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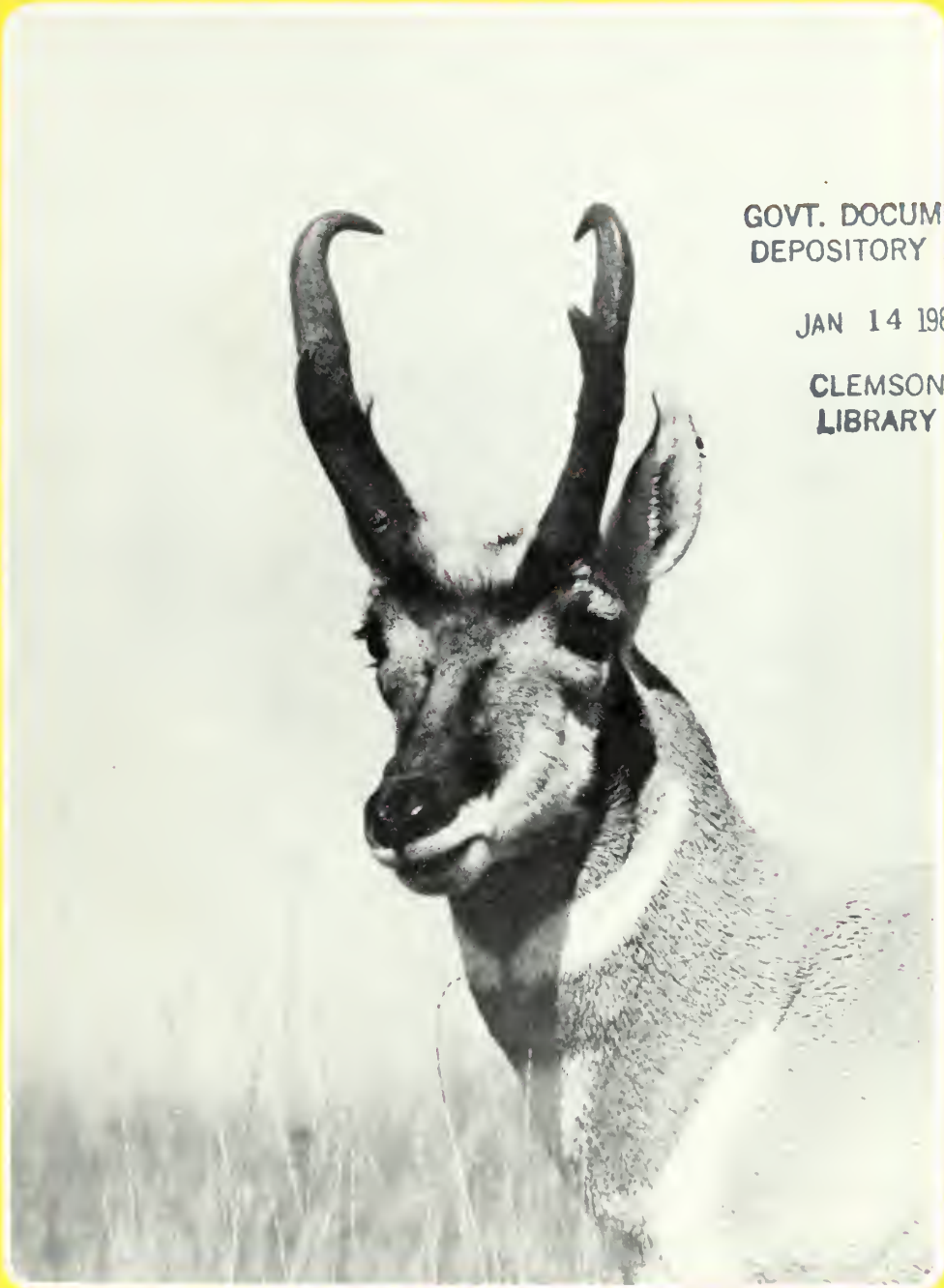
# Fisheries and Wildlife Research

1978

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FISH AND WILDLIFE SERVICE

DIVISIONS OF RESEARCH

As the Nation's principal conservation Agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historic places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Front cover photo.

Increased emphasis on the utilization of coal in energy production lends urgency to the need for research on the ways in which exploitation of coal resources in western States will affect wildlife. The pronghorn is a major species under study because the most productive pronghorn range in North America overlaps much of the area underlain by strippable coal. *Photo by Bart O'Gara.*

# Fisheries and Wildlife Research

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## 1978

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Activities in the Divisions of Research for  
the Fiscal Year 1978

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Reference to trade names does not imply Government endorsement of commercial products.

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The Porcupine Caribou Herd is an international herd that calves on the Arctic coastal plain in the Arctic National Wildlife Range and moves into the Yukon Territory for most of the rest of the year. There is concern about the future of the herd because of potential petroleum development on the Range and because of winter hunting from the Dempster Highway in Canada. The International Porcupine Caribou Committee was formed to evaluate research needs for this herd and to disseminate new research findings for management. *Photo by Dean E. Biggins.*

## Foreword

A primary goal of the U.S. Fish and Wildlife Service is the conservation and sound management of sport fishery and wildlife resources for the benefit of present and future generations of Americans. Attainment of this goal requires the continual collection, analysis, and synthesis of new information on which wise and timely management decisions can be based. The Divisions of Research address the principal informational needs of the various management programs of the Service and provide many of the findings that contribute to the accomplishment of the Service's mission.

This summary of the activities of the Research Divisions during the fiscal year 1978 (October 1, 1977-September 30, 1978) provides an overview of the nature and scope of research completed and directs attention to the results that should be of significance in the management of fish and wildlife.

A substantial portion of the research recounted here concerns cooperative studies between Service scientists and those of other Federal agencies, universities, State agencies, and other countries. We thank the many collaborators for their most valued assistance in advancing the Service's diverse research program.



# Fisheries and Wildlife Research

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The research responsibilities of the Fish and Wildlife Service were carried out by three Divisions: Wildlife Research, Fishery Research, and Habitat Preservation Research. During fiscal year 1978, these Divisions continued to serve as the fact-finding arm of the Service. Information about species of fish and wildlife, the environments required for their existence, and the effects of management practices on them help the U.S. Fish and Wildlife Service and other government agencies to meet their responsibilities for conserving and managing the Nation's fish and wildlife for social, economic, aesthetic, and scientific benefits. In fulfilling the Service's research responsibilities, the Divisions cooperate with agencies of the Departments of the Interior, Agriculture, Defense, and Health, Education, and Welfare; the Atomic Energy Commission; the Agency for International Development; the Environmental Protection Agency; and various State agencies, institutions, and private organizations. Completed research is communicated by talks and lectures, processed reports, and articles in popular and technical publications. A list of publications is provided in this report.

