Variations in population were noted in both species, but there was no suggestion of poor health, disease, or a loss of weight. Changes in numbers could be attributed solely to the observed varying rates of reproduction and may have been the result of a reproductive lull in late summer and autumn. A knowledge of rodent fluctuations might assist foresters in planning the best time to do direct seeding.

701. Jameson, E.W., Jr. 1955. Observations on the biology of *Sorex trowbridgei* in the Sierra Nevada, California. *Journal of Mammalogy* 36(3): 339-345.

Sorex trowbridgei is a common forest-dwelling shrew; it occurs sparingly in brushlands and cutovers. Arthropods comprise the bulk of its food; earthworms and planarians are sometimes eaten. The fall molt occurs from August to November but most often in October; a few adults acquire a second summer (brown) pelage in June, July, or August. The Trowbridge shrew is short-lived; adults disappear rapidly during May, June, and July. Breeding extends from February until early June, after which time, most of the remaining adults are in a nonbreeding condition. The mean number of young was five; extremes were one and six. Evidence indicates that postpartum pregnancies are rather frequent.

702. Jameson, E.W., Jr. 1965. Food consumption of hibernating and nonhibernating *Citellus lateralis*. *Journal of Mammalogy* 46(4): 634-640.

Captive golden-mantled ground squirrels from the central Sierra Nevada were maintained at 4 °C and 20 °C during the period of natural hibernation. Food intake was determined by recovery and analysis of scats. One g of fecal material was found to represent 2.7 g of food. Eight squirrels at 4 °C hibernated from late October until late April and early May. They ate only when aroused, about once every 10 to 14 days; during hibernation their mean daily food intake was 0.3 g, and their mean daily caloric intake 1 kcal (65% of which was absorbed), or 2 kcal per metabolic body size. Eight squirrels at 20 °C were sluggish but not torpid. They ate daily, the mean daily intake being 8 to 11 g. The mean daily caloric intake per animal at 20 °C varied from 16 to

23 kcal or from 60 to 83 kcal per metabolic body size. An extended warm autumn could retard or prevent hibernation and consequently require this species to draw heavily on its body fat and food stores. It appears that hibernation in this species is a protection against the virtual impossibility of foraging on the ground in deep snow.

703. Johnson, Loyal J. 1963. Population dynamics of deer mice and chipmunks in four forest types in western Montana. Bozeman, MT: Montana State University. 99 p. M.S. thesis.

The study was undertaken with the following objectives: to collect population density and movement data for the long-tailed deer mice (*Peromyscus maniculatus*), the yellow-pine chipmunk (*Eutamias amoenus*), and the red-tailed chipmunk (*E. ruficaudus*); to compile a mammal species list; and to obtain information on the presence of *Sorex* in four of the five predominant timber types on the Lubrecht Experimental Forest. The timber types are ponderosa pine, ponderosa pine/Douglas-fir, Douglas-fir/larch and Douglas-fir. Douglas-fir was excluded from the second summer's sampling. In the first year, the density of deer mice was found to vary from 14 animals per acre in the ponderosa-pine area to approximately three per acre in the remaining areas. Chipmunk densities were approximately four per acre in the ponderosa-pine area, two per acre in the lodgepole pine area and three per acre in the remaining areas. Generally home range sizes decreased as densities increased. In the second summer, deer mice were nearly absent from the ponderosa-pine area, presumably due to an absence of mast or lack of summer moisture but averaged approximately three per acre in the remaining areas. Chipmunk densities were slightly less than they were in the first summer. It is suggested that the ponderosa-pine areas support large numbers of seed-eating rodents in good mast-production years but cannot support large populations during years of mast failure. The other areas seem to support comparable populations annually since the animals are probably not so intimately tied to mast production and rely more on the seeds of nontree species.

704. Kenagy, G.J.; Barnes, B.M. 1988. Seasonal reproductive patterns in four co-existing rodent species from the Cascade mountains, Washington. *Journal of Mammalogy* 69(2): 274-292.

In a strongly seasonal environment in the Cascade Range of Washington, *Spermophilus saturatus* hibernated for 6-8 months, whereas *Eutamias townsendii* and *E. amoenus* hibernated for only 4-4.5 months. *Peromyscus maniculatus* did not hibernate. The three sciurids bred only once a year, with a 1- to 2-week mating period between late March and early May. *Peromyscus maniculatus* began breeding in February and continued through October; adult females produced as many as three litters, and the earliest juvenile cohorts reproduced in the year of birth. None of the sciurids became reproductively active until they were yearlings, and some *E. townsendii* and *S. saturatus* did not breed until 2 years old. Average litter size was similar in the four species: *S. saturatus*, 4.1; *E. townsendii*, 3.8; *E. amoenus*, 5.0; *P. maniculatus*, 4.6. Because female *P. maniculatus* bear 2-3 litters per year and juveniles breed within the year of birth, this species has the most flexible timing and greatest annual reproductive potential.

705. Kritzman, Ellen B. 1974. Ecological relationships of *Peromyscus maniculatus* and *Perognathus parvus* in eastern Washington. *Journal of Mammalogy* 55(1): 172-188.

Populations of the deer mouse and the Great Basin pocket mouse were studied from April through September 1969 near Richland in eastern Washington. Live-traps were set along an elevational gradient from 152 to 1,067 m. *Peromyscus* density increased with elevation, and that of *Perognathus* decreased. Edaphic conditions appear to be a major factor in distribution; *Perognathus*, a deep burrower, finds the stoneless, loose, sandy soil of the desert floor optimal habitat, whereas *Peromyscus* prefers shallow holes in the rocky substrate found at upper elevations. Deer mice may also thrive only at higher elevations because more moderate summer temperatures and greater available moisture permit them to remain active and to breed during the warmest months. Analyses of cheek pouch and stomach contents showed the greatest dietary overlap to occur in early spring, before seed ripening, when both species feed on insects. Thereafter *Perognathus* is preferentially granivorous; *Peromyscus* continues to be largely insectivorous. Partial temporal separation exists in both daily and seasonal activity patterns. Home ranges do overlap interspecifically, but fights initiated by the more dominant *Peromyscus* appear to be rare in the naturally open field situation.

706. Larrison, Earl J. 1957. Notes on chipmunks of west-central Washington. *Murrelet* 28(2): 23-30.

Summarizes information on distribution, ecology, and habits of three species and two subspecies of *Eutamias* that occur in west-central Washington, Sagebrush chipmunk (*Eutamias minimus pictus*), Columbian chipmunk (*Eutamias amoenus affinis*), Hollister's chipmunk (*Eutamias amoenus ludibunqus*), Townsend's chipmunk (*Eutamias townsendii townsendii*), and Cooper's chipmunk (*Eutamias townsendii cooperi*).

707. Martinsen, David L. 1965. Seasonal movements and habitats of chipmunks (*Eutamias*) in Montana. Logan, UT: Utah State University. 57 p. M.S. thesis.

Two species of chipmunks existed in the vicinity of West Yellowstone, Montana—*Eutamias amoenus* and *E. minimus*. The former lived mainly in the mature lodgepole-pine forest, whereas the latter inhabited primarily tracts of land logged 3 or more years earlier. Both species reached greatest densities along the borders of cutover areas. The major factor responsible for this "edge-effect" of both species was a source of preferred food plants which characterized the borders of cutover areas. Home ranges of chipmunks changed in size and shape during the summer. These alterations were associated with changes in living requirements, the most influential of which was the location of preferred food plants. Several chipmunks made a long-distance movement, and a small fraction of the population changed home range to a new location. There was much overlap of individual range, and the total summer range of most individuals remained the same from one summer to the next. Changing usage within the revealed boundaries was predictable and orderly for phenologically equivalent time spans of two successive summers. Such change necessitates time-qualified measurements of range, and such predictability substantiates the classical concept of home range.

708. Martinsen, David L. 1968. Temporal patterns in the home ranges of chipmunks (*Eutamias*). *Journal of Mammalogy* 49(1): 83-91.

An observational study of chipmunks in Montana during two consecutive summers revealed marked changes from week to week in the sizes and shapes of the summer ranges of many individuals and in the intensity of use of sites within the boundaries. The two most important factors responsible for such change were reproduction and the dispersion of the plants selected for food. The total summer range of most individual chipmunks remained the same from one summer to the next, and changing use within the observed boundaries was predictable and orderly for phenologically equivalent time spans on both summers. Such predictability substantiates the classical concept of home range. However, such changes, if they occur in most populations of small mammals, would necessitate time-qualified expressions of home range.

709. Maser, Chris; Hooven, Edward F. 1970. Notes on the behavior and food habits of captive Pacific shrews, *Sorex pacificus pacificus*. *Northwest Science* 48(2): 81-95.

Three Pacific shrews, *Sorex p. pacificus*, were maintained in captivity for a total of 80 days. Their general behavior, hunting behavior, and food habits are presented and are compared with those of the wandering shrew, *Sorex v. vagrans*. Survival value of the immobilization and localized storage of prey, as opposed to the direct killing and nonlocalized storage of prey, is discussed.

710. Maser, Chris; Trappe, James M.; Nussbaum, Ronald A. 1978. Fungal/small-mammal interrelationships with emphasis on Oregon coniferous forests. *Ecology* 59(4): 799-809.

Most higher plants have evolved with an obligatory symbiotic relationship with mycorrhizal fungi. Epigeous mycorrhiza formers have their spores dispersed by air currents, but hypogeous mycorrhizal fungi are dependent upon small mammals as primary vectors of spore dissemination. Mammalian mycophagists defecate within the coniferous forest ecosystem, spreading the viable spores necessary for survival and health of the conifers. As one unravels and begins to understand the interrelationships between small-mammal mycophagists and mycorrhizal fungi, it becomes apparent that the various roles of small mammals in the coniferous forest ecosystem need to be reevaluated. One can no longer accept such simplistic solutions to timber management as poisoning forest rodents to enhance tree survival. One must consider the direct as well as the indirect costs and benefits of timber management decisions if one is to maintain balanced, healthy coniferous forests.

711. McIntire, Patrick W. 1984. Fungus consumption by the Siskiyou chipmunk within a variously treated forest. *Ecology* 65(1): 137-146.

Mycophagy (consumption of fungi) by the Siskiyou chipmunk (*Eutamias siskiyou*) was studied during the summers of 1978 and 1979. Fecal pellets were sampled from live-trapped chipmunks in two sites within a shelterwood logged coniferous forest in Jackson County, Oregon. Slash was mechanically piled and burned (treated) in one area but not in another. Habitat analyses indicated that huckleberry was severely reduced,

and exposure to mineral soil increased in the treated study site. Sixteen genera of hypogeous, mycorrhizal fungi, representing three classes, were identified in fecal samples taken from animals in both sites. Spores of *Rhizopogon* spp. were most frequently encountered in both sites. The frequencies of occurrence for 11 of the 16 fungal genera were greater for samples from the untreated site, two significantly so. *Endogone* spp. occurred exclusively in fecal samples from the treated site, but no fungal type from this site exhibited a significantly greater frequency. The reduction of spores in samples from the treated site is thought to be a function of diminished sporocarp availability that resulted from slash treatment. Differential microhabitat selection by the sexes may also account for some differences in the observed spore frequencies.

712. McIntire, Patrick W. 1986. The role of small mammals as dispersers of mycorrhizal fungal spores within variously managed forests and clearcuts. Corvallis, OR: Oregon State University. 154 p. Ph.D. dissertation.

From 1980 to 1982 small-mammal community composition, microhabitat selection, and dispersal of mycorrhizal fungal spores were studied within various coniferous habitats in southwestern Oregon. Discriminant function analysis (DFA) and principal component analysis were used to distinguish clearcut, edge, and forested habitats. Microhabitat preferences were examined by using DFA. For all study sites combined, deer mice, chipmunks, golden-mantled ground squirrels, and red-backed voles were the most numerous species. Relative abundances of small-mammal species varied with overall habitat complexity. As the degree of forest structure increased, the relative proportions of forest specialists influenced community composition. Thus, small-mammal community composition changed with increasing habitat complexity. Ground squirrels, deer mice, and chipmunks moved among the three habitats. Differences in movements between habitats reflected their specific habitat affinities. The greatest abundances of spores in feces were observed for samples from the least disturbed forests. Principal small-mammal mycophagists and fungi occur in greater numbers in minimally disturbed forests and untreated clearcuts. To maximize inocula availability in disturbed sites, adjacent forests and the understory in clearcuts should be left undisturbed.

713. McKeever, Sturgis. 1961. Relative populations of small mammals in three forest types of northeastern California. *Ecology* 42(2): 399-402.

From January through December 1958, small-mammal populations were studied in three forest types at four areas lying between 4,800 and 6,800 feet elevation east of the crest of the Cascade Range in Lassen County, California. The forest types were ponderosa pine, lodgepole pine, and mixed red and white fir. Relative abundance of 12 species was computed; 5 were caught only sporadically. The predominant species were deer mice, golden-mantled ground squirrels, Townsend chipmunks, yellow-pine chipmunks, lodgepole chipmunks, Douglas squirrels, and northern flying squirrels. Deer mice, chipmunks, and golden mantled ground squirrels were most abundant in open stands of ponderosa pine. Douglas squirrels were most abundant in lodgepole pine. Northern flying squirrel populations were approximately the same in each of the three forest types.

714. McKeever, Sturgis. 1964. The biology of the golden-mantled ground squirrel *Citellus lateralis*. Ecological Monographs 34(4): 383-401.

The golden-mantled ground squirrel is a rodent of the open coniferous forests of the Western U.S. and southwestern Canada. Population density in the various forest types is correlated with density of herbaceous vegetation. It breeds once in early spring and produces an average of 5.1 embryos per litter. The gestation period is approximately 28 days. Fungi and leaves constitute 87% of the diet, with seed, flowers, bulbs, fruit, and flesh making up the remainder. The diversified diet enables the squirrels to remain active except when the ground is frozen. They do not store food. Atrophy of the endocrine glands in the fall, a phenomenon common to most hibernators, decreases the metabolic rate and permits accumulation of fat. Hibernation causes a further reduction in metabolism and enables the animals to live approximately 4 months on stored fat. Periodic awakenings are characteristic during the hibernating period; and, during open winters, some squirrels come above ground when they awaken. Few animals consume food from the time they enter hibernation until they awaken in the spring.

715. Medin, Dean E. 1986. Small mammal responses to diameter-cut logging in an Idaho Douglas-fir forest. Res. Note INT-362. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 6 p.

Relative small-mammal populations were estimated on logged and unlogged plots from 1975 (first-year prelogging) through 1979 (third-year postlogging) by using live-trapping and mark-recapture methods. Three species made up 93% of 698 individuals caught: deer mice (*Peromyscus maniculatus*), yellow-pine chipmunks (*Eutamias amoenus*), and Gapper's red-backed voles (*Clethrionomys gapperi*). Deer mice populations were similar on both logged and unlogged plots. Numbers of yellow-pine chipmunks increased on logged sites. Red-backed voles disappeared from the small-mammal community after logging. Other species, including the golden-mantled ground squirrel (*Spermophilus lateralis*) and shrews (*Sorex* spp.) were trapped irregularly and in small numbers.

716. Meredith, Don H. 1972. Subalpine cover associations of *Eutamias amoenus* and *Eutamias townsendii* in the Washington Cascades. American Midland Naturalist 88(2): 348-357.

Yellow-pine chipmunks and Townsend's chipmunks were live-trapped in the sub-alpine zone in Mount Rainier National Park, Washington. Home ranges overlapped, both intra- and interspecifically. Tree islands offered the most dense and least variable cover. Talus slides were not analyzed but were considered to have a high quality cover due to their structure. Both species were significantly more abundant in tree islands than in other cover types. Townsend's chipmunk males were significantly more abundant in talus slides than yellow-pine chipmunk males and females. Niche separation of the two chipmunks on the basis of cover usage is implied.

717. Merkt, Juan R. 1981. An experimental study of habitat selection by the deer mouse, *Peromyscus maniculatus*, on Mandarte Island, BC. Canadian Journal of Zoology 59(4): 589-597.

Mandarte Island, British Columbia, consists of a mosaic of shrubbery and grassland habitats. In a 6-month study, deer mice were found to live at high absolute density and at higher relative densities in shrubbery habitat. A removal experiment was conducted to investigate how the habitat preference and density of mice affect their distribution on Mandarte Island. All resident mice were removed from an area containing both shrubbery and grassland. This gave mice dispersing from other areas the opportunity to colonize these two vacant habitats. Mice settled first in the shrubbery. As population density increased, some later colonists occupied the less favored grasslands. I suggest that intraspecific interaction, associated with high density, was sufficient to prevent settlement of some individuals in the preferred habitat.

718. Morrison, Michael L.; Anthony, Robert G. 1989. Habitat use by small mammals on early-growth clear-cuttings in western Oregon. Canadian Journal of Zoology 67(4): 805-811.

Abundance and habitat relationships of small mammals were studied on two early-growth clearcuttings in the Oregon Coast Range. Ten species were captured in 3 years of study: *Peromyscus maniculatus* accounted for the majority (64%) of captures. Six other species were captured frequently enough for habitat analysis: *Microtus oregoni* (15%), *Eutamias townsendii* (11%), *Zapus trinotatus* (3%), *Sorex vagrans* (3%), *Sorex trowbridgii* (2%), and *Sorex pacificus* (2%). The small-mammal community was composed of a single, numerically dominant habitat generalist (*Peromyscus*) and several numerically subordinate species that showed varying degrees of habitat specificity. An overall significant difference in habitat use among the seven species was demonstrated with discriminant function analysis; this separation was based primarily on differences in the use of forb and grass cover. There was high overlap, however, in microhabitat associations among species, which was likely due to the environment in regenerating coniferous forests.

719. O'Farrell, Thomas P.; Olson, Richard J.; Gilbert, Richard O.; Hedlund, John D. 1975. A population of Great Basin pocket mice, *Perognathus parvus*, in the shrub-steppe of south-central Washington. Ecological Monographs 45(1): 1-28.

A population of Great Basin pocket mice was live-trapped in 1967-72 on a 2.7-ha study area in south-central Washington to determine their density, reproductive performance, longevity, movements, and home range, as well as their functional role in northern shrub-steppe habitat. Most pocket mice remained inactive underground between December and February. The first signs of estrus were observed in April, the first palpable pregnancies in May, and the last pregnant females usually in July. In years of high food availability adult females averaged two litters; in average years they had 1.1 litters; and in poor years, only one female in three became pregnant. They ceased aboveground activities between later summer and autumn depending upon environmental conditions, sex, and age. Adult males had larger home ranges than females; adults had larger home ranges than subadults.

720. Orr-Ewing, A.L. 1950. Life history of the deer mouse. *Forestry Chronicle* 26(2): 115-126.

Studies of the deer mouse in relation to the destruction of Douglas-fir seed were carried out in the Cowichan Lake region of Vancouver Island in 1948 and 1949. The two subspecies of *Peromyscus* found were *P. maniculatus angustus* and *P. maniculatus interdictus*. Two species of shrews, *Sorex obscurus isolatus* and *Sorex vagrans vancouverensis* were also found to be seed eaters to some extent. Systematic trapping of deer mice in forested, logged, and burned areas indicated a higher population on the latter two sites, particularly logged areas which had existed for some time without appreciable regeneration. The mouse population was lowest in the early months of the year, reaching a peak in October and November. The number of young per litter varied from two to seven and there were several generations in a single year. The author concludes that some form of control against the deer mouse is essential for the natural regeneration of forests in the Douglas-fir region.

721. Petticrew, B.G.; Sadleir, R.M.F.S. 1970. The use of index trap lines to estimate population numbers of deer mice (*Peromyscus maniculatus*) in a forest environment in British Columbia. *Canadian Journal of Zoology* 48(2): 385-389.

Monthly live-trapping of 2 1-ha grids in differing forest habitats was carried out over an 8-month period. Immediately after two nights of trapping on each grid, a central index line was trapped for a further two nights. The total capture numbers, numbers of males, and numbers of females on the index line correlated significantly with the same parameters on the grid. In addition, survival rates and body weights were almost identical, and similar representation of other small-mammal species was determined by both arrangements of traps. It is suggested that the index line may be a more efficient method of sampling small-mammal populations.

722. Petticrew, B.G.; Sadleir, R.M.F.S. 1974. The ecology of the deer mouse *Peromyscus maniculatus* in a coastal coniferous forest. I. Population dynamics. *Canadian Journal of Zoology* 52(1): 107-118.

A 3-year live-trapping study of deer mice was carried out on separate 1-ha grids located in a mature forest, a recently logged area, and a young plantation. Despite apparent gross differences in the habitats, populations on the recently logged area were similar in numbers, survival, and recruitment to those in the mature forest. There were greater differences in population parameters between years than between these two areas. Populations of deer mice in the young plantation were lower in numbers and eventually became extinct in the summer of 1970. This was due to the presence of numerous *Microtus oregoni* in this area rather than to the habitat being less suitable for deer mice. By this and previous studies, it is proposed that the numbers of deer mice in a population are regulated as follows. During breeding seasons, the numbers of males and juveniles are regulated by agonistic male behavior while the numbers of females may be a function of the length of the breeding season. During nonbreeding seasons, the changes in numbers of all deer mice are regulated by the length of such seasons.

723. Postovit, Howard R. 1976. The potential effects of urea fertilization on *Peromyscus maniculatus* in northwest forests. Northwest Science 50(2): 87-96.

The potential for adverse effects of urea fertilizer on small forest mammals was investigated in the field and laboratory by using the deer mouse as a test animal. Acceptance of urea by small mammals was studied, disappearance rates of simulated applications of urea were examined under field conditions, and physiological effects of urea intoxication in *P. maniculatus* were observed. Results indicate that the application of urea as a forest fertilizer is not likely to damage populations of deer mice or other small mammals.

724. Ramirez, Pedro, Jr.; Hornocker, Maurice. 1981. Small mammals populations in different-aged clearcuts in northwestern Montana. Journal of Mammalogy 62(2): 400-403.

To understand better the effects of vegetational succession on populations of wolverine, as well as those of other predators, we studied the influence of clearcutting on their small-mammal prey. The study area was in the Sullivan and Quintonkon Creek drainages, Flathead County, Montana, where clearcutting has been practiced since 1959. Two plant associations occurred on the study area: subalpine fir-clintonia (*Abies lasiocarpa-Clintonia uniflora*) found between 1,100 and 1,700 m and subalpine fir-woodrush (*Abies lasiocarpa-Luzula hitchcockii*) found at 1700 to 2125 m. Columbian ground squirrels inhabited clearcuts of all ages of both forest types. They were not present in *Abies-Clintonia* uncut forests or in 1-year-old partial cuts. They preferred clearcuts and open subalpine basins where grasses and sedges were most abundant. They avoided dense forests as do other species of ground squirrels. Because deer mice feed chiefly on insects, fruit, and seeds, the abundance of fruit- and seed-producing vegetation in clearcuts determines their numbers. The *Abies-Luzula* clearcuts had the lowest densities of deer mice. In the *Abies-Clintonia* type, densities of deer mice peak between 2 to 5 years following clearcutting, then decline, and after 15 years are approximately the same as in uncut forests. Rufous-tailed chipmunks, shrews, voles, and western jumping mice were captured in too few numbers to reveal any significant density differences between various vegetation types. The study indicates that clearcuts provide diverse habitats for small mammals through different stages of succession much as wildfire formerly did.

725. Rhoades, Fred. 1986. Small mammal mycophagy near woody debris accumulations in the Stehekin River Valley, Washington. Northwest Science 60(3): 150-153.

The digestive tracts of 32 small mammals (*Sorex monticolus*, *Peromyscus maniculatus*, *Microtus longicaudus*, and *Clethrionomys gapperi*) trapped near woody debris piles were examined for presence and abundance of spores of hypogeous, epigeous, and wood-inhabiting fungi. All animals contained fungal spores, usually in abundance high enough to suggest that each animal had recently consumed fungi. Spores of hypogeous fungi were the most abundant, especially those of genera *Alpova* and *Rhizopogon*.

726. Rickard, W.H. 1960. The distribution of small mammals in relation to the climax vegetation mosaic in eastern Washington and northern Idaho. *Ecology* 41(1): 99-106.

Twenty-four stands representative of 14 relatively undisturbed climax plant associations in eastern Washington and northern Idaho were sampled for their small-mammal species composition during the summers of 1954 and 1955. The same bait, number and arrangement of traps were used in each stand to facilitate the comparison of trap results. Six-hundred small mammals representing 11 species were trapped during 14,715 trap-days. The distribution of each species is discussed in relation to occurrences in the stands sampled.

727. Ritchie, D. Chris; Harestad, Alton S.; Archibald, Ralph. 1987. Glyphosate treatment and deer mice in clearcut and forest. *Northwest Science* 61(3): 199-202.

The relative density of deer mice in an old-growth forest consisting mainly of Pacific silver fir and western hemlock at Kelsey Bay, British Columbia, exceeded by 87% that in recent adjacent clearcuts. Clearcuts treated with 1.2 kg glyphosate/ha showed reduced cover and species composition of the understory and a further reduction in the population of deer mice in young seral stages, though their reproductive rate and body size were unaffected.

728. Sadleir, R.M.F.S. 1974. The ecology of the deer mouse *Peromyscus maniculatus* in a coastal coniferous forest. II. Reproduction. *Canadian Journal of Zoology* 52(1): 119-131.

The duration and intensity of reproduction in deer mice was followed for four seasons by live and dead trapping. Three populations living in different types of forest habitat had synchronous breeding seasons, although there were major differences between years in the time of onset and cessation of breeding and in the proportion of females in breeding condition. No consistent relationship was found between either density changes or the incidence of parasitism and reproductive phenology. In the absence of overt food fluctuations, there was a relationship between unseasonable temperature changes and breeding. Sudden increases in temperature may have stimulated the onset of breeding, but its cessation before the autumn equinox was always associated with a considerable decrease in temperature if this occurred after April. In 57 pregnancies, the corpora lutea count was 4.75, and the embryo count was 4.52.

729. Scrivner, Jerry H.; Smith, H. Duane. 1984. Relative abundance of small mammals in four successional stages of spruce-fir forest in Idaho. *Northwest Science* 58(3): 171-176.

The relative abundance of four small mammal species in successional stages (1-10, 11-39, 40-79, and 80+ years following disturbance) of spruce-fir forest in Idaho is discussed. Species evaluated include *Peromyscus maniculatus*, *Eutamias ruficaudus*, *Zapus princeps*, and *Clethrionomys gapperi*. For the specific sites we investigated, intraspecific comparisons indicated *P. maniculatus* increased with succession; *E. ruficaudus* abundance varied but was generally most common in midsuccessional stages; *Z. princeps* preferred willow-alder thickets within midsuccessional stages; and *C. gapperi* was most abundant in the mature forest.

730. Sheppard, David H. 1969. A comparison of reproduction in two chipmunk species (*Eutamias*). *Canadian Journal of Zoology* 47(4): 603-608.

Eutamias amoenus and *E. minimus* are potential competitors in western Alberta. The former species has larger litters and reproduces at an earlier age, on an average, than the latter. Other aspects of reproduction (breeding season, prenatal mortality) do not appear to differ greatly, though supporting data are somewhat inadequate. The higher reproductive potential should confer an advantage on *E. amoenus* in competition with *E. minimus*. The observed difference in litter size of these two congeners seems to be best explained by a difference in available food in the two habitats. This hypothesis should be tested by a comparative study of the energetics of the two species populations.

731. Sheppe, Walter. 1963. Population structure of the deer mouse, *Peromyscus* in the Pacific Northwest. *Journal of Mammalogy* 44(2): 180-185.

Life history data on *P. oreas* and three races of *P. maniculatus* were gathered in the course of a study of the systematics and ecology of these mice. Five age groups were recognized, based on the amount of wear on the molars. Breeding began in late winter and was at its height in the spring. It declined during the summer and ended in later summer or early fall. *Peromyscus maniculatus* continued to breed for a month or more after *P. oreas* stopped breeding. Animals born early in the breeding season were breeding by June of the same year, but those born late in the season did not breed until the following year. Litter size averaged 6.1 in *P. oreas*, 5.5 in *P. maniculatus*. In June 1/3 of the catch consisted of young of the year, in July 1/2, and in August 3/4, but the proportion of young apparently declined slightly in September. Young males outnumbered young females, but old females outnumbered old males, suggesting that females live longer.

732. Small, Robert J.; Verts, B.J. 1983. Responses of a population of *Perognathus parvus* to removal trapping. *Journal of Mammalogy* 64(1): 139-143.

In a study near Boardman, Oregon, Great Basin pocket mice were trapped, released, and recaptured to attempt to ascertain their dispersal strategy.

733. Smith, Graham W.; Johnson, Donald R. 1985. Demography of a Townsend ground squirrel population in southwestern Idaho. *Ecology* 66(1): 171-178.

The demography of a Townsend ground squirrel population was investigated during a 7-year study in southwestern Idaho. Squirrels were identified as residents, transients, or immigrants based upon the frequency of capture. Immigration peaked in late February and early March, shortly after the termination of the breeding season. Squirrels identified as transients appeared throughout the trapping season (February through June). A majority of the yearling females and nearly all of the adult females produced a single litter annually. The ground squirrel has evolved a reproductive strategy adapted to its unpredictable desert environment. Successful reproduction is related to the availability of a fresh growth of grasses and ultimately to the amount of rainfall in the preceding fall and early winter. During a drought in 1977, population

density was reduced by more than one half. An increase in the pregnancy rate of yearling females was the only process operating during the postdrought period to restore an equilibrium density. There were no significant changes in immigration rate, litter size, or overwinter survival rate in response to density reduction. Both dispersal and predation operated to reduce density. In addition, disease in the form of sylvatic plague (*Yersinia pestis*) was present within the study population. A plague-caused reduction in density over a wide region would have a significant effect on the reproductive success of a variety of reptilian, avian, and mammalian predators.

734. Sullivan, Druscilla S.; Sullivan, Thomas P. 1982. Effects of logging practices and Douglas-fir, *Pseudotsuga menziesii*, seeding on shrew, *Sorex* spp., populations in coastal coniferous forest in British Columbia. *Canadian Field-Naturalist* 96(4): 455-461.

This study was designed to provide a preliminary investigation of the responses of shrew populations to logging and burning of coastal forest habitats, Douglas-fir seeding, and removal of the presumed competitor, the deer mouse. Shrews were trapped in three habitats at Maple Ridge, British Columbia, from May 1975 to November 1978. The average density of shrews was consistently higher in the forest (4.3/ha) compared with the burned (2.0/ha) and unburned areas (2.4 and 3.0/ha). Shrew density was lowest in the year after burning. Douglas-fir seeding produced generally little change in shrew abundance although a slight positive response was recorded at low seed densities on a cutover area. Shrews did not respond consistently to removal of deer mice and vole coinhabitats. Therefore, presumed competition between these species probably did not lower the response of shrews to Douglas-fir seed. Shrews should not be a major concern to reforestation as seed predators in the coastal coniferous forests of southern British Columbia.

735. Sullivan, Thomas P. 1977. Demography and dispersal in island and mainland populations of the deer mouse, *Peromyscus maniculatus*. *Ecology* 58(5): 964-978.

If dispersal is reduced on islands, then the demography of island populations of deer mice should be different than that of mainland populations. Areas of 1.1 ha were periodically cleared of mice on Samuel Island and Saturna Island in the Gulf Islands of southwestern British Columbia. A similar experiment was conducted on the mainland at Maple Ridge, British Columbia. The average density of mice per ha on Saturna (43.5) was two times that on Samuel Island (22.0) and nearly 2.5 times higher than that on the mainland (18.7). The reproductive rate, as measured by length of breeding season, number of successful pregnancies, proportion of breeding animals, and number of recruits surviving to breed, was much higher on Samuel Island than on either Saturna or on the mainland. Mice on Samuel Island grew more than five times faster than mainland animals, and Saturna growth rates were double those on the mainland. Dispersal (or colonization) rate was reduced on the two islands compared with that on the mainland. Recruitment of young animals occurred throughout the breeding season on the islands but was delayed until the end of breeding on the mainland. Seasonal changes in aggressiveness of the adult population may be sufficient but are not necessary to determine breeding density in deer mice. Regulatory processes in populations of *Peromyscus maniculatus* may be different on islands.

736. Sullivan, Thomas P. 1978. Lack of caching of direct-seeded Douglas fir seeds by deer mice. *Canadian Journal of Zoology* 56(5): 1214-1216.

Seed caching by deer mice was investigated by radio-tagging seeds in forest and clearcut areas in coastal British Columbia. Deer mice tend to cache very few Douglas-fir seeds in the fall when the seed is uniformly distributed and is at densities comparable with those used in direct-seeding programs.

737. Sullivan, Thomas P. 1979. Demography of populations of deer mice in coastal forest and clear-cut (logged) habitats. *Canadian Journal of Zoology* 57(8): 1636-1648.

This study was designed to test the widely held hypothesis that clearcut habitats support higher density populations of *Peromyscus* than do forested habitats. Deer mouse populations were live-trapped in forest and clearcut habitats at Maple Ridge, British Columbia, from May 1975 to April 1978. The average density of mice per ha in the forest was 19.6 (1975), 15.8 (1976), 22.3 (1977), and on the clearcut areas was 23.3 (1975), 16.6 (1976), 29.9 (1977). The slightly higher number of animals on the clearcut in 1975 and 1977 reflected a burst of recruitment in the late summer and fall of each year. The density of mice on clearcut areas declined during each winter to a level comparable with that of the forest. Juvenile male deer mice were able to enter into the clearcutting populations during the breeding season in the first year after logging. Recently logged areas may be acting as dispersal or behavioral sinks.

738. Sullivan, Thomas P. 1980. Comparative demography of *Peromyscus maniculatus* and *Microtus oregoni* populations after logging and burning of coastal forest habitats. *Canadian Journal of Zoology* 58(12): 2252-2259.

This study was designed to investigate the abundance and related demographic attributes of *Peromyscus maniculatus* and *Microtus oregoni* populations in successional burned and unburned cutover areas. These populations were live-trapped in three habitats at Maple Ridge, British Columbia, from March to October 1978. The average densities of deer mice and Oregon voles per ha on the burned area were 27.6 and 11.6, and on two unburned areas were 19.1 and 16.0, and 21.9 and 10.4, respectively. There was little variation in the proportion of breeding animals among habitats for either species. Male deer mice survived better on the burned area than in either of the other two habitats; there was little variation in survival among females. Males and females of *M. oregoni* survived equally well. Deer mice generally had greater proportions of reproductive animals and survived better than Oregon voles on all study areas; however, juvenile voles had 1.7 times higher survival than young deer mice. Demographic parameters within populations of *P. maniculatus* and *M. oregoni* tend to be similar in successional burned and unburned habitats 4-5 years after logging.

739. Sullivan, Thomas P.; Krebs, Charles J. 1981. An irruption of deer mice after logging of coastal coniferous forest. *Canadian Journal of Forest Research* 11(3): 586-592.

This study describes an irruption of *Peromyscus maniculatus* after clearcut logging of a coastal forest. The abundance of deer mice increased seven to eight times above previous levels in an old field habitat adjacent to the clearcut. This outbreak occurred

during and after a logging operation in the fall of 1973. Several alternative explanations for this irruption include increased reproduction or reduced mortality in the deer mouse population, immigration of mice from the surrounding undisturbed forest, or immigration of animals from the clearcut area. We conclude that the removal of timber has the capacity to trigger an irruption of deer mice.

740. Sullivan, Thomas P.; Sullivan, Druscilla S. 1981. Responses of a deer mouse population to a forest herbicide application: reproduction, growth, and survival. *Canadian Journal of Zoology* 59(6): 1148-1154.

The study was designed to monitor some of the demographic responses of a deer mouse population to a forest application of glyphosate. Populations of *Peromyscus maniculatus* were live-trapped from July 1978 to November 1980 on a control area and in a herbicide-treated 20-year-old Douglas-fir plantation at Maple Ridge, British Columbia. The herbicide had no apparent adverse effects on reproduction, growth, or survival of deer mice 1 year after treatment. Inconsistencies in growth rates and juvenile survival between control and experimental deer mice in 1980 could be due to the herbicide or demographic factors. Field dose applications of this herbicide should not have a direct effect on the dynamics of deer mouse populations.

741. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. Responses of small mammal populations to a forest herbicide application in a 20-year-old conifer plantation. *Journal of Applied Ecology* 19(1): 95-106.

The responses of small-mammal populations to a forest application of glyphosate herbicide have been investigated at the University of British Columbia Research Forest, Maple Ridge, British Columbia. These populations included the deer mouse, Oregon vole, Townsend chipmunk, and shrews. Treatment of a 20-year-old Douglas-fir plantation did not have any negative effects on the distribution and abundance of small-mammal populations during the first year after this habitat alteration. Movements of deer mice were monitored by drift lines. There was not an influx of new animals from the surrounding regions onto the treated area nor was there a significant movement of marked animals away from the sprayed area. Future changes in composition of the small-mammal community may occur in association with successional stages advancing from the herbicide-induced habitat alteration.