During the fiscal year, research was carried out

at 21 major facilities, approximately 60 satellite field stations, and 46 Cooperative Research Units under the following programs: Animal Damage Control, Environmental Contaminant Evaluation, Coastal and Anadromous Fish, Endangered Species, Great Lakes Fisheries, Inland Fisheries and Reservoir Management, Land and Water Resources Development, Migratory Birds, Mammals and Nonmigratory Birds, Biological Services, and Cooperative Units. This alignment of programs permits the application of total agency resources to the attainment of specific objectives and encourages careful priority assessment of ongoing research programs.

The planning, coordination, and administration of the research programs continue to be centralized in the Office of the Associate Director of Environment and Research in Washington, D.C. Fiscal, personnel, and property management and a variety of supporting services are provided the research facilities by the six Regional Offices of the Service. By the end of fiscal year 1978, the Divisions of Research had 729 full-time permanent employees. The budget included approximately \$31,000,000 of appropriated funds and \$3,000,000 of other funds.

# Animal Damage Control

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## DENVER WILDLIFE RESEARCH CENTER

**Starling and Blackbird Populations Increase in North America.** The North American Breeding Bird Survey was used to estimate population trends (1966-76) of starlings, red-winged blackbirds, brown-headed cowbirds, and common grackles in the United States and Canada. The analysis indicated an upsurge in starling and blackbird populations across much of North America. Combined with the progressive growth of the human population and intensification of agriculture, this upsurge leads us to anticipate greater man vs. bird conflicts in the future.

On a continental scale, starlings, redwings, and cowbirds showed significant increases in population. Starlings, which showed the greatest increase (19.4%), made their highest gains in the western States. Increases in redwing populations were highest in the St. Lawrence Valley and in parts of the Midwest and the Lower Plains. Cowbird populations increased most in the Plains area from Iowa to Saskatchewan, but decreased in parts of the eastern and midwestern United States. Grackles showed no overall change in population but made strong gains in the Midwest and the Lower Plains and declined in Appalachia. This knowledge of starling and blackbird population trends should enable us to devise improved methods of dealing with man vs. bird conflicts.

**Remote Sensing Tested for Locating Blackbird and Starling Roosts.** Multispectral scanning techniques were used to determine whether a 3-million blackbird and starling roost in a mixed conifer-hardwood area near Chapel Hill, Tennessee, could be identified from a flight altitude of 1,500 feet. High effective radiation temperatures (on thermal imagery) in a 1.1-ha area and in some small areas among dense stands of coniferous trees were caused by great concentrations of birds. Land-use imagery had to be used to determine that areas outside the roost but with similar temperatures were not roost habitat. The inconclusive findings of the test, resulting in the enforced use of land-use imagery, indicate that remote sensing is an impractical method of surveying extensive areas for

blackbird and starling roosts.

In the future it may be feasible to locate winter roosts quickly by using remote sensing equipment installed in high-altitude aircraft or in satellites. People experienced in censusing large numbers of birds could then determine the number and species composition at each roost, enabling researchers to obtain a more reliable estimate of the winter distribution and populations of blackbirds and starlings in the United States.

**Winter Blackbird and Starling Roosts Dispersed.** Large aggregations of wintering blackbirds and starlings gather at feeding and roosting areas in our southeastern States, sometimes causing serious agricultural losses as well as creating health hazards and nuisance problems.

During the winter of 1977-78, a population of 700,000 blackbirds and starlings roosting in 11 acres of cedars at Munfordville, Kentucky, was dispersed during 8 evenings of harassment by five people firing noise cartridges projected by pistol and shotgun. In Bartlett, Tennessee, about 98% of 650,000 roosting blackbirds and starlings were dispersed from 20 acres of cedars after 7 evenings of similar harassment by five persons. Most dispersed birds formed new roosts in nearby habitat and, when left undisturbed, most remained at the new locations after harassment ended. Birds radio-instrumented during these trials roosted at other locations up to 29 miles from their original roosts. These trials and those conducted during the preceding winter show that large concentrations of birds at winter roosts can be relocated with relatively little manpower and equipment when control measures become necessary.

**Baiting Starlings at Staging Areas.** In January 1978, Starlicide Complete pellets were used to bait 1.5 acres of pasture near a 15-acre hardwood-cedar roost containing a peak population of 874,000 birds (about 55% starlings, 45% blackbirds), near Madison, Tennessee. Birds consumed 327 of the 428 pounds of bait broadcasted. Bait consumption and observations of feeding behavior indicated that 88,000 birds (estimated number) were killed. Starlings made up 52% and blackbirds 48% of the mortalities on transects in





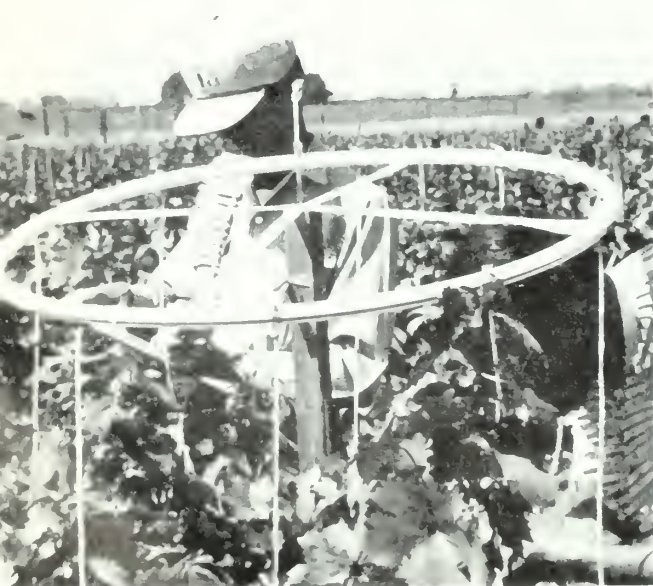
Troublesome blackbirds and starlings were decoyed, prebaited, and then baited with a toxicant at a staging area adjacent to a Madison, Tennessee, winter roost. *Photo by C. Edward Knittle.*



Large roosts of wintering blackbirds and starlings are a potential health hazard and nuisance when they lie in the path of urban expansion. Nearly 650,000 birds were dispersed from this Bartlett, Tennessee, roost by using noise cartridges. *Photo by Olin E. Bray.*



Ripening wine grapes near Calistoga, California, are experimentally treated with methiocarb to evaluate its effectiveness as a bird repellent to alleviate production losses. *Photo by Richard W. DeHaven.*



Biologists assess bird damage to wine grapes to estimate economic losses and to determine the effectiveness of protection methods. The hoop device is used to locate random bunches for examination. *Photo by David N. Johnson.*

the roost. Fourteen other birds found dead, including 11 cardinals, were obviously victims of the bait.

A reduction of less than 10% of the starling roost population was not considered successful in terms of the cost and effort expended, but severe weather precluded more extensive baiting. The hazard to nontarget species of birds, resulting from the method of bait exposure, the location of the baited area, and the bait carrier used, was considered significant. Future trials will involve efforts to improve the effectiveness of baiting and to reduce hazards to nontarget species.

**Control of Starling Damage at Dairy Feedlots in Tennessee.** Bird consumption and contamination of feed at livestock feedlots probably constitute the single greatest agricultural problem caused by the large winter aggregations of blackbirds and starlings in the southeastern United States. In February and March 1978, the distribution and relative magnitude of this problem and the effectiveness of a registered product in controlling bird depredations were investigated in Monroe County, Tennessee, which has a purportedly substantial bird-feedlot problem. One feed trough at each of 34 randomly selected dairies, within a 12-mile radius of a roost of 1.2 million birds, was ob-



This scrub jay is one of several species of birds that damage ripening grapes in California. *Photo by David N. Johnson.*

served for bird activity during one 30-minute period. Birds were active in 22 (65%) of the troughs during the observation period. Almost all of these birds were starlings, even though starlings constituted only 12% of the roosting population. Of the 34 troughs observed for 30 minutes, the number of bird-minutes of activity exceeded 150 at 8 (24%) and 1,800 at 3 (9%). We do not know how these activity figures relate to actual feed loss caused by starlings, but other researchers have estimated this loss to be 0.3 to 1.7 g of feed per bird-minute, depending on the circumstances and on the type of ration consumed. In our study, silage corn and protein supplement rations constituted more than half of the diet of starlings collected at two dairies.

In a companion study, we evaluated Starlicide, a registered and selective starling toxicant, for efficiency in reducing this type of feedlot damage. We diluted Starlicide with an equal amount of corn-base crumbles and placed the mixture in rubber bait pans on the roofs of the feed troughs at two dairies in Monroe County. One dairy, about 3 miles east of the roost, was baited in mid-February; the second, 11 miles southwest of the roost, served as an untreated control. The average of six counts of bird activity in feed troughs before and after 5 days of baiting indicated that starling

activity at the baited site was reduced by 97% (from 1,487 to 40 bird-minutes per 30-minute observation). No reductions in starling activity were observed at the control site; later, this site was baited for 6 consecutive days (early March). Starling feed-trough activity at this site was reduced 93% from a six-observation average of 10,428 bird-minutes before baiting. Because of the extreme variability of the starling feed-trough activity, however, the observed reduction was not statistically significant.

These findings indicate that Starlicide baiting can effectively reduce starling damage at dairy feedlots located near blackbird and starling roosts.

**Development of a Blackbird and Starling Roost Toxicant.** Tests of a formulation of an acetamide compound called CAT, as a candidate toxicant for reducing large concentrations of birds at winter roosts, showed it to be of low oral and dermal toxicity to mammals but to possess a significant potential for eye injury. The oral median lethal dose (LD50) of the formulation to rats was 7.1 ml/kg, and the dermal LD50 to rabbits was 12 g/kg. Application of the material to the eyes of rabbits produced corneal opacity, some of which lasted over a week. The eye injury was caused by a solvent used in the formulation; in other tests,



technical grade CAT produced no eye irritation.

The potential danger to hawks from eating blackbirds treated with roost applications of CAT was investigated in tests with captive hawks. Five each of red-tailed and sharp-shinned hawks were maintained for 7 days on a diet of blackbirds killed by CAT sprayed at the proposed field rate. Control hawks, two red-tailed and three sharp-shinned, were fed asphyxiated untreated blackbirds. After a 14-day observation period the hawks were sacrificed and necropsied. Two sharp-shinned hawks, one treatment and one control, died of ectoparasite infestation during the test, but no other deaths occurred. Gross necropsies revealed no lesions attributable to the treatment, and histopathological examinations of hawk tissues were also negative.

Initial field tests of the CAT formulation at blackbird and starling winter roosts will be conducted under an Experimental Use Permit granted by the Environmental Protection Agency.

**Red-winged Blackbird Migration Studies in Colorado-Montana Region.** Nearly 44,000 red-winged blackbirds have been banded in Colorado, Wyoming, and Montana since 1960 to determine the migratory behavior and breeding areas of birds involved in regional crop depredations. About half this number were also color-marked. Band recoveries, retrapping records, and sightings of color-marked birds show that redwings nesting in the South Platte Valley, Colorado, are normally nonmigratory, whereas those that winter in Colorado include populations that nest in Wyoming, Nebraska, Montana, Alberta, and Saskatchewan. Redwings that winter farther south, in the Arkansas Valley of Colorado, appear to originate in more northerly parts of the breeding range than those wintering in the South Platte Valley. These findings are useful in the formulation of sound management plans for these populations.

**Horned Lark Feeding Patterns.** In California, horned larks frequently damage seeds and seedlings of lettuce, sugar beets, and other crops. Methiocarb, a bird repellent, was tested for alleviation of this problem, with encouraging results. Apparently, however, protection was often limited, because several types of damage occurred over relatively long periods.

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Bird damage totally destroyed this bunch of Pinot Noir wine grapes near Geyserville, California. Birds, primarily house finches, destroyed 12% of the vineyard's crop. Photo by David N. Johnson.

Feeding studies were conducted to gather information that might be useful in devising the optimum treatment form of methiocarb. Food items from the stomachs and esophagi of 122 horned larks collected during 1975 were estimated by volume. Grit (45%), 24 genera of farmland weed seeds (28%), 3 genera of cultivated grains (17%), 2 orders of insects (6%), and vegetative parts of plants (4%) all occurred in proportions similar to those found in two earlier California studies. The relatively low volume of plant parts, even though most birds were collected from fields exhibiting heavy sprout damage, prompted digestion-rate tests with captive birds. It was found that sugar beet and lettuce sprouts were digested in less than 20 minutes, whereas hard seeds were identifiable after 18 hours. Obviously, sprouts were far more important than the percentage volume indicated, and, to avoid bias, future estimates of the larks' diet will require conversion factors based on digestion rates for the kinds of foods consumed. Probably the most useful finding was the homogeneity of the weed seeds selected for food. Most were small (<3 mm), hard, rounded, and dark. Seeds, pellets, or grit of this description may be useful as bait for delivering methiocarb to horned larks.