742. Sullivan, Thomas P.; Sullivan, Druscilla S. 1984. Influence of range seeding on rodent populations in the interior of British Columbia. *Journal of Range Management* 37(2): 163-165.

This study was designed to determine the influence of range seeding on rodent populations inhabiting cutover lodgepole pine forest land in the interior of British Columbia. Both deer mice and voles were strongly attracted to an area seeded with grass mixture in the early spring, even though overwinter mortality had dramatically reduced the average density to under two animals per ha. Five rodents as well as several seed-eating birds appeared on this seeded area; however, no animals were recorded on a nearby control. Subsequent seeding experiments in the summer also produced significant increases (2 to 2.2 times) in rodent populations. Success of

range seeding in British Columbia. can be quite variable, possibly due to seed predation by mice and voles. Consequently, both the quality and quantity of seed remaining for germination and forage production may be radically altered.

743. Sullivan, Thomas P.; Sullivan, Druscilla S.; Krebs, Charles J. 1983. Demographic responses of a chipmunk (*Eutamias townsendii*) population with supplemental food. *Journal of Animal Ecology* 52(3): 743-755.

If chipmunk populations are limited by food when independent of other factors, then provision of a preferred supplemental food should increase density and related demographic attributes. Chipmunk populations were live-trapped from the autumn of 1976 to the spring of 1980 in two coastal forest cutover ecotones at Maple Ridge, British Columbia. Extra food was supplied during 1977 and 1978. The fed population increased 40-50% above the control population and maintained this difference through the 2 years of the experiment. Juvenile survival, during the summer and through the winter hibernation period, was increased in the fed population over that of the control. Body weights were higher and juveniles grew significantly faster in the population with extra food than in the control. Range length tended to be less for chipmunks in the fed population. After the food was withdrawn, the population density declined on the experimental area, and related demographic variables became similar with those in the control. We conclude that food limits population size in Townsend's chipmunk.

744. Taitt, Mary J. 1981. The effect of extra food on small rodent populations: I. Deer mice (*Peromyscus maniculatus*). *Journal of Animal Ecology* 50(1): 111-124.

Deer mice were supplied with extra food between December 1973 and June 1975. Late winter addition of food to two areas resulted in more male and female deer mice. Immigration to areas with extra food was nearly triple that of controls. The size of home ranges of residents became significantly smaller in populations with extra food. Breeding on control areas was delayed in spring 1974, when weather was poor. However, mice on grids with extra food bred early and began to breed in winter. Mice with extra food produced more young and reached sexual maturity at a lower weight. Extra food reversed the normal winter weight loss so that mice maintained high weights and reproduced in spite of temperate winter weather. The annual fluctuations in numbers of deer mice may be a consequence of seasonal reproductive behavior which is proximately limited by food availability.

745. Taitt, Mary Joan. 1978. Population dynamics of *Peromyscus maniculatus austerus* and *Microtus townsendii* with supplementary food. Vancouver, BC: University of British Columbia. Ph.D. dissertation.

A number of field studies suggest that some vertebrate populations are limited by spacing behavior. Small mammals of the genus *Peromyscus* and *Microtus* exhibit spacing behavior by possessing home ranges, but they have contrasting patterns of population fluctuation. Deer mice fluctuate annually but maintain fairly constant numbers from year to year, whereas voles "cycle", reaching peak densities every 2 to 5 years. One use of the home range is for food-gathering. Therefore, these

experiments were designed to investigate the influence of food availability on the home range and population dynamics of local deer mice and voles. The addition of food in later winter resulted in a doubling of the number of deer mice. Immigration was 2.5 times that of an unfed control. This could be explained since resident deer mice reduced the size of their home ranges. Deer mice populations with extra food increased their reproductive output compared with controls. We believe that the onset and cessation of breeding in deer mice are proximate responses to food availability. Vole populations with low- and intermediate-levels of food peaked at twice the control density, and a population with a high-level of food reached seven times control density. Voles immigrated to established populations and colonized vacant areas in proportion to the food available. Like deer mice, residents reduced the size of their range. Breeding was enhanced in all fed vole populations. The results indicate that home range size in both species is responsive to food availability.

746. Terry, Carol J. 1978. Food habits of three sympatric species of Insectivora in western Washington. *Canadian Field-Naturalist* 92(1): 38-44.

Sorex vagrans vagrans, *S. trowbridgii trowbridgii*, and *Neurotrichus gibbsi minor* were maintained in captivity and fed seeds of various herb, shrub, and tree species. Invertebrates, carrion, and mushrooms were also provided. The only seed species rejected by all individuals tested was purple foxglove (*Digitalis purpurea*). *Neurotrichus*, the largest of the species studied, readily consumed all other food items offered. *Sorex vagrans* and *S. trowbridgii* were restricted to smaller food items, seemingly because of their inability to penetrate heavy seed coats and capsules, and thick exoskeletons.

747. Terry, Carol J. 1981. Habitat differentiation among three species of *Sorex* and *Neurotrichus gibbsi* in Washington. *American Midland Naturalist* 106(1): 119-125.

Environmental parameters in seral stages of the *Tsuga heterophylla* vegetation zone in King County Washington were measured and correlated with the presence of four insectivores: *Neurotrichus gibbsi*, *Sorex trowbridgii*, *S. vagrans*, and *S. monticolus*. Correlation coefficients were used to determine the specific habitat occupied by each of the species. *Neurotrichus* occupied forested areas where it burrowed deeply in the soil. *Sorex trowbridgii* also burrowed, it yet was commonly found on the surface of the soil, foraging among the litter and moss. *Sorex monticolus* was more restricted to the layer of debris on the forest floor and perhaps was more successful at foraging there than *S. trowbridgii*. *Sorex vagrans* did not burrow and was found in patchy open areas, alder stands, and in areas with high water tables where the numbers of *S. trowbridgii* were low.

748. Tevis, Lloyd, Jr. 1953. Stomach contents of chipmunks and mantled squirrels in northeastern California. *Journal of Mammalogy* 34(3): 316-324.

This paper presents an interpretation of stomach analyses of 509 chipmunks of four species (*Eutamias amoenus*, *speciosus*, *townsendii*, and *quadrimaculatus*) and 273 mantled squirrels (*Spermophilus lateralis*) in Plumas County, California. Hypogeous fungus, which rodents obtain by digging, is the most important food. Because of this

nutritious food, many diurnal rodents now present in many areas would be sharply reduced. The proportion of seed in the diet was surprisingly small. Had the 1950 seed crop of woody plants not failed, consumption during the following spring probably would have been greater. Grasses and forbs were the principal spring food of mantled squirrels. Chipmunks took green vegetation only when forced to do so by scarcity of other food. Flowers are often a major component of the diet of both species. Fruits appeared very little, but this may have been because the least amount of trapping was done at the time of maximum fruiting. Bulbs and roots were of little consequence in the diet. Only during insect outbreaks did squirrels and chipmunks capture large quantities of insects. Mantled squirrels were more carnivorous than chipmunks, but the degree of cannibalism varied with locality. The mantled squirrel is a gross feeder which endeavors to consume massive amounts of food. The chipmunks are more fastidious and need less food than squirrels.

749. Tevis, Lloyd, Jr. 1955. Observation on chipmunks and mantled squirrels in north-eastern California. *American Midland Naturalist* 53(1): 71-78.

Near Quincy, California, 1,340 chipmunks (*Eutamias amoenus*, *speciosus*, *townsendii*, and *quadrimaculatus*) and mantled squirrels (*Spermophilus lateralis*) were trapped and autopsied. Embryo counts, method of determining fecundity, and other reproductive data are given. Squirrels began to hibernate before the weather changes; chipmunks after the first major storm. Hibernation fat was found in chipmunks as well as squirrels. In the more arid areas to the east, animals emerged from hibernation earlier (March) than in moister habitats to the west (April). Adults and subadults could be distinguished by appearance of reproductive organs, amount of tooth wear, and development of cranial crests. Most began with cessation of reproductive activities. Weights of caeca and stomachs varied from 1 to 29% of gross body weight, depending on amount of contained food. Differential distribution between two species of chipmunk fleas (*Monopsyllus eumolpi* and *ciliatus*) was correlated with conditions of moisture rather than species of chipmunk. Squirrels and chipmunks did not decline in numbers at a time when failure of coniferous seed crop adversely affected mouse populations. Mortality rate was lowest during hibernation. A spring decline in numbers was balanced by a successful breeding season.

750. Tevis, Lloyd, Jr. 1956. Invasion of a logged area by golden-mantled squirrels. *Journal of Mammalogy* 37(2): 291-292.

Sometime between 1949 and 1953, golden-mantled ground squirrels moved from their homes on the Trinity-New River Divide of northwestern California, through a dense forest, and into recently logged land, where they established and reproduced. Because they prefer meadows and avoid forests, previous generations for centuries past had probably failed to find suitable new habitat when they left the parental dens, and, therefore, had died. When they reached the newly logged land, exposed to sunlight and with a variety of herbaceous vegetation, however, they multiplied rapidly. Now they are a threat to reforestation, both natural and artificial, because of their seed-eating habits.

751. Tevis, Lloyd, Jr. 1956. Response of small mammal populations to logging of Douglas-fir. *Journal of Mammalogy* 37(2): 189-196.

Logging of the forest causes an increase in numbers of white-footed and big-eared mice, Townsend chipmunks, dusky-footed woodrats, digger squirrels, chickarees, and gray squirrels. It causes a decrease in numbers of Trowbridge shrews, red-backed mice, flying squirrels, and shrew-moles. The species that become most numerous are white-footed mice and Townsend chipmunks. They are the animals chiefly responsible for failure of artificial seeding of conifers. Also, along with the chickaree, they are responsible for the destruction of large amounts of naturally-produced seed.

752. Trombulak, Stephen C. 1985. The influence of interspecific competition on home range size in chipmunks (*Eutamias*). *Journal of Mammalogy* 66(2): 329-337.

The influence of interspecific competition on home range size of two sympatric chipmunks, *Eutamias amoenus* and *E. townsendii*, was studied experimentally on two 6.24-ha grids in the Cascade Range of eastern Washington from 1980 to 1982. The species overlap in habitat use, diet, and time of daily activity. Regression analysis of eight measures of vegetation structure with number of chipmunk captures suggests that in the study area these species do not use separate microhabitats. Behavioral interactions between the species are highly agonistic and *E. townsendii* is dominant over *E. amoenus*. In June 1981, all resident *E. townsendii* were removed from one of the grids. Relative to the control grid, the home range size of resident *E. amoenus* on the experimental grid increased after the removal of *E. townsendii*. In addition, the absence of *E. townsendii* led to an increase in juvenile recruitment of *E. amoenus*. These results are interpreted with respect to the cost and benefits to an animal of using a given amount of space. When resources are not partitioned and interactions between species are aggressive, interspecific competition results in an increase in the cost of using an area and a decrease in home range size.

753. Trombulak, Stephen Christopher. 1984. The ecology of montane sciurids: pattern and process in population and community structure. Seattle, WA: University of Washington. Ph.D. dissertation.

Patterns of population and community structure of chipmunks and ground squirrels were studied in the Cascade Range of Washington from 1980 to 1982. The influence of interspecific competition on home range size of two sympatric chipmunks, *Eutamias amoenus* and *E. townsendii*, was studied on two 6.2-ha forested grids. The two species overlap in diet, microhabitat use, and time of daily activity. Behavioral interactions are highly antagonistic, and *E. townsendii* is dominant over *E. amoenus*. A graphical model is presented that relates the amount of space used by an individual to the costs and benefits of using the space. The influence of habitat structure on the expression of life history traits by *Eutamias amoenus* and the golden-mantled ground squirrel *Spermophilus saturatus* was studied in contiguous forest and meadow habitats. Compared to the forest, the meadow had a greater food density, longer growing season, a greater density of both species, and probably a greater risk of predation. All age classes of *S. saturatus* had a greater body

mass in the meadow than in the forest. Time of juvenile emergence in both species was earlier in the meadow. Some yearling male *S. saturatus* in the forest became reproductively active as yearlings, whereas no yearlings became reproductively active in the meadow. In both species, juvenile dispersal distances by both sexes were greater in the meadow.

754. Turner, Larry W. 1972. Habitat differences between *Spermophilus beldingi* and *Spermophilus columbianus* in Oregon. *Journal of Mammalogy* 53(4): 914-917.

Spermophilus columbianus and *S. beldingi* have extensive geographic ranges in the Northwestern U.S., overlapping only in the Blue and Wallowa mountains of north-eastern Oregon. The range of *S. columbianus* extends north into Washington and British Columbia and east into Idaho and Montana; the range of *S. beldingi* extends south into Nevada and California and east into Idaho and Utah. In the Blue Mountains, in each of the observed instances of close association of the two ground squirrels, it was found that *S. beldingi* occupied the lower, more arid habitats often associated with sagebrush, whereas *S. columbianus* occupied the higher, wetter habitats. Soil moisture is the most important single factor in determining climax vegetation, and it is exhausted earlier in the growing season in the shrub-steppe communities than in forest communities.

755. Turner, Larry Webster. 1971. Autecology of the Belding ground squirrel in Oregon. Tucson, AZ: University of Arizona. 149 p. Ph.D. dissertation.

The autecology of *Spermophilus beldingi oregonus* Merriam was investigated in central and eastern Oregon, primarily in grasslands and agricultural lands in Grant County. Taxonomy, range and habitat, activity, behavior, food, ectoparasites, reproduction, and populations are discussed.

756. Whitaker, John O., Jr.; Cross, Stephen P.; Maser, Chris. 1983. Food of vagrant shrews (*Sorex vagrans*) from Grant County, Oregon, as related to livestock grazing pressures. *Northwest Science* 57(2): 107-111.

Major foods of the vagrant shrew in a relatively nongrazed portion of a mountain meadow in Grant County were earthworms, spiders, crickets, caterpillars, moths, slugs and snails, and June beetles and their larvae. In two similar areas subjected to greater recent grazing, flightless forms (except caterpillars) were much less used; they were replaced primarily by caterpillars and flying insects. The hypothesized cause for these changes was that grazing trampled and compressed the ground, and thus decreased the populations of some forms.

757. Whitaker, John O., Jr.; Maser, Chris. 1976. Food habits of five western Oregon shrews. *Northwest Science* 50(2): 102-107.

The 5 most important foods, by decreasing percentage volume, among 158 Trowbridge shrews, *Sorex trowbridgii*, were centipedes, spiders, internal organs of larval invertebrates (probably mostly beetles), slugs and snails, and unidentified invertebrates. Among 30 vagrant shrews, *S. vagrans*, the five most important foods were

insect larvae, slugs and snails, unidentified invertebrates, *Endogone*, and spiders. In 30 Pacific shrews, *S. pacificus*, the five most important foods were slugs and snails, centipedes, amphibian flesh, insect larvae, and unidentified invertebrates. In 27 Yaquina shrews, *S. yaquinae*, the five most important foods were invertebrate internal organs, unidentified insect larvae, slugs and snails, coleopterous larvae, and unidentified invertebrates. Among 24 marsh shrews, *S. bendirii*, the five most important foods were insect larvae, slugs and snails, Ephemeroptera naiads, unidentified invertebrates, and earthworms.

758. Black, Hugh C. 1969. Fate of sown coniferous seeds. In: Black, Hugh C., ed. Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 42-51.

Reviews the early failures of reforestation by direct seeding and the mixed success of seeding practices today. An extensive literature describes small mammals and birds as important consumers of coniferous seeds. The feeding habits of animals, particularly the consumption and preference of seeds, are emphasized. Factors that influence results of direct seeding are outlined, and the implications for seeding practices are illustrated. Methods for determining success of reforestation from natural or artificial seeding are compared; these are not synonymous with determining the fate of seeds. Radio tagging appears the most efficient means of relocating seeds in the field to study their fate. Recent studies demonstrate the significance of seed losses before germination and identify the causes. After seeding, there is continued loss of seeds to animals, chiefly deer mice. Among various needs is an effective repellent to protect seeds. Improvements in seeding practices are suggested.

759. Gashwiler, Jay S. 1967. Conifer seed survival in a western Oregon clearcut. Ecology 48(3): 431-438.

A study of the survival of naturally disseminated tree seed was made in a clearcut area on the H.J. Andrews Experimental Forest in western Oregon. From start of seed fall until the end of germination in late spring the following year, 12% of the Douglas-fir seed survived. Ground-feeding birds and small mammals caused 63% of the seed loss and other agents 25%. Thirty-one percent of the seed of western hemlock lived from the start of seed fall until the end of germination. Of the amount lost, birds and mammals took 16% and all other factors 53%. A large proportion (65%) of western redcedar seed survived during the same period. The entire loss was attributed to causes such as nonviable filled seeds, disease, invertebrates, and others. Ground-feeding birds and small mammals showed a definite preference for Douglas-fir seeds. Most of the seed depredations by birds and mammals occurred from start of seed fall to start of germination; other factors took heaviest toll during the germination.

760. Gashwiler, Jay S. 1970. Further study of conifer seed survival in a western Oregon clearcut. Ecology 51(5): 849-854.

The survival of naturally disseminated, filled seed of Douglas-fir, western hemlock, and western redcedar was studied from 1960 to 1967. Ten percent of the Douglas-fir seed survived from the start of seed fall until the end of germination the following

year. Mice and shrews, mostly deer mice, destroyed an estimated 41% of the seed; birds and chipmunks (mostly birds) took 24%; and other factors (nonviability of filled seeds, invertebrates, disease, and others) accounted for 25%. Western hemlock seed survival was 22%. Mice and shrews (mostly deer mice) destroyed an estimated 22% of the seed, birds and chipmunks (mostly birds) 3%, and other agents 53%. The sample of western redcedar seed was too small to be reliable. Douglas-fir seeds were preferred by ground-feeding birds and small mammals—less than half as many hemlock were taken. Most Douglas-fir and hemlock seed mortality occurred before germination occurred.

761. Hooven, Edward. 1975. Baiting to reduce losses of conifer seeds to small forest mammals. Res. Note 55. Corvallis, OR: Oregon State University, School of Forestry, Forest Research Laboratory. 3 p.

Deer mice may comprise 60% or more of small mammals on clearcuts in western Oregon. The remainder of the small-mammal community is composed mainly of shrews (*Sorex trowbridgii* and *S. vagrans*), and chipmunks (*Eutamias townsendii*). All of these small mammals will eat conifer seeds, but the heaviest consumers are deer mice, chipmunks, and creeping mice. They are sufficiently numerous to nullify seeding efforts before germination can occur. Early control efforts were based on the use of strychnine, thallium sulfate, sodium fluoroacetate (1080), or zinc phosphide. These rodenticides were replaced with endrin. Now research is focusing on new anticoagulants such as Rozol (active ingredient chlorophacinone).

762. Hooven, Edward F. 1966. Pine regeneration in Oregon: habits and control of seed-eating mammals. Res. Pap. 5. Corvallis, OR: Oregon State University, Forest Research Laboratory. 24 p.

A 4-year investigation of the habits and population densities of small seed-eating mammals was made in central Oregon as a basis for possible control measures. The study concentrated on the chipmunk, ground squirrel, and mouse in an area chosen as average in ability to regenerate naturally. Live-trapping and tagging determined estimates of population. Baiting the area with wheat soaked in 1080 or thallous sulfate and further trapping produced data which indicated that these poisons may be only initially effective in reducing populations of seed-eating animals because the area was soon invaded by outside populations. More frequent baiting on a larger area might produce better results. Chemical treatment of pine seed with tetramine or endrin as a repellent appeared to offer some protection for the individual seed. The most effective assistance to regeneration is probably a combination of baiting, treating seeds with repellent, and removing debris which provides protection for the seed-eating animals.

763. Hooven, Edward F. 1970. Animal damage to seed and seedlings. In: Hermann, R.K., ed. Regeneration of ponderosa pine: Proceedings of a symposium; 1969 September 11-12; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 36-39.

Discusses rodents and birds that consume tree seed in the ponderosa pine area and reviews methods of seed protection.

764. Kangur, Rudolph. 1954. Shrews as tree seed eaters in the Douglas-fir region. Res. Note 17. Oregon State Board of Forestry. 23 p.

A study was undertaken to provide more information concerning the food habits of shrews. Quantity consumption of tree seeds and the seasonal fluctuations in acceptance of tree seeds were the main objectives considered. The results showed that shrews, although classed as insectivores, eat a great amount of tree seed. In captivity they ate from 185 to 250 Douglas-fir seeds in a 24-hours. In the field they took from 50 to 100% of all Douglas-fir seed placed in acceptance spots in each 3-day test period. Sitka spruce seed, usually considered to be safe from seed-eating mammals, was taken from 15 to 55%. The amount taken varied with the season; more seeds were eaten in the winter and early spring when natural foods were scarce. Control measures for shrews, as well as deer mice, are a must for any direct seeding project.

765. Lindsey, G.D. 1977. Evaluations of control agents for conifer seed protection. In: Jackson, W.B.; Marsh, R.E., eds. Test methods for vertebrate pest control and management materials: A symposium; 1976 March 8; Monterey, CA. ASTM Spec. Tech. Publ. 625. Philadelphia, PA: American Society for Testing and Materials: 5-13.

Standardized test procedures have been developed for evaluating repellent and toxic treatments on Douglas-fir and toxic baits for use against deer mice—a primary target species in the Pacific Northwest. This sequential series of repellent and toxicant evaluations includes various bioassay, phytotoxicity, enclosure, hazard, and field studies with each step providing more detailed information on the properties, efficacy, and potential hazards associated with specific candidate chemicals. The primary objective of these evaluations is to provide a safe, effective method to achieve the minimum stocking criteria of 7,400 Douglas-fir seedlings per ha.

766. Marsh, Rex E.; Howard, Walter E.; Cole, Ronald E. 1977. The toxicity of chlorophacinone and diphacinone to deer mice. *Journal of Wildlife Management* 41(2): 298-301.

Oat groat baits containing various concentrations of the anticoagulant rodenticides chlorophacinone or diphacinone were offered to 400 individually caged deer mice, with and without the availability of supplemental food, to determine their comparative effectiveness as control agents. No significant difference occurred in mortality with or without supplemental food. In the 2-day tests, only 0.02% chlorophacinone gave 100% mortality. Diphacinone produced 70 to 90% mortality in the 4-day tests with concentrations of 0.0025% or higher, while chlorophacinone gave 100% mortality at all concentrations of 0.0025% or above. The collective results of chlorophacinone were significantly more effective than the comparable concentrations of diphacinone on both the 2- and 4-day tests. The mortality difference between the 2- and 4-day results was significant for both compounds.

767. Matschke, George H.; Fagerstone, Kathleen A. 1984. Efficacy of a two-ingredient fumigant on Richardson's ground squirrels. In: Clark, Dell O., ed. Proceedings, 11th vertebrate pest conference; 1984 March 6-8; Sacramento, CA. Davis, CA: University of California: 17-19.

In July 1981, efficacy data were obtained on a new 2-ingredient gas cartridge by field testing against Richardson's ground squirrels in a sagebrush-rangeland pasture. The gas cartridge contained 97 g of a sodium nitrate (65%) and charcoal (35%) mixture and upon ignition generated mainly carbon monoxide with a small quantity of carbon dioxide. Ground squirrels were live-trapped, equipped with a radiocollar, and released. Later they were located and their main burrow was treated with the gas cartridges. After treatment, dead squirrels were located and confirmed by burrow excavation. Success rate was 84% as 41 of 50 died and 8 survived. Efficacy as estimated at 83.7%, which exceeds the 70% minimum standard established by the EPA. Recommendations for further testing are presented.

768. Matschke, George H.; Fordham, Carolyn L.; Hurlbut, Susan C.; Engeman, Richard M. 1988. Comparative toxicity of strychnine to eight species of ground squirrels. In: Uresk, Daniel W.; Schenbeck, Greg L.; Cefkin, Rose, tech. coords. 8th Great Plains wildlife damage control workshop proceedings; 1987 April 28-30; Rapid City, SD. Gen. Tech. Rep. RM-154. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station: 75-80.

The toxicity of three strychnine bait concentrations, 0.20%, 0.35%, and 0.50% was evaluated on eight species of ground squirrels (*Spermophilus* spp). Significant species-specific differences were evident in the relative toxicity of strychnine in our tests.

769. Moore, A.W. 1942. Shrews as a check on Douglas-fir regeneration. *Journal of Mammalogy* 23(1): 37-41.

Oregon coastal shrews vary their insect diet, and contents of stomachs examined show at times a preponderance of vegetable matter. Seed of the Douglas-fir appears to be readily consumed by these insectivores. These seeds are the largest of the evergreen conifer seeds common to the Oregon coastal strip. The high shrew population may be a partial cause of the relatively sparse stand of Douglas-fir and the dominants consisting of smaller seeded conifers—spruce, lodgepole pine, hemlock, and alder.

770. Moore, A.W. 1943. The pocket gopher in relation to yellow pine reproduction. *Journal of Mammalogy* 24(2): 271-272.

On the Ochoco National Forest in Oregon, grazing and the presence of pocket gophers are responsible for the lack of reproduction of ponderosa pine. When pressed for food, livestock will consume most growing green vegetation within reach, which greatly reduced the natural reproduction of ponderosa pine. Pocket gophers consumed a variety of vegetation including roots, tops and bark of pines, but not pine

seed. Use of pocket gopher runways by white-footed mice is the primary cause of the lack of pine reproduction in areas inhabited by gophers. When gophers are removed from an area, the tunnels collapse and do not afford shelter to the mice, and, as a result, pine seeds are gleaned less thoroughly by the seed-eating mice.

771. Pank, Larry F. 1974. A bibliography on seed-eating mammals and birds that affect forest regeneration. Spec. Sci. Rep.—Wildl. 174. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife. 28 p.

Citations are arranged alphabetically by author and are restricted to journal articles and technical papers written in English and published between 1900 and 1971. Subjects covered include studies identifying birds and mammals that consume forest tree seed; methods of reducing populations of seed-eating animals (that is, toxic baits, toxic seed treatments, and habitat manipulation); methods of deterring or repelling seed-eating species (for example, mechanical barriers, silvicultural practices, and chemical and physical seed treatments); and the effects of control measures on nontarget species and seed viability.

772. Pank, Larry F.; Matschke, George H. 1972. Decline and reinvasion of deer mouse populations after baiting Douglas-fir clearcuts with 6-aminonicotinamide. *Journal of Forestry* 70(11): 678-680.

Oat groats treated with 1% 6-aminonicotinamide by weight were broadcast at 1/2 pound per acre on three 40-acre clearcuts in Douglas-fir timber types. Live-trapping 1 week after baiting indicated a 100% reduction of resident deer mouse populations, but within 1 month reinvasion had brought enough population to justify rebaiting according to the criterion of 5 mice per 100 trap nights.

773. Radwan, M.A. 1970. Destruction of conifer seed and methods of protection. In: Dana, Richard H., ed. *Proceedings, 4th vertebrate pest conference; 1970 March 3-5; West Sacramento, CA*. Davis, CA: University of California: 77-82.

Reviews seed protection by mechanical methods, poison baiting, chemical treatment of seed, biological methods (predation, disease, chemosterilants), and cultural methods.

774. Record, C. Raymond; Marsh, Rex E.; Howard, Walter E. 1976. Olfactory responses of deer mice to Douglas-fir seed volatiles. In: Siebe, Charles C., ed. *Proceedings, 7th vertebrate pest conference; 1976 March 9-11; Monterey, CA*. Davis, CA: University of California: 291-297.

An attempt was made to identify the olfactory cues produced by Douglas-fir seeds which attract deer mice to the seeds. The olfactometers used are described, and the merits of different statistical analyses of the data are discussed. The odors produced by whole Douglas-fir seed and by the endosperm were preferred among the fractions tested to date. Deer mice were repelled by Douglas-fir turpentine, cedar oil, and, to a lesser degree, one extract.

775. Salmon, Terrell P.; Schmidt, Robert H. 1984. An introductory overview to California ground squirrel control. In: Clark, Dell O., ed. Proceedings, 11th vertebrate pest conference; 1984 March 6-8; Sacramento, CA. Davis, CA: University of California: 32-37.

Techniques for controlling California ground squirrels (*Spermophilus beecheyi*) include trapping, shooting, acute toxicants, anticoagulants, and fumigants. These techniques are described and compared and the available information on their efficacy and economics is discussed. This kind of analysis is essential if growers are to make logical decisions regarding the various control options.

776. Sullins, G. Lamont; Verts, B.J. 1978. Baits and baiting techniques for control of Belding's ground squirrels. *Journal of Wildlife Management* 42(4): 890-896.

Belding's ground squirrels consumed significantly different amounts of 12 bait materials tested for preference during February-July 1975. More of the succulent baits than grain baits were consumed during the first 2 months after ground squirrels emerged from hibernation. Oat groats were consumed in significantly greater quantities than other grain baits. Consumption of crimped oats (commonly used in commercially prepared baits) was more variable than for any other bait. Amounts of bait applied in a single application had more effect than placement of bait on proportions of ground squirrels consuming oat groats with Rhodamine B added as a marker dye. Broadcasting bait was the most economical means of application.

777. Sullivan, T.P. 1987. Understanding the resiliency of small mammals to population reduction: poison or population dynamics? In: Richards, C.G.J.; Ku, T.Y., eds. *Control of mammal pests*. London, UK: Taylor and Francis Ltd: 69-82.

Populations of wilderness rodents and lagomorphs inflict damage upon forests and agricultural crops wherever these small mammals coincide with land development. The main method of control involves the use of rodenticides and related poisons. This approach seldom considers the importance of resiliency in maintaining small-mammal populations. The repopulation of experimentally depopulated areas by five species of small mammals shows that poison cannot effectively suppress these populations for long, at least in limited areas. Alternative control strategies based on population dynamics, behavioral and feeding ecology, and predator odor repellents point the way to more effective and long-term control than is currently achieved by using standard methodology. Small-mammal species studied include the deer mouse, montane vole, northern pocket gopher, snowshoe hare and Columbian ground squirrel.

778. Sullivan, Thomas P. 1978. Biological control of conifer seed damage by the deer mouse (*Peromyscus maniculatus*). In: Howard, Walter E., ed. Proceedings, 8th vertebrate pest conference; 1978 March 7-9; Sacramento, CA. Davis, CA: University of California: 237-250.

Describes the development of a biological technique that successfully controls conifer seed damage by the deer mouse. Eleven experiments have been conducted on three

study areas in British Columbia. Populations of deer mice have been monitored in all experiments with data from 56,000 trap nights. The technique involves a mixture of conifer seed (Douglas-fir) with sunflower seed and oats, which is uniformly distributed on logged areas in the late winter-early spring. Survival of conifer seed with these alternate foods was excellent, compared with control Douglas-fir by itself, for an 8-week period during this time of year. Populations of seed-eating birds and chipmunks are not present on clearcut areas from late October to early April. In addition, deer mice are at their lowest density during the spring. Thus, the use of alternate foods with Douglas-fir seed in a direct-seeding operation at the appropriate time of year will result in successful regeneration of cutover forest lands.

779. Sullivan, Thomas P. 1979. Repopulation of clear-cut habitat and conifer seed predation by deer mice. *Journal of Wildlife Management* 43(4): 861-871.

If deer mice are removed from cutover forest lands, conifer seed survival on these areas should be higher than that obtained on a control. Areas of 1.1 ha in coastal British Columbia were cleared of deer mice and related small mammals. Colonization of these depopulated areas by deer mice and the survival of Douglas-fir seed dispersed over the clearcut were monitored. Mice immigrated into the vacant habitat from the surrounding forest and clearcut. During the fall, 98 mice colonized a depopulated area. There was a continuous movement of animals onto the area and a resultant loss of 95% of the Douglas-fir seed within 3 days. Similarly, during a removal experiment in the spring, 48 mice immigrated into the vacant habitat. These animals destroyed 92.6% of the seed within 5 days. In all experiments, conifer seed survival was low and showed little variation between control and removal areas even though mice were continually removed from the experimental area. Poison baiting of deer mice will not help direct seeding programs because mice reinvade too rapidly and are efficient at seed destruction.

780. Sullivan, Thomas P. 1979. The use of alternative foods to reduce conifer seed predation by the deer mouse (*Peromyscus maniculatus*). *Journal of Applied Ecology* 16(2): 475-495.

The use of alternative foods as a biological control technique has successfully reduced conifer seed predation by deer mice. The upper limits to the number of mice and number of seeds taken per mouse were determined over a wide range of densities of Douglas-fir seed. The number of mice stabilized at approximately 36 per ha, and the number of seeds taken stabilized at about 860,000 seeds per ha. Experiments with alternative foods were done at this seed density in ratios of seven sunflower seeds to one Douglas-fir seed and five sunflower to two oats to one Douglas-fir seed. These mixtures produced the best results: 70% survival of conifer seed after 2 weeks and 50% after 4 weeks compared with 5% survival of Douglas-fir without alternative food. Similarly favorable results were obtained in the early spring (March to April) and in early winter (November to December). Seeding experiments with alternative foods during other times of the year and with lower densities of sunflower seeds were not successful. The application of this technique should result in successful regeneration of cutover forest lands by direct seeding.

781. Sullivan, Thomas P.; Sullivan, Druscilla S. 1980. The use of weasels for natural control of mouse and vole populations in a coastal coniferous forest. *Oecologia* 47(1): 125-129.

If the natural enemy component of biological control is functional in small mammals, then the introduction of weasels should effectively reduce populations of deer mice and Oregon voles (*Microtus oregoni*). Seven weasels introduced to an area of forest habitat in coastal British Columbia did not appreciably lower the abundance of mice or voles. The natural predators may have contributed to the localized extinction of the vole population on the experimental area. Weasels were generally more abundant in the late summer and early fall and preferred clearcut successional habitats compared with forested areas. The results of this study are discussed with respect to the futility of poison baiting and related techniques of removing rodent pest populations from forest and agricultural land developments.

782. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. Reducing conifer seed predation by use of alternative foods. *Journal of Forestry* 80(8): 499-500.

By supplying alternative foods, damage to seed by rodents and birds was greatly reduced in seeding trials with Douglas-fir and lodgepole pine in British Columbia. Although the trials did not demonstrate that a stand of seedlings will actually be obtained, the technique appears to warrant further study as a way to improve the reliability of direct seedings.

783. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. The use of alternative foods to reduce lodgepole pine seed predation by small mammals. *Journal of Applied Ecology* 19(1): 33-45.

Lodgepole pine seed predation by deer mice and related small mammals has been studied at three interior areas of British Columbia. When the distribution and abundance of rodent seed predators was taken into account, the amount of seed damage was directly related to the relative density of animals. Deer mice and voles destroyed the majority (85%) of pine seed within 3 weeks of application when the abundance of these rodents was >five animals per ha. In areas with prolonged low densities (<three animals per ha), lodgepole pine showed very good survival (60-70% after 3 weeks). The use of sunflower seeds as an alternative food successfully reduced pine seed predation. A ratio of two sunflower seeds to one pine seed produced a range of 50-82% survival of pine seed after 3 weeks and 42-72% after 6 weeks compared with 12-15% and 8-10% survival of pine without sunflower. This technique could be used for direct seeding cutover forest lands in areas suitable for growth of lodgepole pine in North America.

784. Sullivan, Thomas Priestley. 1979. Conifer seed predation by the deer mouse: a problem in reforestation. Vancouver, BC: University of British Columbia. 181 p. Ph.D. dissertation.

Little research has been done on methods involving biological control of the small mammals and birds that eat conifer seed. This thesis will describe the development of a biological technique for reducing conifer seed predation in deer mice. The first

chapter was designed to test the hypothesis that clearcut habitats support higher density populations of deer mice than do forested habitats. Deer mouse populations were live-trapped in forest and clearcut habitats from May 1975 to April 1978. The average density of mice per ha for 1975, 1976, and 1977, respectively, was 19.6, 15.8, and 22.3 in the forest and 22.3, 16.6, and 29.9 in the clearcut. The density of mice on the clearcut area declined during each winter to a level comparable to that in the forest. The second chapter was designed to test the hypothesis that removal of all deer mice from a given area would result in satisfactory survival of conifer seed. During the fall, 99 mice colonized a depopulated area of 1.1 ha. Animals continually moved onto the area, and 95% of the conifer seed was lost with 3 days. The third chapter discusses the use of alternative foods as a biological control technique. The upper limits of mice and seeds taken per mouse were determined; the number of seeds taken stabilized at about 860,000 seeds per ha. Experiments with alternative foods were done at this seed density in ratios of seven sunflower to one Douglas-fir and five sunflower to two oats to one Douglas-fir seed. These mixtures produced the best results: 70% survival of conifer seed after 2 weeks and 50% survival after 4 weeks. The best time for seeding was late winter to early spring.

785. Tevis, Lloyd, Jr. 1956. Effect of a slash burn on forest mice. *Journal of Wildlife Management* 20(4): 405-409.

A 16-acre clearcut in the California Douglas-fir region was live-trapped for 5 days before a slash burn and was snap-trapped for 2-1/2 weeks thereafter. The objective was to determine if fire could be used to control seed-eating mice which hinder reforestation. Before the burn, 41 mice were captured, marked, and released. After the burn, 13 of these marked individuals were found in the forest and 4 on small, non-burned islands in the center of the cutover. The fire had killed or driven out all resident mice except the few that had stayed on areas not reached by flames. There was no reinvasion of the clearcut until rain settled the ashes. Then in 2-1/2 weeks, 72 mice were trapped. A slash burn, therefore, does not control mice.

786. Johnson, Murray L.; Johnson, Sherry. 1982. Voles (*Microtus* species). In: Chapman, Joseph A.; Feldhamer, George A., eds. *Wild mammals of North America: biology, management, and economics*. Baltimore, MD: Johns Hopkins University Press: 326-354.

Reviews nomenclature, distribution, description, physiology, genetics, reproduction, ecology, food habits, behavior, mortality, status, and management of the various species of *Microtus*.

787. Anderson, Judith L.; Boonstra, Rudy. 1979. Some aspects of reproduction in the vole *Microtus townsendii*. *Canadian Journal of Zoology* 57(1): 18-24.

Changes in various reproductive parameters have pronounced effects on microtine population fluctuations. This study presents a detailed account of reproduction in *Microtus townsendii*. Populations in two areas were studied. On Westham Island, litter size, estimated by autopsy, was correlated positively with weight. There was no significant difference in litter size between primiparous and multiparous females. Females pregnant in spring had more embryos than those pregnant in summer or

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fall. Breeding was concentrated in spring and summer, with most females continuously pregnant. In the University of British Columbia Research Forest, litter size at recruitment was unrelated to parity, size, or LAP genotype of the mother. Although the size of consecutive litters was significantly repeatable within a individual mother, recruitment litter size was not. Autopsy litter size, as at Westham Island, was largest in the spring, but recruitment litter size was largest in autumn. Entire litters were lost most often during winter and summer.

788. Anthony, R.G.; Forsman, E.D.; Green, G.A. [and others]. 1987. Small mammal populations in riparian zones of different-aged coniferous forests. *Murrelet* 68(3): 94-102.

The purpose of the study was to compare small-mammal populations inhabiting low-order riparian zones in three age classes of forests and to contrast species composition and capture rates for streamside versus riparian fringe transects. Small mammals were snap-trapped in young, mature, and old-growth forests. Deer mice were the most abundant species and made up 76 and 83% of the total captures during spring and summer, respectively. Total small-mammal abundance was greater in old-growth forests than in young and mature forests. *Microtus oregoni*, *Phenacomys albipes*, *Neotoma cinerea*, *Sorex palustris*, *S. monticolus*, and *Neurotrichus gibbsii* were captured only in old-growth or mature forests. Six species of insectivorous mammals including five species of shrews were captured, which exemplifies the importance of riparian zones for this group. More species, but fewer individuals, were captured on the streamside transects in comparison to the riparian fringe transects. Additional studies with more intensive trapping designs are needed to define the specific habitat relationships of *Sorex palustris*, *S. bendirii*, *Phenacomys albipes*, *Neurotrichus gibbsii*, and *Microtus richardsoni*.

789. Anthony, Robert G.; Morrison, Michael L. 1985. Influence of glyphosate herbicide on small-mammal populations in western Oregon. *Northwest Science* 59(3): 159-168.

The effect of glyphosate application on vegetation and small-mammal populations in the Coast Range of western Oregon was investigated. Diversity, abundance, and biomass of small-mammal populations increased 1 year postspray on glyphosate-treated sites as compared to control sites. These changes were ephemeral, and the above parameters were similar to prespray values 2 years after glyphosate application. The changes in diversity, abundance, and biomass were primarily a result of the increase in numbers of *Microtus oregoni* after an increase in grass and forb cover on treated grids one year postspray. The temporary effects of glyphosate treatment on vegetation had no detrimental effects on small-mammal populations.

790. Beacham, Terry D. 1979. Dispersal tendency and duration of life of litter mates during population fluctuations of the vole. *Oecologia* 42(1): 11-22.

In increasing and peak populations of the vole *Microtus townsendii*, litter mates, whether they did or did not disperse, tended to have similar lifespans. Identifiable families tended to survive or disperse as a unit. Tendency to disperse from peak populations was nonrandomly distributed among litters, and litter mates dispersed at the same age.

791. Beacham, Terry D. 1979. Size and growth characteristics of dispersing voles, *Microtus townsendii*. *Oecologia* 42(1): 1-10.

In a peak population of *Microtus townsendii*, adults and subadults dispersed during the spring decline, and subadults and juveniles dispersed during the summer and fall. Voles born in the spring dispersed before the start of the next year's breeding season, and fall-born voles dispersed during the next year's breeding season. Voles under 50 g, when they dispersed, had faster growth rates than similar-sized residents, but voles over 59 g, when they dispersed, had slower growth rates than similar-sized residents. Dispersing and resident voles 50-59 g had no consistent trend in growth rates.

792. Beacham, Terry D. 1979. Survival in fluctuating populations of the vole *Microtus townsendii*. *Canadian Journal of Zoology* 57(12): 2375-2384.

Four populations of the vole *Microtus townsendii* were trapped concurrently with live traps and pitfalls from May 1976 until June 1978. The capture of a large number of young in pitfalls indicated that mortality was higher among postweanlings than among any other age group. Juvenile survival was highest in increasing populations and lowest in declining ones, but preweanling survival was lowest in peak populations. Larger voles survived better than smaller ones, and females survived better than did males. Minimum survival rates of different size and sex classes of voles were dependent upon the trapping technique used.

793. Beacham, Terry D. 1980. Demography of declining populations of the vole, *Microtus townsendii*. *Journal of Animal Ecology* 49(2): 453-464.

Eight spring declines in population size of *Microtus townsendii* were monitored by mark-recapture techniques near Vancouver, British Columbia. In light-to-moderate spring declines, most of the loss is due to dispersal; in severe declines, most of the loss is due to death. In moderate spring declines, there is a positive correlation between rate of decline and proportion of heavy-weight voles; in severe declines, the correlation is negative. Males disappear more rapidly than do females. Wounding rates are higher in moderate declines. In moderate spring declines, large voles of both sexes survive better than do small voles, but in severe declines, large and small females survive equally poorly. Smaller voles in the postpeak winter lost weight. Intrinsic and extrinsic factors contributed to the postpeak winter decline, but spacing behavior seems the most likely explanation for the rapid decrease in survival at the start of the decline breeding season.

794. Beacham, Terry D. 1980. Growth rates of the vole (*Microtus townsendii*) during a population cycle. *Oikos* 35(1): 99-106.

Four populations of the vole *Microtus townsendii* were trapped concurrently with live traps and pitfalls from May 1976 to June 1978. Males always grew faster than females. Voles born in the spring had the highest growth rate of any season, and growth rates decreased throughout the summer and autumn. Spring growth rates of male *M. townsendii* less than 40 g remained constant through the population cycle, but summer and autumn growth rates became progressively less. Growth rates of

males over 40 g generally declined seasonally through the population cycle. Heavy-weight males present in peak populations gained weight throughout the preceding winter while all other males lost weight; they also grew faster than medium-weight males at all weight ranges from the increase until the peak spring. After the peak spring, heavy-weight and medium-weight males grew at similar rates, which suggests that they had different asymptotic weights during this portion of the cycle.

795. Beacham, Terry D. 1980. Survival of cohorts in a fluctuating population of the vole *Microtus townsendii*. *Journal of Zoology* 191(1): 49-60.

Survival patterns of cohorts are described during a population cycle of the vole *Microtus townsendii* near Vancouver, British Columbia. A 2-year live-trapping study on both enclosed and unfenced populations showed that cohorts during the increase phase of growth lived longest and had the best survival. Smaller voles in the peak density spring cohort had poor survival, but survival increased during the peak density summer. Survival of cohorts in the decline phase breeding season was very poor. The suggestions are made that changes in spacing behavior may cause changes in cohort survival and that the causes of rapid changes in survival need to be determined.

796. Beacham, Terry D. 1980. Survival of large and small adults in fluctuating populations of *Microtus townsendii*. *Journal of Mammalogy* 61(3): 551-555.

Large adult *Microtus townsendii* of both sexes survived better than small adults in increasing and peak populations. In declining populations, however, large adults lost their survival advantage. The suggestion that large *M. townsendii* of both sexes had different patterns of survival advantage was not supported by this study. This study further demonstrates that partial correlations of survival differentials, population growth rates, and densities were influenced in sign and magnitude by different groupings of data. Microtine populations typically undergo spring declines in population size, and these declines are usually more severe in males than in females. The decreased survival of smaller adult males in the spring of 1977 may be accounted for by the increased dispersal at that time. The poorer survival of small rather than of large adult females in the summer of 1977 may be partly accounted for by dispersal of smaller females and perhaps by increased mortality of small adult females due to botfly parasitism. The spring of 1978 was characterized by a rapid decrease in vole density as breeding began, and large and small adults of both sexes had similarly poor survival rates, with essentially no dispersal at that time. Males survived more poorly than females in this period, and the cause of this rapid decrease in density concurrent with low survival remains the enigma of the microtine cycle.

797. Beacham, Terry D. 1981. Some demographic aspects of dispersers in fluctuating populations of the vole *Microtus townsendii*. *Oikos* 36(3): 273-280.

Dispersal of the vole *M. townsendii* was studied by enclosing two populations and by providing an area inside each enclosure into which the voles could disperse. More males dispersed than females, but the excess of males was restricted to the adult weight class. At least 40% of the subadult dispersers were in breeding condition

during the nonwinter periods, compared with a maximum of 15% of the resident subadults. Dispersers attained sexual maturity at lower weight than did residents. Juvenile and subadult dispersal was common during the peak summer. Selective dispersal during the increase and peak phases may be an important component of the microtine cycle.

798. Beacham, Terry Dale. 1979. Dispersal, survival, and population regulation of the vole *Microtus townsendii*. Vancouver, BC: University of British Columbia. 226 p. Ph.D. dissertation.

Several field studies on voles have suggested that dispersal is an important mechanism of population regulation. To investigate whether voles disperse from declining populations, I made two vole-proof enclosures, each having an area into which the voles could disperse. These two fenced populations and two unfenced control populations were trapped from May 1976 until June 1978. All four vole populations declined for 3 months after breeding began in spring 1977, the declines being concurrent with dispersal of the smaller voles. More males dispersed than females during this spring decline. Dispersal of subadult voles was common in the peak populations of summer 1977, with these individuals more often in reproductive conditions than were resident subadults. I suggest that aggressive behavioral interactions between smaller animals attaining sexual maturity and larger sexually-mature adults prompted the dispersal of the smaller individuals. All four vole populations declined for a second time in October 1977 for 8 months, with the decline spanning both the nonbreeding and subsequent breeding season. Most of the losses occurred in the nonbreeding season, when the voles were neither wounded nor dispersing. I suggest that interference competition between large and small voles for a limited food supply may have accounted for some of the nonbreeding season losses. The concurrent use of live-traps and pitfalls showed that live-traps failed to enumerate completely any size or sex category of voles. Live-traps sample the dominant individuals preferentially, pitfalls the subordinates.

799. Black, H.C.; Hooven, E.F. 1974. Response of small mammal communities to habitat changes in western Oregon. In: Black, Hugh C., ed. Wildlife and forest management in the Pacific Northwest: Proceedings of a symposium; 1973 September 11-12; Corvallis, OR. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University: 177-186.

Habitat changes after wildfire, clearcutting, or herbicide application profoundly affect species composition of small-mammal communities. Small-mammals responded to habitat changes after disturbances according to their habitat preferences. Shrews, voles, and Townsend's chipmunks were few or absent on Douglas-fir clearcuts after wildfire, but shrews and voles were abundant in early successional stages of unburned Douglas-fir clearcuttings. Red-backed voles rarely were found on clearcuts, even in the shrub stage of succession. Golden-mantled ground squirrels and Great Basin pocket mice were abundant on clearcuts in the mixed conifer region, although they were not found on uncut stands. After herbicide treatments of Douglas-fir clearcuts, vagrant shrews, Pacific jumping mice, and Oregon voles were less abundant on treated areas, but small-mammal habitat recovered markedly within 2 years after herbicide treatment of clearcuts in the grass-shrub stage of succession. In southwestern Oregon, small-mammal communities were less affected by herbicide-induced

habitat changes because microtines and other species associated with grassy habitats were only minor components of the community. On areas with complete vegetation control, however, abundance of pocket gophers was reduced greatly 1 year after treatment.

800. Borrecco, John E.; Black, Hugh C.; Hooven, Edward F. 1979. Response of small mammals to herbicide-induced habitat changes. *Northwest Science* 53(2): 97-106.

In studies in western Oregon, half of each of three areas that had been logged and burned 8-12 years earlier were sprayed in spring 1970-71 with a combination of atrazine and 2,4-D. Dalapon and Silvex were included in 1970. The herbicides reduced the competition from other vegetation and provided a more favorable environment for survival and growth of Douglas-fir seedlings. The reduction in ground cover and numbers of species of grasses and herbs led to increases in numbers of *Peromyscus maniculatus* and *Sorex trowbridgii* and reductions in numbers of *S. vagrans*, *Microtus oregoni* and *Zapus trinotatus*.

801. Borrecco, John Edward. 1972. The response of animals to herbicide-induced habitat changes. Corvallis, OR: Oregon State University. 92 p. M.S. thesis.

The objectives of this investigation were to examine the changes in vegetation resulting from application of herbicides and to study the effects of these vegetative changes on the abundance and composition of small-mammal populations and on deer usage of treated and untreated plots. On three areas in Oregon, half of each was treated with a combination of herbicides designed to control grasses and forbs without injuring Douglas-fir. Small mammals primarily associated with grass or meadow habitats decreased in abundance. The Oregon vole was the species most affected by the reduction in grassy vegetation. Species that find optimum habitat in brushy areas increased in abundance on treated plots. The deer mouse was the most common species to demonstrate a positive response on treated plots. Deer activity, as measured by pellet-group counts, was greater on treated plots during the growing seasons. No significant differences were found in the occurrence of browsing as a result of herbicide-induced habitat changes. Browsing was influenced by season. Herbicide treatments improved deer habitat during the growing season without significantly increasing the browsing of Douglas-fir seedlings.

802. Cowan, I. McT.; Arsenault, Margaret G. 1954. Reproduction and growth in the creeping vole, *Microtus oregoni serpens* Merriam. *Canadian Journal of Zoology* 32(3): 198-208.

The growth and reproduction of this rodent was studied in the laboratory and in the wild. Growth data are largely from 28 captive-born litters. Gestation is 23.5 days; mean litter size is 2.95; a postparturient estrus is usual but frequently does not occur; puberty occurs at 22-24 days in females and 34-38 days in males; there is a sterile period of 5-14 days between first estrus and first conception; longevity in captivity exceeds 320 days, but in the wild there is a complete annual turnover. Instantaneous relative growth rates were determined for four distinguishable phases of growth. A limited experiment using light and heat to stimulate increased reproduction had doubtful results.

803. Gashwiler, Jay S. 1970. Plant and animal changes on a clearcut in west-central Oregon. *Ecology* 51(6): 1018-1026.

Plant composition and coverage and small-mammal populations were compared in virgin forest and clearcut areas from April 1954 to October 1956. Changes in ground-cover vegetation were modest on the forest but marked on the clearcut. Ground plant coverage was less than 23% in the virgin forest; 1 year after the clearcut was burned, the cover was 2%; and by 10 years it was above 53%. Woody plant coverage was slightly more abundant the first 2 years after burning. Herbaceous species then became dominant for 3 years, after which woody plants gradually gained dominance. Deer mice increased on the clearcut soon after the burn. The populations varied from an estimated 0.9 to 12.8 animals per acre and fluctuated widely and irregularly. Townsend's chipmunk, Oregon vole, and snowshoe hare populations also increased on the area at different periods after the burn. Trowbridge's shrews, vagrant shrews, and ermine were present on both areas in relatively low numbers. Red-back voles, Douglas squirrels, and northern flying squirrels were not found on the clearcut. California ground squirrels migrated to the clearcut and established a modest population. Richardson's voles, jumping mice, bushy-tailed woodrats, and a pika were visitors.

804. Gashwiler, Jay S. 1972. Life history notes on the Oregon vole, *Microtus oregoni*. *Journal of Mammalogy* 53(3): 558-569.

Life history and population data and other information were obtained from 713 Oregon voles captured in poor habitat in western Oregon from 1952 to 1967. With one exception, greater numbers were caught annually in clearcut areas than in virgin forest habitat even during the early stages of plant succession. The population increased on clearcut areas until 4 years after burning, but there was no consistent relationship between the age of a clearcut area and the abundance of voles. Estimated number of voles per acre ranged from 0.0 to 6.0 and averaged 0.8 in spring and 1.6 in autumn. Fifty-one percent of live-trapped animals were recaptured after the first month and only 1% after 12 months. Greatest longevity recorded was for a female at least 16 months old. Average area and length of home ranges, determined on the basis of 6-night trapping periods, were 0.224 acre and 178 feet for adult males and 0.142 acre and 110 feet for adult females. Ranges for adults were roughly similar for three to five captures and were not greatly influenced by the type or density of live vegetation. The sex ratio was 47:53, males to females. Juveniles were found in each month except February, and their number was greatest in October (51%). The average breeding season extended from mid-February to mid-September. Litter size, based on embryos and uterine scars, ranged from one to eight (average 3.2), with a mode of three. Calculations suggested an average of 4.8 litters per female per year.

805. Goertz, John W. 1964. Habitats of three Oregon voles. *Ecology* 45(4): 846-848.

Voles of the species *Microtus oregoni oregoni*, *M. townsendii townsendii*, and *M. montanus canicaudus* were collected from the Coast Range and Willamette Valley habitats in western Benton County, Oregon, from June 1957 to January 1959, in an effort to determine habitat preferences. Collecting results indicate that

the Oregon vole is a species of the Coast Range. It is found in all Coast Range (Douglas-fir) habitats but prefers grassy cutover areas. Townsend voles are most closely associated with both Coast Range and valley riparian situations, especially where dense stand of sedge and grass occur. The gray-tailed vole is found on all agricultural lands, especially in fields and pastures of grass and legumes and along fence row. This species is not associated with Coast Range habitats.

806. Gunther, Pamela M.; Horn, Brenda S.; Babb, Geoffrey D. 1983. Small mammal populations and food selection in relation to timber harvest practices in the western Cascade mountains. *Northwest Science* 57(1): 32-44.

Small mammals were snap-trapped in a mature conifer forest, unburned clearcuts, and a burned clearcut in the western Cascade Range in central Washington. The largest populations were in unburned clearcuts, and the smallest overall population was in the forest. *Sorex trowbridgii* was the most abundant insectivore caught. *Clethrionomys gapperi* was the most abundant rodent caught in most clearcuts, and its population was the largest of any species in the study area. Other species caught include *Sorex monticolus*, *Neurotrichus gibbsii*, *Eutamias townsendii*, *Glaucomys sabrinus*, *Peromyscus maniculatus*, *Microtus townsendii*, and *Zapus trinotatus*. Vegetation and percent cover were analyzed in the study area, and small-mammal stomach contents of all nine animal species were examined. In the forest and burned clearcut, small mammals ate more invertebrates than any other food type. In unburned clearcuts, fungi and epiphytic lichens, especially *Alectoria sarmentosa*, and conifer seeds were the major foods eaten by rodents.

807. Halvorson, Curtis H. 1982. Rodent occurrence, habitat disturbance, and seed fall in a larch-fir forest. *Ecology* 63(2): 423-433.

Small-mammal population changes were measured for 5 years by live trapping on broadcast burned western larch/Douglas-fir clearcuts and in uncut timber on a north and a south slope in western Montana. Four species comprised 96% of the 1,324 animals caught: deer mice 42%; red-backed voles 27%; red-tailed chipmunks 22%; and long-tailed voles 5%. Deer mice and chipmunks were common on clearcut and timber plots. The voles were associated with moist sites but showed local allopatry. The red-backed vole were present only under tree canopy, and the long-tailed vole was found only in absence of tree canopy. A hard-burn effect was to eliminate most of the organic mantle and all small mammals except deer mice. A light burn effect which left duff intact was associated with retention of species diversity. Deer mice increased sharply on all plots the first fall after a heavy conifer seed crop. From these pattern observations it is theorized that red-backed voles may dominate deer mice, but a heavy seed crop can temporarily enhance competitive standing of deer mice. An open, xeric, pioneering situation (hard burn) was conducive to persistently high deer mouse populations. Clearcutting appeared to be the principal determinant of total population size, but burn intensity seemed to influence species composition.

808. Hooven, Edward F. 1969. The influence of forest succession on populations of small animals in western Oregon. In: Black, Hugh C., ed. *Wildlife and reforestation in the Pacific Northwest: Proceedings of a symposium*; 1968 September 12-13; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 30-34.

Reviews the influence on populations of small animals of logging, wildfire, and other factors that create abrupt vegetational changes. Studies at two locations in western Oregon demonstrated marked changes in composition and abundance of populations of small mammals after logging and wildfire. Small mammals were more abundant in a recently logged area than in a mature stand of Douglas-fir. Wildfire selectively reduced populations of small mammals, but recovery, particularly of deer mice, was rapid. This recovery primarily resulted from a reinvasion by the animals of habitat made favorable by the fire. The succession of important species of small mammals and seed-eating birds is related to vegetative succession and other changes in habitat.

809. Hooven, Edward F. 1973. Effects of vegetational changes on small forest mammals. In: Hermann, Richard K.; Lavender, Denis P., eds. *Even-age management: Proceedings of a symposium*; 1972 August 1; Corvallis, OR. Corvallis, OR: School of Forestry, Oregon State University: 75-97.

Certain physical and biotic changes that occur relative to clearcutting can affect small-mammal populations. Soil moisture and soil temperature may increase for the first few years but decrease as revegetation occurs. These factors affect the small-mammal populations through their influence on food availability, shelter, and habitat. Although habitat preferences were readily observable by changes in species density, most of the small-mammals were found on all units. Different small-mammal populations result from different cutting systems, but regardless of the treatment, the small mammals exert an influence on regeneration whether by seed or seedlings. After clearcutting, regardless of the change of species, composition, and densities, the small-mammal biomass remains comparable to that of the uncut forest and exerts the same detrimental effect upon regeneration.

810. Hooven, Edward F. 1973. Response of the Oregon creeping vole to the clear-cutting of a Douglas-fir forest. *Northwest Science* 47(4): 256-264.

Describes the life history and population changes in the Oregon creeping vole as affected by habitat during 3 years of secondary succession after logging a 125-year-old Douglas-fir forest.

811. Hooven, Edward F. 1976. Changes in small-mammal populations related to abundance of Douglas-fir seed. Res. Note 57. Corvallis, OR: Oregon State University, School of Forestry, Forest Research Laboratory. 2 p.

Small-mammal populations were observed on study plots near the South Fork of the McKenzie River, Lane County, Oregon, from 1965 through 1975. Generally, a direct relation appeared between moderate-to-good cone crops and the high populations of small mammals that appeared the next year. A total of 21 species was caught overall during the 11 years of observations, but 6 species comprised 92% of all individuals

caught: shrews (*Sorex trowbridgii*, *S. vagrans*), chipmunk (*Eutamias townsendii*), deer mouse (*Peromyscus maniculatus*), Oregon creeping vole (*Microtus oregoni*), and jumping mouse (*Zapus trinotatus*). Douglas-fir seed is only a small part of the diet of shrews, but the other species eat it more readily, and chipmunks have a tendency to cache the seeds. Because of the sharp increase of animals the summer after a good Douglas-fir cone crop, any control attempts would be quickly nullified by immigrating seedeaters from surrounding areas.

812. Hooven, Edward F.; Black, Hugh C. 1976. Effects of some clearcutting practices on small-mammal populations in western Oregon. *Northwest Science* 50(4): 189-208.

Changes in small-mammal populations and vegetation on two clearcuttings and one uncut stand of 125-year-old Douglas-fir in the foothills of the Cascade Range in western Oregon were noted from 1964 to 1970. Mark-release-recapture methods were followed each summer on a monthly basis. In all, more than 3,630 small mammals of 23 species were caught during 3 years of live-trapping from 1968 to 1970. Five species comprised more than 90% of the total catch. Logging and controlled slash burning profoundly affected habitats occupied by small mammals. Rapid changes in plant abundance occurred in the unburned unit, and vegetative recovery was dominated by herbaceous annuals two years after clearcutting. Shrews and chipmunks were affected adversely by logging. Conversely, populations of deer mice and Oregon creeping voles were affected favorably by both logging and slash burning and increased in abundance after treatment on both clearcuttings.

813. Hooven, Edward Frank. 1972. Effects of clearcutting a Douglas-fir stand upon small animal populations in western Oregon. Corvallis, OR: Oregon State University. 202 p. Ph.D. dissertation.

An ecological study of small forest mammals was conducted from 1964 to 1970 in the west-central Cascade Range of Oregon. The objectives were to obtain chronological information relative to the effects of current logging practices on vegetational succession and small-mammal populations. The study areas were composed of a 125-year-old timbered control unit, a clearcut nonburned unit, and a clearcut slash-burned unit. Density and distribution of the small mammals were determined by live-trapping and release of marked animals. Reproductive information of some species was noted. Home range areas was computed for the more numerous species of rodents. More than 4,530 individual small mammals of 23 species were marked on the three areas during the 6 years of the study. Over 90% of the total animals caught consisted of five species: *Sorex* spp., *Eutamias townsendii*, *Peromyscus maniculatus*, and *Microtus oregoni*. The small-mammal densities varied from year to year. They were comparable between units on a monthly basis except for the unburned clearcut unit which differed for a year following logging. Shrews, abundant in the forest, were less on the unburned and sharply reduced on the slash-burned unit. Deer mice, scarce in the closed forest, increased greatly in numbers on the clearcuts. Chipmunks were abundant in the forest, less on the slash-burned unit, and sharply reduced in numbers on the unburned unit. The results of this study suggest that more information is required relative to the diet of the small mammals, and the effects of vegetation manipulation should be examined.

814. Krebs, Charles J.; Myers, Judith H. 1974. Population cycles in small mammals. *Advances in Ecological Research* 8: 267-399.

Summarizes current information on population cycles in small rodents, especially in reference to voles and lemmings. Looks at some general questions about cycles, discusses the demographic machinery which drives the changes in numbers, and analyzes the current theories which purport to explain population cycles in rodents.

815. MacFarlane, Joan D.; Taylor, J. Mary. 1982. Pregnancy and reproductive performance in the Townsend's vole, *Microtus townsendii* (Bachman). *Journal of Mammalogy* 63(1): 165-168.

Describes the aspects of basic reproductive biology, from both field and laboratory analyses, of Townsend's voles captured in the Fraser River Delta of British Columbia.

816. Maser, Chris; Trappe, James M.; Nussbaum, Ronald A. 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. *Ecology* 59(4): 799-809.

Most higher plants have evolved with an obligatory symbiotic relationship with mycorrhizal fungi. *Epigeous mycorrhiza* formers have their spores dispersed by air currents, but hypogeous mycorrhizal fungi are dependent upon small mammals as primary vectors of spore dissemination. Mammalian mycophagists defecate within the coniferous forest ecosystem, spreading the viable spores necessary for survival and health of the conifers. As one unravels and begins to understand the interrelationships between small mammal mycophagists and mycorrhizal fungi, it becomes apparent that the various roles of small mammals in the coniferous forest ecosystem need to be reevaluated. One can no longer accept such simplistic solutions to timber management as poisoning forest rodents to enhance tree survival. One must consider the direct as well as the indirect costs and benefits of timber management decisions if one is to maintain balanced, healthy coniferous forests.

817. Morrison, Michael L.; Anthony, Robert G. 1989. Habitat use by small mammals on early-growth clear-cuttings in western Oregon. *Canadian Journal of Zoology* 67(4): 805-811.

Abundance and habitat relationships of small mammals were studied on two early-growth clearcuttings in the Oregon Coast Range. Ten species were captured in 3 years of study: *Peromyscus maniculatus* accounted for the majority (64%) of captures. Six other species were captured frequently enough for habitat analysis: *Microtus oregoni* (15%), *Eutamias townsendii* (11%), *Zapus trinotatus* (3%), *Sorex vagrans* (3%), *Sorex trowbridgii* (2%), and *Sorex pacificus* (2%). The small-mammal community was composed of a single, numerically dominant habitat generalist (*Peromyscus*) and several numerically subordinate species that showed varying degrees of habitat specificity. An overall significant difference in habitat use among the seven species was demonstrated with discriminant function analysis; this separation was based primarily on differences in the use of forb and grass cover. There was high overlap in microhabitat associations among species, however, which was likely due to the environment in regenerating coniferous forests.

818. Rhoades, Fred. 1986. Small mammal mycophagy near woody debris accumulations in the Stehekin River Valley, Washington. *Northwest Science* 60(3): 150-153.

The digestive tracts of 32 small mammals (*Sorex monticolus*, *Peromyscus maniculatus*, *Microtus longicaudus*, and *Clethrionomys gapperi*) trapped near woody debris piles were examined for presence and abundance of spores of hypogeous, epigeous, and wood-inhabiting fungi. All animals contained fungal spores, usually in abundance high enough to suggest that each animal had recently consumed fungi. Spores of hypogeous fungi were the most abundant, especially those of genera *Alpova* and *Rhizopogon*.

819. Sheehan, Mark Vincent. 1978. The ecology of *Microtus oregoni* in the subalpine zone of the Olympic Mountains, Washington. Bellingham, WA: Western Washington University. 44 p. M.S. thesis.

The objective of this research was to determine which subalpine plant communities are optimum habitats for *M. oregoni* as indicated by population data, and to identify what aspects of the habitat (diet, protection from predation, living space, lack of competition) most affect the relative densities of *M. oregoni*. The habitat of *M. oregoni* in the subalpine zone of the Olympic Mountains is largely unknown. Preliminary observations indicated that the voles preferred the *Carex spectabilis*, *Valeriana sitchensis*, and *Saussurea americana* communities where vegetation was tall and dense. Little is known about the diet of *M. oregoni* in any habitat. I observed that *M. oregoni* mainly ate green plants in the summer, fungi on occasion, and rhizomes in the winter.

820. Sullivan, Thomas P. 1980. Comparative demography of *Peromyscus maniculatus* and *Microtus oregoni* populations after logging and burning of coastal forest habitats. *Canadian Journal of Zoology* 58(12): 2252-2259.

This study was designed to investigate the abundance and related demographic attributes of *Peromyscus maniculatus* and *Microtus oregoni* populations in successional burned and unburned cutover areas. These populations were live-trapped in three habitats at Maple Ridge, British Columbia, from March to October 1978. The average densities of deer mice and Oregon voles per ha on the burned area were 27.6 and 11.6, and on two unburned areas were 19.1 and 16.0, and 21.9 and 10.4, respectively. There was little variation in the proportion of breeding animals among habitats for either species. Male deer mice survived better on the burned area than in either of the other two habitats; there was little variation in survival among females. Males and females of *M. oregoni* survived equally well. Deer mice generally had greater proportions of reproductive animals and survived better than Oregon voles on all study areas. However, juvenile voles had 1.7 times higher survival than young deer mice. Demographic parameters within populations of *P. maniculatus* and *M. oregoni* tend to be similar in successional burned and unburned habitats 4-5 years after logging.

821. Sullivan, Thomas P.; Krebs, Charles J. 1981. *Microtus* population biology: demography of *M. oregoni* in southwestern British Columbia. Canadian Journal of Zoology 59(11): 2092-2102.

Populations of *Microtus oregoni* were live-trapped from 1971 to 1974 in old field and grassland habitats at the University of British Columbia Research Forest. Forest and shrub habitats were also sampled intensively. An additional population was live-trapped in abandoned grassland near Ladner, British Columbia. *Microtus oregoni* exhibited a 3-4 year cyclic fluctuation in abundance in the old field and shrub habitats. Maximum density (72 voles per ha) was recorded on the old field grid which was optimum habitat for this species. Winter breeding and a long reproductive period before the peak year, and larger body size during the peak than in other phases of the cycle were characteristic features of the old field population. This vole species did not have a multiannual cycle in habitats where the competitor, *M. townsendii*, was present. Oregon voles were 3-4 g heavier at the Research Forest than at the Ladner study area. Female voles were more prevalent than males in all populations.

822. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. Responses of small mammal populations to a forest herbicide application in a 20-year-old conifer plantation. Journal of Applied Ecology 19(1): 95-106.

The responses of small-mammal populations to a forest application of glyphosate herbicide have been investigated at the University of British Columbia Research Forest, Maple Ridge, British Columbia. These populations included the deer mouse, Oregon vole, Townsend chipmunk, and shrews. Treatment of a 20-year-old Douglas-fir plantation did not have any negative effects on the distribution and abundance of small-mammal populations during the first year after this habitat alteration. Movements of deer mice were monitored by drift lines. There was neither an influx of new animals from the surrounding regions onto the treated area nor was there a significant movement of marked animals away from the sprayed area. Future changes in composition of the small-mammal community may occur in association with successional stages advancing from the herbicide-induced habitat alteration.

823. Sullivan, Thomas P.; Sullivan, Druscilla S. 1984. Influence of range seeding on rodent populations in the interior of British Columbia. Journal of Range Management 37(2): 163-165.

This study was designed to determine the influence of range seeding on rodent populations inhabiting cutover lodgepole pine forest land in the interior of British Columbia. Both deer mice and voles were strongly attracted to an area seeded with grass mixture in the early spring, even though overwinter mortality had dramatically reduced the average density to under two animals per ha. Five rodents as well as several seed-eating birds appeared on this seeded area, however, no animals were recorded on a nearby control. Subsequent seeding experiments in the summer also produced significant increases (2 to 2.2 times) in rodent populations. Success of range seeding in British Columbia can be quite variable, possibly due to seed predation by mice and voles. Consequently, both the quality and quantity of seed remaining for germination and forage production may be radically altered.

824. Sullivan, Thomas P.; Sullivan, Druscilla S. 1988. Influence of alternative foods on vole populations and damage in apple orchards. *Wildlife Society Bulletin* 16(2): 170-175.

Three experiments with alternative foods were conducted to test the hypotheses that provision of alternative foods would reduce vole damage to apple trees and that they would do so without increasing vole populations. In the first experiment, plywood sticks were treated with sucrose, soybean oil, or sorbitol and placed around the base of each tree. They had little effect in reducing attack but did identify that soybean oil was the most suitable food. In the second experiments, "logs" composed of Douglas-fir bark mixed with wax and soybean oil or apple powder were placed around the tree bases. Experiment three used these same "logs" but tested placement. Reduction in damage occurred with the soybean oil logs but not the apple powder logs, possibly because the latter was too similar in composition to real apple tree bark. These results indicate that certain alternative foods may have potential for reducing apple tree damage by voles without affecting population size.

825. Taitt, Mary J.; Gipps, J.H.W.; Krebs, C.J.; Dundjerski, Z. 1981. The effect of extra food and cover on declining populations of *Microtus townsendii*. *Canadian Journal of Zoology* 59(8): 1593-1599.

Microtus townsendii populations were supplied with extra food and extra cover during a spring decline in numbers in 1979. Compared with the control population, late-winter addition of food resulted in lower rates of decline of males and females. On the area with extra cover, the rate of decline was significantly lower in males, and females actually increased in number. Breeding was earlier in the population with extra cover, and four times as many females became pregnant during the spring. This resulted in twice as many young voles entering the population in early summer. Survival was higher in both experimental populations during the spring. Females with extra food and males with extra cover had the smallest home ranges for their sex group. The addition of cover reduced bird predation. If this was the only effect of added cover, the demography of the covered population suggests that predation may be important in the spring decline of *M. townsendii*. Further, we suggest that the severity of the spring decline, particularly in females, may determine when the population "cycles."

826. Taitt, Mary Joan. 1978. Population dynamics of *Peromyscus maniculatus austerus* and *Microtus townsendii* with supplementary food. Vancouver, BC: University of British Columbia. Ph.D. dissertation.