**Birds Damage California Wine Grapes.** In 1977, weekly flush counts of birds known or suspected of feeding on wine grapes were made at 24 California vineyards—12 in the San Joaquin Valley and 12 in the North Coast area. Twenty-two species of birds were observed during 138 perimeter censuses made at the times the vineyards were susceptible to damage. House finches and robins were the most frequently encountered species in the two areas. Starlings ranked third in abundance in the valley area, and California quail were third in the coast area. These four species made up 68% of the total number of birds recorded and are assumed to have caused most of the damage to the grapes.

When bird densities and damage levels for vineyards in each area were compared by regression analyses, the relationships were significant but accounted for less than 37% of the observed variation ( $r^2$ ). These weak correlations may have been due to census techniques that did not account for differences in species preference for areas within vineyards (edge versus middle) and in flushing rates, variations in daily activity patterns, and site-specific use of grapes (associated with the food supply in nearby habitat). Our censuses obviously provided only general estimates of the densities of

grape depredators. Because the measured densities are not good indicators of damage levels, the census results probably cannot be used alone to measure the effectiveness of a bird repellent treatment. Efficacy evaluations must be based primarily on damage assessments.

**Movement and Feeding Patterns of Blackbirds Frightened from Sunflower Fields.** Blackbirds roosting each August to October in the marsh at Fuller's Lake, Steele County, North Dakota, damage ripening sunflower fields within a seven-township area of Steele, Traill, and Cass counties. In 1977, Avitrol FC Corn Chops-99, a frightening agent, was applied whenever needed to 31 of the most heavily damaged fields in this area. To monitor flock movement and feeding patterns, we tracked 15 radio-equipped adult male red-winged blackbirds during August 10–September 15. During 643 hours of monitoring, blackbird flocks containing instrumented birds spent 53% of their feeding time in sunflower fields vulnerable to damage—30% in unbaited fields and 23% in baited fields. The 15 instrumented birds fed in 48 sunflower fields within 18 miles of the roost, but 95% of 166 visits were restricted to fields within 9 miles.

The study did not support the claim of many growers that birds displaced from ripening sunflower fields merely move to other vulnerable fields. In 21 (62%) of 34 instances they moved to stubble fields and other types of feeding sites. In recent years, however, local sunflower fields have tripled in size, and narrower rows and heavy fertilization have produced denser canopies, which obscure the baits and bait-affected birds. As a result, blackbirds use the denser-canopied fields more intensively for loafing, and fewer suitable alternative feeding sites are available. These changes make it more difficult to frighten birds from ripening sunflower fields.

**Blackbirds and Crows Damage Sprouting Corn in Kentucky.** To determine the amount and extent of blackbird and crow damage to sprouting field corn in Kentucky, investigators surveyed 270 corn fields in 36 randomly selected counties in the spring of 1978. After sprouting began, five 55-yard sections of corn row in each cornfield were sampled every other day (939,000 observations of 219,000 sprouts) until the corn was no longer susceptible to bird damage. An average of 0.15% of the sprouts were destroyed. No bird damage occurred in 73% of the fields, and the greatest damage sustained by any one field was 5.8%. Damage



Large flocks of red-winged blackbirds feeding on ripening sunflowers near Hope, North Dakota. These depredations are of serious concern to growers. *Photo by Olin E. Bray.*

by insects (0.21%) and by weather (0.17%) exceeded bird damage. Miscellaneous damage amounted to 0.05%.

Although the survey indicates that bird damage to sprouting corn is usually negligible, it can be relatively severe in some fields. Most damage occurs along field edges near trees or brush when corn sprouts are less than 4 inches high. Sprouts may be vulnerable to damage for 3 weeks after germination, depending on growing conditions. Grackles and crows, the main depredators in the Southeast, dig up newly germinated corn by chiseling dirt from around the sprouts with their beaks until the developing corn embryos are uncovered. In shallow plantings, birds also tug at sprouts to reach the corn seed. Only a few of the 254 farmers contacted felt it necessary to control losses to birds and only 3 used Mesurol, a bird repellent registered for treatment of corn seed.

**Survey of Bird Damage to Ripening Field Corn in Kentucky and Tennessee.** To determine the extent of blackbird and mammal damage to ripening field corn, we surveyed 268 0.5-ha plots in 23 counties of Kentucky and 170 plots in 13 counties of Tennessee in the fall of 1977. Plots were randomly chosen in a manner to ensure that counties with high corn acreages were likely to be surveyed.

In Kentucky, blackbird damage to ripening corn averaged 0.48%, or about 609,000 bushels worth \$1.2 million out of a total crop valued at \$253.8 million. Damage in Tennessee averaged 0.39%, or about 185,000 bushels worth \$380,000 out of a total crop valued at nearly \$97.3 million.

Although relatively minor, bird damage has increased in both States since earlier surveys. In Kentucky, mean bushel-per-acre loss was estimated at 0.3 in 1970, 0.1 in 1971, and 0.4 in 1977. The percentages of corn ears opened by birds were 2.5 (1970), 1.9 (1971), and 5.0 (1977). In Tennessee, the mean bushel-per-acre loss to birds amounted to 0.1 in 1970 and 0.2 in 1977. Birds opened 1.6% of corn ears in 1970 and 8.1% in 1977. Damage by mammals (mainly raccoons) was also negligible, averaging 0.17% in both States and representing losses of about \$430,000 for Kentucky and \$165,000 for Tennessee.

Although the overall damage by birds and mammals to ripening corn in Kentucky and Tennessee during 1977 was estimated to be 1,114,000 bushels valued at nearly \$2.2 million, the loss per acre is too low to justify the use of most damage control techniques. However, damage in a few sample plots was sufficiently high to warrant the use of Avitrol FC Corn Chops-99, a frightening



Blackbird damage to maturing field corn can be locally severe. These birds characteristically peck the center of dough-stage kernels, leaving a shredded cornhusk. *Photo by Jon F. Heisterberg.*

agent registered for this purpose.