Many field studies suggest that some vertebrate populations are limited by spacing behavior. Small mammals of the genus *Peromyscus* and *Microtus* exhibit spacing behavior by possessing home ranges, but they have contrasting patterns of population fluctuation. Deer mice fluctuate annually but maintain fairly constant numbers from year to year, whereas voles "cycle", reaching peak densities every 2 to 5 years. One use of the home range is for gathering food. Therefore, these experiments were

designed to investigate the influence of food availability on the home range and population dynamics of local deer mice and voles. The addition of food in later winter resulted in a doubling of the number of deer mice. Immigration was 2.5 times that of an unfed control. This could be explained since resident deer mice reduced the size of their home ranges. Deer mice populations with extra food increased their reproductive output compared with controls. We believe the onset and cessation of breeding in deer mice are proximate responses to food availability. Vole populations with low and intermediate levels of food peaked at twice the control density, and a population with a high level of food reached seven times control density. Voles immigrated to established populations, and colonized vacant areas in proportion to the food available. Like deer mice, residents reduced the size of their range. Breeding was enhanced in all fed vole populations. The results indicate that home range size in both species is responsive to food availability.

Damage and Management

827. Bell, Christina M.; Harestad, Alton S. 1987. Efficacy of pine oil as repellent to wildlife. *Journal of Chemical Ecology* 13(6): 1409-1417.

Pine oil, a by-product of the pulp industry, is a feeding repellent to snowshoe hares and voles. In pen trials with snowshoe hares and field trials with voles, when given a choice between food in a pine oil-treated bowl, two hares showed a reduced rate of food consumption, and one hare did not feed at all. Pine oil contains monoterpenes which may inhibit microbial symbionts in the digestive tracts of hares and voles. The repellent action of pine oil is likely based on this interference of digestive processes, and it is of adaptive advantage for cecal digestors to avoid it. Pine oil has potential as a commercial repellent for snowshoe hares and voles.

828. Gashwiler, Jay S. 1967. Conifer seed survival in a western Oregon clearcut. *Ecology* 48(3): 431-438.

A study of the survival of naturally disseminated tree seed was made in a clearcut area on the H.J. Andrews Experimental Forest in western Oregon. From start of seed fall until the end of germination in late spring the following year, 12% of the Douglas-fir seed survived. Ground-feeding birds and small-mammals caused 63% of the seed loss and other agents 25%. Thirty-one percent of the seed of western hemlock lived from the start of seed fall until the end of germination. Of the amount lost, birds and mammals took 16% and all other factors 53%. A large proportion (65%) of western redcedar seed survived during the same period. The entire loss was attributed to causes such as nonviable filled seeds, disease, invertebrates, and others. Ground-feeding birds and small mammals showed a definite preference for Douglas-fir seeds. Most of the seed depredations by birds and mammals occurred from start of seed fall to start of germination; other factors took heaviest toll during germination.

829. Harper, Paula A.; Harestad, Alton S. 1986. Vole damage to coniferous trees on Texada Island. *Forestry Chronicle* 62(5): 429-432.

Microtus townsendii injured trees by removal of bark and cambium from stems, branches and roots of Douglas-fir, western hemlock and, rarely, white pine on Texada Island, British Columbia. Damage occurred more frequently in precommercially thinned stands 40-years-old than in unspaced stands. Trees with d.b.h.

<19 cm were damaged by voles, but there was no selection by diameter or age class. No trees of a height over 16 m were damaged. For trees under 16 m, damage increased as height decreased. There were no significant differences in growth rates of trees damaged by voles when comparing the 2-year average before spacing and vole damage with the average after these events. Stands should continue to be monitored to evaluate long-term effects of vole damage. On the basis of these results, control of voles is not recommended.

830. Pank, Larry F. 1974. A bibliography on seed-eating mammals and birds that affect forest regeneration. Spec. Sci. Rep.—Wildl. 174. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife. 28 p.

Citations are arranged alphabetically by author and are restricted to journal articles and technical papers written in English and published between 1900 and 1971. Subjects covered include studies identifying birds and mammals that consume forest tree seed; methods of reducing populations of seed-eating animals (that is toxic baits, toxic seed treatments, and habitat manipulation); methods of deterring or repelling seed-eating species (that is mechanical barriers, silvicultural practices, and chemical and physical seed treatments); and the effects of control measures on nontarget species and seed viability.

831. Pauls, Ronald W. 1986. Protection with Vexar cylinders from damage by meadow voles of tree and shrub seedlings in northeastern Alberta. In: Salmon, Terrell P., ed. Proceedings, 12th vertebrate pest conference; 1986 March 4-6; San Diego, CA. Davis, CA: University of California: 199-204.

Plastic mesh cylinders (trade name Vexar) have proven effective in preventing seedling damage and are durable in the climatic extremes occurring in northern Alberta. Growth and survival rates of all species of protected seedlings have been at least equal to unprotected seedlings and substantially greater in some. The purchase and installation cost of Vexar cylinders is approximately 25% of the cost of growing and planting a seedling.

832. Sullivan, T.P. 1987. Understanding the resiliency of small mammals to population reduction: poison or population dynamics? In: Richards, C.G.J.; Ku, T.Y., eds. Control of mammal pests. London, UK: Taylor and Francis Ltd: 69-82.

Populations of wilderness rodents and lagomorphs inflict damage upon forests and agricultural crops wherever these small mammals coincide with land development. The main method of control involves the use of rodenticides and related poisons. This approach seldom considers the importance of resiliency in maintaining small-mammal populations. The repopulation of experimentally depopulated areas by five species of small-mammals shows that poison cannot effectively suppress these populations for long, at least in limited areas. Alternative control strategies based on population dynamics, behavioral and feeding ecology, and predator odor repellents point the way to more effective and long-term control than is currently achieved by using standard methodology. Small-mammal species studied include the deer mouse, montane vole, northern pocket gopher, snowshoe hare, and Columbian ground squirrel.

833. Sullivan, Thomas P.; Crump, Douglas R.; Sullivan, Druscilla S. 1988. Use of predator odors as repellents to reduce feeding damage by herbivores. III. Montane and meadow voles (*Microtus montanus* and *M. pennsylvanicus*). *Journal of Chemical Ecology* 14(1): 363-377.

This study investigated the influence of the major anal-gland compounds from the stoat and fecal and urine compounds from the red fox in generating an avoidance response by montane voles, as well as suppressing feeding by montane and meadow voles on apple trees in orchards. In trap bioassays, a 1:1 mixture of 2-propylthietane and 3-propyl-1,2-dithiolane significantly reduced vole captures. Other mixtures of stoat compounds reduced the number of new voles captured but not total individuals. 2,5-Dihydro-2,4,5-trimethylthiazoline, a component of fox feces, significantly reduced vole captures in one of two bioassays. In overwinter field bioassays, mixtures of 2-propylthietane and 3-propyl-1,2-dithiolane clearly reduced vole feeding on apple trees in four test blocks. 2,5-Dihydro-2,4,5-trimethylthiazoline and a synthetic fox urine mixture also significantly reduced vole attack in respective orchard blocks. Similarly, the intensity of vole feeding, in terms of amount of bark and vascular tissues removed from trees, was reduced by 60% to 97% in predator odor treatments compared with the control.

834. Sullivan, Thomas P.; Sullivan, Druscilla S. 1980. The use of weasels for natural control of mouse and vole populations in a coastal coniferous forest. *Oecologia* 47(1): 125-129.

If the natural enemy component of biological control is functional in small mammals, then the introduction of weasels should effectively reduce populations of deer mice and Oregon voles (*Microtus oregoni*). Seven weasels introduced to an area of forest habitat in coastal British Columbia did not appreciably lower the abundance of mice or voles. The natural predators may have contributed to the localized extinction of the vole population on the experimental area. Weasels were generally more abundant in the late summer and early fall and preferred clearcut successional habitats compared with forested areas. The results of this study are discussed with respect to the futility of poison baiting and related techniques of removing rodent pest populations from forest and agricultural land developments.

835. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. The use of alternative foods to reduce lodgepole pine seed predation by small mammals. *Journal of Applied Ecology* 19(1): 33-45.

Lodgepole pine seed predation by deer mice and related small mammals has been studied at three interior areas of British Columbia. When the distribution and abundance of rodent seed predators was taken into account, the amount of seed damage was directly related to the relative density of animals. Deer mice and voles destroyed the majority (85%) of pine seed within 3 weeks of application when the abundance of these rodents was >five animals per ha. In areas with prolonged low densities (<3 animals per ha), lodgepole pine showed very good survival (60-70% after 3 weeks).

The use of sunflower seeds as an alternative food successfully reduced pine seed predation. A ratio of two sunflower seeds to one pine seed produced a range of 50-82% survival of pine seed after 3 weeks and 42-72% after 6 weeks compared with 12-15% and 8-10% survival of pine without sunflower. This technique could be used for direct seeding cutover forest lands in areas suitable for growth of lodgepole pine in North America.

836. Sullivan, Thomas P.; Sullivan, Druscilla S.; Crump, Douglas R. [and others]. 1988. Predator odors and their potential role in managing pest rodents and rabbits. In: Crabb, A. Charles; Marsh, Rex E., eds. Proceedings, 13th vertebrate pest conference; 1988 March 1-3; Monterey, CA. Davis, CA: University of California: 145-150.

The snowshoe hare, several species of voles, the northern pocket gopher, and the red squirrel cause serious damage to forest plantations and stands by their feeding activities. Certain synthetic predator odors are reviewed which have produced significant avoidance responses in these pest species and reduced damage to crop trees on an experimental basis. In addition, the specific study reported in this paper was designed to assess the influence of predator odors on population density and survival of montane vole populations in natural grassland habitat. Vole populations declined significantly in three consecutive winters on an area treated with predator odors. These declines were caused by significantly lower survival in the treatment than control populations. Concurrent feeding damage to young apple trees was significantly reduced on the treatment area. We suggest that the predator odors may have attracted additional predators to the study area, thereby increasing predation, as well as perhaps inducing behavioral-physiological stress in the vole populations. This technique could be implemented in forest plantations and tree fruit orchards as a means to disrupt resident vole populations and protect crop trees from damage.

Beaver General

837. Avery, Ed L. 1983. A bibliography of beaver, trout, wildlife, and forest relationships with special references to beaver and trout. Tech. Bull. 137. Madison, WI: Department of Natural Resources. 23 p.

A total of 446 references to beaver ecology and the relationships of beaver to trout, waterfowl and other wildlife, and forests are presented. References are arranged alphabetically by author, with a subject index. Annotations are included for 36 papers which deal specifically with the relationship of beaver and their activities to wild trout in low to moderately high gradient streams.

838. Hill, Edward P. 1982. Beaver (*Castor canadensis*). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 256-281.

Reviews distribution, description, physiology, reproduction, ecology, behavior, mortality, economic status, and management of *Castor canadensis*.

839. Hodgdon, Harry E.; Larson, Joseph S. 1980. A bibliography of the recent literature on beaver. Res. Bull. 665. Amherst, MA: Massachusetts Agricultural Experiment Station, University of Massachusetts at Amherst. 128 p.

Covers the world literature from 1955 through 1979. References are arranged by subjects, then alphabetically by author, with an author index. Updates an earlier bibliography "Contribution toward a bibliography on the beaver", by L.E. Yeager and K.G. Hay.

840. Medin, Dean E.; Torquemada, Kathryn E. 1988. Beaver in western North America: an annotated bibliography, 1966 to 1986. Gen. Tech. Rep. INT-242. Ogden, UT: U.S. Department of Agriculture. Forest Service, Intermountain Research Station. 18 p.

This annotated bibliography of published literature on the beaver contains 206 references to both technical and popular articles and covers a period from 1966 to 1986. Emphasis is on the Western United States and Canada. A subject index is keyed to an alphabetical list of authors.

841. Yeager, Lee E.; Hay, Keith G. 1955. A contribution toward a bibliography on the beaver. Tech. Bull. 1. Denver, CO: Colorado Game and Fish Department. 103 p.

Covers the world literature on beaver through 1954.

842. Allred, Morrell. 1981. The potential use of beaver population density in beaver resource management. Journal of the Idaho Academy of Science 17(1): 14-24.

Beaver population behavior can be used in selective propagation or removal of different classes of beavers. The floating segment of a beaver population may replace casualties from within the breeding portion of the population, and the excess can be selectively removed as it migrates into areas not occupied by the residents. Of 47 beavers selectively removed from two small tributaries to the South Fork of the Snake River in western Wyoming, 46 were in the 2-year-old class and 1 was an adult male.

843. Basey, John M.; Jenkins, Stephen H.; Busher, Peter E. 1988. Optimal central-place foraging by beavers tree-size selection in relation to defensive chemicals of quaking aspen. *Oecologia* 76(2): 278-282.

At a newly occupied pond, beavers preferentially felled aspen smaller than 7.5 cm in diameter and selected against larger size classes. After 1 year of cutting, 10% of the aspen had been cut, and 14% of the living aspen exhibited the juvenile growth form. A phenolic compound which may act as a deterrent to beavers was found in low concentrations in aspen bark, and there was no significant regression of relative concentration of this compound on tree diameter. At a pond which had been intermittently occupied by beavers for over 20 years, beavers selected against aspen smaller than 4.5 cm in diameter and selected in favor of aspen larger than 19.5 cm in diameter. After more than 28 years of cutting at this site, 51% of the aspen had been cut, and 49% of the living aspen were juvenile form. The phenolic compound was

found in significantly higher concentrations in aspen bark than at the newly occupied site, and there was a significant negative regression of relative concentration on tree diameter. The results of this study show that responses to browsing by trees place constraints on the predictive value of standard energy-based optimal foraging models and limitations on the use of such models. Future models should attempt to account for inducible responses of plants to damage and increases in concentrations of secondary metabolites through time.

844. Basey, John Martin. 1987. Central-place foraging by beavers in the Sierra Nevada: tree-size selection and inducible defenses in quaking aspen. Reno, NV: University of Nevada. 60 p. M.S. thesis.

At a newly occupied site, beavers preferentially cut quaking aspen less than 8 cm in diameter. Small aspen occur in two growth forms: juvenile-form suckers abundant at sites which have received heavy prior use by beavers, and adult-form suckers, which predominate at newly occupied sites. Cafeteria-style feeding experiments in the field showed that beavers selected for branches from large trees and adult-form suckers and against juvenile-form suckers. An unidentified compound which may be a feeding deterrent was present in juvenile-form suckers at significantly higher concentrations than in branches from mature trees or adult-form suckers. At a site with a long history of beaver use, there was a higher concentration of this compound in trees less than 10 cm in diameter than in larger trees, and the beavers at this site preferentially cut large trees, unlike beavers at the newly occupied site.

845. Beier, Paul; Barrett, Reginald H. 1987. Beaver habitat use and impact in Truckee River basin, California. *Journal of Wildlife Management* 51(4): 794-799.

Stepwise logistic regression was used to identify factors important for habitat use by beavers on streams. Increasing stream width and depth and decreasing gradient had the strongest positive effects on habitat use; food availability variables added little explanatory power. Some abandoned colony sites appeared to have been located on physically unsuitable habitat, whereas others appeared to be physically suitable sites abandoned due to resource depletion. Because few unused or uncolonized reaches were misclassified as suitable habitat, we believe suitable habitat has been saturated. Impact of beaver on woody plants was assessed for eight forage species. Local extinction of quaking aspen and black cottonwood occurred on 4-5% of stream reaches. Willow showed good vigor despite heavy use in most reaches.

846. Busher, Peter E. 1987. Population parameters and family composition of beaver in California. *Journal of Mammalogy* 68(4): 860-864.

Presents a 34-year demographic history of an unexploited marked beaver population in California and examines the demographic structure of the population during a period of population growth and increasing population density.

847. Busher, Peter Edward. 1975. Movements and activities of beavers, *Castor canadensis*, on Sagehen Creek, California. San Francisco, CA: San Francisco State University. 86 p. M.A. thesis.

The movement and activity patterns of two beaver colonies on Sagehen Creek, Nevada County, California, were studied from July 1973 to September 1974. Observation, live-trapping and radio-tracking were the methods used to collect the data. Five beavers at the Taylor Meadow colony used seven different locations as daytime rest sites. Six were bank burrows and one was a lodge. The adult female was the only colony member to use the lodge as a daytime rest site. Of the six burrows, two were preferred by all colony members. These beavers spent 11.5 hours per day resting and 12.5 hours per day active. The activity period began at approximately 6 p.m. and ended at approximately 7 a.m. The adult male and one yearling were the most closely associated, and the adult female was associated the least with the other colony members. Three beavers were present at the Rockslide colony in 1973, but one, a yearling, was not observed in 1974. In 1974, the same pair of adults and a kit were present in the colony. Most of the information was collected on the adult male, and it shows him to prefer one bank burrow as a daytime rest site, to rest 11.2 hours per day and be active 12.8 hours per day, and to become active at 6 p.m. and remain active until 7 a.m. The behavior patterns of beavers at the two colonies are similar. The only differences between the colonies are the number of beavers present at each colony, and in the area of each colony.

848. Collins, Thomas Charles. 1976. Population characteristics and habitat relationships of beavers, *Castor canadensis*, in northwest Wyoming. Laramie, WY: University of Wyoming. 188 p. Ph.D. dissertation.

Unexploited beaver populations of Grand Teton National Park were investigated from 1974 to 1976 to assess population characteristics and habitat relationships. In the park, the beaver populations appear at carrying capacity. Beaver abundance on the major streams was 0.9 colonies per km with an average of 5.2 beavers per colony. Eighty percent of adult females were lactating between May and July. Parturition usually occurred between mid-May and mid-June. The first age of breeding was usually 3 years. There were 2.1 kits and 2.0 yearlings per colony for those colonies with these age classes, suggesting low realized fertility. Adult mortality appeared low. Most offspring dispersed from family groups at age 2. Colonies on the major streams exhibited territorial packing with no home range overlap unless vacant habitat separated colonies. There were no expansions or contractions of territories, and active marking of territorial boundaries appeared related to the potential for encountering beavers from neighboring colonies or transients. Fecal analysis of food habits demonstrated a seasonal change in selectivity correlated positively with availability of alternate food resources. Forbs and graminoids constituted 50% of the summer diet. Populations on one impaired and two unimpaired streams were studied to assess the influence of seasonal flow regimes on population abundance, distribution, and movements. Seasonal movements caused by fluctuations in streamflow were typical. Reduction of habitat and scarcity of dwelling sites at low flow restricted potential colony density and dictated beaver carrying capacity.

849. Cottle, Walter Henry. 1951. A study of the ecology of beaver in central British Columbia. Vancouver, BC: University of British Columbia. 58 p. M.A. thesis.

In 1942, two pairs of beaver were released in Meldrum Creek in the intermountain plateau of British Columbia. By 1950, these had increased to 21 colonies in addition to animals harvested in 1950. Examination of areas inhabited by beaver showed that although water is apparently important to the animals as protection from the climate and for escape from certain enemies, it also provides the means whereby the beaver store winter food. Water level records showed that beaver dams act as a regulating mechanism and tend to prolong the flow of water in Meldrum Creek. Food habit studies revealed that although beaver consume mostly the bark of aspen and willow, several other foods were taken. A study of the conditions affecting the rate of growth and reproduction of aspen was made. Tallies were made of the stumps of the aspen trees cut in 1949 by beaver of 12 colonies and of trees in sample areas in stands available to these colonies. Beaver cut all sizes of aspen without preference, and mean weight of bark and twigs made available by cutting was approximately 3,700 pounds per colony. Studies of the rate of cutting by beaver in relation to the availability and to the rate of reproduction of aspen demonstrated that beaver on the study area occupy two somewhat distinct habitats, namely lakes and streams. Populations of lakes tend to be stable as there is sufficient reproduction in the large stands available to maintain the stand during use by beaver. Populations on creeks eat out their food supplies and are thus forced to emigrate. By developing the aquatic habitat, beaver were observed to have increased the habitat suitable for other species.

850. deRoos, Roger McClean. 1958. The reproductive cycle of the beaver. Logan, UT: Utah State University. 61 p. M.S. thesis.

This study is based on examination of 247 beaver trapped in Cache County, Utah, December 1955 through April 1957. Some males attain sexual maturity the first breeding season after birth; the remainder become sexually mature the second breeding season. Some females become sexually mature the second breeding season after birth, and the remainder become sexually mature the third breeding season. Spermatogenesis and an increase in the size of the testes begins in October and early November. The male is sexually active during the winter. A decrease in spermatogenesis and in the size of the testes begins in April and continues through May. The male is sexually inactive during the summer. The ovary of sexually immature females and the ovarian cycle of sexually mature females is described. The corpus luteum does not differ significantly from other rodents and persists until, or shortly before, parturition. The beaver is seasonally polyestrous. The large number of females experiencing sterile cycles suggests that ovulation is spontaneous. Ovulation may occur from late December to early May, but the majority of females ovulate in late January or February. The long season results from the later breeding among females reproducing for the first time and sterile cycles resulting in successive periods of estrus. The period of mating in the beaver is limited by the female. Based on an estimated gestation period of 100 days, parturition could be expected to occur from the first week in April to mid-August, peaking in May and June. The average litter size excluding resorbed embryos was 3.03. The sex ratio was 106 males to 100 females.

851. Hall, Joseph G. 1960. Willow and aspen in the ecology of beaver on Sagehen Creek, California. *Ecology* 41(3): 484-494.

Two pairs of beaver were introduced on Sagehen Creek in 1945. Ten years later the number had increased to about 30 animals distributed in five colonies along the stream. Three of the colonies were studied for several seasons to explore the interaction between beaver and their two chief food and building resources, willow and aspen. The rate at which beaver cut aspen was correlated directly with the supply. On the other hand, rate of willow use showed no correlation with willow supply but was related inversely to aspen supply. These relationships show that aspen is the first choice item; as it is used up the beaver take more and more willow. The principal factor influencing the size of tree to cut by beaver is the relative numerical availability of the sizes in the stand. A slight but significant preference for trees of the 2-inch diameter class was demonstrated. This preference is thought to be due primarily to superiority of 2-inch trees as building material. The exceptional sprouting vigor of willow makes it much more tolerant of the inroads of beaver activities than is aspen. Even so, beaver tend to overbrowse within the immediate colony area and sprouting vigor gradually declines and rate of growth falls behind rate of harvest. As one site becomes exhausted of willow, the beavers shift up or downstream to better stands, thus permitting the original area to recuperate.

852. Jonas, Robert James. 1955. A population and ecological study of the beaver (*Castor canadensis*) of Yellowstone National Park. Moscow, ID: University of Idaho. 188 p. M.S. thesis.

This study to determine the status of the beaver in Yellowstone National Park was conducted during 1952, 1953, and 1954. The purpose was to determine and investigate factors which might have been significant in affecting the status of the beaver. Detailed comparison was made with areas previously studied to determine the changes which had taken place and the factors which brought about those changes. Three factors were thought to be the best indicators of population dynamics: (1) beaver cuttings, including location, freshness, number, size, and species; (2) beaver trails as to number, usage and freshness; and (3) beaver canals with reference to number, size, and condition. Each area is described carefully in terms of the above factors. Analysis of the data indicates that the beaver had decreased in number, especially in the past 30 to 40 years. The lack of food appeared to be the most important factor limiting beaver activity. The beaver have depleted the deciduous species in the primarily coniferous habitat. Overpopulation of elk has destroyed much vegetation and prevented regrowth. Forest fire protection reduces the early stages of forest succession which includes willow and aspen. Poor water conditions were the second factor limiting beaver activity. This was due to increasingly heavy spring water runoff and a drought. The lack of water limited beaver activity directly in their ponds and indirectly by restricting vegetation regrowth. The early runoff was probably due to the overpopulation of elk which have reduced range vegetation. A drought period occurred between 1919 and 1937 and may partially account for the decrease in beaver population.

853. Kindschy, R.R. 1985. Response of red willow to beaver use in southeastern Oregon. *Journal of Wildlife Management* 49(1): 26-28.

The purpose of this investigation was to document the effect of beaver usage on red willow in an area never used by domestic livestock. Red willows used by beaver were able to maintain high growth rates and increases in basal diameter similar to the rates of unused trees. Beaver use normally occurred after the willow completed all growth and had translocated the majority of food reserves to the stumps and roots for winter. Natural and prolonged heavy usage of red willow by beaver did not appear to be responsible for the deterioration, reduction, and loss of this riparian species. Additional factors, including the continual cropping of willow regrowth by cattle during the growing season, were involved in limiting red willow stands in many riparian communities of southeastern Oregon.

854. Leege, Thomas A. 1968. natural movements of beavers in southeastern Idaho. *Journal of Wildlife Management* 32(4): 973-976.

Data from 192 live-trapped and tagged beaver helped determine the origin of troublesome beaver on private lands. The yearling age class and males of all groups migrate the most frequently.

855. Leege, Thomas A.; Williams, Roger M. 1967. Beaver productivity in Idaho. *Journal of Wildlife Management* 31(2): 326-332.

Includes data on sex and age ratios, litter size, and rate of pregnancy from live-trapping and fur-trapping operations in 1953-56 and 1962-64. Males consistently outnumbered females in kit and yearling age classes, and females were more abundant among the adults. The sex ratio of 352 beavers examined was 113 males per 100 females. A disturbed population had a lower percentage of kit and yearling beavers than did an undisturbed population.

856. Leege, Thomas Allen. 1964. Beaver productivity and movements in southeastern Idaho. Moscow, ID: University of Idaho. 52 p. M.S. thesis.

A study was made of beaver productivity and movements in Bear Lake and Caribou Counties, Idaho, from summer 1962 through May 1964. An examination of 119 live beavers and 233 beaver carcasses showed the sex ratio to be in favor of the males, 113:100. The ratios of each age class were kits 171:100, yearlings 142:100, and adults 88:100, thereby indicating a heavier mortality rate for males. The 199 beavers live-trapped on the study area consisted of 24% kits, 25% yearlings, and 51% adults. In the fall, 169 beaver carcasses obtained from southeastern Idaho were comprised of 20% kits, 15% yearlings, and 65% adults. Evidence that some yearling females do breed was found; however, lack of known-age animals prohibited any definite conclusions. The time when parturition occurred most frequently was the first week in May. The range of birth dates was from mid-April until late May. Average litter size was estimated to be 3.5 in 1962 and 2.9 in 1963 according to placental scar counts. In 1963 and 1964, fetus counts averaged 2.9 and 4.5, respectively. The most common litter size was found by scar counts and two by fetus counts. In 1962, 35.6% of

the 101 females examined had bred the previous spring. In 1963, the percentage of bred females dropped to 28.6%. Of 52 tag returns, only 10 beavers showed significant movements. The shortest move was 2 miles and the longest, 14 miles. One-half of the 10 movements were the natural migrations of 2-year-olds. The other moves were brought about by food shortage or colony disturbance. The movement was predominantly from national forest land downstream to private land where the beavers interfered with irrigation and agriculture.

857. Masslich, William J.; Brotherson, Jack D.; Cates, Rex G. 1988. Relationships of aspen (*Populus tremuloides*) to foraging patterns of beaver (*Castor canadensis*) in the Strawberry Valley of central Utah. *Great Basin Naturalist* 48(2): 250-262.

Eight study sites were examined in Strawberry Valley, Utah, to assess the response of aspen to cutting activities of beaver and to determine patterns by which the animals use aspen stands. Sites used by beaver, along with adjacent control plots in mature, uncut aspen stands, were sampled. Age-class profiles of control plots were composed of a broad age distribution with trees ranging from 3 to 108 years old. Age-class profiles for aspen sprouts in areas previously used by beavers were composed of trees averaging 7 years of age with a range of 1 to 24 years. Age distribution of sprouts in areas used by beaver show a tendency to be skewed toward younger age classes. Average density of aspen in areas used by beaver was 15,800 stems per ha compared to 2,980 stems per ha in controls. Stump densities in use areas ranged from 900 to 5,066 stems per ha. Densities of stumps in the 0.5-cm size class were greater in areas used by beavers than in the corresponding size class in the mature forests. A regression equation describing age versus diameter relationships was calculated by using data from 312 aspen trees. Total phenolics and mineral nutrients in the twigs and bark of mature aspen trees and aspen sprouts were also examined to determine if variations could explain foraging patterns of beaver in the valley.

858. McGinley, Mark A.; Whitham, Thomas G. 1985. Central place foraging by beavers (*Castor canadensis*): a test of foraging predictions and the impact of selective feeding on the growth form of cottonwoods (*Populus fremontii*). *Oecologia* 66(4): 558-562.

In testing theories of central place foraging among beaver along the San Juan River in southern Utah, the authors found that large branches were favored at all distances. This differed from patterns observed in previous studies.

859. Naiman, Robert J.; Johnston, Carol A.; Kelley, James C. 1988. Alteration of North American streams by beaver. *BioScience* 38(11): 753-762.

Summarizes the history of beaver in North America, describes some of the ecosystem-level responses of streams to beaver-induced alterations, and describes beaver-induced changes in the landscape that take place over broad spatial and temporal scales, based on research conducted in Quebec, Minnesota, Montana, and Alaska.

860. Pearson, Arthur M. 1960. A study of the growth and reproduction of the beaver (*Castor canadensis* Kuhl) correlated with the quality and quantity of some habitat factors. Vancouver, BC: University of British Columbia. 103 p. M.S. thesis.

This study was concerned with analysis of the habitat of beaver and the hypothesis that the condition of an animal reflects the adequacy of its environment. The growth rates of beaver on two different habitat types in Prince Albert National Park, Saskatchewan, are compared, and the habitats are classified accordingly. Beaver were raised under experimental conditions at the the University of British Columbia and the growth rates and food consumption recorded. The bioenergetics of the beaver are calculated and the results used to elucidate the energy relations of the natural colonies of beaver under study. The relative growth of some organ weights and body measurements are described. These studies indicated that the condition of a beaver accurately designates the value of its habitat. Difference in condition of beaver occurred most prominently during the winter as a result of the strict limitations in the quality and quantity of available food. The reproductive rates of beaver from Elk Island National Park, Alberta, and Prince Albert National Park, Saskatchewan, are compared. Beaver from the former park showed a significantly higher reproductive rate. This was correlated with habitat differences between the two areas, thereby indicating that the reproductive rate is another attribute of the animal which will reflect the adequacy of the environment.

861. Provost, Ernest E. 1958. Studies on reproduction and population dynamics in beaver. Pullman, WA: Washington State University. 85 p. Ph.D. dissertation.

Data from 481 beaver were studied, focusing on the ovarian cycle with the view of elaborating techniques applicable to management of the species. Observations were also made on the breeding cycle in males. Data on sex and age composition of various populations were compiled, together with observations on minimum breeding age and litter size. A general description of the gross morphology of the female urogenital system was given, and a tentative fetal growth curve, based on weight and hind foot length, was elaborated. As a record of the number of eggs released, two types of landmarks, the corpora lutea and corpora albicantia are found as easily recognized structures in the beaver ovary. The former provide a measure of the number of eggs produced during the current breeding season, and the latter provide a measure of the egg production of the previous season. With certain limitations, both can be used as a measure of reproductive performance. Fetal counts made shortly before parturition provide the most accurate measure of the number of potential living young, but correlating such counts with ovarian structures provides a parturition frequency which permits the investigator to interpret reproductive performance with reasonable confidence the year-around. The value of ovarian characteristics is enhanced because they are available before embryos can be detected and after the placental scars from the previous breeding season have disappeared. Satisfactory resolution of several ambiguous factors in the reproductive cycle, such as identifying characteristics and duration of corpora lutea of cycle, has not been possible to date.

862. Provost, Ernest E. 1962. Morphological characteristics of the beaver ovary. *Journal of Wildlife Management* 26(3): 272-278.

Corpora lutea and corpora albicantia are prominent in beaver ovaries and are often superior to uterine characteristics for population studies. The discrepancy between numbers of corpora lutea and fetuses requires establishment of a factor, here called parturition frequency, for estimating population increments from ovarian structures. Fetal counts made close to term provide an accurate, practical measure of parturition frequency. This statistic is defined as the number of viable young per 100 corpora lutea in the population sampled. Controlled breeding experiments are desirable to refine the techniques discussed.

863. Raedeke, Kenneth J.; Taber, Richard D.; Paige, Dwayne K. 1988. Ecology of large mammals in riparian systems of Pacific Northwest forests. In: Raedeke, Kenneth J., ed. *Streamside management: riparian wildlife and forestry interactions: Proceedings of a symposium; 1987 February 11-13; Seattle, WA. Contrib. 59.* Seattle, WA: University of Washington, College of Forest Resources: 113-132.

The literature is reviewed relating to the ecological needs of large, free-living mammals to the riparian environment to determine these species' degrees of need and the particular habitat characteristics important in meeting their ecological requirements. Species covered are Virginia opossum, snowshoe hare, Nuttall's and eastern cottontail, mountain beaver, beaver, muskrat, nutria, red fox, grey fox, fisher, mink, striped skunk, western spotted skunk, river otter, bobcat, elk, mule and black-tailed deer, white-tailed deer, and moose. Native species considered dependent on riparian areas or that find optimum habitat there are beaver, muskrat, raccoon, mink, river otter, elk and mule deer. Native species more abundant in riparian areas than in adjacent uplands are snowshoe hare, grizzly bear, western spotted skunk, white-tailed deer, and moose. The other species listed use riparian areas but are as abundant in other habitats. The significant features of riparian systems were abundance of prey species; productivity of the shrub/herb layer; early spring phenological development of food plants; reduced snow accumulations; aquatic habitat, and lineal continuity of habitat.

864. Slough, Brian G. 1978. Beaver food cache structure and utilization. *Journal of Wildlife Management* 42(3): 644-646.

Observations were made on beaver food cache structure, composition, and usage at 115 beaver colony sites in northern interior British Columbia. Construction involves the formation of a "raft", followed by placement of other materials under the raft. Eventually the raft becomes waterlogged, forcing the material beneath it to sink. Food is thus secured below ice level. Cache constituents contained both food items and nonfood items. Aspen and willow, preferred food items, were found through the caches. Low preference and nonfood species were also found, apparently for lodge and dam renovation.

865. Townsend, Joseph E. 1953. Beaver ecology in western Montana with special reference to movements. *Journal of Mammalogy* 34(4): 459-479.

A study in beaver ecology with emphasis on movement was conducted in Missoula County, Montana, from 1949 to 1952. Data were obtained from live-trapping and recapturing 31 beavers and from commercially trapping 15 beavers, 10 of which were previously live-trapped. Beaver activities as manifested by structures, plant cuttings, and scats were recorded. Dam building activity was greatest near the first of September. Scent mound activity was greatest in July. Food cuttings were principally willow. Aquatic plants were heavily used in August. Movement from the study area was suggested by six live-trapped yearlings which were not recaptured. Three live-trapped as kits, and later recaptured, supplied evidence suggesting movement occurred during the second year of life. Adult males made considerable summer movements. None was found with breeding females in April, July, or August. Four were found in areas with breeding females in September and March. Nonbreeding females possibly showed a movement similar to adult males. Breeding females showed relatively little movement. Territorial behavior of residents rather than grouping of beaver structures appeared to delimit colony boundaries in at least two instances. The home range of a breeding female was reduced after the "settling" of another breeding female in the same group of structures, thereby indicating population pressure may determine colony limits.

866. Willis, Mitchell J. 1979. A beaver habitat classification system for the Truckee River. Reno, NV: University of Nevada. 69 p. M.S. thesis.

Thirty-one physical and vegetation characteristics of beaver foraging habitat were studied to evaluate which components were most important for habitat suitability and to generate a predictive equation describing foraging habitat. Discriminant analysis results indicate that 13 variables interpreted jointly can discriminate between desirable and unused habitat. The most important factors in decreasing order of their discriminating power were neighbor cut status; tree species; streambank slope; tree circumference, percentage of forb between the focus tree and the river; percentage of cottonwood and percentage wood debris in the immediate area; the number of trees within 9 m of the focus tree; neighbor aspect; percentage grass in the immediate area; total percentage understory cover between the focus tree and the river; aspect of the focus tree; and shrub cover in the immediate area. Use of the discriminant function equation derived can significantly separate desirable from unused habitat on the middle and lower Truckee River. The methods used to generate this equation are amenable to other applications where a quantitative habitat evaluation is desired.

867. Fisher, Philip H. 1986. Keeping beavers from plugging culvert inlets. *Engineering Field Notes*. Washington, DC: U.S. Department of Agriculture, Forest Service. 18: 9-13.

The San Dimas Equipment Development Center tested four methods for keeping beavers from plugging culvert inlets: the perforated pipe method, the perforated culvert method, the downspout method, and the baffle method. The downspout approach showed the greatest promise.

868. Fitzgerald, Wendy S.; Thompson, Ronald A. 1988. Problems associated with beaver in stream or floodway management. In: Crabb, A. Charles; Marsh, Rex E., eds. Proceedings, 13th vertebrate pest conference; 1988 March 1-3; Monterey, CA. Davis, CA: University of California: 190-195.