**Increased Growth of Undamaged Kernels May Partly Compensate for Bird Damage to Maturing Field Corn.** The response of maturing field corn to simulated bird damage was measured in Ohio in 1975 and 1977. In both years the loss in grain production caused by bird damage to maturing corn kernels was related to the number of kernels damaged, the maturity of ears at time of damage, and the amount of associated secondary damage (e.g., mold). These studies suggested that, in the absence of secondary damage, increased growth of undamaged kernels may partly compensate for bird depredations and that the degree of compensation depends on the maturity of the ears sustaining the damage. Most kernels destroyed by birds have not fully matured and therefore do not contain all their potential biomass. Thus, a portion of the potential biomass may be channeled into the re-



Bird damage to sprouting corn, such as uprooting of sprouts by grackles, reduces crop stands and production. *Photo by Jon F. Heisterberg.*

maintaining undamaged kernels. These findings indicate that conventional techniques for surveying damage may overestimate actual losses.

**Effectiveness of Alternate Treatment Forms of 4-Aminopyridine for Reducing Blackbird Damage to Field Corn.** The dissatisfaction of farmers with the commercial 4-aminopyridine (4-AP) cracked corn bait (Avitrol FC Corn Chops-99) as a frightening agent for reducing blackbird damage to maturing field corn prompted Service biologists to compare the registered treatment with three alternate 4-AP treatment forms in three northern Ohio counties in 1976. They studied the effects of modified dilution rates and bait distribution within cornfields on the performance of 4-AP and on prospective hazards to nontarget birds.

The experiment indicated that in spite of rapid bait disappearance, caused by cricket feeding, a 3% dilution of 4-AP baits was significantly more effective in reducing damage than the 1% dilution (the registered form). More than 3 times as many blackbirds were found dead in fields receiving the 3% treatment as in fields given the 1% treatment, indicating an increase in the number of reacting birds. Mortality of nontarget birds was negligible. Although costlier, the 3% dilution of baits provided a more effective treatment form of 4-AP; the net benefit would depend on the potential damage by birds. Changes in method of application and perhaps in dilution rate are advisable to

make 4-AP treatment forms an effective, flexible, and economical management tool for reducing blackbird damage to maturing field corn.

**Corn Hybrid Resistance to Bird Damage.** Not all ears of corn in a field planted to one hybrid variety are equally damaged by birds. Similarly, experimental plantings of many hybrids in one field show marked differences among varieties in the amount of damage sustained. Physical characteristics of ears (length, height, angle, thickness of husk, extent of tip coverage by the husk) and characteristics of plant development (relative rates of tasseling and silking, number of leaves, yield) have been statistically analyzed to identify factors correlating with decreased bird damage. When the maturity of corn is controlled, the average length of the husk beyond the tip of the ear is the best predictor of susceptibility and resistance to bird attack. Comparing varieties with respect to this simple measurement would help farmers select the most suitable hybrids for planting in areas likely to receive bird damage.

**Commercial Bird Toxicant Reformulated.** Starlicide Complete is a pelleted, slow-acting starling toxicant registered for control of starlings at feedlots. Although the chemical and original pellet formulation were developed by the Fish and Wildlife Service, the manufacturer made major changes in the size and base formula for the pellets in 1976. The original pellets, composed of a mixed grain-alfalfa mash, were extruded through a die 0.16 inch (0.4 cm) in diameter and weighed about 70 mg each. The reformulated pellets were composed primarily of cornmeal extruded through a 0.19-inch (0.5-cm) die and weighed about 160 mg each. Service specialists were concerned that the reformulated pellets would be more hazardous to nontarget granivorous bird species and less acceptable to starlings, resulting in decreased effectiveness. Field and laboratory tests conducted between 1976 and early 1978 substantiated these concerns. The efficacy and hazard data persuaded the manufacturer to revert to a formulation similar to the original one, beginning with the September 1978 production runs.

**Registrations for Bird Damage Control Chemicals.** One of the most important tasks of the Animal Damage Control Program is to bring into practical use the materials and techniques developed by research to reduce wildlife-caused damage while protecting the resource and the environment. One of many methods of alleviating damage caused by birds involves the prudent use

of chemicals to reduce immediate problems and allow time for development of acceptable biological or cultural alternatives. Although the registration process required by the Environmental Protection Agency for approval of the use of chemicals is painfully slow and costly, the fruits of many years' labor are being realized by the Service and by cooperators in private industry. During the last 10 years the Service has been instrumental in obtaining or in helping other registrants to obtain the following registrations for bird damage control:

*DRC-1339* (Starlicide) is a commercially available, selective toxicant for reducing starling problems at feedlots and for controlling gulls that are displacing breeding colonies of other seabirds in the northeastern United States. Use of Starlicide to control gulls is restricted to governmental agencies trained in bird control.

*PA-14* is a biodegradable detergent registered for use only by governmental agencies to reduce concentrations of roosting blackbirds and starlings when the roosts constitute an imminent hazard to human health or cause serious economic and nuisance problems.

*Methiocarb* (Mesurol) is a carbamate insecticide with excellent bird repellent properties. It is now commercially available as two registered products to help growers protect ripening cherries and seeded corn from bird depredations.

*4-Aminopyridine* (Avitrol) is a commercially available chemical frightening agent that is useful in reducing bird damage to agricultural crops. Present registrations cooperatively developed by the Service and the producers are used to protect ripening sweet and field corn and sunflowers.

**Service Participates in Developing Test Methods.** As part of the Service's responsibility for conserving and managing the country's fauna and flora, researchers have been instrumental in the development of methods designed to test the efficacy and safety of pesticidal chemicals with regard to wildlife species. Because of the Service's extensive activities in environmental conservation and in animal damage control, it is in the unique position of having extensive experience and expertise in both. The Service has cooperated with the Environmental Protection Agency, the American Society of Testing and Materials, the American Institute of Biological Sciences, numerous universities, and many other interested groups in de-



veloping test methods that can be used for pesticide evaluation. The methods developed incorporate the best state-of-the-art procedures, along with a realistic view of the need for, and application of, each method. Continued participation of Service employees should further enhance this important research and should improve the science of developing methods that are reliable in predicting hazards and efficacy.

**Successful Vampire Bat Control Project Completed in 1978.** In 1968 the Agency for International Development (AID) provided the Denver Wildlife Research Center (DWRC) with funds for the development of techniques for controlling vampire bats, which are vectors of paralytic rabies. At that time it was estimated that 1 million cattle died annually in Latin America from vampire bat-transmitted rabies.

In the first 5 years of the project, biologists at the Center working with biologists in Mexico City developed two species-specific control methods:

*Topically treating vampire bats with diphenadione.*—Vampire bats are captured with mist nets that are set around corralled cattle or at cave entrances. About 1.5 cc of a vaseline-diphenadione mixture is placed on the dorsal surface of each captured bat and the bat is released. The bats return to their roost, and because they live in compact colonies, they pass the chemical from one to another through physical contact. The bats die after ingesting the chemical during grooming.