In California, beaver are considered desirable if not essential components of stream and wetland ecosystems. Where beaver and human activity overlap, beaver have become nuisance animals causing direct damage through dam building, flooding, bank denning, and loss of agricultural crops. Problems such as the threat of levee failure and subsequent flooding, increases in undesirable brush growth due to a raised water table, restricted access due to flooding, and an increased mosquito population resulted in the Department of Water Resources developing a beaver management program. In a 20-mile stretch of human-made Cherokee Canal in Butte County, California, a large existing beaver population, and subsequent re-invading individuals, were removed. In addition, existing dams, lodges, dens, and heavy brush growth were removed in an attempt to insure flood safety and modify the existing habitat to be less suitable for reinvading beavers. Costs and results of this program are discussed, as well as the long-term management strategy for the project.

869. Owen, Carlton N.; Adams, Danny L.; Wigley, T. Bently. 1984. Inefficacy of a deer repellent on beavers. *Wildlife Society Bulletin* 12(4): 405-408.

This study, conducted in the bottomland and mixed pine-hardwood forests of Arkansas, evaluated the effectiveness of Magic Circle as a potential beaver repellent. Contrary to previous reports, Magic Circle did not discourage beavers from repairing dams.

870. Hooven, Edward F. 1959. Dusky-footed woodrat in young Douglas-fir. Res. Note 41. Corvallis, OR: Forest Lands Research, Oregon Forest Research Center. 24 p.

Reviews the literature on distribution, habitat, habits, life history, and predators of the woodrat. A mixed stand of young Douglas-fir and Oregon white oak was studied for 1 year to determine diet, population changes, and damage to Douglas-fir. The principal damage noted was severe barking to secure material for nests; some leaders were also cut. Numerous laterals were cut, but apparently they were cut for house building, not for food. Control is most feasible by baiting or by removing logging debris and pruning and thinning young stands to inhibit house building.

871. Linsdale, Jean M.; Tevis, Lloyd P., Jr. 1951. The dusky-footed wood rat. Berkeley, CA: University of California Press. 664 p.

This comprehensive treatise on the woodrat is based on observations made on the Hastings Natural History Reservation in central coastal California. The animal is made conspicuous by the stick houses it builds. In 1947, 100 houses were examined; 28 were in dense bushes, 5 in lone trees, 8 in parkland, and 59 in closed woods. A woodrat rarely goes far from a house already built and ready for occupancy. This restriction to a small-home area allows only a slow spread into new areas, for new houses are rarely begun outside an occupied colony. Many rats are involved in the maintenance of a few houses. Houses remain much longer than any

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single occupant; when a house is not occupied, it disintegrates rapidly. A woodrat can be active outside its house about 9 hours in June, when the nights are short, and more than 14 hours in December. The amount of activity and the time of occurrence are highly variable. On many rainy or moonlit nights, some woodrats do not venture out. Food stores help them to avoid unfavorable conditions outside. Rats avoid plants that are obviously harmful or that do not contain sufficient nutrition. When they are available, flowers, fruits, and leaves are eaten more than bark and wood. Of the 543 flowering plants on the reservation, rats eat only 72. Pregnancies were recorded in every month but November; the largest number occurred in April. Survival of the 69 litters born in 1946 was poor. When young woodrats leave the maternal house they take up residence in the nearest unoccupied, usable house. An important characteristic of the population is that the number of adults remains fairly constant.

Ecology

872. Atsatt, P.R.; Ingram, T. 1983. Adaptation to oak and other fibrous phenolic-rich foliage by a small mammal, *Neotoma fuscipes*. *Oecologia* 60(1): 135-142.

Dusky-footed woodrat, a small mammalian herbivore with apparently generalized food habits, was laboratory tested to determine its degree of dietary specialization. Woodrats from both oak woodland and coastal sage communities preferred *Quercus agrifolia* leaves (containing 40% phenolics and about 16% condensed tannin) over foliage from other dominant species. Approximately 1/3 of the oak phenolics and <10% of the oak condensed tannin remained in the feces. Their performance on pure oak leaves was comparable to that on a mixed diet of *Quercus*, *Salvia*, *Eriogonum* and *Rhus*, with respect to weight maintenance, digestive efficiency and total amount ingested. Digestive efficiency was low on the oak diet (55%) relative to *Salvia* (77%) and to achieve similar weight levels, approximately twice as much oak as *Salvia* was ingested. Woodrats retained more nitrogen as oak consumption increased. In natural populations, the dusky-footed woodrat selectively feeds on evergreen sclerophyll vegetation high in fiber, tannins and related polyphenolics. Individuals ingest 2-3 plant types at a time, with a single species (oak when available) constituting most of the material consumed.

873. Cavallaro, Janet I.; Menke, John W.; Williams, William A. 1981. Use of discriminant analysis and other statistical methods in analyzing microhabitat utilization of dusky-footed woodrats. In: Capen, David Ed, ed. The use of multivariate statistics in studies of wildlife habitat: Papers presented at a workshop; 1980 April 23-25; Burlington, VT. Gen. Tech. Rep. RM-87. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station: 222-231.

By using the dusky-footed woodrat as an example, we present a method for interpreting discriminant functions when the purpose is both to characterize microhabitats used by a species and to explain why individuals of a species occur in some microhabitats and not in others. Three types of discriminant functions were identified from which hypotheses of different forms were developed. More complete interpretation of two group discriminant functions can be made if a multiple regression is calculated for the dependent variable, presence or absence of woodrats, and whether partial correlations are calculated for the independent variables.

874. Cranford, Jack A. 1977. Home range and habitat utilization by *Neotoma fuscipes* as determined by radiotelemetry. *Journal of Mammalogy* 58(2): 165-172.

Seasonal, reproductive, and usage aspects of home range for dusky-footed woodrats were analyzed from data obtained by radio telemetry over 1 year of continuous study in northern California. Home ranges were stable for 34 of 37 woodrats periodically monitored but changed seasonally with reproductive activity and habitat conditions. The size of male home ranges (2,289 square m) was significantly larger than females (1,924 square m) and juveniles (1,719 square m). Home range overlap is lower than 28% except during the reproductive season. A usage index based on vegetative cover was calculated. Woodrat activity was significantly higher in areas of 75 to 100% cover than in areas with less cover. Comparisons with traditional trapping methods of home range determination were made.

875. Dial, Kenneth Paul. 1978. Copulatory behavior of the dusky-footed woodrat *Neotoma fuscipes* (Rodentia: Cricetidae). Long Beach, CA: California State University. 68 p. M.A. thesis.

Quantitative measurements of copulatory behavior were tabulated for the dusky-footed woodrat. Test subjects were caged and observed under red-light conditions. Females were injected with hormones to stimulate them into a behavioral estrus. Over 900 copulations were observed. Several tests were photographed with movie film. Woodrat does not lock during copulation and does not display intravaginal thrusting. It can potentially ejaculate on a single insertion and does obtain multiple ejaculations during a single test period. The special role of tail-thumping as a cue for the female to assume a copulatory position is discussed.

876. Frazier, Brent D. 1977. A study of home range in two *Neotoma fuscipes* colonies in Klamath County, Oregon. Portland, OR: Portland State University. 31 p. M.S. thesis.

Home ranges of dusky-footed woodrats were determined by the exclusive boundary strip method in two colonies 630 m apart in Klamath County, Oregon. The mean home range area was 1,800-1,900 square m. Densities of trees and shrubs were determined on selected home ranges, and densities of woodrat houses and nests were determined on all home ranges. No significant correlation was found between home range areas and densities of various trees and shrubs, home range areas and densities of woodrat houses and nests, or home range areas and weights of woodrats in those areas. No movement between colonies was observed.

877. Hammer, E. Wayne; Maser, Chris. 1973. Distribution of the dusky-footed woodrat, *Neotoma fuscipes* Baird, in Klamath and Lake Counties, Oregon. *Northwest Science* 47(2): 123-127.

The dusky-footed woodrat was first reported in Oregon east of the Cascade Range in 1969. In 1970 and 1971, we searched for their lodges in Klamath and Lake Counties. The purpose of this paper is to record the presently known habitat preference and distribution of *Neotoma fuscipes* in Oregon east of the Cascade Range. The species

was found to be common in the southeastern portion of Klamath County and is reported in Lake County as well. Specific distribution is shown. Where juniper trees were absent, *N. fuscipes* were not found. Therefore, the northward range expansion seems to depend upon the availability of junipers. *Neotoma fuscipes* is a potential source of sylvatic plague, *Yersinia (Pasteurella) pestis*, in Oregon east of the Cascade Range.

878. Linsdale, Jean M.; Tevis, Lloyd, Jr. 1956. A five-year change in an assemblage of wood rat houses. *Journal of Mammalogy* 37(3): 371-374.

The house of the dusky-footed woodrat is an impressive structure of sticks, bark, plant cuttings, and miscellaneous objects deposited in a conical heap which may reach 6 feet in height and 8 feet in basal diameter. Old and dominant individuals maintain and control several houses from which they exclude all other members of the colony. As a rule, only established rats build new houses. When young rats leave the maternal abode, they must find unoccupied dwellings in which to live, for construction of new homes is time consuming, and homeless rats cannot survive long enough to make a new shelter. Increase of a population of rats, therefore, is dependent in part upon the frequency with which established animals build houses and the vigor with which they maintain old houses. Examination of marked houses after a 5-year interval at the Hastings Natural History Reservation in Monterey County, California, showed that the interval was one of intense house building and maintenance. Drastic environmental changes occurred during the 5-year interval, but the number of usable houses increased from 95 to 139. The chief cause of the increase was the killing of many huge willows by drought. The dead limbs and trunks yielded an abundance of building material and provided support for subsequent erection of massive structures. Evidence indicates that despite seemingly adverse changes in the environment, woodrats increased in number because the fallen branches and trunks of the willow stimulated house building by resident woodrats, thus providing dwellings for more young.

879. Murray, Keith F.; Barnes, Allan M. 1969. Distribution and habitat of the woodrat, *Neotoma fuscipes*, in northeastern California. *Journal of Mammalogy* 50(1): 43-48.

The dusky-footed woodrat is distributed along the Pacific Coast from the Columbia River to northern Baja California. In California, it was well known in the coastal belt and the west slope of the Cascade Range. The authors have also found woodrats to be widespread and abundant east of the Cascade Range divide over much of the Great Basin sector of northeastern California. Throughout most of its range, the woodrat occupied relatively dense chaparral and broad-sclerophyll woodland, streamside thickets, and mixed coniferous forest with well-developed undergrowth. East of the Cascade divide, the species occurs most consistently in juniper woodland.

880. Smith, Michael H. 1965. Dispersal capacity of the dusky-footed woodrat, *Neotoma fuscipes*. *American Midland Naturalist* 74(2): 457-463.

Fifty-eight individuals of *Neotoma fuscipes* were displaced an average of 1,127 m. The average distance moved by the 28 recovered animals from the release site was

885 m. Approximately half of the recovered animals moved in a direction away from their previous nest sites. No evidence of homing was found. The highest rate of movement recorded was 1,600 m in 5 nights.

881. Tevis, Lloyd, Jr. 1956. Response of small mammal populations to logging of Douglas-fir. *Journal of Mammalogy* 37(2): 189-196.

Logging of the forest causes an increase in numbers of white-footed and big-eared mice, Townsend chipmunks, dusky-footed woodrats, digger squirrels, chickarees, and gray squirrels. It causes a decrease in numbers of Trowbridge shrews, red-backed mice, flying squirrels, and shrew-moles. The species that become most numerous are white-footed mice and Townsend chipmunks. They are the animals chiefly responsible for failure of artificial seeding of conifers. Also, along with the chickaree, they are responsible for the destruction of large amounts of naturally produced seed.

882. Wallen, Kurt. 1982. Social organization in the dusky-footed woodrat (*Neotoma fuscipes*): A field and laboratory study. *Animal Behavior* 30(4): 1171-1182.

The dusky-footed woodrat has been characterized as solitary and asocial. Some of the parameters of woodrat social organization were investigated. In the field, a distinct group of woodrats was live-trapped, marked, and released at bi-weekly intervals from February to June. Residents (22) were identified, and 21 of 34 houses were occupied. Visiting occurred regularly, most often at nonoccupied houses. Males were unlikely to be visited at their house and were more likely to visit occupied houses than females. Females were visited at home and visited each other. In June the population was removed to the laboratory where paired encounters with familiar and unfamiliar woodrats were used to examine the effect of sex and familiarity of social interactions. Both females and males interacted little with familiar same-sex conspecifics, with the behavior of one member of such pairs being very inhibited. Females with strange females were more interactive and spent more time in contact. Neither sex clearly differentiated between familiar and strange conspecifics of the opposite sex. Males were agonistic or affiliative in encounters with females. The type of response was consistent for a given male, and females responded differently to the two types. Woodrats differentiate between same-sex conspecifics and show sufficient individual variability to make individual recognition possible and adaptive.

883. Walters, Roland Dick. 1949. Habitat occurrence and notes on the life history of the dusky-footed wood rat, *Neotoma fuscipes* Baird. Corvallis, OR: Oregon State College. 122 p. M.S. thesis.

The dusky-footed woodrat is a typical animal of the chaparral but has migrated northward into the Willamette and has entered a different vegetation type. In so doing, the question arises as to what type of habitat this animal is found in most frequently. The answer to this question, as well as the comparative density in the different habitats, is the main objective of this study. Observations have also been made on the habits, associations, development, and reproduction.

**Damage and
Management**

884. Nettleton, Harry I. 1957. Wood rats damage young Douglas-fir. *Journal of Forestry* 55(11): 845.

Damage to 22-year-old Douglas-fir has been noticed near Corvallis, Oregon. Of 136 trees removed in a thinning, 43.3% had been either partially or completely girdled by woodrats. The damage was largely confined to the upper third of the tree boles where the bark was most tender. Numerous side branches were also gnawed or completely girdled. Bark was gnawed to the sapwood, and toothmarks were often evident. The removed bark, finely shredded, was found in nests, but thus far has not been found in stomach content analysis of captured woodrats.

Livestock

**Damage and
Management**

885. Adams, S.N. 1975. Sheep and cattle grazing in forests: a review. *Journal of Applied Ecology* 12(1): 143-152.

World literature on forest grazing by domestic livestock is reviewed. Author concludes that the practice must be controlled if it is to be successful. He further states that livestock will always do some damage to trees; sheep by browsing and cattle by trampling.

886. Black, Hugh C.; Vladimiroff, B.T. 1964. Effect of grazing on regeneration of Douglas-fir in southwestern Oregon. In: *Proceedings, Society of American Foresters meeting; 1963 October 20-23; Boston, MA.* Washington, DC: Society of American Foresters: 69-76.

A cooperative study between the U.S. Department of Interior, Bureau of Land Management (B.L.M.) and Oregon State University was begun in 1962, primarily to determine the long-range effects of controlled grazing by sheep on Douglas-fir planted on cutover areas typical of foothill land administered by the B.L.M. Data is being sought on the frequency and severity of browsing of Douglas-fir seedlings by sheep; the effect of grazing on survival and growth of Douglas-fir; the influence of time of planting on damage by sheep; the influence of planting stock type on amount and effects of browsing by sheep; whether natural seedlings are browsed equally with planted seedlings; whether treatment with TMTD would influence the amount of damage; and the depletion of soil moisture by sheep. At this time, only tentative conclusions can be made because of atypical climatic conditions which prevailed. The results do lend tentative support to controlled grazing by sheep as a management procedure since sheep performed well and did not interfere seriously with establishment of Douglas-fir seedlings.

887. Clark, M.B.; McLean, A. 1974. Compatibility of grass seeding and coniferous regeneration on clearcuts in the south-central interior of British Columbia. *Res. Note 63.* Victoria, BC: British Columbia Forest Service. 10 p.

Nine clearcut areas of various sizes in the region were, in part, sown from the air with nonrhizomatous domestic grass species in 1971-72. The effects of sowing with grass and of grazing of cattle, on the establishment, survival, and growth of coniferous seedlings (mainly lodgepole pine) were studied. In general, the grass had little

effect on germination or survival of the trees and, where tree growth was inhibited, competition from native vegetation had as much influence as that from grass. Provided that the numbers of cattle were properly regulated, damage to conifer seedlings by grazing was negligible.

888. Clark, M.B.; McLean, A. 1978. Compatibility of grass seeding and coniferous regeneration of clearcuts in the south-central interior of British Columbia. Res. Note 83. Victoria, BC: British Columbia Ministry of Forests. 25 p.

The effects of sowing nonrhizomatous species of domestic grasses on clearcuts and the subsequent grazing of these on the establishment, survival, and growth of coniferous tree species, primarily lodgepole pine, was investigated. The degree of forage usage and period of time when, and over which, the forage is used, are the most critical factors in the overall question of tree-grass compatibility. Where damage to lodgepole pine and spruce occurs, it is a result of repeated trampling rather than browsing. Therefore, clearcuts should be intensively grazed for short periods of time only, particularly during the first year of tree establishment. If there is a group of clearcuts in an area, grazing should be on a rotational basis, if possible. Forage yields can be significantly increased on clearcuts by seeding domestic grasses. Overstocking by lodgepole pine on some sites may be reduced by temporarily grazing heavily. Grass should not be sown more than 1 year before restocking of a clearcut by artificial reforestation methods unless there exists a critical need for forage on the specific area concerned.

889. Edgerton, Paul J. 1971. The effects of cattle and big game grazing on a ponderosa pine plantation. Res. Note PNW-172. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Mixed conifer stands that have been clearcut, planted with trees, and seeded to grass are a potential source of summer forage for livestock and wildlife. Heights of planted trees in portions of a clearcut that had been ungrazed, grazed only by deer and elk, and by deer, elk, and cattle were compared. After five growing seasons, grazing had neither greatly harmed nor benefited growth and survival of the trees in the plantation.

890. Eissenstat, D.M.; Mitchell, J.E.; Pope, W.W. 1982. Trampling damage by cattle on northern Idaho forest plantations. *Journal of Range Management* 35(6): 715-716.

Douglas-fir seedlings planted in April were monitored every 3 weeks from June to October 1978. Only 36% of trees trampled in the first growing season (about 19% of the seedling population) survived in contrast to 77% of untrampled trees. Trampling damage was negligible in second and third growing seasons because of greater protective measures. Browsing damage was low.

891. Hall, F.C.; Hedrick, D.W.; Keniston, R.F. 1959. Grazing and Douglas-fir establishment in the Oregon white oak type. *Journal of Forestry* 57(2): 98-103.

In a study of farm forestry and grazing in the productive oak woodlands of the Willamette Valley of Oregon, it was determined that (1) Douglas-fir can be established under these stands with a considerable degree of success; (2) sheep grazing, when carefully managed, appears to be compatible with the establishment of Douglas-fir; and (3) the animal production per acre is influenced by the amount of crown cover of the oak, by the composition of forage species, and by livestock management. Proper timing (season of use) and correct use of palatable plants is absolutely essential to avoid damage to the Douglas-fir.

892. Hedrick, D.W. 1975. Grazing mixed conifer forest clearcuts in northeastern Oregon. *Rangeman's Journal* 2(1): 6-9.

Experimental work on forest grazing conducted by researchers at Oregon State University is summarized. The author proposed livestock management practices for minimizing damage to coniferous regeneration and sustaining forage productivity.

893. Hedrick, D.W.; Keniston, R.F. 1966. Grazing and Douglas-fir growth in the Oregon white oak type. *Journal of Forestry* 64(11): 735-738.

Douglas-fir seedlings planted in an Oregon white oak foothill area grew faster in plots subjected to carefully controlled short-term spring sheep grazing than in ungrazed plots. In 1952 and 1953, 2+0 Douglas-fir seedlings were planted in three situations: (1) clearcut, (2) thinned white oak, and (3) fully stocked white oak. From 1955 to 1960, inclusive, yearling ewes were grazed 3 or 4 weeks each spring on 1/2 of each of the three original plots. Animals were brought in each spring when there was adequate herbaceous forage; they were removed when they ceased to gain weight. Soil moisture was measured through the growing season on all grazed and ungrazed plots. After 3 years of spring grazing, Douglas-fir tree height growth became significantly greater on the grazed plots and continued so during 4 more years of grazing and until the third year after grazing was terminated. More abundant soil moisture correlated well with removal of much palatable herbage by sheep. Seedling growth was most rapid on the clearcut plot, fair on the thinned plot, and slowest on the plot with the full oak canopy. Ten years after grazing started, Douglas-fir tree heights averaged 25 inches greater (27%) on the grazed than on the ungrazed plots.

894. Hess, J.P. 1983. Forestland grazing policy and practices on private timberlands in central Washington. In: Roche, B.F., Jr.; Baumgartner, D.M., eds. *Forestland grazing: Proceedings of a symposium*; 1983 February 23-25; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 101-103.

Livestock grazing on Boise Cascade timberlands is described. The author concludes that the investment in plantation or natural regeneration effort is too great to allow grazing damage to occur at any stage of reproduction. Nevertheless, coordinated resource planning has aided in achieving proper livestock grazing on private timberland.

895. Horton, Alan J. 1987. Animal damage prediction models in conifer plantations. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 29-36.

Forest Service districts in south-central Oregon have implemented site-specific models for predicting damage by pocket gophers, big game, and livestock. Prediction models are based upon habitat, history/experience, population cycles, weather and disturbance factors (big game), usage patterns and travel routes (big game and livestock), and available controls. Plantation establishment costs have declined significantly, however, the models have failed to accurately predict damage on a few plantations. Ongoing refinement of the models is necessary, particularly in separating "high risk" from "moderate risk" conclusions. Samples of the models are included.

896. Kingery, James L.; Graham, Russell T. 1987. Cattle grazing and forest animal damage interaction. In: Baumgartner, David M.; Mahoney, Ronald L.; Evans, James; Caslick, James; Breuer, David W., eds. Animal damage management in Pacific Northwest forests; 1987 March 25-27; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 119-132.

On three study areas in northern Idaho, direct damage to tree seedlings by livestock was less than expected, but it was found that grazing activities can influence the role of other causes of damage. Where grazing was light and ground cover was high, damage to tree seedlings by aboveground rodents was the highest. Percentage of damage and mortality resulting from deer and elk was similar to those of livestock, except in areas of steep terrain. Contrary to some earlier research, this study revealed that poorest tree seedling performance occurred on the more favorable habitat types. Temperature and moisture conditions that favor tree establishment also favor those factors that most contribute to damage and mortality to tree seedlings.

897. Kingery, James L.; Graham, Russell T.; White, Jeffrey S. 1987. Damage to first-year conifers under three livestock grazing intensities in Idaho. Res. Pap. INT-376. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 8 p.

Three study areas with a high potential for both forage and timber production were planted with 2+0 seedlings of ponderosa pine with Douglas-fir (one area) or with white pine (two areas). Within each area, uniform sites were located to represent light, medium, and heavy intensities of livestock grazing. Frequent observations were made after planting to define and quantify causes of seedling damage and mortality. The intensity of livestock use and livestock management practices appeared to influence damage associated with livestock, big game, pocket gophers, other rodents, and nonanimal factors. Considering all sites together, livestock caused little direct damage. Rotation grazing appeared to reduce damage and mortality to seedlings. Pocket gophers caused most damage, with the greatest damage occurring on sites with the least livestock grazing.

898. Kosco, Barbara H.; Bartolome, James W. 1983. Effects of cattle and deer on regenerating mixed conifer clearcuts. *Journal of Range Management* 36(2): 265-268.

In a study near Georgetown, California, cattle grazed the study area from June 1 until September 20 each year. Deer are primarily migratory, passing through the study area in March and April and again in October and November each year. The results of treatments on two clearcuts indicate cattle do not harm tree regeneration. Browsing on trees occurred, but no significantly higher numbers of trees were browsed by cattle and deer than by deer alone. White fir seedlings were browsed the most heavily. No trampling damage occurred. Browsing has made no difference in overall tree seedling height or basal diameter between treatments. Brush cover was significantly reduced on grazed treatments on both clearcuts. The reduction in brush cover has had no effect on tree seedling heights or basal diameters yet. Results from this study indicate that proper cattle grazing does not harm tree regeneration on young mixed conifer plantations, and furthermore, cattle grazing may be used as a vegetation management tool in reducing brush on these clearcuts.

899. Kosco, Barbara Hope. 1980. Combining forage and timber production in young-growth mixed conifer forest range. Berkeley, CA: University of California. 124 p. Ph.D. dissertation.

The study was carried out at Blodgett Forest Research Station on the west slope of the Sierra at 1,300 to 1,500 m elevation. Both herbaceous and browse forages play important roles in the diets of livestock on mixed conifer forest range. Meadows were studied to determine species composition, production, and usage. Research results from study on the effects of cattle and deer on young-growth conifer clearcuts show cattle do not damage tree regeneration. Rather, deer cause most of the browsing damage to conifer seedlings, concentrating on white fir. Trampling damage is negligible. In addition, cattle and deer significantly reduce brush cover on the clearcuts over the ungrazed control plots by grazing most immature brush species. Therefore, managed livestock grazing can reduce unwanted brush and enhance conifer tree regeneration on mixed conifer clearcuts. Most conflicts between timber management and grazing have resulted from poor livestock management practices which can be easily corrected. Additionally, livestock can significantly aid vegetation manipulation by resource managers. With increasing restrictions on costly site preparations, the use of livestock as a silvicultural tool needs to be put into practice.

900. Leininger, Wayne Carl. 1984. Silvicultural impacts of sheep grazing in Oregon's Coast Range. Corvallis, OR: Oregon State University. 211 p. Ph.D. dissertation.

A 3-year investigation was conducted during 1980-82 to evaluate the potential of using herded sheep as a silvicultural tool to suppress brush in Douglas-fir plantations. Sheep browsing of Douglas-fir was highest in May soon after bud break. Averaged over the 2 years of grazing, sheep consumed 28% of the Douglas-fir current year's growth in two May-grazed plantations. Browsing was generally light during July and August. Browsing of terminal leaders by sheep decreased as seedling height increased. Less than 3% of the study trees were mechanically impacted by sheep. In a 2-year-old plantation in which seedlings were heavily browsed by sheep in both May and August, annual height and mean diameter increment were reduced by sheep grazing. However, annual mean diameter increment was 8 to 17% higher in the

grazed portion of three 4-6-year-old study plantations. Survival of regeneration over the 2 years of investigation was high in all study plantations and was unaffected by grazing. Increased available nitrogen deposited as urine in grazed plantations may have contributed to the increased diameter growth. Vegetational composition of sheep diets varied by year, season, and plantation age class. In older plantations, graminoids and forbs were used nearly equally, 40% each. In contrast, diets of sheep in young grass seeded plantations averaged 70% graminoids and only 16% forbs. Browse averaged 15 and 12% of sheep diets in older and younger plantations, respectively. Douglas-fir comprised less than 3% of sheep diets throughout the grazing season.

901. McLean, A.; Clark, M.B. 1980. Grass, trees, and cattle on clearcut-logged areas. *Journal of Range Management* 33(3): 213-217.

In this study, eight areas in the Engelmann spruce/subalpine fir and Douglas-fir zones of British Columbia were clearcut and seeded with a mixture of grasses (leaving unseeded control strips) between 1971 and 1974. Some areas were restocked with spruce and lodgepole pine, and height growth was measured after 6 years for spruce and pine planted as 2-year-olds and after 4 years for naturally regenerated pine in grazed and ungrazed areas; there were no consistent differences due to grazing or seeding with grass. Data on grass production, forage use, and cattle performance were also collected. Although cattle did cause appreciable conifer mortality (20-56%, mainly by trampling rather than browsing), adequate stocks remained. There was no consistent difference in cattle-caused mortality between grass-seeded and unseeded areas and no significant relation between cattle-caused mortality and amount of forage use.

902. Monfore, J.D. 1983. Livestock—a useful tool for vegetation control in ponderosa pine and lodgepole pine plantations. In: Roche, B.F., Jr.; Baumgartner, D.M., eds. *Forestland grazing: Proceedings of a symposium; 1983 February 23-25; Pullman, WA.* Pullman, WA: Washington State University, Cooperative Extension Service: 105-107.

By quantifying forage production, controlling the timing, placement, and numbers of livestock, and maintaining effective herd distribution, forest managers minimized damage on pine plantations. Further, grazing was found to control understory vegetation, reduce fire hazard, and increase potential growth gains to planted pines.

903. Moore, A.W. 1943. The pocket gopher in relation to yellow pine reproduction. *Journal of Mammalogy* 24(2): 271-272.

On the Ochoco National Forest in Oregon, it was noted that grazing and the presence of pocket gophers are responsible for the lack of reproduction of ponderosa pine. When pressed for food, livestock will consume most growing green vegetation within reach, which greatly reduced the natural reproduction of ponderosa pine. Pocket gophers consumed a variety of vegetation including roots, tops and bark of pines, but not pine seed. Use of pocket gopher runways by white-footed mice is the primary cause of the lack of pine reproduction in areas inhabited by gophers. When gophers are removed from an area, the tunnels collapse and do not afford shelter to the mice, and as a result, pine seeds are gleaned less thoroughly by the seed-eating mice.

904. Nordstrom, Lance O.; Newman, Reg F.; Wikeem, Brian M. 1985. An annotated bibliography on forest-range ecosystems in the Pacific Northwest. Land Mgt. Rep. 38. Victoria, BC: British Columbia Ministry of Forests. 96 p.

The subject matter covered is largely concerned with the autecology and synecology of plants and animals in forest-range ecosystems, primarily in relation to resource management. Main topics addressed include (1) the seeding of grass in logged environments; (2) the silvics and regeneration of conifers; (3) synecological interactions among introduced grasses and legumes, trees, and native vegetation; (4) impacts of livestock and wildlife on seeded and native forages and coniferous tree seedlings; (5) effects of silvicultural treatments on forage production; (6) dietary overlap between livestock and big game; (7) principles and practices of livestock management on forest-range; and (8) the economics of the interactions of trees, forage, and livestock.

905. Ross, B.A. 1977. Compatibility of cattle grazing with timber production on British Columbia's interior rangelands. Vancouver, BC: University of British Columbia. 43 p. B.S.F. thesis.

Literature is reviewed on forest grazing in British Columbia, with emphasis on overstory-understory relationships, grass-conifer competition, livestock damage to coniferous regeneration, forest-range seeding and fertilization, and grazing management. The author concludes that grazing and timber production can be complementary through proper management.

Grouse Ecology

906. Armleder, Harold M. 1980. Habitat use and movements of hens and broods in relation to the demography of blue grouse. Toronto, Ontario: University of Toronto. 71 p. M.S. thesis.

The habitat use, movements, and survival of hens and broods were examined to determine the influence that habitat has on aspects of the demography of blue grouse. During 1977 and 1978, 691 observations were made using radio-telemetry equipment on 29 hens on Vancouver Island. Hens and their broods preferred habitats with little canopy cover, but use of habitats with greater cover increased as the chicks matured. The size of home range, however, was not correlated with the amount of preferred habitat on the home range. A positive correlation was found between the home range size and the amount of habitat not preferred on the home range. Also, the size of home range was negatively correlated with both the degree of interspersion of habitat types on the home range, and the brood size 6 weeks after hatch. Additionally, the degree of habitat interspersion on an area was positively correlated with the density of the breeding population. Home range sizes were not significantly different among study areas but displayed wide local variation. The almost exclusive home ranges occupied by hens during the posthatch period may actually be territories which are maintained without overt aggression. The results suggest that habitat affects the young and the females and may have an influence on population regulation.

907. Ash, Andrew N.; Bendell, James F. 1979. Trials of nitrogen fertilizer on foods of blue grouse. *Journal of Wildlife Management* 43(2): 503-508.

This report shows how application of urea and ammonium nitrate to the summer range of blue grouse increased amount of nitrogen in four important food plants. In addition to increasing N, fertilization increased growth, coloring, flowering, fruiting, and setting of seed. The amount of cover afforded by plants was greatly increased. Fertilization increased foliar N in Douglas-fir, but shrubs and herbs concentrated more N than coniferous trees. The ability to concentrate N may explain the rapidity of colonization and speed of growth of pioneer herbaceous vegetation. The study was preliminary to a longer fertilization project which is underway to test the idea that quality of food limits breeding density of blue grouse.

908. Bauer, Richard Donald. 1962. Ecology of blue grouse on summer range in north central Washington. Pullman, WA: Washington State University. 81 p. M.S. thesis.

This study terminates a series of investigations on blue grouse conducted in the Methow Valley of north-central Washington since 1956 to determine ecological factors affecting summer populations. It was determined in 1960 and 1961 that blue grouse were usually in close association with *Amelanchier alnifolia*, *Rosa* spp., and *Symphoricarpos albus*, as these plants were often used as food and protective cover. Blue grouse chicks up to 7 weeks of age usually were found on grasslands, whereas older chicks were observed near shrubs. Uniform daily habits were altered by extreme hot or cold and rainy weather. A mean juvenile male to female sex ratio of 105:100 was found for the period 1957-61. For this same period, the mean age composition was 80% juveniles, 5% subadult females, and 15% adult females. The ages of juvenile grouse were determined by backdating primary feathers from which the hatching periods and juvenile growth rates were calculated. The summer blue grouse population declined, as shown by four separate indices, from 1957 to 1960, and increased from 1960 to 1961. This fluctuation in numbers was attributed to weather conditions before and after the hatching period and vegetation conditions during late spring and early summer. It was concluded that hatching success was not influenced by the time and duration of the peak of hatching and thus had negligible effects on the summer population. This contradicts that shown by most other gallinaceous birds when the shorter and earlier the peak of hatching, the more successful the hatch.

909. Beer, James. 1943. Food habits of the blue grouse. *Journal of Wildlife Management* 7(1): 32-44.

Stomachs of 128 blue grouse from 7 counties in Washington, 2 in Idaho, and 1 in Oregon were examined. Also 58 samples of droppings were examined in the laboratory and many others in the field. Parts of plants of 69 genera are known to be eaten, and representatives of 45 of these were found in the stomachs examined. Plant foods of 16 genera and 27 species are reported here for the first time. The

yearly food comprised 98.3% plant foods and 1.7% animal matter. Of this, 63.8% is needles, 17.0% berries, and 17.2% miscellaneous plant materials. Little animal matter is taken by adults, but the food of the young is entirely of insects at first; by mid-August it becomes the same as that of the adults. The birds have three feeding periods. The first early in the morning, the second just before noon, and the third and heaviest during the last 3 hours of daylight. Free drinking water is not necessary for the blue grouse. The distribution of the genus appears to be limited by that of the plant genera *Abies* and *Pseudotsuga*.

910. Bendell, J.F.; Elliott, P.W. 1966. Habitat selection in blue grouse. *Condor* 68(5): 431-446.

Blue grouse were shot and observed in very open and very dense cover to find their selection of habitat. New adult and yearling grouse selected the open type of vegetation, and this was apparently a response to part or parts of the habitat other than grouse. Within open cover, hooting males selected heights of land and established territories. Yearling males were attracted by territorial males. The attraction of yearlings to hooting males probably perpetuates the use of a territory. Lone hens were attracted by territorial males. Hens with brood moved over the breeding range independently of territorial males or their territories. Blue grouse apparently select their habitat on the breeding range in spring and respond to the structure of the vegetation. The breeding habitat of blue grouse may be defined as open and dry, with shrubs and herbs interspersed with bare ground. The winter range is in montane forest, apparently in the parkland coniferous stands of the alpine, subalpine ecotone, and open ridges in subalpine forest. The cover preference of blue grouse may help determine population. New recruits are attracted to open areas and avoid dense vegetation. As a result, population might increase or decrease partly because of the ingress or egress of grouse. The habitat selection may be partly explained by an evolutionary origin from prairie-dwelling species of grouse. They seem adapted to dry, open habitat in many ways, including an innate response to open habitat, aspects of behavior, color, form, and the economical use of water.

911. Bendell, James F. 1955. Age, breeding behavior and migration of sooty grouse, *Dendragapus obscurus fuliginosus* (Ridgway). In: Trefethen, James B., ed. Transactions of the 20th North American wildlife conference; 1955 March 14-16; Montreal, Quebec. Washington, DC: Wildlife Management Institute: 367-381.

Sooty grouse were studied on a part of the breeding range at Quinsam Lake, Vancouver Island. Adult sooty grouse return to the same part of the summer range each year between March 6 and April 13. The territorial behavior of the breeding male sooty grouse consists of song and isolation upon a well defined area. Within the area, intruding males are repelled and females are courted. The male remains on his territory throughout the breeding season. Most yearling males do not breed and do not migrate from the winter range in their first spring after hatch. The breeding males are polygamous. The range of females is not related to the territory of a particular male. Activity in the spring follows a well-marked diurnal rhythm with two

peaks of relatively intense activity in each day. Light intensity between 2- and 4-foot candles is important as a factor regulating the activity peaks. The production of ova begins in late April and early May and continues while the eggs are laid from the second to the last week of May. The average clutch size is six eggs with a range between five and seven. Breeding yearling and adult hens are equally productive. Peak hatch occurs between June 15 and June 21. The upward migration of the males begins in late April and early May and is near completion by August. The upward migration of the hens and young does not begin until July. There is variation between years in time and rate of migration, probably influenced by food supplies on the summer range.

912. Bendell, James F. 1955. Age, molt, and weight characteristics of blue grouse. *Condor* 57(6): 354-361.

Observations on age groups of blue grouse on Vancouver Island, British Columbia, are presented. By October, chicks of the first year are in plumage similar to the adults with the exception of shorter and narrower rectrices. The chick, postjuvenile and annual molt follows a recognizable pattern of replacement of flight and contour feathers. There is evidence that the annual molt of flight feathers is not complete in adult birds. Several criteria of age are defined. The average length of the outer pair of rectrices in yearlings (birds between the first and second falls) ranges between 13.2 and 15.2 cm in males and probably between 11.1 and 13.4 cm in females. The same measurement in adults ranges between 16.2 and 19.4 cm in males and probably between 13.8 and 16.1 cm in females. The presence of the bursa of Fabricius in a blue grouse in adult plumage indicates a bird 2 to 3 years old. Its absence from males in adult plumage indicates a bird of 4 years of age and older. A sample of 138 young was 100:100 in sex ratio. From June 15 to September 23 (1 to 15 weeks of age) the average growth rate of young males and females is approximately 60 and 50 g per week, respectively. The average weights of adult birds on the summer range showed no statistically significant change between April and September. The adult males averaged 1,230 g; adult females, 845 g. Eight yearling males and 11 yearling females weighed in May, June, and July averaged 1,110 and 790 g, respectively, an indication that yearlings do not attain adult weight until after June or July of their second year.

913. Bendell, James F.; King, David G.; Mossop, David H. 1972. Removal and re-population of blue grouse in a declining population. *Journal of Wildlife Management* 36(4): 1153-1165.

One-hundred seventy adult and yearling blue grouse of both sexes were shot from an area of 900 acres on Vancouver Island in the spring of 1970. The area was virtually emptied. In 1971, about 90% of the population on the removal area was replaced, mostly by yearling males and females in an equal sex ratio. The control population was essentially unchanged in density, sex ratio, and age structure. The ingress of yearlings did not reduce the number of yearlings in the breeding populations on the control and surrounding areas. The main conclusion is that established or resident adult and yearling grouse interacted with yearlings to regulate yearling

recruitment, and, in turn, to regulate the level of the breeding population. This interaction apparently happened in the early spring and on the summer range. Yearlings not recruited to the breeding population were surplus and disappeared. This process of population regulation occurred in the sparse and declining population and in a nearby dense and expanding population. It also operated in the sparse and declining population when this population was dense and stable. Hence, the process seems general in blue grouse and perhaps also in other animal populations. The behavior of grouse in relation to each other and the causes of this behavior may be most relevant to population regulation and density. Future work should concentrate on when, how, and why some yearlings become established in the breeding population and others are excluded.

914. Boag, D.A. 1963. Significance of location, year, sex, and age to the autumn diet of blue grouse. *Journal of Wildlife Management* 27(4): 555-562.

Analyses of the contents of 775 crops taken from blue grouse during September and October of 1958-61, inclusive, in north-central Washington are presented for statistical comparisons. Based on the eight foods which appeared with greatest frequency and volume, these comparisons showed that autumn diets of the grouse varied significantly with location, year taken, and age category. It is suggested that preference may largely determine the food of these grouse and that the resulting diet may have a bearing on reproductive performance.

915. Boag, D.A. 1966. Population attributes of blue grouse in southwestern Alberta. *Canadian Journal of Zoology* 44(5): 799-814.

A population of blue grouse was studied over a 10-year period in southwestern Alberta. During this time, many population attributes were documented. Density declined from a maximum of 47 adult males in 1955 to a minimum of 6 in 1964 on the 620-acre study area. Dispersion of adult male blue grouse on the breeding grounds was accomplished by establishing territories which averaged 1.5 acres. Adult females inhabited overlapping home ranges which averaged 43 acres. The age distribution among marked birds on the breeding grounds in May and June indicated 75% adult (2 years and older) and 25% subadult (1 year of age). Of the adults, approximately 1/2 were 2-year-olds with decreasing proportions in older age classes until none remained after they were 9 years old. Juveniles formed 40% of the fall population each year. The average hatch was 5.1 chicks per breeding female. Recruitment to the population has been inadequate to maintain numbers. Excessive mortality or dispersal rates must account for this. Minimum recorded loss of chicks during their first summer averaged 27%. Mortality rate of birds more than 1-year-old averaged 56% per annum. Dispersal to other breeding ranges was recorded only in juvenile grouse.

916. Boag, David A. 1965. Indicators of sex, age, and breeding phenology in blue grouse. *Journal of Wildlife Management* 29(1): 103-108.

Three separate populations of blue grouse, representing three subspecies, are compared from the standpoint of plumage, weight, and breeding phenology. The

color of postjuvencal cervical feathers can be accurately used in sex determination of birds over 6 weeks of age. Juvenile grouse can be recognized during their first summer on the basis of plumage and smaller size. Subadult (yearling) birds during their second summer possess pointed outer primaries and shorter narrower rectrices. Adults have rounded outer primaries and longer, broader rectrices. Weight as a criterion for separation of adults and subadults is reviewed and shown to be of limited value. Onset of molt in breeding adult and subadult females can be used as a criterion for estimating breeding phenology in at least one population. The age of juveniles, as reflected by the primary molt, can also be used to post-date the sequence of events during the breeding season.

917. Boag, David Archibald. 1964. A population study of the blue grouse in southwest Alberta. Pullman, WA: Washington State University. 137 p. Ph.D. dissertation.

A population of blue grouse was studied over a 4-year period on the east slopes of the Rocky Mountains in southwestern Alberta, Canada. During this period, the life histories of 89 individuals were followed in an attempt to determine when and where limiting factors were having the greatest impact. Within the population on the breeding grounds in May and June, which is composed of adults and subadults, there exists an unequal sex ratio in favor of females. An estimated 29% of the population is adult male, whereas 44% is adult female and subadults the remaining 27%. Territoriality is highly developed in adult males; the average territory encompasses 1.5 acres. Adult females appear to inhabit home ranges which average 43 acres in size. Homing is a trait well developed in both sexes, especially in birds 2 years of age and older. Males and females suffer a differential mortality. There is an annual loss of 46% in males over 1 year of age, however, females suffer only a 25% loss annually with some birds living to be 11 years of age. It is suggested that the territoriality of adult males forces the younger male birds into marginal habitat, thus exposing them to increased mortality. Juvenile blue grouse form an estimated 65% of the July-August population. The survival of juveniles during the 5-week posthatching period appears to be correlated with meteorological conditions. Heavy rainfall, lack of insolation, and low ambient temperatures are apparently detrimental. The population under consideration has declined steadily over the last 7 years. Possible reasons for this decline were examined.

918. Buss, Irven O.; Schottelius, Byron A. 1954. Breeding age of blue grouse. *Journal of Wildlife Management* 18(1): 137-138.

Fourteen adult blue grouse, shot in the Blue Mountains of southeastern Washington, were examined. Collectively, the evidence indicates that (1) blue grouse do not molt their outer two pair of juvenile primaries during the first fall of life; (2) at least some blue grouse retain the burse of Fabricius until about 2 years of age when they apparently begin to breed. These findings are of significance to investigators who analyze wings and tails of blue grouse for sex and age data.

919. Caswell, Edwin B. 1954. A preliminary study on the life history and ecology of the blue grouse in west-central Idaho. Moscow, ID: University of Idaho. 105 p. M.S. thesis.

The study was made in the Cuddy and Hitt Mountains of west-central Idaho from May 6, 1952, to May 2, 1953. The young grow fast and the postjuvenile molt is complete about October 1. No apparent differences were found between the sexes in downy young. A new sexing technique, based on the presence of white, dark sepia-tipped feathers around the cervical air sacs in the male, was developed. A downward movement is made in the spring which takes the grouse from the higher snow-clad mountains to the snowless sagebrush-grass and bunchgrass slopes. This movement coincided with the development of the vegetation, and some buttercups were in blossom on south facing slopes by the time the grouse arrived. An upward movement is started by adult males in late June but is not readily apparent until late July. The females and broods gradually work upslope during August. Conifer needles assure birds in the timbered areas an unlimited source of food regardless of the fruit, berry, and seed crops. Morning and evening feeding and midday resting periods are the most common to all seasons. During the winter, movement was generally upslope in the morning and downslope in the afternoon. Display activities of the male may be heard at all times of the day but are most intense during the morning and evening twilight periods. Twelve nests were found, and all but two faced north to some degree. The nest, formed of dried grass and nearby litter, is built on the ground, well concealed from above. The incubation period was judged to be 25 days. The average clutch contains 7 to 10 eggs, but the chick loss is high and broods are reduced to 4 by August.

920. Doerr, Joseph G.; Barescu, Claudia L.; Brighenti, James M., Jr.; Morin, Marie P. 1984. Use of clearcutting and old-growth forests by male blue grouse in central-southeast Alaska. In: Meehan, William R.; Merrell, Theodore R., Jr.; Hanley, Thomas A., eds. Fish and wildlife relationships in old-growth forests: Proceedings of a symposium; 1982 April 12-15; Juneau, AK. [Place of publication unknown]: American Institute of Fishery Research Biologists: 309-313.

Singing male grouse were located during spring 1980 and 1981 in 1,360 ha of 1- to 23-year-old clearcutting and 1,900 ha of adjacent old-growth forests on Kuiu Island, Mitkof Island, and a mainland area at Thomas Bay in central-southeast Alaska. Densities of singing males were 45 times higher in old-growth forests than in clearcuttings (7.2 vs. 0.16/100 ha). Ninety-nine percent of all singing grouse were located in live trees, of which 82, 9, and 9% were in western hemlock, Sitka spruce, and either western hemlock or Sitka spruce, respectively. Diameters of trees used ranged from 15 to 137 cm, with approximately 60% of the trees exceeding 512 cm d.b.h. Territories in old growth were not distributed with respect to distance to clearcutting, muskegs, or other stand openings.

921. Fowle, C. David. 1960. A study of the blue grouse (*Dendragapus obscurus* Say) on Vancouver Island, British Columbia. Canadian Journal of Zoology 38(4): 701-713.

A study was made of the summer habitat, seasonal movements, fluctuations in populations, population density, breeding cycle, and summer feeding habits of

Dendragapus obscurus fuliginosus. During the summer, the grouse were found mainly in the early stages of the developing second-growth forests following fire or logging. The birds descended to the lowlands in late March and early April. Most of the adult males returned to the uplands by the end of July. The females and broods left the lowlands by the end of September. There is evidence of several well-marked fluctuations in the numbers of blue grouse in British Columbia since 1904. A density of about 0.2 adults per acre was recorded in late June and early July. Nesting took place in May, and the first young appeared early in June. After the first of July, it was not uncommon to see two females with their intermingled broods feeding together. The summer foods of both adults and young were almost entirely vegetable. Grit was the main item in gizzards from birds collected before the middle of July but later it was largely replaced by hard seeds. The grouse were not observed to drink free water except in captivity. There is a rough parallelism between frequency of occurrence of the main items of food in the environment and the proportion of each occurring in the diet.

922. Frandsen, D.H. 1980. Density, habitat, and behaviour of blue grouse. Toronto, Ontario: University of Toronto. 142 p. M.S. thesis.

A new rapid method of censusing hooting blue grouse and analysing the results was developed. Transects with 20 to 25 listening stations with 100-yard intervals between stations were established on 17 study areas on Vancouver Island. A female call (cackle) was used to stimulate hooting. Censuses were repeated five to seven times on each area. An equation was developed to compensate for males that were not heard consistently and to estimate the actual numbers of males on the censused area. The distance from the transect to the edge of the area censused was the mean distance that hooting could be heard in each study area. Density estimates from this method on two test areas were within 4% of densities determined from extensive ground search by others. Other checks of the method were also favorable. The method is fast, simple, and accurate and could be adapted for use on other tetraonids or other territorial birds that produce distinctive calls, songs, or sounds for some period of their life cycle.

923. Hannon, S.J.; Simard, B.R.; Zwickel, F.C.; Bendell, J.F. 1979. Differences in the gonadal cycles of adult and yearling blue grouse. *Canadian Journal of Zoology* 57(6): 1283-1289.

Gonadal cycles of adult and yearling female and male blue grouse collected from Vancouver Island, British Columbia, are described and compared. Reproductive organs of yearling females develop later, produce eggs at a lower oviduct weight, and regress faster to a lower oviduct weight than do those of adults. Yearling males, although most do not breed, go through the entire gonadal cycle and produce viable sperm. Testes of yearlings develop later, have a lower volume, and regress earlier than those of adults. Yearlings of both sexes appear less sexually mature than adults, but delays in or lack of breeding could be partly a result of social interaction with resident adults.

924. Hannon, Susan J. 1978. The reproductive cycle, movements, and pre-nesting behavior of adult and yearling females in a population of blue grouse. Edmonton, Alberta: University of Alberta. 127 p. M.S. thesis.

Aspects of the reproductive cycle and prenesting behavior of female blue grouse were investigated on Vancouver Island, British Columbia, during the summers of 1976 and 1977. Emphasis was placed on comparison between adult and yearling hens. Oviducts of yearlings recrudescence later, reach a lower laying size, and regress faster than those of adults. Yearlings appear less sexually mature than adults, however, they are able to accelerate gonadal development in years when adult numbers are low. Two groups of yearlings were identified: those which could potentially breed, termed "breeders," and those unlikely to breed, termed "nonbreeders." Both groups of yearlings were present on the breeding range in April, but nonbreeders disappeared soon after yearlings began to lay eggs. Breeders weighed more than nonbreeders throughout the spring. Reproductive status of live hens was determined by measuring total plasma calcium. Prelaying hens in the slow phase of gonadal recrudescence could be distinguished from those in the rapid phase by using this method, but the precise reproductive status could not be ascertained. Yearlings move over longer distances and localize later than adults during the prenesting. Site attachment was a necessary prerequisite to gonadal development. Hens replied to an aggressive call (the cackle) during the prenesting, primarily when they were localized and in the rapid phase of gonadal recrudescence. Hens may space themselves on the breeding range by mutual avoidance, by using the cackle call. A model is presented which relates the above to a mechanism for regulating density of hens on the breeding range.

925. Hannon, Susan J.; Sopuck, Lennart G.; Zwikel, Fred C. 1982. Spring movements of female blue grouse: evidence for socially induced delayed breeding in yearlings. *Auk* 99(4): 687-694.

When compared to adults, yearling female blue grouse breed later in the season, and some may not breed at all. Movements of adults and yearlings in spring are strikingly different. Adult movements become restricted early, whereas yearlings continue to wander over large areas for a longer period. Gonadal development in yearlings begins soon after they have localized, and localization of yearlings occurs when movements of adults are restricted around nests. Aggressive calling begins when hens have localized and continues until incubation is initiated. We suggest that adults interact aggressively with yearlings, preventing them from settling until adults begin to nest.

926. Hannon, Susan J.; Zwikel, Fred C. 1979. Probable non-breeders among female blue grouse. *Condor* 81(1): 78-82.

Two groups of yearling females were identified from a series of blue grouse examined on Vancouver Island, British Columbia. Birds collected during a continuous yearling-only removal had a high proportion of apparent nonbreeders when compared to hens that had bred. Early presence on the breeding range did not increase or decrease the chance of joining the breeding population, but the heaviest birds were most likely to become established.

927. Hatter, J. 1955. Problems in the management of sooty grouse in British Columbia. In: Proceedings of the 35th annual conference of the Western Association of State Game and Fish Commissioners; 1955 June 16-18; [Place of meeting unknown]. Moran, WY: [Publisher unknown]: 262-265.

The original habitat of the blue grouse consisted of timbered slopes and mature Douglas-fir/hemlock/cedar association common before the advent of logging. In this environment, the bird apparently showed preferences for the drier sites where rocky outcrops and soil conditions relieved the continuity of mature timber. The influence of logging and slash burning has produced remarkable densities. Optimum conditions vary with site, but in less than 15 years, regeneration advances to the point at which optimum conditions no longer prevail. Management of hunting is difficult because of the migratory behavior of the birds and the likelihood of fire hazard in late summer.

928. Heebner, Gordon C. 1956. A study of the life history and ecology of the blue grouse in west-central Idaho. Moscow, ID: University of Idaho. 51 p. M.S. thesis.

This is the second study in a long-term research program on the blue grouse in the Hitt and Cuddy Mountains of west-central Idaho. A downward movement is made in the spring which takes the grouse from their winter range in the Douglas-fir zone to their spring and summer range in the wheatgrass-bluegrass and sagebrush-grass zones. In 1955, this movement coincided with the melting of snow and consequent development of vegetation on south-facing slopes. April 2-5 was the period during which most of the blue grouse arrived on their spring and summer ranges. The upward migration is initiated by the adult males in late June and early July. Females and their broods gradually begin this movement in August. Adult males prefer an open, sparsely-covered area with low-growing vegetation on which to establish their breeding territories. Courting activities did not begin on a full scale until the last week in April, although the earliest hooting was witnessed on April 6. Nesting females prefer native vegetation, but plant species do not appear to determine nest site selections. Four nests located all faced south between and elevations of 3,100 and 5,440 feet and were well concealed from above. The average clutch size laid in 1955 was 10 eggs. No evidence was found to indicate the female grouse will reneest if her first attempt is destroyed. The peak hatching date occurred between June 16 and June 26. The association of this hatching and the flowering of arrow-leaved balsamroot are quite closely associated. Defense of young chicks by the female is generally of a nonaggressive nature.

929. Henderson, Upton Bruce. 1960. A study of blue grouse on summer range, north-central Washington. Pullman, WA: Washington State University. 102 p. M.S. thesis.

The objectives of this study were (1) to determine the densities of broods on their breeding range; (2) to analyze the movements of the broods on their summer range and the fall dispersal of broods; (3) to ascertain the sex and age composition of the late summer brood population on the breeding range; (4) to interpret brood behavior and fidelity to the breeding range; (5) to determine the age, growth, and molt characteristics of juveniles; (6) to resolve the year-to-year population trends on the Frazier Creek study area, north-central Washington, and (7) to ascertain the cover

preference and other ecological factors affecting blue grouse on their breeding range. The chronology of the reproductive events of blue grouse was determined by the stage of molt of the primaries of juvenile blue grouse capture on the summer range. The peak of hatch occurred in the last 10 days of May. A 104:100 sex ratio was computed for the juveniles from 4 to 14 weeks of age. The age ratio of the late summer brood population was approximately 80% juveniles, 14% adult females, and 6% subadult females. The mean average brood size after the first week in July varied from 3.3 to 5.0. The brood bond is strong but deteriorates in late summer and flocking of broods occurs. Grouse on their summer range prefer an edge situation where undisturbed grasslands are interrupted by aspen thickets of shrubs. Movements indicate a relatively restricted home range of 1/4 to 1/2 mile. The majority of blue grouse leave the summer range by the end of the second week in August, but no external stimuli could be isolated. A mean average growth rate of 63 g per week was determined for juveniles from 6 to 12 weeks of age.

930. Hines, James E. 1986. Social organization, movements, and home ranges of blue grouse in fall and winter. *Wilson Bulletin* 98(3): 419-432.

Social organization, movements, and home ranges of blue grouse were investigated on Hardwicke Island, British Columbia, from 1979 to 1982. Most broods disbanded by the end of September, and young grouse did not associate with their mothers or siblings in winter. The tendency to form flocks was lowest in fall. Grouping increased gradually until midwinter and then declined until spring. Approximately half of the grouse observed during winter were in groups that usually consisted of two or three birds. Daily movements were usually small during winter, and home ranges averaged 16.8 ha. Although blue grouse did not show the strong segregation of sexes found in some other tetraonines, birds most frequently associated with individuals of their own sex and age. The partial segregation of grouse by sex and age may have resulted because females wintered at lower elevations than males, and juveniles migrated longer distances than adults. Segregation of sexes of other species of grouse may be explained by a similar mechanism. Flock formation is most frequent in species of grouse that winter in open areas and less frequent in species that winter in forests.

931. Hines, James E. 1986. Survival and reproduction of dispersing blue grouse. *Condor* 88(1): 43-49.

Dispersal in a declining population of blue grouse was studied over 4 years on Hardwicke Island, British Columbia, by radio-tracking 66 individuals and reobserving or recapturing 126 banded individuals. On a 464-ha main study area, numbers of territorial males decreased from 152 to 94, breeding females from 276 to 113, and young grouse alive in late summer from 847 to 224 during the period of study. Despite this, dispersal distances did not vary between years and bore no clear relationship with adult densities in spring or density of juveniles in the previous fall. Rates of survival and reproduction of "long dispersers" (grouse moving greater than the median dispersal distance) and "short dispersers" (grouse moving less than the median dispersal distance) were similar. Similar results were noted from grouse that left the study area (dispersers) and those that remained on the study area (non-dispersers). Overall, there was little evidence that dispersers fared poorly or that dispersal was greatly influenced by population density.

932. Hines, James E. 1987. Winter habitat relationships of blue grouse on Hardwicke Island, British Columbia. *Journal of Wildlife Management* 51(2): 426-435.

Winter habitat of radio-tagged and color-banded blue grouse was studied. Western hemlock was the dominant tree at 94% of all sites where grouse were observed in winter. Hemlock and Douglas-fir needles made up most of the winter food. Habitat tolerances of blue grouse were broad. Radio-tagged juveniles were found in successional stages ranging from 4 to over 250 years with trees from 1 m to over 60 m in height. Mature forest (over 250 years old) was preferred winter habitat, early successional stages were used frequently, and midsuccessional stages were less frequently used. A sample of nonradioed grouse of all ages indicated that males and females wintered at different elevations, on average, and may have used different successional stages. Mortality of grouse living in early successional stages was high in fall but after fall migration, survival did not seem to be influenced by habitat.

933. Hines, James Edward. 1986. Recruitment of young in a declining population of blue grouse. Edmonton, Alberta: University of Alberta. 256 p. Ph.D. dissertation.

Animal populations do not grow indefinitely and recruitment, the process whereby new animals are added to the breeding population, is potentially important in determining animal numbers. Hypothetically, the "surplus" of young produced in populations of blue grouse might be eliminated by (1) mortality over winter, or (2) spacing behavior in spring. These hypotheses were tested on Hardwicke Island, British Columbia, from 1979 to 1983 on a declining population of blue grouse. The second objective was to investigate the ecology of blue grouse in autumn and winter. Survival of young blue grouse over winter was not adequate to maintain a stable population, indicating that high over-winter mortality caused the population to decline. The proportion of yearling females that nested varied inversely with population density, suggesting that spacing behavior prevented some females from breeding when numbers were high. Fall migration was not highly synchronized and was spread over several months. Juveniles moved 1 to 15.0 km to winter range, whereas older grouse move 0 to 5.4 km. Grouse wintered in a variety of successional stages (all dominated by western hemlock) ranging from recently-logged areas to mature forest. Preferred habitats were mature forests at higher elevations (300 m) close to breeding range. Needles of western hemlock and Douglas-fir comprised much of the winter diet. Broods disbanded before migration. In winter, the median daily movement was 69 m, and home ranges averaged 16.8 ha. Although females usually were solitary in spring, I found no evidence that they spaced themselves or their nest sites in a regular pattern.

934. Hoffmann, Robert S. 1956. Observations on a sooty grouse population at Sage Hen Creek, California. *Condor* 58(5): 321-337.

Observations on the behavior of a small semi-isolated population of sooty grouse at Sage Hen Creek, California, are compared with published observations on other populations. The grouse at Sage Hen Creek differ from most previously described populations in that they do not perform a seasonal altitudinal migration and in that no flocking behavior has been observed. These differences may be a reflection of low population density. Evidence presently available points to pronounced differences in

courtship behavior between the dusky grouse (*obscurus* group) of the interior and the sooty grouse (*fuliginosus* group) along the Pacific coast. These differences appear to be correlated with differences in summer range chosen by the two groups. The tendency toward communal display with no obvious territoriality is found in dusky grouse on open summer range, whereas solitary display and strongly developed territoriality occurs among sooty grouse on more wooded summer range. Although the grouse at Sage Hen Creek occupy the extreme eastern portion of the range of the *fuliginosus* group, the population has maintained the pattern of courtship display and breeding habitat preference found in the main populations of the *fuliginosus* group. They show no tendency to resemble the *obscurus* group of the Great Basin in these respects, although the topography and vegetation of the Sage Hen drainage makes such a shift in habits theoretically possible. The occurrence of displaying male grouse in the spring, and of winter roost sites, was determined at Sage Hen Creek from 1951 through 1955. These two indices of population density suggest that the numbers of sooty grouse declined in late 1952.

935. Hoffmann, Robert S. 1961. The quality of the winter food of blue grouse. *Journal of Wildlife Management* 25(2): 209-210.

Certain species undergo regular, large fluctuations in population density which have been called "cycles." Some authors have pointed out that "cyclic" herbivores characteristically feed upon vegetative plant parts during the winter, and some have suggested a possible correlation between the low quality of winter food and the cyclic nature of population fluctuation. Grouse feed on twigs, needles, buds, and catkins—materials which are assumed to be of low nutritive quality. Grouse at Sage Hen Creek, Nevada County, California, have a monotonous winter diet of almost entirely white fir needles. This presents the opportunity for food analysis that avoids the complexities inherent in a mixed diet. The objective of the nutrition phase of the present study was to collect samples of needles from representative individual white fir trees, and analyze these samples chemically. Samples were collected through the year and from different heights and exposures, so that variations in chemical quality of the needles could be detected. Crude protein content in samples from a height of 50 feet was 6-7%; samples from a height of 10 feet were around 4-5%. There was no significant annual variation in crude protein content. The grouse population was high in 1951, declined abruptly in 1952, and remained low through 1955. There seems to be no correlation between the population trends and the crude protein of their winter food. The ability to subsist on a diet of low quality but abundant quantity provided by the fir needles suggests considerable digestive efficiency of the grouse.

936. Jamieson, Ian G. 1983. Seasonal changes in spatial patterns and behavior of yearling male blue grouse on the breeding range. *Canadian Journal of Zoology* 61(12): 2777-2780.

Changes in spatial patterns and behavior of yearling male blue grouse equipped with radio transmitters were recorded during spring and summer, 1980 and 1981, on Hardwicke Island, British Columbia. Sizes of home ranges decreased and yearlings appeared to become less dispersed as the season progressed. Most birds moved off their initial home range and onto new areas on the breeding range by late summer although the timing of this movement varied among individuals. Interactions involving

yearling males with females and territorial males decreased as the season advanced. Changes in spatial patterns and behavior appear to be related to seasonal changes in levels of hormones in yearling males.

937. Jamieson, Ian G. 1985. Behavior of yearling male blue grouse and its relation to delayed breeding. *Wilson Bulletin* 97(1): 71-77.

Yearling male blue grouse were inactive during the day and were usually in or near vegetative cover; overt activity increased at dusk. Adult males displaced yearling intruders from their territories. However, some yearling males appeared to initiate agonistic interactions with territorial males. Other yearlings localized near unoccupied territorial sites but did not behave territorially. Yearlings displayed to, and courted, females away from territories of adult males but did not show the full range of courtship behaviors given by territorial males, and made no attempt to copulate. Results partially support predictions on behavior of yearling males derived from the sexual bimaturism hypothesis to explain why first-year males of most promiscuous species of grouse delay breeding.

938. Jamieson, Ian G.; Zwickel, Fred C. 1983. Dispersal and site fidelity in blue grouse. *Canadian Journal of Zoology* 61(3): 570-573.

Ten years of banding and censusing data from blue grouse were analyzed with respect to dispersal of juveniles and site fidelity of yearlings and adults. Juvenile females dispersed farther than juvenile males. In sibling pairs of same sex, brothers settled closer to one another than sisters. In sibling pairs with birds of opposite sex, females dispersed farther than males. Adult males first established territories close to where they had been sighted as yearlings, or nonterritorial adults, and most females returned in spring to the same general area where they had previously nested. Two-year-old females showed less fidelity to breeding sites they had used as yearlings than older females to sites they had used in previous years.

939. Jamieson, Ian G.; Zwickel, Fred C. 1983. Spatial patterns of yearling male blue grouse and their relation to recruitment into the breeding population. *Auk* 100(3): 653-657.

Movements of yearling male blue grouse were monitored by radio telemetry during the springs of 1980 and 1981, on Hardwicke Island, British Columbia. The locations of the birds were clumped around territories of adult males. Most birds were associated with a few occupied territories, others settled near vacant sites that had been used as territories in previous years, and a few moved widely over the breeding range. Some territories attracted more yearlings than others. Presumed costs and benefits that may be associated with different types of spatial patterns of yearling males are discussed.

940. King, D.G. 1971. The ecology and population dynamics of blue grouse in the sub-alpine. Vancouver, BC: University of British Columbia. 139 p. M.S. thesis.

This study was designed to follow up previous studies which suggested blue grouse regulated their numbers through juvenile mortality over winter, and to examine the

population of grouse that lived their entire lives on winter range. Grouse were observed and collected in the subalpine of Vancouver Island between May 1965 and June 1966. Data from the uplands were compared to grouse on lowland breeding ranges. The major findings were (1) A low density and apparently stable breeding population lived in the subalpine with sex and age ratios and recruitment similar to those of lowland populations. (2) All events of reproduction following spring migration were delayed approximately 1 month compared to the lowlands. Further, the nesting season was shorter by approximately 4 weeks. (3) Grouse in the subalpine selected open forest and hilly areas as on the lowlands. (4) In winter, some males at least, lived separately from hens and chicks. The males lived in the open forest of the upper elevations of the subalpine, but the habitat used by the hens and chicks is unknown. (5) The main source of juvenile mortality, and hence population regulation, probably occurred in autumn with first snowfall or brood breakup. Late winter behavioral interaction may also be important in regulating numbers. (6) No factor of the subalpine was found that could explain the size and success of lowland populations. There was some evidence to suggest that the quality of food in the subalpine may be important to reproductive success on the lowlands.

941. King, R. Dennis; Bendell, James F. 1982. Foods selected by blue grouse (*Dendragapus obscurus fuliginosus*). *Canadian Journal of Zoology* 60(12): 3268-3281.

The spring and summer diet was determined from 811 blue grouse crops collected from 1957 through 1966 near Campbell River on Vancouver Island. Main foods eaten were conifer needles, broad-leaved vegetation, flowers, fruits, and invertebrates. More than 80% of the plant diet was from nine species. Most foods were selected and selection varied with season, sex, and age. In the spring, females apparently ate more broad-leaved plants than did males, and chicks up to approximately 3 weeks of age fed largely on invertebrates, mainly ants. We attempt to explain selection by relating known nutrients in plants and animals to their use as food. Nutrients apparently selected most frequently were ash and nitrogen. The diet of females in May and June seemed richer than that of males in ash, nitrogen, and magnesium. In June, chicks had a diet likely higher in nitrogen, phosphorus, and potassium but lower in carbohydrate, fat, and calcium when compared with adults. The diet of blue grouse compared with that recommended for some other grouse was possibly deficient in ash, phosphorus, and calcium. We postulate food on the summer range might limit populations of blue grouse by the amount of nitrogen and minerals, especially calcium, available to hens in spring and by a range of nutrients available to very young chicks.

942. King, Richard Dennis. 1968. Food habits in relation to the ecology and population dynamics of blue grouse. Vancouver, BC: University of British Columbia. 62 p. M.S. thesis.

In late spring and summer, diet of blue grouse on lowland breeding ranges on Vancouver Island was determined by examination of the contents of 875 crops taken from birds collected on three study areas in the years 1950 through 1952 and 1957 through 1966. The spring and early summer diet of males was mostly conifer needles, and adult females ate mainly leaf material and flowers during the same period. The food of chicks was mainly invertebrates until the birds reached the age of approximately 3 weeks, at which time plant material formed the greater portion of the diet.

In late summer, the diet of both adult and juvenile grouse was primarily fruits and seeds of trailing blackberry, salal, huckleberry, and other plants. Selection of plant foods occurred at the time of ovulation and molt. As a result, the protein and mineral content of the diet was highest during periods of greatest need. No apparent differences in the spring diet of females were found which could be related to poor early survival of chicks or to a delayed hatch in 1962. The various food types were eaten in similar relative proportions by adult and yearling grouse, and differences in reproductive performance of these two age classes could not be related to the diet of the grouse. The altitudinal migration of blue grouse in later summer and autumn does not appear to be related to the availability or condition of the food supply at the time of departure of the birds.

943. Lance, Arthur Norman. 1967. A telemetry study of dispersion and breeding biology in blue grouse. Vancouver, BC: University of British Columbia. 100 p. M.S. thesis.

A general property of animal populations is their failure to continue increasing in number indefinitely, even when the habitat may contain enough resources to support more animals than are present at the time. Certain populations of blue grouse have expressed this property by failing to increase when the habitat has undergone changes that have produced striking increases in past cases. Other populations have expressed it by arresting their increase before the resources of the habitat were exhausted. In blue grouse populations on Vancouver Island, adult mortality is constant, and it is restricted recruitment that has held these populations stable in the periods they have been studied, even though sufficient young have been produced to support an increase. The hypothesis that the behavior of territorial adult males affects the local occurrence of recruits and other grouse in general on the summer range was tested by studying dispersion during the breeding period. The principal finding is that there was no evidence of social interaction causing females and immature males to occur in special places, and no interaction of a sort that could affect recruitment occurs between blue grouse on their summer range. It is alternatively suggested that such behavior occurs in winter. Other conclusions are that the onset of estrus induces hens to seek out and become localized near a mate, that several hens may seek out the same mate, and that no lasting pair-bonds are formed. Each type of reproductive activity in blue grouse has a distinctive movement pattern, and perhaps movement rate, associated with it.

944. Lewis, R.A.; Zwickel, F.C. 1980. Removal and replacement of male blue grouse on persistent and transient territorial sites. *Canadian Journal of Zoology* 58(8): 1417-1423.

In the springs of 1978 and 1979, we removed all male blue grouse, both original occupants and subsequent replacements, from a series of persistent and transient territorial sites (those used regularly and intermittently, respectively). In both years, more replacements settled on persistent than on transient sites. Most replacement males were adults, most of which likely would not have taken territories had we not made these sites available. The presence of nonterritorial adults, reported here for the first time, suggests that territorial behavior limits breeding densities of male blue

grouse. Testes of replacement adults, although smaller than those of resident males collected at comparable times, all contained mature sperm. Yearling males are seldom territorial, but of eight that took territories on removal sites, all except one selected persistent sites.

945. Lewis, Richard A. 1981. Characteristics of persistent and transient territorial sites of male blue grouse. *Journal of Wildlife Management* 45(4): 1048-1051.

Intensive studies on Vancouver Island, British Columbia, have demonstrated that areas used by male blue grouse for territories had unequal frequencies of use. Those used regularly were called "persistent" and those used intermittently were called "transient". This study examines physical and vegetative characteristics of persistent and transient territorial sites to identify those features that may be important in their selection by blue grouse. Persistent and transient sites did not differ with respect to ground-level density of forbs, shrubs, trees, and debris or measures of canopy cover. Neither relative slopes of activity centers nor average distances to nearest areas of equivalent elevation differed between 11 persistent and 11 transient sites. However, the difference between the two types of site for the latter variable approached significance. In another study with 25 persistent and 25 transient sites, the distance from activity centers of persistent sites to nearest areas of equivalent elevation was greater than that for transient sites. Thus, persistent and transient sites differed only in relative height. Hooting by male blue grouse advertises occupancy of a territory and attracts females. The topography of territorial sites affects the distance from which sounds can be heard. Data suggest that elevation may not be important, but rather height of the activity center in relation to the surrounding area is.

946. Lewis, Richard A. 1985. Use of space by territorial male blue grouse. *Wilson Bulletin* 97(1): 97-101.

In previous studies, the activities of territorial males were followed by observers either working alone or with pointing dogs. These methods have a bias in that birds are more likely to be found when they are hooting than when they are silent. Consequently, they are most likely to be found within activity centers. To overcome this bias, territorial males were radio-tagged, and some new questions were addressed: (1) Where are territorial males located when they are not hooting? (2) Are the same areas used consistently throughout the breeding season? (3) What portion of a male's spring/summer home range should be considered a territory? During the breeding period, males spent much of their time hooting, and most of their movements were restricted to areas within or near activity centers. Hooting diminished in the post-breeding period, and there was an increase in home range size. Similarly, males that hooted the most had the smallest home ranges, possibly because their movements were more limited to their activity centers than were those of males that hooted less. Home ranges of adjacent radio-tagged males overlapped only slightly even when all observations between April 8 and the time territories were abandoned were included. Also, males do expel other males from areas outside their activity centers. Thus it is suggested that the total area occupied until moving to new areas after the breeding season constitutes a territory. However, the activity center appears to be the focal point of the territory, especially during the breeding period. These centers usually are located on the most elevated portion of the territory, presumably facilitating the broadcasting of hooting and the detection of predators and conspecifics.