*Systemically treating cattle with diphenadione.*—Cattle are given intraruminal injections of 1.0 mg of diphenadione per kilogram of body weight. The drug is absorbed and circulates in the blood. Vampire bats that feed on a properly treated animal within 72 hours after treatment receive lethal doses of the drug.

Since 1974, the main objective of the project has been to help Latin American countries develop and initiate control campaigns by providing them with training and technical support. Training seminars were held in seven countries, and personnel from the Center have worked in every Latin American country suffering from vampire bat predation. As a result of these efforts, 13 nations now have their own self-funded vampire bat control programs.

The intent of this joint project was to help Latin nationals develop expertise in vampire bat control and then to encourage other countries to seek assistance from Latin American experts rather than from AID. Nicaraguan veterinarians have as-



Sustained baiting experiments with coconuts showed that a producer would receive \$28 for every dollar spent on control. *Denver Wildlife Research Center photo.*

sumed this leadership role and have assisted Costa Rica, Honduras, Guatemala, and Paraguay in developing vampire bat control programs.

The direct involvement of the Center and AID in this project ended in 1978 with the solution of the problem—a classic success story in man's effort to control wildlife damage without endangering wild populations.

**Crown Baiting with Anticoagulant Rodenticides Protects Coconut Plots from Rat Damage for 3 Years.** Rat damage to growing coconuts has been a significant problem in most areas where coconuts are grown. The problem is particularly acute in the Philippines, the world's leading supplier of copra. Banding trees and ground baiting with rodenticides are techniques often used for rodent control in plantations, but this type of control is costly.

Recently a 3-year study of crown baiting of coconut trees was completed in the Philippines. The objectives of the study were to determine whether a sustained baiting program was effective in lowering the rodent population and whether this type of control was economically feasible for small producers.

For treatment, plastic packets containing 0.025% warfarin with polished rice were placed in the palm fronds monthly. Records were kept on amounts of bait used, rat activity, numbers of fallen nuts, coconut production, copra value, and costs of rat control.

About 36,800 nuts were harvested in 1977 from the trees used in the study, an average of 8.36 nuts

per tree per month. This harvest represents a production averaging 2.8 times greater than that before treatment. On the basis of the current market value of copra (\$0.30/kg) and the increased production, we estimate that for every dollar invested in this control method, the producer would receive \$28.

**Zinc Phosphide Controls Feral Rabbits.** In 1970, 10 domestic rabbits were illegally released on Destruction Island, a 36-acre brushy, flat-topped, steep-sloped island off the Washington coast in the Washington Islands National Wildlife Refuge system. Ideal environmental conditions, including a lack of predators, resulted in such a rapid increase in rabbits that by 1974 they were causing noticeable destruction to vegetation, increased erosion problems, and disturbances of a major summer breeding population of burrow-nesting seabirds. Despite attempts to manage the rabbits by shooting them each year since 1974, the number of breeders steadily increased from about 50 in 1974 to about 150 in 1978. The 1978 summer population was forecast as 10 or more rabbits per acre, a density that could have a serious impact on habitat and wildlife. Population control appeared necessary; however, introducing predators was biologically unsound because of the burrow-nesting seabirds, shooting by itself was ineffective, and trapping and gassing did not seem feasible because of dense brush and rugged terrain.

Tests showed that the feral rabbits readily accepted fresh-cut apples and carrots and that apples and carrots treated with zinc phosphide were effective with caged domestic rabbits. Data on wildlife use of Destruction Island and information derived from research on jack rabbits and nutria favored the use of fresh bait with zinc phosphide. Other data indicated that baiting would be most successful between January and early March, at the onset of the breeding season when the rabbit population is relatively low and food is in short supply.

During March 1978 apple and carrot baits treated with 0.75% zinc phosphide were distributed on the island. Application involved pre-baiting with untreated apples and carrots placed in a line on flat areas and in selected spots on steep areas of the island, followed on the 3rd night by line- and spot-baiting with treated apples and carrots. All bait was collected and buried on the 5th day.

Pre- and post-treatment counts of rabbits and constant monitoring of wildlife indicated that the

control program resulted in a 97% reduction of rabbits and had no observable effects on nontarget animals.

Thirty-eight recovered rabbits were examined to obtain breeding data. All females were pregnant or had just had young (or aborted), indicating 100% breeding efficiency; litter size was 6.6 live embryos per female. Embryo aging data and the one young rabbit found indicated that January 10 was the onset of breeding and that some newborn rabbits could survive without parents.

Basically, the baiting program was safe and successful. The rabbits are now so reduced in number that shooting may control the population sufficiently to prevent serious damage to other wildlife and to wildlife habitat.

**Deer Readily Accept Herbicide-treated Forage.** Selective feeding by black-tailed deer of foliage treated with herbicides at rates normally used in forest management was studied in enclosures at Olympia, Washington. Two common food plants, Douglas-fir and salal, were sprayed with herbicides formulated in water, diesel oil, and mixtures of both. The herbicides tested were Esteron 245 (2,4,5-T), Esteron 99 Concentrate (2,4-D), Atrazine, Dalapon, Krenite, and Roundup.

Deer readily accepted herbicide-treated foliage and liked certain herbicide formulations better at higher application rates than at lower ones. A finding of special interest was that deer showed no preference between untreated Douglas-fir seedlings and those treated with 2,4,5-T at 1, 2, 3, 4, and 5 pounds per acre formulated in water. Diesel formulations on Douglas-fir and salal were not rejected, even though alternate food was available.

Deer showed no apparent ill effects from ingesting herbicide-treated foliage.

**Forest-animal Damage to Timber Resources in the Northwest—\$60 Million Annual Liability.** Defining damage by wildlife has long been an integral part of the Center's research program on forest-animal damage control in the western United States. Some of the undertakings have been fairly simple—describing injuries by various animals to conifers or determining through mail questionnaires that damage by pocket gophers affects over 120,000 ha of forest land in the Pacific Northwest. Conversely, quantitative surveys have taken considerable time, effort, and money but are now paying substantial dividends.

For example, a cooperative study was undertaken with Oregon State University to assess the economics of damage by wildlife in forest planta-

tions in Oregon and Washington. Measurements of tree growth, survival, and damage, recorded for up to 20 years on plantations throughout these two States, were provided for the study. From this data base, a sequential model was developed for appraising animal damage and assessing timber losses. Using current planting rates, costs, prices, and a 3% discount rate, we used the model to show that animals cause about \$60 million worth of damage to Oregon and Washington forests each year, representing a net capitalized reduction in timber resources of \$1.8 billion.