947. Lewis, Richard A.; Jamieson, Ian G. 1987. Delayed breeding in yearling male grouse: an evaluation of two hypotheses. *Condor* 89(1): 182-185.

We studied the demography and behavior of blue grouse in two areas of coastal British Columbia from 1977 to 1983. This species has a mating system in which there are no pair bonds between males and females, and thus males breed promiscuously. Our objective is to use information from this intensive study of a single species to evaluate Wiley's and Wittenberger's hypotheses for the evolution of delayed breeding in male grouse. If delayed breeding by yearling males is almost solely an evolutionary consequence of female choice, then most yearlings should take territories when adult males are not present. This clearly does not occur in blue grouse as substantial proportions of yearlings did not take territories even when most adults were removed and when high quality areas for territories were known to be available. Wittenberger's female choice hypothesis therefore is not supported by these results. However, if Wiley's hypothesis, which advocates that delayed breeding occurs at least partly because the cost of breeding is higher for younger than older males, is to be accepted as an alternative, the fact that some yearling males do take territories in the absence of adults must be reconciled. However, before it will be possible to understand the basis for delayed breeding more fully, more information is needed, and other factors should be considered. Evidence suggests that there is much individual variation among males in the respect of morphology, physiology, behavior, and movements.

948. Lewis, Richard A.; Zwikel, Fred C. 1981. Differential use of territorial sites by male blue grouse. *Condor* 83(2): 171-176.

We examined the pattern of use of territorial sites occupied by male blue grouse on a 485-ha area on Vancouver Island over a 10-year period, 1969 to 1978. Some sites were occupied continuously and others were used only intermittently; these were called "persistent" and "transient" sites, respectively. Approximately 1/2 of the transient sites were vacant in any given year. Males on persistent sites survived significantly longer and had significantly more females near their territories during the breeding season than those on transient sites. Thus, males on persistent sites may have better opportunities for breeding than males on transient sites. These results help to explain why yearling males delay breeding, despite being physiologically able to do so, and they also provide new insights into how breeding densities of males are regulated.

949. Lewis, Richard A.; Zwikel, Fred C. 1982. Survival and delayed breeding in male blue grouse. *Canadian Journal of Zoology* 60(8): 1881-1884.

We present an analysis of survival of male blue grouse by using known-aged individuals and examine the results in terms of the evolution of delayed breeding. Males had low rates of mortality and, among 2-year-olds, mortality rates of territorial and nonterritorial birds were the same. Up to 6 years old, males had life expectancies of

at least 2 years. Males that postponed breeding and survived had a 40-45% chance of eventually obtaining a high-quality site for a territory. If males had not delayed breeding they likely would have had to settle on areas where opportunities for breeding appear to be low. Thus, survival patterns of males are consistent with the hypothesis that it is advantageous for some males to delay breeding if high quality sites cannot be obtained.

950. Lewis, Richard Arnold. 1979. Suitability and selection of territorial sites used by male blue grouse. Edmonton, Alberta: University of Alberta. 85 p. M.S. thesis.

Pattern of occupancy of territorial sites used by male blue grouse was examined on a 485-ha area on Vancouver Island, British Columbia. Numbers of territorial males increased from 1969 to 1971 and then remained relatively stable at approximately 80 males per year to and including 1978. Some sites were used for territories every year, and others showed intermittent use. Sites used at least 9 of 10 years were termed "persistent", those used less than 9 years "transient". Over a period of 10 years, (1969-1978) there were 41 persistent and 82 transient sites on Comox Burn. Males occupying persistent sites survived longer, and more females were found near their territories in early spring than those on transient sites. Thus, males using persistent sites may be more successful, reproductively, than those using transient sites. Experimental removal of males from persistent and transient sites indicated that males preferred persistent sites for territories. Although males occupying the two types of sites had different rates of survival, no vegetative or topographic differences were found between persistent and transient sites. Vegetative parameters measured included availability of food and cover and evaluations of "openness". Slopes around activity centers and height of territories in relation to surrounding areas were the topographic features investigated. The alternative, that demographic differences between males using the two types of site are due to behavioral differences between the two groups of males is considered unlikely. Physical differences between persistent and transient sites may be subtle, rather than marked, and more intensive examinations may be required.

951. Lewis, Richard Arnold. 1984. Survival, behavior, use of territories, and breeding densities of male blue grouse in coastal British Columbia. Edmonton, Alberta: University of Alberta. 127 p. Ph.D. dissertation.

Survival and behavior of male blue grouse and their use of territories were examined in two populations in coastal British Columbia. Results were interpreted in relation to the role of these variables in determining densities of breeding males. Data from a long-term study on Vancouver Island indicated that 2-year-old and older males had an average annual mortality rate of 28%, and at 2 years of age life expectancy was 3.1 years. At least 22% of 2-year-old males were nonterritorial (that is, delayed breeding) and these birds survived as well as males that took territories. Of nonterritorial males that survived, 40-55% subsequently obtained high quality territorial sites. Nonterritorial adult males were present on Hardwicke Island, and they also survived as well as territorial birds. These results support the hypothesis that it is advantageous to delay breeding if high quality territorial sites cannot be obtained. On Hardwicke Island, 10 territorial males concentrated their movements within or near

the activity centers of their territories during the main period of breeding. After peak breeding, larger areas were used. Habitat characteristics were compared between areas used and not used for territories and between high and low quality sites. Males distinguished suitable sites primarily on topography, but vegetative characteristics also seemed important. Preferences were related to height, amount and dispersion of cover, and visibility within activity centers. Habitat does not appear to directly limit densities of breeding males but may limit them indirectly through its effect on females.

952. Marshall, William H. 1946. Cover preferences, seasonal movements, and food habits of Richardson's grouse and ruffed grouse in southern Idaho. *Wilson Bulletin* 58(1): 42-52.

Field observations over a 2-year period were made in the Boise National Forest on Richardson's grouse (*Dendragapus obscurus richardsoni*) and the Idaho ruffed grouse (*Bonasa umbellus phaios*). From October through March, Richardson's grouse lived on the higher ridges, where they were dependent on scattered stands of conifers for both food and cover. In May, June, and early July they stayed at lower elevations and ate chiefly the flowering parts of various plants. In late July and early August, broods and females were concentrated along water courses, while single birds (mostly males) were in the higher timber types. The food at this time consisted largely of insects, berries, fruits, and leaves of various shrubs. By mid-September, the females and broods had moved to the higher ridges, where at first they continued to feed on berries and leaves of shrubs and later shifted to a diet of conifer needles and buds. The movements of the Richardson's grouse seem to be influenced by the differing rates of plant development at different altitudes.

953. Martinka, Robert R. 1972. Structural characteristics of blue grouse territories in southwestern Montana. *Journal of Wildlife Management* 36(2): 498-510.

Structural characteristics of male blue grouse territories and relationship to land-use practices and forest succession were studied from 1967 to 1969 on a 700-acre area of the Sapphire Mountains in southwestern Montana. During 130 observation trips, 1,010 sightings of males on 40 territories were made. About 60% of the males were leg-banded for individual identification. Vegetation and physical characteristics were recorded for 27 territories where males were observed 14 or more times. Territory size averaged 2.0 acres. Thickets of coniferous trees, the major vegetational component of territories, averaged 0.2 acre and provided about 675 feet of edge. The density of thickets averaged about 1,200 trees per acre. The average diameter of trees in the thickets was 4.9 inches. Most trees in the thickets were from 10 to 60 years old. Thickets comprised mostly of Douglas-fir were generally of greater density and smaller total area than those comprised largely of ponderosa pine. The longevity of thickets used by males was apparently about 40 to 50 years. Territories that were occupied intermittently during an 8-year known history averaged 2.3 acres; those occupied continuously averaged 1.8 acres. Discriminant function analysis indicated that territories could be distinguished from unused areas with a high degree of success (96%) when 10 variables were used. Breeding habitat was associated with a ponderosa pine-fire successional stage in the Douglas-fir vegetational zone and with young climax stages in both the ponderosa pine and Douglas-fir vegetational zones.

954. Mussehl, Thomas W. 1960. Blue grouse production, movements, and populations in the Bridger Mountains, Montana. *Journal of Wildlife Management* 24(1): 60-68.

During 1957 and 1958, a study of blue grouse was carried on in the Bridger Mountains of southwest Montana. Information was obtained on seasonal movements, development of young, population characteristics, and general life history. Observations during the breeding season indicated a minimum of seven males present on a 17-acre area. The sites of three nests are described. Hatching dates, determined by ages of juveniles, ranged between May 25 and July 14. The peak of hatching occurred the third week of June for both years. Observations of marked broods indicated movements within approximately a 1/2-mile area on the summer brood range. During both years, dispersal from the summer brood range became evident in August, and upward altitudinal migration was well underway by mid-September. Lateral movements up to 2.1 miles and altitudinal movements up to 3.4 miles were recorded. Seven and 12% return of banded birds occurred during the hunting seasons of 1957 and 1958, respectively. No 1957 bands were returned in 1958, and hunting was interpreted as a minor influence in yearly population turnover.

955. Mussehl, Thomas W. 1963. Blue grouse brood cover selection and land-use implications. *Journal of Wildlife Management* 27(4): 547-555.

Over 700 observations of blue grouse broods were made in three areas of Montana from 1957 to 1962. These observations indicated that broods used areas with specific types of ground vegetation. Quantitative measurements of the characteristics of vegetation at 87 brood observation locations were obtained in 1960, 1961, and 1962. These measurements indicated that broods used herbaceous cover with relatively consistent physical characteristics of height, canopy coverage, and plant interspersion. The importance of adequate herbaceous brood cover, consisting mainly of native bunchgrasses and associated forbs, is significant, as summer brood range of blue grouse often overlaps grazing areas of domestic stock and big game.

956. Niederleitner, Joe F. 1987. Use of early successional, midsuccessional, and old-growth forests by breeding blue grouse (*Dendragapus obscurus fuliginosus*) on Hardwicke Island, British Columbia. *Canadian Journal of Zoology* 65(1): 151-155.

Numbers of breeding blue grouse observed along standardized transects on Hardwicke Island, British Columbia, were significantly higher in early successional stages than in midsuccessional or old-growth forests. Numbers in old-growth and midsuccessional forests were not statistically different. Cover percentage of the herbaceous stratum may be an important component of the preferred habitat.

957. Redfield, J.A.; Zwickel, F.C.; Bendell, J.F. 1971. Effects of fire on numbers of blue grouse. In: *Proceedings, 10th annual Tall Timbers fire ecology conference; 1970 August 20-21; Fredericton, New Brunswick*. Tallahassee, FL: Tall Timbers Research Station: 63-83.

Natural populations of blue grouse have been studied on Vancouver Island, British Columbia, almost continuously since 1950. High densities of blue grouse found near

Campbell River in the early 1950s do not appear to be related to a large lowland wildfire that occurred there in 1938. Densities of grouse appear to have been as high on areas that had been logged and slash-burned only. Thus, large wildfires in lowland areas are not a necessary prerequisite to high grouse populations. A second large wildfire near Campbell River in 1951 did not prevent a spectacular decline in grouse populations. Clearly, large wildfires and a subsequent setback in plant succession are not sufficient to maintain densities of grouse. Another wildfire near Courtenay in 1961 was followed by a period of relative stability in grouse populations. Therefore, the immediate effect of wildfire may be inconsequential to blue grouse populations. Areas near Port Alberni that are logged and slash-burned support no more grouse than nearby areas that are merely logged. Hence, clearcut logging is sufficient to stimulate increases in grouse population.

958. Schottelius, Byron Arthur. 1951. Studies of the blue grouse, *Dendragapus obscurus pallidus* Swarth., in the Methow Valley of Washington. Pullman, WA: Washington State College. 41 p. M.S. thesis.

Observations were made on 584 adult and juvenile birds in the Methow Valley during 1950 and the spring of 1951. Twenty birds were collected from the region for field examination and laboratory autopsy. External measurements are given for 15 specimens, 11 males and 4 females. Mean body weight for males was 1,236 g, for females 839 g. Population indices derived from the numbers of grouse observed on six transects at specified hours and seasons are presented for 1950 and 1951. The sex ratio of adults observed during the entire period was 100 males to 106 females. Eighty-two brood counts were made; the mode frequency distribution was 3.0 and the average brood size 3.77. The first spring migrants reach the valley during the last week of March. The upward migration of males is earlier than that of females with broods and is well underway by early July. The hatching period extended from approximately May 31 to June 18. Apparently, the grouse do not reuse old nest sites in subsequent years. Neither intraspecific nor interspecific friction was observed, although definite home ranges seem to be used. Computations of growth rate are given for 12 juveniles. Accidental mortality was found to be negligible, and only one instance of predation was observed.

959. Smith, Neil D.; Buss, Irven O. 1963. Age determination and plumage observations of blue grouse. *Journal of Wildlife Management* 27(4): 566-578.

The primary purpose of this study was to obtain data on the molt pattern and growth rate of captive known-age young blue grouse upon which to base a system of age determination. Secondly, observations were made on the molt pattern of adult and subadult blue grouse raised in captivity. The average weight (measured at weekly intervals) of the young birds in 1960 was conspicuously different from the average weight obtained in 1961. This variation in weight was attributed to a difference in diet during the first 4 weeks of life. The average weight of young wild blue grouse closely approximated the average weight of the 1960 captive juveniles at corresponding ages, whereas the wild birds were heavier than the 1961 captive birds at a corresponding age. The growth rates of postjuvinal primaries and rectrices, rather than sequence of feather loss, provided the principal means for placing young blue grouse

in weekly categories from the third to the eleventh week. This loss of the primary and secondary remiges in subadult male blue grouse (about a year of age) commenced earlier than did the loss in adult males, remaining in advance of the adults until October.

960. Smith, Neil Douglas. 1962. Molt patterns and breeding behavior in captive blue grouse. Pullman, WA: Washington State University. 93 p. M.S. thesis.

The chief purposes of this study were to obtain data on the molt patterns and growth rates of known-age juvenile blue grouse for weekly age determination and to observe the breeding behavior of captive blue grouse. This study was conducted on blue grouse captured in the Methow Valley of north-central Washington and held in pens at Washington State University, and on the young birds of known age which resulted from successful breeding of the captive adults. Out of 11 birds hatched in 1960, 5 survived until 20 weeks of age. Weekly records were kept on the weight, molt sequence of the primary remiges, and the length of the foot. For four juveniles hatched in 1961, the above data plus length of the remiges and rectrices, length of the antebrachium, and general molt patterns in the principle feather tracts was recorded at weekly intervals. The average weekly growth rate of juvenile blue grouse to 18 weeks was 64.9 g for the 1960 males, 50.0 g for the 1960 females, 56.3 g for the 1961 males, and 42.5 g for the 1961 females. Evidence available indicated that the difference in the average weekly increase between the 2 years was a result of a difference in diet during the first 4 weeks of life. The molt of the juvenile primary remiges commenced at 3 weeks of age, and the molt of the juvenile rectrices and secondary remiges commenced at 5 weeks of age. The molt of the remiges was discovered to be useful for placing the birds in 2-week age classes, whereas the molt occurring in the principle feather tracts and the total length of all postjuvenile rectrices on one side of the tail was useful for further dividing the birds into weekly age classes.

961. Sopuck, Lennart G. 1979. Movements and breeding biology of blue grouse in relation to recruitment, reproductive success, and migration. Edmonton, Alberta: University of Alberta. 96 p. M.S. thesis.

Movements of yearling and adult female and yearling male blue grouse were studied in spring and summer 1976 and 1977 on Vancouver Island, British Columbia. Movements of yearlings during the period of spring recruitment were emphasized. Most yearlings entered the breeding population. About 46% of radio-marked yearlings localized soon after arrival on breeding range, while 54% moved widely well into the recruitment period. Seventeen percent of potential yearling recruits entered sub-optimal habitat. By contrast, all adult females established on prime habitats. Yearling females moved more widely and localized later in their reproductive cycles and nested later in the breeding season than adult females. Many yearling may have been delayed in nesting by established hens. Yearling males did not appear to breed, but most showed prolonged site attachment. They generally returned to this area of site attachment as territorial adults the following year. Radio-tagged hens hatched 47% of their clutches. Because of reneating, 52% of nesting females were successful. Nesting success was independent of time of nest initiation, age of hen, and extent of movement before nesting. Yearlings that entered suboptimal habitat had low nesting success and brood survival. Reneating was more frequent among

adult than yearling females. Hens with broods moved widely during the first 2 weeks after hatching and then gradually expanded their ranges at varying distances from their nests. Broodless hens and yearling males were more secretive in their behavior, selected denser cover, and migrated earlier than brood hens and adult males, respectively.

962. Standing, Keith Mifflin. 1960. Factors in relation to population fluctuations in the blue grouse. Pullman, WA: Washington State University. 193 p. Ph.D. dissertation.

The primary purpose of this investigation was to study various factors of reproduction in blue grouse related to or responsible for the varying number of birds known to occur from year to year in fall populations. Stimulus for reproduction in blue grouse precedes and influences spring migration to breeding grounds. Initiation of this stimulus, which varies from year to year, is apparently influenced by climatic factors. Proportionately fewer subadult males migrate than subadult females. Ovulation reached a peak near mid-May in 1956 but showed a bimodal curve in 1957 with one peak the latter part of April and another peak the latter part of May. A 24-day increase in the breeding period in 1957 reflects earlier onset of recrudescence as well as reneesting that occurred. A greater number of subadult females ovulated in 1957 than in 1956. This increase in number of subadult females breeding could account for a lengthened breeding season as well as the marked population increase. Since the number of subadult males migrating to breeding rounds is proportionately fewer than adult males, since subadult males that reach breeding areas do not undergo testicular recrudescence to the same extent as adult males, and since their breeding potential does not appear to vary from year to year, it is assumed that they have a minor influence on population fluctuations. Subadult females, however, have a marked potential influence on the population since more migrate to breeding areas, and since the proportion of migrants that breed exhibits annual variations.

963. Stauffer, Dean F.; Peterson, Steven R. 1985. Ruffed and blue grouse habitat use in southeastern Idaho. *Journal of Wildlife Management* 49(2): 459-466.

Seasonal trends in ruffed and blue grouse habitat selection are summarized for all seasons. Blue grouse preferred high elevation (2,285 m) open conifer stands in winter. In spring and summer, low elevation (2,100 m) bigtooth maple (*Acer grandidentatum*), curleaf mountain mahogany (*Cercocarpus ledifolius*), and mixed shrub stands with an open understory and overstory were selected for breeding and brood rearing. Ruffed grouse preferred stands dominated by quaking aspen and was associated with stand structures characteristic of early successional stages. Little overlap in habitat use between ruffed and blue grouse was observed; in all seasons, blue grouse selected habitats more open than those used by ruffed grouse.

964. Stauffer, Dean F.; Peterson, Steven R. 1986. Seasonal microhabitat relationships of blue grouse in southeastern Idaho. *Great Basin Naturalist* 46(1): 117-122.

Microhabitat characteristics of blue grouse were analyzed in breeding and wintering habitats in southeastern Idaho. Breeding habits typically were open sagebrush (*Artemisia* spp.), mixed shrub, mountain mahogany (*Cercocarpus ledifolius*), and maple (*Acer grandidentatum*) stands on east- to south-facing aspects of slopes

below 2,100 m elevation. Breeding grouse selected areas with approximately a 50:50 or greater open to cover ratio. Blue grouse selected areas with higher tree coverage than that available on average within the mixed shrub vegetation type. Hens with broods preferred sites with relatively tall (>50 cm) herbaceous vegetation. During autumn and winter, blue grouse preferred high elevation (>2,285 m) stands of open (50% tree cover) conifer. Douglas-fir were preferred as winter roost trees. Sites selected in winter had significantly more Douglas-fir than those selected in autumn.

965. Stauffer, Dean Fiske. 1983. Seasonal habitat relationships of ruffed and blue grouse in southeastern Idaho. Moscow, ID: University of Idaho. 121 p. Ph.D. dissertation.

Seasonal habitat selection by ruffed and blue grouse was investigated in the Caribou National Forest from October 1978 through May 1981. Ruffed grouse primarily used aspen and aspen/conifer vegetation types in all seasons. Stands with >50% aspen cover, below 7,500 feet elevation and on slopes less than 30 degrees on east to southwest aspects were preferred. Blue grouse preferred sagebrush, mixed shrub, mountain mahogany, and maple vegetation types for breeding and brood rearing. High elevation open conifer stands were most important as fall and winter habitat. Breeding blue grouse males were found in open vegetation types with 40 to 70% cover of trees and tall shrubs. Blue grouse broods were found in areas with >50% cover of herbaceous vegetation >50 cm tall. Douglas-fir were preferred for roost sites in winter. On breeding areas, sites with about 50% tree cover had more blue grouse than more open areas. Not all portions of available habitat were used by ruffed or blue grouse. Structural characteristics of sites selected by each species differed from the average characteristics for the habitats in which the grouse were found. A key to evaluate the potential of an area to support ruffed and blue grouse was developed and specific management recommendations were presented. Grazing was determined to be detrimental to grouse, especially broods. If used properly, timber removal can be used to enhance grouse habitat.

966. Stewart, Robert E. 1944. Food habits of blue grouse. *Condor* 46(3): 112-120.

The food habits of blue grouse vary from a simple winter diet that is made up predominantly of coniferous needles to a complex diet during the summer months, characterized by great variety of foods including green leaves, fruits and seeds, flowers, animal matter and coniferous needles. The spring and fall, which represent the transition periods between these two, are characterized by feeding habits that are generally intermediate. The diets of the two species of blue grouse, *Dendragapus obscurus* and *Dendragapus fuliginosus*, are quite similar as far as major types of food are concerned, but they differ considerably in the species that are taken. Such differences reflect differences in the vegetation within the ecological and geographic ranges occupied by the two species.

967. Stirling, Ian. 1968. Aggressive behavior and the dispersion of female blue grouse. *Canadian Journal of Zoology* 46(3): 405-408.

In the field, nesting hen blue grouse show fidelity to home ranges and these are evenly spaced. Explanation of this is difficult. Hen blue grouse in an aviary were

tested for aggressive behavior that might function to space them in the field. Reaction of hens to their mirror image was recorded, and this was greatest during the period hens squatted and laid eggs and decreased through incubation. The difference was statistically significant. Of the five acts which determined the index of activity, three were apparently aggressive, one was apparently investigative, and one was apparently conflict and fear. The results support the idea that dispersion of hens during the breeding season is caused by aggressive behavior.

968. Stirling, Ian; Bendell, J.F. 1970. The reproductive behaviour of blue grouse. *Syesis* 3(1-2): 161-171.

The reproductive behavior of blue grouse is described and explained. In courtship, males hoot, wing flutter, feather spread, rush and hoot, head bob, mount and tread, and copulate. Hens give the quaver cry and whinny, squat, and copulate. In aggression, males growl, assume the horizontal posture, fight, and stand tall. Females give the hard cluck and fight. Reproductive behavior is influenced by levels of light and varies between years and with age. Hooting advertises a breeding male and functions as a signal between grouse out of view. It attracts hens and adult and yearling males. The wing flutter and feather spread are auditory and visual displays that direct the hen to the male. The rush and hoot, mounting, and treading induce copulation in the hen. Sex recognition is based on plumage and posture. The quaver cry stimulates peak testicular development and the whinny is an inducement to copulate. Threat posture and calls and fighting function to space grouse.

969. Wing, Leonard. 1947. Seasonal movements of the blue grouse. In: Quee, Ethel M., ed. Transactions of the 12th North American wildlife conference; 1947 February 3-5; San Antonio, Texas. Washington, DC: Wildlife Management Institute: 504-511.

A review of the published literature, supplemented by the authors data on the species, shows that the general geographical distribution of the blue grouse corresponds closely to the range of the Douglas-fir. It is associated with the firs and pines during most of the year but occupies open land in the foothills during the summer. Downward migration in the spring has been witnessed by only one author to date but appears to occur in early March. Birds nest in timber or the edge of timber, but broods regularly wander out into the open. The upward migration occurs over a longer period than the springtime descent, beginning in midsummer and lasting until October.

970. Wing, Leonard; Beer, James; Tidyman, Wayne. 1944. Brood habits and growth of blue grouse. *Auk* 61(3): 426-440.

In an area in Okanogan County, Washington, the brood range consisted of the lower slopes composed of open, parklike areas, dry but watered by a few springs, streams, or water holes. Although vegetation covered the ground, it was bunched so that bare space was present in varying proportions. The broods immediately take to the open slopes upon hatching; as the young become larger, they work back into the tree-covered areas during late afternoon, probably for night roosting. Broods of young not able to fly spend the night in the open. Broods were often found around springs and water holes, but we do not have enough data to determine whether or not they visit water regularly. It is probably that *Ribes* and *Amelanchier* berries provide water as well as food. Late in July, the brood organization appears to break down to some

extent and shuffling of young takes place. Our brood studies lead us to believe that the brood instinct is rather low in the female and perhaps nonexistent in the male. The breakdown of the brood instinct occurs much earlier in the blue grouse than in other gallinaceous birds. Males migrate to winter grounds at the higher altitudes earlier than the females. Birds migrate up earlier on the dry western slope than on the moister eastern ones. Migrating females accompanying the young paid little attention to them and apparently the brood composition had almost completely broken down, at least among the migrating birds. The earliest upward movement, at least among the young birds, may begin shortly after the middle of July and migration is well underway by mid-August. Most grouse are on their winter grounds by the first of October.

971. Zwickel, Fred C. 1958. Fall studies of forest-grouse in north-central Washington. Pullman, WA: Washington State College. 129 p. M.S. thesis.

Fall forest-grouse populations (principally blue grouse) are discussed from the standpoint of hunter checking station data, fall road-count transects, and miscellaneous supporting data. Checking-station statistics come primarily from the Chumstick and Conconully areas on north-central Washington, covering the weekend grouse season for 5 years, 1953-57. Fall road-count transects, which have been conducted since 1954, indicate a relatively stable grouse population from 1954 to 1955, with a small increase in 1956 and a large increase in 1957. Hunter success data and hunting pressure data correspond to grouse population data only in a general way. Other factors enter in to make hunter success a relatively poor criterion of fall populations. Blue grouse comprise about 64% of the population of forest grouse with the remainder composed of 26% Franklin grouse and 10% ruffed grouse. The peak production in 1957 correlates with a warm, wet May, which permitted excellent cover conditions to develop, and a dry early brood period in June. Fall sex ratios of blue grouse indicate a slight excess of females in both the juvenile and adult segments of the fall population. Bursal regression, average weights, and primary molt all indicate that juvenile males are slower in development than juvenile females. Primary molt progression and bursal depths both indicate that the outer primary method of age determination is a valid technique for determining age classes in blue grouse. Better management of grouse would include season and bag limit liberalizations, active encouragement of better grazing-land management, and studies to increase our knowledge of grouse populations and harvests.

972. Zwickel, Fred C. 1972. Removal and repopulation of blue grouse in an increasing population. *Journal of Wildlife Management* 36(4): 1141-1152.

An experimental study involving the removal of blue grouse from lowland breeding range was conducted on Vancouver Island, British Columbia, from 1969 to 1971. Practically all breeding birds were removed from a 625-ha area in the spring and summer of 1970. These birds were all replaced by new recruits, mainly yearlings, in the summer of 1971. Had vacancies created by the removal not been available, most of these animals presumably would have died. Populations were increasing on a nearby 485-ha control area, and there was no evidence that heavy recruitment of yearlings to the removal area affected recruitment to nearby regions. These data indicate that large numbers of overwintered surplus yearlings of both sexes were

available for recolonization of the removal area. Hence, behavioral interaction in spring between resident adults and potential yearling recruits seems the best explanation for the regulation of numbers of breeding birds. Data presented here agree with the results of a similar experiment that was conducted on a declining population approximately 50 km to the north during the same period.

973. Zwickel, Fred C. 1973. Dispersion of female blue grouse during the brood season. *Condor* 75(1): 114-119.

Blue grouse were studied on a heavily grazed and an ungrazed area in the Methow Valley, Washington. During June, the first month after peak hatch, brood females were dispersed widely at both areas. Lone females were dispersed widely on the ungrazed area but aggregated, in or near thickets, on the grazed area. In July and August, both classes of females were more aggregated. The dispersed pattern of distribution of brood hens in June may not be related to extrinsic differences in the two environments and offers a possible explanation for behavioral limitation of numbers of females in a promiscuous species such as blue grouse.

974. Zwickel, Fred C. 1975. Nesting parameters of blue grouse and their relevance to populations. *Condor* 77(4): 423-430.

Data on clutch size, fertility and hatchability of eggs, and nesting success were obtained from 136 nests of blue grouse during 9 years of studies on Vancouver Island, British Columbia. Only clutch size differed significantly between yearling and adult females, with yearlings having the smallest clutches. This difference is likely related to physiological maturity of the two groups of females. Clutch size varied among years, but these variations showed no relation to subsequent breeding density. Fertility of eggs was high (95-100%) in all years but did show some significant differences among years. Hatchability of fertile eggs was high (97.3%) and constant among years. Nesting success showed one significant difference among years, but this had no apparent effect on subsequent breeding density. Overall, the parameters measured were relatively constant among years, and deviations that did occur bore no relationship to breeding density in the following year. None of the four variables examined were significantly different between a period of relatively low and stable population density and a period of increasing and higher population density. Hence, no variations were necessary in any of the parameters examined to bring about population change.

975. Zwickel, Fred C. 1977. Local variations in the time of breeding of female blue grouse. *Condor* 79(2): 185-191.

Timing of breeding of female blue grouse was studied in two populations living about 2-3 km apart. Timing of breeding varied among years, between populations, and between adults and yearlings. Variations in time of breeding among years showed some correlation with annual differences in April weather. Breeding was about 1 week later on the area that was higher in elevation, cooler, wetter, had more snowpack, and held its snowpack longer in spring. Most yearling females copulated only after most adult females were beginning to nest. The period of

copulation was up to 10 weeks long in adult females but only up to 7 weeks long in yearlings. Most females were on breeding range only about 2-3 weeks before copulation. Although there was a 3-4 week difference in timing of loss of snow between areas, there was only a 1 week difference in time of breeding. Differences in timing of breeding between age classes may relate to differences in physiological maturity, amount of time on the breeding range before copulation, harassment of yearlings by adults, or interactions among new recruits (yearlings) themselves. Proximate control of the reproductive cycle of females appears most subject to local ecological conditions. The breeding period of males has likely been selected to cover the entire receptive period of females, including annual, geographical, and age-class variations.

976. Zwickel, Fred C. 1980. Surplus yearlings and the regulation of breeding density in blue grouse. *Canadian Journal of Zoology* 58(5): 896-905.

An experiment in which yearlings of both sexes of blue grouse were removed from breeding range showed that about two times, or more, yearlings of each sex were identified here as compared with a nearby control area, though numbers of "surplus" yearlings varied among years. The removal of large numbers of yearlings from the experimental area neither reduced breeding density, except ephemerally in 1 year, nor affected populations in the surrounding area. These data confirm results from earlier studies with blue grouse, that surplus yearlings of both sexes are present on the breeding range. Replacement yearlings of both sexes (those taking the place of birds removed) were able to breed, but those removed sequentially (1974 to 1976) were lighter in body weight than those captured on control areas or those that settled synchronously after a near-total removal experiment in the same area. I infer from these results that some form of behavior keeps surplus yearlings from settling on the breeding range and that this behavior is a key mechanism involved in the regulation of breeding density. The important behavior may involve either yearling-yearling or adult-yearling interactions.

977. Zwickel, Fred C. 1983. Factors affecting the return of young blue grouse to breeding range. *Canadian Journal of Zoology* 61(5): 1128-1132.

From 1969 to 1976, 1,958 juvenile blue grouse were marked with patagial wing tags and leg bands in east-central Vancouver Island. Return and recovery records from these birds in the second year of life or greater indicate no significant differences among annual cohorts, between sexes, by time of hatch, by body weight at hatch, or by age of maternal parent (yearling or adult). However, a difference in the returns of smaller and larger chicks at time of hatch approached significance (smaller, least). There was a constant and significant increase in rate of return of chicks first marked at from 1 to 10 weeks of age.

978. Zwickel, Fred C.; Bendell, J.F. 1972. Blue grouse, habitat, and populations. In: Voous, K.H., ed. *Proceedings of the XVth International Ornithological Congress; 1970 August 30-September 5; The Hague, The Netherlands*. Leiden: E.J. Brill: 150-169.

The authors have studied the population ecology of blue grouse on Vancouver Island almost continuously since 1950. This paper is a comparative review of past studies

to examine the relationship of habitat to numbers of breeding grouse. No clear relationship was found between population responses of blue grouse and such major features of habitat as structure of vegetation, soil fertility, and the quantity or quality of food. Weather, predation, and disease have been studied less thoroughly, but there seems to be little relationship between these factors and numerical changes. The authors believe that there is some common mechanism of regulation among study areas of different breeding densities that operates through mortality of juveniles from autumn to spring. Present research is being directed toward the hypothesis that differences in the breeding abundance of blue grouse may be related to differences in the quality of the grouse.

979. Zwickel, Fred C.; Bendell, James F. 1967. Early mortality and the regulation of numbers in blue grouse (*Dendrogapus obscurus fuliginosus*). *Canadian Journal of Zoology* 45(5): 817-851.

This study was designed to test the hypothesis that the level of summer mortality in young blue grouse is determined by the condition of the hen, as a reflection of her summer range, and that this mortality, in turn, determines the level of subsequent autumn and spring densities. Early mortality was studied in a series of field and aviary comparisons of chicks on, or from, two areas of Vancouver Island that were in different stages of vegetative succession following logging and burning. No differences were found in the survival of young between areas, but differences were found between years. There were always sufficient young produced into autumn to replace annual losses in the breeding population. The major conclusions are that early mortality varied between years but not between different habitat types or areas with different breeding densities, variations in early mortality between years appeared to be a result of undetermined parental influences which acted before laying, and this mortality did influence autumn numbers but was not involved in the regulation of spring numbers.

980. Zwickel, Fred C.; Bendell, James F. 1985. Blue grouse--effects on, and influences of, a changing forest. *Forestry Chronicle* 61(2): 185-188.

Blue grouse may increase spectacularly in lowland Pacific coast forest that has been logged by clearcutting. They can be sufficiently abundant to affect the survival of young conifers, the distribution of seeds and, perhaps, nutrient cycling. Blue grouse can represent a major component of the faunal biomass on a given area. Newly logged lowlands are colonized rapidly by "surplus" grouse from nearby, established populations. They may persist in variable, but unpredictable, densities until forest canopy approaches 75% coverage. The productive period for occupancy by grouse may be shortened by early planting, planting everywhere, fertilization with urea, and by large, even-aged plantations. The productive period may be extended by delayed planting, a wider spacing within plantations, not planting sites of low timber productivity and, perhaps, by intensive thinning throughout the forest rotation, or cutting in small patches.

981. Zwickel, Fred C.; Bendell, James F.; Ash, Andrew N. 1983. Population regulation in blue grouse. In: Bunnell, Fred L.; Eastman, Donald S.; Peek, James M., eds. Symposium on natural regulation of wildlife populations; 1978 March 10; Vancouver, BC. Proc. 14. Moscow, ID: Forest, Wildlife and Range Experiment Station, University of Idaho: 215-225.

Populations of blue grouse were studied on three areas of Vancouver Island, British Columbia, beginning in 1950. Adult and yearling survival rates were constant in increasing, decreasing, and stable population. Productivity to autumn varied markedly but showed no relationship to trends in breeding numbers. Annual production always exceeded losses to the breeding population by a factor of about two. Population regulation was effected by variations in recruitment of yearlings in spring, on the breeding range. "Surplus" yearlings appear to be excluded from breeding populations by the behavior of conspecifics. We have been unable, however, to clearly identify factors in the environment to which such behavior might be related. Fertilization of breeding areas with urea produced striking effects on the vegetation but had no apparent effects on the breeding density of blue grouse. There is some evidence from both field and aviary for qualitative differences among birds from different populations. Our data are most consistent with the hypothesis that populations are regulated by intra-specific behavior before depletion of environmental resources.

982. Zwickel, Fred C.; Buss, Irvan O.; Brigham, James H. 1968. Autumn movements of blue grouse and their relevance to populations and management. *Journal of Wildlife Management* 32(3): 456-468.

Hunting season recoveries of blue grouse banded on a breeding range in north-central Washington indicate that autumn migrations of blue grouse are often much longer than is commonly believed. The longest movement recorded was 31 miles. Fifty percent of the birds were recovered over 5 miles, and 30% over 10 miles, from where they were banded. Most movements were toward the north; most recoveries were from the Douglas-fir or spruce-fir vegetative zones, mainly between 3,000 and 5,000 feet in elevation. Birds dispersed over an area some 25 times as large as the breeding range where banded. Those from different sections of the breeding range apparently went to different wintering areas. Only 4.2% of the banded birds were reported as being recovered by hunters. Breeding populations appeared to be much higher on an ungrazed range, where banding was done, than on surrounding rangelands. Breeding densities appear to be related to the condition of breeding range.

983. Zwickel, Fred C.; Dake, Jane A. 1977. Primary molt of blue grouse and its relation to reproductive activity and migration. *Canadian Journal of Zoology* 55(11): 1782-1787.

A total of 906 blue grouse were examined for primary molt from 1969 to 1976 on east-central Vancouver Island. First birds to molt were yearling males, followed by adult males, lone (broodless) females, and brood females, in that order. General reproductive activity of the different sex-age classes followed the same rank order (least to greatest). No brood hens molted until after their chicks were hatched, with adult females molting earliest, in relation to yearling females. The rates of molt of

yearling males, adult males, and lone females were all linear, but brood females, which began their molt latest, had an accelerated curvilinear rate of molt. Our data most closely fit the hypothesis that molt is inhibited by reproductive activities. The close relationship between initiation of molt and reproductive activity agrees with data for most other species of north-temperate birds. There was no separation of molt and summer-autumn migration. The most likely explanation for an accelerated rate of molt in late starters is a preparation for winter.

984. Zwickel, Fred C.; Lance, Art N. 1965. Renesting in blue grouse. *Journal of Wildlife Management* 29(2): 402-404.

Two instances of renesting by individually marked blue grouse were observed on Vancouver Island, British Columbia. One of these demonstrated that renesting can occur in this species even though a first clutch is destroyed in the late stages of incubation.

985. Zwickel, Fred C.; Redfield, James A.; Kristensen, John. 1977. Demography, behavior, and genetics of a colonizing population of blue grouse. *Canadian Journal of Zoology* 55(12): 1948-1957.

The demography, behavior, and genetics of a population of blue grouse that colonized an area from which most grouse were removed were compared with those of grouse on a nearby control area. Population density increased on the removal area from 1971 to 1974 but remained essentially stable on the control area. Although there were some differences in survival and reproductive rates among years and between areas, none appeared related to the experimental removal and subsequent replacement by new founders. No consistent differences in potentially aggressive behavior were observed between birds in the two populations. Behavioral differences that occurred were likely related to differences in age structures of the two populations or to the synchronous settling of a cohort of mostly young birds on the experimental area. The increase in the population on the experimental area compared with the control area must have resulted from an increased recruitment of yearlings. No clear evidence was found that this increase was related to qualitative differences between stocks on the two areas.

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management

986. Curtis, James D.; Elder, Frank S. 1965. Blue grouse feeding on planted ponderosa pine. *Journal of Wildlife Management* 29(1): 199-200.

A study of 495 ponderosa pine seedlings planted on a burned-over area in central Idaho indicates that foraging by blue grouse may have disfigured some seedlings or inhibited their growth but did not significantly affect their survival.

987. Mitchell, K.J. 1964. Height growth losses due to animal feeding in Douglas-fir plantations, Vancouver Island, B.C. *Forestry Chronicle* 40(3): 298-307.

Douglas-fir plantations on the east coast of Vancouver Island were examined to determine the effect of animal feeding upon height growth. Length of internodes and evidence of past leader damage were recorded and cumulative average height-age

growth curves compared for undamaged trees and for trees suffering various intensities of damage. The average reduction in tree height attributable to animal feeding in heavily browsed plantations varied from 1/2 to 2 feet over a period of 8 to 10 years. It is unlikely that either tree volume or quality at rotation age would be seriously affected. Exposed trees were browsed more heavily than those protected by vegetation or logging slash.

Tree Squirrels

General

988. Flyger, Vagn; Gates, J. Edward. 1982. Fox and gray squirrels (*Sciurus niger*, *S. carolinensis*, and allies). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 209-229.

Reviews distribution, description, physiology, reproduction, ecology, food habits, behavior, mortality, economic status, and management of the various *Sciurus* species, including *S. griesus*.

989. Flyger, Vagn; Gates, J. Edward. 1982. Pine squirrels (*Tamiasciurus hudsonicus* and *T. douglasii*). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 230-238.

Reviews distribution, description, anatomy, physiology, reproduction, ecology, food habits, behavior, mortality, economic status, and management of *Tamiasciurus hudsonicus* and *T. douglasii*.

Ecology

990. Cross, Stephen Paul. 1969. Behavioral aspects of western gray squirrel ecology. Tucson, AZ: University of Arizona. 185 p. Ph.D. dissertation.

The role of behavior of the western gray squirrel in relation to the basic ecology of the species was investigated during a 36-month period near Ashland, Oregon. Data were collected regarding population characteristics, daily activity patterns, egocentric behavior, reproductive behavior, movements, and social behavior. Two separate populations of squirrels were studied, one of which was estimated to be at least twice as dense as the other. The higher population density probably resulted from the presence of a thicker and more continuous forest vegetation. Daily activity began close to the time of civil sunrise (before actual sunrise). The highest level of activity occurred between 30 and 90 minutes after civil sunrise. A lower level of activity was maintained through the remainder of the day. Normally, most feeding took place on the ground, and the main constituents of the diet were hypogeous fungi, acorns, and pine or fir nuts. Most nesting occurred in stick nests which were built in oaks and pines. Average home ranges differed seasonally, with late summer ranges averaging larger than late winter ranges. They also differed annually. In general, home range size increases with age. None of the individuals completely shifted its range out of the area originally recorded, but some individuals made irregular movements far outside of the normal home range in conjunction with mating, feeding, and avoidance of harassment.

991. Fancy, Steve G. 1981. Daily movements of red squirrels, *Tamiasciurus hudsonicus*. Canadian Field-Naturalist 95(3): 348-349.

A study of the daily movement of red squirrels near Atlin, British Columbia, in 1978 showed that the shortest movements were in the prebreeding season (averaging 34.4 m for females, 88.1 m for males). Males made the greatest movements (mean to 169.9 m) during breeding and gestation, whereas females made long movements (mean to 190.1 m) during lactation and postweaning. Both the breeding cycle and the availability of food supplies influence the daily movements.

992. Gilman, Kathleen Nettie. 1986. The western gray squirrel (*Sciurus griseus*), its summer home range, activity times, and habitat usage in northern California. Sacramento, CA: California State University. 71 p. M.S. thesis.

This study was undertaken to determine the summer home range, activity times, and habitat usage of the western gray squirrel in a northern California oak woodland-pine community. Home ranges were within normal size compared to others reported in the literature, averaging 6.3 acres, with a range of 4.6-9.2 acres. A rough population estimate based on visual observations was determined as 0.48-0.57 squirrels per acre. Areal overlap of the individual squirrels' home ranges was extensive, ranging from 0 to 84.8% of the squirrels' total home ranges, with an average overlap of 24.1%. Female home ranges overlapped less than those of males. Mixed conifer-oak associations were preferred. Of the 22 active stick nests, 59% were in mixed forest habitat. Preference existed for certain nest tree types, with 14 of the 22 nests (63.7%) located in knobcone pines, and 4 nests (18.2%) in California black oaks. A survey of the literature and recent findings indicate that the breeding season is longer than previous thought, from December to July, with peaks in January-February and May-June. Onset of activity centered around civil sunrise. Light may be one of the primary factors which induces diurnal activity, but further study is needed. Most activity was centered around the first 2.0-2.5 hours of the morning. Activity levels were lower during the rest of the day.

993. Hatton, Lester E., Jr.; Hoffmann, Robert S. 1979. The distribution of red squirrels in eastern Oregon. Murrelet 60(1): 23-25.

The ranges of *Tamiasciurus hudsonicus* and *T. douglasii* meet in northwestern Washington and adjacent British Columbia. Published records, however, show a gap between the range of the two species in northeastern Oregon. Normally, the ranges of mammalian populations do not abruptly cease in the midst of an area where ecological conditions continue unchanged. Field collections in the Blue Mountain area resulted in 125 being taken, demonstrating that the ranges of the two species do meet. The squirrels taken in this contact zone are at present taxonomically indeterminate, and variation in coloration suggests the possibility of hybridization between the two taxa.

994. Ingles, Lloyd G. 1947. Ecology and life history of the California gray squirrel. *California Fish and Game* 33(3): 139-158.

A study was made of the ecology and life history of the California gray squirrel in Butte County, California, between 1940 and 1946. The daily activity and response to weather conditions differed from that described for the eastern gray squirrel. The animals were more active in the morning than at midday or late afternoon. Activity before sunup and after sundown was rarely observed. The weather had little effect on activity. The senses of smell and sight appear to be well developed. The most important competitors are the acorn woodpecker, Beechey ground squirrel, and the Douglas chickaree. Very few predators are known. The fruits of many native and introduced plants are used for food. Flower buds and leaves of chickweed are frequently eaten by lactating females. The rut may occur any time during the first six months of the year. Each female appears to have but one litter of two to four young each year. The gestation period is probably over 43 days. Home ranges of the males varied from 1.15 to 1.53 acres each. These overlap greatly the ranges of other squirrels. The home range of individual females varied from 0.30 to 0.85 acres. Females were generally incompatible during the breeding months. The population varies with the type and amount of plant cover.

995. Kemp, Gerald A.; Keith, Lloyd B. 1970. Dynamics and regulation of red squirrel (*Tamiasciurus hudsonicus*) populations. *Ecology* 51(5): 763-779.

This paper describes red squirrel population dynamics on two intensive study areas in mixed-forest types near Rochester, Alberta. It also examines local and regional population fluctuations and their relationship to cone crops and weather factors. Adult red squirrel numbers varied little from 1967 to 1968. Yearly differences in reproductive output were caused principally by changing ovulation and pregnancy rates. Mean litter size increased significantly from 3.4 in 1967 to 4.3 in 1968; and the percent adult females breeding increased significantly from 67 to 88. A life-table analysis of age-ratio data estimated mean annual mortality among juveniles at 67%; and an adult mortality rate of 34% for yearlings and 61% for older cohorts. Red squirrel territories appeared to be of two distinct types: (1) defended winter food caches which were subsequently abandoned during the summer, and (2) "prime" territories in which a specific area was defended year-round. A statistically significant correlation was found between white spruce cone crops and red squirrel populations. The negative correlation between cone crops in late summer and rainfall during summer of the preceding year was almost significant. This supported the widely held view that weather factors influence bud differentiation and hence determine the size of the following year's cone crop. Cone production may in this way provide a vehicle through which weather affects squirrel populations. Such a mechanism would explain the observed widespread synchrony of population fluctuations, since extensive regional weather patterns could be involved.

996. Koford, Rolf Ramage. 1980. Behavior and ecology of a California population of *Tamiasciurus douglasii*. Berkeley, CA: University of California. 136 p. Ph.D. dissertation.

This study has examined the social organization of the Douglas squirrel in the southern part of its range. The dispersion and abundance of the major food items

were monitored to relate estimates of the amount of energy available to individual squirrels to their overwinter survival and reproductive activities. Population density, timing of breeding, and overwinter survival varied among years in ways that suggested that they were responding mainly to food availability. The proportion of individuals surviving the winter was relatively high during the winters after the good seed crops of 1975 and 1976, and breeding in the subsequent years started around March 1. Overwinter survival was relatively poor in the winters after the relatively poor cone crops of 1974 and 1977, and breeding did not start until April in 1975. The extent of summer breeding each year seemed to be related to the size of that year's seed crop. Territoriality was used in two contexts. During much of the year, both sexes occupied individual territories on which they did not tolerate other squirrels of either sex. Such behavior serves to protect an area that contains a seasonal food source that is critical for overwinter survival. In support of this suggested function, I show that the amount of stored seed energy on each territory affects the probability of individual overwinter survival.

997. Maser, Chris; Trappe, James M.; Nussbaum, Ronald A. 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. *Ecology* 59(4): 799-809.

Most higher plants have evolved with an obligatory symbiotic relationship with mycorrhizal fungi. Epigeous mycorrhiza formers have their spores dispersed by air currents, but hypogeous mycorrhizal fungi are dependent upon small mammals as primary vectors of spore dissemination. Mammalian mycophagists defecate within the coniferous forest ecosystem, spreading the viable spores necessary for survival and health of the conifers. As one unravels and begins to understand the interrelationships between small-mammal mycophagists and mycorrhizal fungi, it becomes apparent that the various roles of small mammals in the coniferous forest ecosystem need to be reevaluated. One can no longer accept such simplistic solutions to timber management as poisoning forest rodents to enhance tree survival. One must consider the direct as well as the indirect costs and benefits of timber management decisions if one is to maintain balanced, healthy coniferous forests.

998. McKeever, Sturgis. 1961. Relative populations of small mammals in three forest types of northeastern California. *Ecology* 42(2): 399-402.

From January through December 1958, small-mammal populations were studied in three forest types at four areas lying between 4,800 and 6,800 feet elevation east of the crest of the Cascades in Lassen County, California. The forest types were ponderosa pine, lodgepole pine, and mixed red and white fir. Relative abundance of 12 species was computed; 5 were caught only sporadically. The predominant species were deer mice, golden-mantled ground squirrels, Townsend chipmunks, lodgepole chipmunks, yellow-pine chipmunks, Douglas squirrels, and northern flying squirrels. Deer mice, chipmunks, and golden mantled ground squirrels were most abundant in open stands of ponderosa pine. Douglas squirrels were most abundant in lodgepole pine. Northern flying squirrel populations were approximately the same in each of the three forest types.

999. McKeever, Sturgis. 1964. Food habits of the pine squirrel in northeastern California. *Journal of Wildlife Management* 28(2): 402-404.

Food of the pine squirrel, based upon volumetric analysis of the stomach contents of 207 animals, consisted mainly of fungi and tree seed. Tree seed was an important food during the fall and winter, but fungi constituted more than half the annual diet. Cambium was an important food item during the winter and spring. Some leaves of herbs, flowers, and arthropods were eaten but were a minor part of the diet.

1000. Medin, Dean E. 1986. The impact of logging on red squirrels in an Idaho conifer forest. *Western Journal of Applied Forestry* 1(3): 73-76.

Population densities of red squirrels were studied before and after logging to a 10-inch diameter limit in two catchments in Valley County, Idaho, with Douglas-fir and ponderosa pine as the dominant overstory trees. In the unlogged forest, there were 0.75-1.25 squirrels per acre. In the 2 years after logging, squirrel populations were less than a fifth of those on an unlogged control plot.

1001. Millar, John S. 1970. The breeding season and reproductive cycle of the western red squirrel. *Canadian Journal of Zoology* 48(3): 471-473.

Breeding in the red squirrel in southern British Columbia differed in some respects from that reported in eastern North America. The period during which males were capable of breeding varied from 2 to 6 months, and their reproductive organs showed only a single peak in size each year. All breeding females produced two litters in 1966 but only one litter in 1967. Females did not breed during the year of their birth, and, in 1967, some did not breed as yearlings. February appeared to be the earliest date for the onset of breeding in southern British Columbia. The timing of breeding may be influenced by weather conditions.

1002. Millar, John Steven. 1968. The reproductive biology of the western red squirrel. Vancouver, BC: University of British Columbia. 95 p. M.S. thesis.

The reproductive condition of male and female red squirrels in southern British Columbia was studied in relation to age, season, relative population level, and foods used. The reproductive cycle of males and females is described on the basis of gross anatomy and histological characteristics. A low population on Vancouver Island was studied in 1966 and 1967, and a high population was studied near Princeton, British Columbia in 1967. The habitats are similar in both regions. The low 1966 population had a late breeding season in which all females sampled produced two large litters. In 1967, both populations had early breeding seasons when nearly all adults bred, yet only 1/3 of the yearling females participated, and only single litters were produced. The ovulation rate of 4.11 per litter in the low Vancouver Island population and 3.58 per litter in the high Princeton population. Similarities between the high and low 1967 populations and difference between the low 1966 and low 1967 populations suggest that density was not the primary force influencing productivity. Another explanation is found in the evaluation of the primary food sources, conifer cones. Lodgepole pine cones were the main food source before the highly productive breeding season in 1966, and Douglas-fir cones made up the diet before the less successful breeding season in 1967. The fruiting habits of the conifers are discussed, and it appears that

it is advantageous for the squirrel to feed on lodgepole pine cones. Winter food supply may influence the relative capacity of the female to produce young. The timing of the breeding season seems to be affected by the severity of the winter weather.

1003. Rusch, Doris A.; Reeder, William G. 1978. Population ecology of Alberta red squirrels. *Ecology* 59(2): 400-402.

Temporal changes and spatial differences in population structure and density of red squirrels were investigated in three habitats near Rochester, Alberta. Between 1966 and 1969, red squirrels were most abundant in spruce stands, less abundant in jack pine stands, and least abundant in aspen woods. Summer populations fluctuated between 67 (1966) and 151 (1968) per 100 ha of mixed habitat, but spring populations were more stationary (32-49/100 ha of mixed habitat). Ovulation rates of adult and yearling squirrels and the percentage of yearling females which bred varied annually. Variation in annual reproductive (2.4-4.4 young per female) was correlated with the date of onset of breeding and the number of days of snow cover after January 1. Although sex ratios were close to 1:1 during early summer, late-summer mortality of adult females resulted in a preponderance of males (60%) during the remainder of the year. Equality of sex ratio was restored during the breeding season when males experienced high mortality rates. After fall dispersal, the percentage of adults was higher in the spruce than in pine, but virtually 100% of the squirrels occupying aspen habitat were juveniles. Dispersal movements occurred in spring and fall; squirrels were relatively sedentary the remainder of the year. Almost all fall dispersants were young of the year. In the wild, an average of 639 meristematic buds and the seeds from 35 pine cones were consumed by a single squirrel each day. Captive feeding trials indicated that an average of 176 black spruce cones or 123 white spruce cones per day were necessary to sustain one squirrel when offered no supplementary foods.

1004. Shellhammer, Howard S. 1966. Cone-cutting activities of Douglas squirrels in Sequoia groves. *Journal of Mammalogy* 47(3): 525-526.

Describes an incident when a Douglas squirrel was observed cutting 537 cones in 30 minutes. The rate varied from 9 to 34 per minute with but one 70-second break about midway through. Nearly all the cones were green and appear to have been cut with a single bite. In less than 3 days, all but 15 of the cones that this squirrel cut were cached in small pits around the base of the tree and under fallen logs.

1005. Smith, Christopher C. 1970. The coevolution of pine squirrels (*Tamiasciurus*) and conifers. *Ecological Monographs* 40(3): 349-371.

Field observations of discriminatory feeding behavior of squirrels indicate that in the process of maximizing their own feeding efficiency, squirrels act as selective agents on several characteristics of plant reproduction. The reproductive characteristics of conifers which are affected include several details of cone anatomy, the number of seeds per cone, the time at which cones shed their seeds, the thickness of seed coats, and annual fluctuations in the size of cone crops. A general analysis of selective pressure influencing terrestrial plant reproduction indicates that seed eaters could have a marked influence on the evolution of plant reproduction.

1006. Smith, Christopher Carlisle. 1965. Interspecific competition in the genus of tree squirrels *Tamiasciurus*. Seattle, WA: University of Washington. 306 p. Ph.D. dissertation.

A field study of competitive interactions between the red squirrel and the Douglas squirrel was performed in the area where their ranges overlap in southwestern British Columbia. Data on social organization, predation, food, daily activity patterns, and physical differences between the species are presented. It was found that both species of squirrels defend territories ranging from 1/2 to 3 acres throughout the year. Territories are defended by one squirrel either male or female. The major food items of the genus are the energy-rich, reproductive structure of fungi, conifers, and deciduous trees and bushes. During periods of general food shortage, adult squirrels defended stable territories which contained from 0.7 to 2.9 times their yearly energy requirements. The size of stable adult territories in two different forests were significantly different, but territories in both forests contained about the same amount of food. Thus territory size appears to be adjusted to the quantity of food contained on the territory. One lactating red squirrel extracted energy from Douglas-fir cones four times as fast as she did from lodgepole pine cones. Her time budget shows that if she had been completely dependent on lodgepole pine for conifer seeds, she would not have had enough daylight hours to consume her daily energy requirements. This finding demonstrates the selective value of the red squirrel's adjustment of litter size to food supply. Red squirrels had significantly smaller litters the years in which Douglas-fir cones were not available during the height of lactation.

1007. Stienecker, Walter E. 1977. Supplemental data on the food habits of the western gray squirrel. *California Fish and Game* 63(1): 11-21.

Supplemental data from Kern, Mendocino, Sonoma, Napa, Shasta and Tehama Counties substantiates the feeding habits pattern of the western gray squirrel over much of its California distribution. Hypogeous fungi, oak acorns, pine nuts and California bay fruits comprise the bulk of the food eaten by gray squirrels. The types of fungi and principal food items are eaten in a pronounced seasonal pattern.

1008. Stienecker, Walter; Browning, Bruce M. 1970. Food habits of the western gray squirrel. *California Fish and Game* 56(1): 36-48.

Fungi were the staple food item of 310 western gray squirrels collected in Trinity, Tehama, and Monterey Counties, California. Hypogeous (subterranean) fungi were the most important. In Trinity and Tehama Counties, pine nuts and acorns also were important items, eaten mainly in the summer and fall. In Monterey County, fruit of the California bay (*Umbellularia californica*) was second in importance. Forb leafage and stems, used principally in the spring, made up most of the green vegetation eaten. Although hypogeous fungi are the staple food, acorn and pine mast may be the more critical. These high-energy foods prepare the squirrels for overwintering.

1009. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. Population dynamics and regulation of the Douglas squirrel (*Tamiasciurus douglasii*) with supplemental food. *Oecologia* 53(2): 264-270.

If food is in short supply, then provision of additional food should increase the density of Douglas squirrels. A squirrel population was supplied with extra food during the summers of 1977 and 1978 and winter of 1978-1979 in coastal coniferous forest at Maple Ridge, British Columbia. Food produced a 5- to 10-fold increase in squirrel density compared with control populations. Control densities generally varied from 3-10 squirrels per trapping area with the experimental populations increasing to 65 animals during the winter feeding. This irruption was produced by immigration, more reproduction in females, and increased survival. After the food was withdrawn, the population declined to a level comparable to the controls. Douglas squirrel populations thus fluctuate according to the abundance of food. Territorial behavior may space individuals within populations of *T. douglasii* to density levels determined by the available food supply.

1010. Swift, Riley John. 1977. The reproductive cycles of the western gray squirrel in Butte County, California. Chico, CA: California State University. 78 p. M.A. thesis.

Forty-six male and 50 female western gray squirrels were collected between March 1972 and July 1973 in Butte County, California. They were aged and examined for evidence of reproductive activity. The annual breeding season was found to extend from December through July with peaks of pregnancy occurring in January, March, and June. Male testicular, prostate-seminal vesicle, and bulbo-urethral gland weights were maximal in May with involution completed by August. Juvenile squirrels did not participate in breeding activities in the year of their birth, but subadults were capable of breeding early in the following season. A small percentage of sexually mature females did not participate in reproductive activities during the breeding season. One ovary from all females collected was analyzed for patterns of follicular development and atresia. Eight functional reproductive states were recognized: prepuberal, quiescent, prebreeding growth, gestation, near parturition, lactation, and postreproductive. Prepuberal ovaries held the largest number of primary and secondary follicles, but no graafian follicles. Quiescent ovaries contained a large number of primary follicles but few developing follicles; and a high percentage of atresia was noted among follicles in the incipient antral stage. As the squirrels moved through the reproductive period the diameter and number of developing follicles increased. Before ovulation atresia was reduced, but after ovulation, atresia increased significantly and follicular maturation ceased. Ovarian characteristics of postreproductive animals were similar to those of quiescent animals. Litter size ranged from one to four.

1011. Tevis, Lloyd, Jr. 1956. Response of small mammal populations to logging of Douglas-fir. *Journal of Mammalogy* 37(2): 189-196.

Logging of the forest causes an increase in numbers of white-footed and big-eared mice, Townsend chipmunks, dusky-footed woodrats, digger squirrels, chickarees, and gray squirrels. It causes a decrease in numbers of Trowbridge shrews, red-backed mice, flying squirrels, and shrew-moles. The species that become most numerous

are white-footed mice and Townsend chipmunks. They are the animals chiefly responsible for failure of artificial seeding of conifers. Also, along with the chickaree they are responsible for the destruction of large amounts of naturally produced seed.

Damage and Management

1012. Baldwin, R.J.; Howard, W.E.; Marsh, R.E. 1987. Debarking of conifers by the western grey squirrel (*Sciurus griseus*). In: Richards, C.G.J.; Ku, T.Y., eds. Control of mammal pests. London, UK: Taylor and Francis Ltd: 45-54.

Debarking of conifers by various species of tree squirrels to feed on the phloem and cambium tissues and to obtain nesting material has been known for some time. One such unusually serious but quite localized debarking problem involving ponderosa pine and Douglas-fir was first observed in 1977 near Butte Falls, Jackson County, in southern Oregon. An ensuing field study confirmed that grey squirrels were responsible for this localized but serious loss of timber production. The affected trees, often up to 0.8 m in diameter and with the damaged parts at heights up to 21 m, often look like spiralled barbers' poles. The squirrels initiate the debarking with their teeth, then strip the long slender bark chips free by using their forefeet. Grey squirrels can debark very rapidly and as many as four chips per squirrel have been seen falling at one time, the forest floor becoming littered with them. Debarking activity occurs between mid-February and the end of April. We have no explanation as to why particular populations of grey squirrels have adopted this bark-stripping behavior.

1013. Brockley, R.P.; Elmes, E. 1987. Barking damage by red squirrels in juvenile-spaced lodgepole pine stands in south-central British Columbia. *Forestry Chronicle* 63(2): 28-31.

A survey was undertaken to assess the incidence and magnitude of barking injuries by red squirrels in juvenile stands of spaced lodgepole pine. Eleven of the 40 stands surveyed (27.5%) showed evidence of squirrel damage. Within damaged stands, an average of 51% of lodgepole pine crop trees exhibited barking injuries. Squirrels preferentially attacked the larger diameter stems in damaged stands. Data indicate that fire-origin stands are more susceptible to barking damage than stands naturally regenerated following harvesting. Inability to accurately assess either squirrel damage potential or its impact on growth and yield indicates that a conservative approach is necessary in spacing juvenile lodgepole pine in areas susceptible to squirrel attack. A two-step spacing strategy may be the most practical method of minimizing the impact of squirrel barking injuries.

1014. Brockley, Robert P.; Sullivan, Thomas P. 1988. Relationship of feeding damage by red squirrels to cultural treatments in young stands of lodgepole pine. In: Schmidt, W.C., comp. Proceedings—future forests of the mountain West: a stand culture symposium; 1986 September 29-October 3; Missoula, MT. Gen. Tech. Rep. INT-243. Ogden, UT: U.S. Department of Agriculture. Forest Service, Intermountain Research Station: 322-329.

Red squirrels cause significant damage in many juvenile stands of lodgepole pine in the mountain West. This review paper discusses the relationship of squirrel damage to lodgepole pine stand tending treatments, in particular, juvenile spacing and fertilization. Emphases are on research studies conducted in the interior of British Columbia. Squirrels feed extensively on rapidly growing crop trees within stands of juvenile-

spaced lodgepole pine. In south-central British Columbia, damage to 90% of crop trees in spaced stands has been recorded. Fertilized crop trees are particularly susceptible to squirrel barking injuries. Inability to assess accurately small-mammal damage potential or its impact on growth and yield indicates that a conservative approach is necessary in managing juvenile lodgepole pine in areas susceptible to squirrel attack.

1015. Fisch, Gordon G.; Dimock, Edward J., II. 1978. Shoot clipping by Douglas squirrels in regenerating Douglas-fir. *Journal of Wildlife Management* 42(2): 415-418.

Offers evidence that a sizable portion of injuries to the upper crowns of sapling to pole-sized Douglas-fir trees, especially to terminal shoots, is attributable to clipping by Douglas squirrels. Such damage has been attributed to frost, snow, ice, aborted buds, and birds.

1016. Franklin, Jerry F. 1964. Douglas' squirrel cut Pacific silver fir cones in the Washington Cascades. Res. Note PNW-15. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 3 p.

Cone cutting by the Douglas' squirrel was observed in two localities on the eastern slopes of the Cascade Range. Most cones were still attached to twigs up to 9-1/2 inches long. Many of these twigs bear female buds which could produce next year's cones. The squirrels' cutting can reduce cone production in both the current and succeeding years.

1017. Hooven, Edward F. 1970. Animal damage to seed and seedlings. In: Hermann, R.K., ed. *Regeneration of ponderosa pine: Proceedings of a symposium; 1969 September 11-12; Corvallis, OR.* Corvallis, OR: School of Forestry, Oregon State University: 36-39.

Discusses rodents and birds that consume tree seed in the ponderosa pine area and reviews methods of seed protection.

1018. Scheffer, Theo H. 1952. Spring incidence of damage to forest trees by certain mammals. *Murrelet* 33(3): 38-41.

Describes the damage caused by three mammals in the second-growth forests of the Puget Sound area. Western gray squirrels girdle tree tops in the spring when the sap is rising and the bark is looser. Mountain beaver prune seedlings and sometimes slender saplings, to a height of 10 feet or more, leaving stubs of severed branches as a ladder. The black bear strips the bark from boles of trees to get at the cambium layer, soon after the animals come out of hibernation. It appears that damage by bears has increased in recent years.

1019. Stilling, C.R. 1944. Damage to conifers in northern Idaho by the Richardson red squirrel. *Journal of Forestry* 42(2): 143-145.

In late May and June 1942, considerable barking and girdling of young conifers was noted in the Kalispell Creek drainage in the Kaniksu National Forest of northern

Idaho. Further observations revealed scattered injury of this type elsewhere. The cause of this damage was revealed when the author observed a Richardson red squirrel in the act of rapidly removing the bark from a young larch tree. The trees most commonly and severely attacked were western larch and lodgepole pine from 7 to 40 feet tall. The bark was removed only on the internodes of the trunk but not on the limbs. In most cases, the girdling was on a single internode, but occasionally almost every internode from the ground up was girdled. Preference was shown for trees growing in openings or for dominant trees where the point of attack was somewhat above the tops of the surrounding trees. The squirrel chose locations from which his view would be unobstructed. All the girdling apparently is done in May and June, possibly due to the absence of more suitable food during the early part of the season. The squirrel was observed licking the sap from the freshly exposed surface after removing the bark. The damage may prove serious locally and add to the many problems already present in forest management.

1020. Sullivan, Thomas P. 1987. Red squirrel population dynamics and feeding damage in juvenile stands of lodgepole pine. FRDA Report 019. Victoria, BC: British Columbia Ministry of Forests and Lands and Canadian Forestry Service. 20 p.

This study measured the incidence of red squirrel feeding injuries to thinned lodgepole pine during the first 7 years after spacing. Squirrel feeding damage in two manually spaced stands was monitored from 1979 to 1986 in Prince George and 1980 to 1986 in Cariboo. Squirrel populations were monitored from 1981 to 1986 in a juvenile (unspaced stand) and mature stand at each area. At Prince George, squirrel populations increased on two occasions (1980-81 and 1984-85) in association with substantial cone crops of interior spruce. Squirrel abundance in the mature stand peaked in the year after each cone crop, with a surplus of squirrels appearing in juvenile stands in subsequent years. In general, damage incidence and feeding intensity in the spaced stand tended to be associated with increased densities of squirrels, but exceptions to this pattern also occurred. This pattern was less evident in the Cariboo, where the absence of spruce stands presumably resulted in consistent squirrel densities over time. The inconsistent periodicity of cone crops and squirrel population cycles, as well as the preference by squirrels to attack large diameter stems, negates the possibility of strategic timing of spacing operations. Several silvicultural recommendations are suggested to alleviate squirrel damage to spaced lodgepole pine.

1021. Sullivan, Thomas P.; Moses, Richard A. 1986. Red squirrel populations in natural and managed stands of lodgepole pine. *Journal of Wildlife Management* 50(4): 595-601.

We investigated the response of red squirrel populations and squirrel-caused damage to thinning of lodgepole pine stands in the central interior of British Columbia. A secondary objective was comparison of demographic attributes of squirrel populations in juvenile and mature stands of pine. Although thinning of pine stands reduced red squirrel densities, it may not consistently reduce feeding damage. Increasing the size of thinnings of >100 ha may help reduce damage. Squirrel densities in unthinned juvenile and mature pine stands were similar throughout the year. This pattern was evident despite a low proportion of breeding females, low survival, and high fall

recruitment among squirrels in the juvenile stand. Young stands may provide dispersal sinks for juvenile and yearling squirrels thereby making this habitat comparable to mature coniferous forest.

1022. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. Barking damage by snowshoe hares and red squirrels in lodgepole pine stands in central British Columbia. *Canadian Journal of Forest Research* 12(2): 443-448.

Barking damage by snowshoe hares and red squirrels is common in overstocked stands of juvenile lodgepole pine in central British Columbia. Average proportion of potential crop trees damaged by hares was 30% and by squirrels was 37.7%. Most hare feeding injuries occurred in heavily stocked (>20,000 stems/ha) stands, whereas squirrel damage was most common in less dense stands. Both animal species damaged trees in thinned stands and hence may have a serious impact on stocking control programs in lodgepole pine.

1023. Sullivan, Thomas P.; Sullivan, Druscilla S. 1982. Influence of fertilization on feeding attacks to lodgepole pine by snowshoe hares and red squirrels. *Forestry Chronicle* 58(6): 263-266.

Lodgepole pine shows favorable growth and yield responses to spacing and potentially to fertilization, but is susceptible to feeding injuries by snowshoe hares and red squirrels. This study was designed to determine the incidence of animal damage to crop trees in a fertilized, spaced stand, compared with those in spaced only and control (unspaced) stands. There was little variation in the percentage of crop trees (range 53.6% to 63.3%) damaged by hares in the three stands. Hares removed an average of 92.2 cubic cm of bark and associated vascular tissues per attack from fertilized stems compared with 46.2 cubic cm in the spaced only stand. This latter value was nearly double that recorded in the control stand (27.4 cubic cm). Squirrels damaged more fertilized trees (38.9%) than trees in the spaced (30.9%) or control (14.3%) stands. Squirrels removed the largest average amount of bark (66.9 cubic cm) per attack from fertilized stems with little difference between spaced (41.6 cubic cm) and control (42.3 cubic cm) stands. We conclude that hares and squirrels clearly prefer to feed on fertilized lodgepole pine stems over those in nonfertilized or unmanaged stands.

1024. Sullivan, Thomas P.; Vyse, A. 1987. Impact of red squirrel feeding damage on juvenile spacing of lodgepole pine in the Cariboo Region of British Columbia. *Canadian Journal of Forest Research* 17(7): 666-674.

This study measured the impact of red squirrel feeding damage on spaced stands of lodgepole pine. A limited regional assessment of animal damage in spaced stands indicated that squirrels were the most important small-mammal damage agents and that lodgepole pine was the only tree species susceptible to squirrel feeding (bark and vascular tissues) injuries. Intensive assessment of damage in two stands showed the squirrel attack was significantly greater among large than small-diameter stems. Significantly more spaced than control (unspaced) crop trees were attacked. There

was a general decline in the proportion of trees wounded from 1980 to 1985. Some damaged trees grew faster in diameter than undamaged trees of the same size. However, at one study area, damaged trees showed faster radial growth than undamaged trees before and after squirrel attack. Squirrels appear to prefer feeding on vigorous stems and the lost growth of these trees may be substantial. Height growth of damaged trees was significantly reduced in one stand in the years following squirrel damage. Some limit to a tree's capacity to sustain damage, beyond which mortality is inevitable, seems likely. Impact of damage to spaced stands may be minimized by delaying spacing in susceptible areas or by increasing the prescribed number of stems remaining after spacing to compensate for expected mortality and severe damage.

1025. Walters, J.; Soos, J. 1961. Douglas squirrel damage to Douglas-fir. Res. Note 32. Vancouver, BC: University of British Columbia, Faculty of Forestry. 2 p.

In February 1961, considerable damage to young Douglas-fir was observed. A Douglas squirrel was observed cutting the terminal and lateral shoots of young trees and throwing the cut portion to the ground. The buds on these portions were eaten by the squirrel on returning to the ground. This is the first record of extensive squirrel damage to young Douglas-fir on the UBC Research Forest, and it may be related to the absence of seed production in 1960.

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This annotated bibliography of published literature provides a comprehensive source of information on animal damage assessment and management for forest land managers and others in the Pacific Northwest. Citations and abstracts from more than 900 papers are indexed by subject and author. The publication complements and supplements a *Silvicultural Approach to Animal Damage Management in Pacific Northwest Forests*, a compendium focusing on interactions between silviculture and animal damage management. The bibliography compiles the current knowledge and experience about managing animal species causing damage to forest stands, the response of those species to silvicultural practices, and manipulation of silvicultural practices to prevent or limit animal damage.

Keywords: Bibliographies (forestry), animal damage, Pacific Northwest.

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