A publication is being prepared that shows how to use the model and how to determine whether damage control is economically justified in young stands of timber in the Pacific Northwest.

**Mountain Beaver Damage 275,000 Acres of Forest Lands in the Pacific Northwest.** Feeding by mountain beavers on conifer seedlings, saplings, and pole timber is one of the three most serious forest-wildlife problems in the Pacific Northwest. Such feeding can result in growth suppression, deformity, or mortality of trees and can occur anytime during the first 25 (or more) years after reforestation.

The magnitude of mountain beaver damage to conifers was determined under the auspices of the Northwest Forest-animal Damage Committee. According to a 1978 questionnaire survey of timber owners in the Northwest, beaver damage was occurring in 275,000 acres of forest lands, mostly in Washington and Oregon west of the Cascade Mountains. Damage was most prevalent in Douglas-fir stands (206,340 acres) and in western hemlock and mixed conifer stands (55,500 acres). New plantations received most damage, followed by sapling stands. The survey indicated that the major concern of forest managers was the lack of reliable methods of detection and control of damage.

**New Use Proposed for Zinc Phosphide in Hawaii.** Uncultivated land adjacent to sugarcane fields and macadamia nut orchards in Hawaii harbors rat populations. These rats damage cane and nuts at the field interface and invade maturing cane fields, then reinvade them after in-field rat control treatments. Studies designed to extend the use of zinc phosphide, registered for rat control in sugarcane, to include treatment of noncrop areas adjacent to cane fields and nut orchards were completed this year.

A single aerial broadcast application of bait-treated zinc phosphide reduced wasteland rat



Black rats are the primary target species of rodent control programs in Hawaiian macadamia nut orchards. Photo by John K. Crier.

populations by about 80% on a high-rainfall sugar plantation. No hazards to terrestrial fauna were observed. However, inadvertent contamination of a stream in the study area killed many aquatic crustacea. Attempts to establish untreated aquatic buffer zones for bait application by fixed-wing aircraft or helicopter were only partly successful. Results indicated that a buffer zone at least 150 feet wide was usually needed for both types of aircraft when wastelands in high-rainfall areas with permanent streams were treated.

The technique may therefore be most useful on macadamia orchards and low-rainfall plantations without flowing water. Efficacy evaluations for dry wastelands suggest that rat populations are reduced about 80% in areas adjacent to macadamia orchards and 88% in areas adjacent to sugarcane plantations. Treatment in dry areas posed no hazards to nontarget species in either crop.

Data warrant a 24-C registration for zinc phosphide baiting on wastelands adjacent to both crops. If the bait is kept out of streams, the treatment should provide cost-effective rat control with little hazard.

**Oat Baits Readily Accepted by Rats in Hawaiian Macadamia Nut Orchards.** Three baiting techniques (broadcast bait, in-tree bait, and burrow bait) and a tracking grease system were evaluated for resident black rats in a macadamia nut orchard near Hilo, Hawaii. Declomycin was added to nontoxic oat groat bait and tracking grease to label the rats consuming the bait or grease. Each treatment was applied to three randomly chosen 5-acre plots in the orchard. Rats were later trapped in trees in and adjacent to the plots and were examined for Declomycin labels. Treatment was applied at the end of the harvest



Dense vegetation in wastelands adjacent to Hawaiian sugarcane provides excellent rat harborage. *Photo by Larry F. Pank.*

season, when the nut supply was low.

Bait in trees, broadcast bait, burrow bait, and tracking grease labeled 97, 80, 76, and 70%, respectively, of the rats captured within the plots; differences among treatments were not significant. Few of the rats trapped two to four rows outside the plots were labeled by any treatment, and no treatment differences in areas of effectiveness were evident. Efficacy of all treatments appeared to be independent of size and sex of rats.

Results indicated that (1) nontoxic oats are readily accepted by orchard rats when preferred nuts are scarce, (2) bait placed in burrows or on the ground is as acceptable to rats as bait placed in trees, and (3) tubes containing grease and a toxicant offer a viable alternative to baits for control

of orchard rats.

**Noncrop Habitat Manipulation Reduces Losses to Adjoining Sugarcane.** Areas adjoining Hawaiian sugarcane fields are generally heavily vegetated gulches supporting large rat populations that damage cane along the field edges. The gulches also serve as reservoirs for establishment of in-field rat populations and for repopulation of fields between applications of rodenticides. This study was initiated to determine the feasibility of controlling sugarcane damage by the manipulation of noncrop habitat.

Each of three areas containing gulches and sugarcane fields received four treatments: (1) herbicide treatment in the gulch only, (2) herbicide treatment in the gulch and zinc phosphide treat-

ment in the field, (3) zinc phosphide treatment in the field only, and (4) no treatment. Zinc phosphide bait was applied by aircraft at a rate of 5 pounds per acre four times during the 26-month crop cycle, when the sugarcane was between 10 and 19 months old. Herbicide was applied by helicopter as often as required to control the gulch vegetation, starting when the sugarcane was 3 months old. Gulch vegetation and rat population levels were monitored throughout the crop cycle, and rat damage to adjoining sugarcane was assessed at harvest.

Herbicide treatment gradually reduced the mean height of gulch vegetation from 225 cm pre-treatment to 17 cm at sugarcane harvest (26 months later). Trapping and tracking-board data indicated that the herbicide treatment had little effect until late in the crop cycle, when about 50% fewer rats were recorded in the area treated with herbicide than in areas not treated. Differences in damage levels at harvest were not significant among treatments; however, damage was 33-43% lower in fields adjoining the herbicide-treated gulches than in fields adjoining the untreated gulches. The zinc phosphide treatment alone reduced damage by only 18 to 26%. Unexpected delays in harvesting caused a 7-month lag between the final bait application and harvest and thus reduced the efficacy of the zinc phosphide treatment.

The herbicide treatment was neither economically feasible nor environmentally desirable. However, the results of our study suggested that the manipulation of noncrop habitat can reduce reservoir rat populations. Other methods of habitat manipulation, such as forestation or grazing in idle noncrop areas, may result in dual economic benefits to the local sugar plantations.

**Florida Sugarcane Rodents Show Poor Acceptance of 2% Zinc Phosphide Baits.** The LD50 values of zinc phosphide were determined by oral gavage for three species of rodents that damage sugarcane in Florida. The LD50 values and confidence intervals obtained were: 33 (26-42) mg/kg for cotton rats, 39 (32-46) mg/kg for roof rats, and 42 (21-80) mg/kg for Florida water rats. Acceptance of 1.88% technical zinc phosphide on oat groats was laboratory tested on cotton and roof rats. Prebaiting with untreated oat groats appeared to enhance consumption by, and mortality of, roof rats but not cotton rats. Accurate consumption data could not be obtained because the quantities of toxic bait ingested were small and be-



A biologist tags a rat-damaged stalk in a Florida sugarcane field. Damage was assessed monthly in two fields over two crop cycles and reached a high of 53% of the stalks sampled in one field. *Photo by N. R. Holler.*

cause errors were introduced by bait spillage. Consumption estimates indicated that a mean of about two LD50 values was ingested on the day of greatest consumption by cotton and roof rats during a 4-day test period. Mortality of cotton rats was greater than that of roof rats: 18 of 27 cotton rats (67%) and 3 of 14 roof rats (21%) were killed.

**Time and Distribution of Rodent Damage to Florida Sugarcane.** Cotton, roof, and Florida water rats cause substantial losses to Florida sugarcane. Damage to sugarcane in one plantation was conservatively estimated at \$95 per acre. Knowledge of when rodent damage occurs during the sugarcane crop cycle is essential for development of control methods.

Cumulative rodent damage was assessed monthly in two Florida sugarcane fields for two crop cycles. Damage first became appreciable in August. Treatment before that date (as currently practiced) may not be necessary. A significant increase in the rate of damage after August was followed by a decrease in damage as harvest approached. There was a strong correlation between total number of stalks damaged and total number of internodes damaged ( $r = 0.852-0.991$ ). Rats tended to return to freshly damaged stalks but

made no selection between stalks with old damage and undamaged stalks. Stratified sampling indicated that damage may not be uniform throughout the field and that in-field treatment would probably be required to achieve adequate control.

**Aerial Photogrammetry Provides a Method for Defining the Dynamics of Black-tailed Prairie Dog Colonies.** Remote sensing by aerial photogrammetry is being evaluated as a means for plotting the distribution and size of black-tailed prairie dog colonies in South Dakota. Each year for the past 5 years, flights have been made in late September at an altitude of 7,920 feet above ground level (scale = 1:15,840). Kodak 2402 Plus X film is exposed and processed to provide high-contrast black and white 9- by 9-inch contact prints.

A mirror stereoscope equipped with a 1.8x objective lens is used to scan each stereo pair of photographs for the presence of prairie dog colonies. The colonies are visible as groupings of white dots representing soil mounds. The colonies are verified with a 3.0x objective lens and outlined with a fine-tipped pen. The outline of each colony is then transferred from the black and white print to 1:24,000 scale topographic maps (U.S. Geological Survey) by using a variable scale reflecting projector, which projects the print image onto the topographic map at the map scale. The acreage occupied by an individual prairie dog colony is then measured from the outline on the topographic map with a disc planimeter calibrated to measure in units of 0.1 acre.

Preliminary ground truth surveys indicate that colonies can be accurately located throughout the study area and that their acreage can be defined to within about 3% accuracy. The total cost is less than \$0.04 per acre, including the flight, the two sets of contact prints, and the time and manpower required.

**Black-tailed Jack Rabbits Feed Extensively on Cultivated Crops.** The farming areas in southern Idaho have a long history of crop damage by black-tailed jack rabbits. To determine how heavily jack rabbits rely on farm crops for spring and summer food, we compared the diets and population densities of rangeland jack rabbits with those of jack rabbits on cultivated areas. Jack rabbits concentrated near cultivated areas where crops were adjacent to rangeland. Jack rabbit densities were significantly higher near cultivated crops than on the isolated rangeland.

Where barley and crested wheatgrass plants

were available to jack rabbits, they were preferred foods and made up a large part of the spring and summer diet. Potato plants were not a highly preferred food. Therefore, on cultivated areas adjacent to rangeland, crop damage by jack rabbits could probably be reduced by planting potatoes in a buffer strip between the rangeland and the preferred grain crops. Plant phenology was a major factor in determining food preferences of jack rabbits collected on rangeland. In the spring, 85% of the rangeland diet consisted of grass. In early summer, grasses and forbs were eaten in equal amounts; and by fall, forbs and shrubs made up 71% of the diet.

**A 1974 Coyote Harvest Estimate for 17 Western States.** To help clarify the coyote damage and control controversy, we obtained coyote harvest estimates from representatives of Federal, State, and County predator control programs in each of the 17 western States. Additional fur and hunter harvest data from over half of the 17 States were also made available to us. These two sets of data yielded a total estimated kill of over 295,400 coyotes for 1974. Considering that data from several States were incomplete, this number appears to be low, although it is close to a 1946 estimate of 294,000. Mortality studies indicate that 88% of coyote mortality is man-induced, primarily by shooting. Much of this mortality is not recorded in hunter and fur harvest reports. The unreported kill is believed to equal or exceed the 295,400 recorded estimate. There is little evidence that man-caused mortality results in reduced coyote populations. The figures of the cooperative Federal-State Animal Damage Control (ADC), which were the most reliable, showed a 1974 ADC kill of 71,572 coyotes, or about 24% of the total. Fur and hunter harvests accounted for most of the remainder. Bounties (in a few counties in seven States) and local predator control programs contributed smaller numbers. When within-State variations were high, usually the most conservative estimates were used. It was estimated that 48,509 coyotes were taken in California, 44,632 in Nebraska, 35,862 in Kansas, 25,492 in Idaho, and 21,478 in Texas. With little information available, Arizona accounted for only 997 coyotes, North Dakota took about 3,900, and South Dakota about 6,800. Four of the five States reporting the highest kills were among the top six western States that reported the highest coyote populations in the annual predator abundance survey.

**Coyote Density-Food Base Studies.** Coyote

feeding patterns in Jackson Hole, Wyoming, during 1974-76 were similar to those found in comparable studies in the 1940's. Field voles, ground squirrels, and pocket gophers made up the bulk of the summer diet; over 85% of the winter diet consisted of carrion from dead ungulates, mainly elk. It is evident that the summer distribution and abundance of coyotes reflect the previous winter's distribution and abundance of elk. The number of elk dying throughout the winter appeared more important to the coyote diet than remains of elk killed by hunters in the late fall. There was little indication that abundance of summer prey influenced coyote abundance.

**Predator Control in Relation to Livestock Losses in Central Texas.** Records of the Federal-State predator control program for 1971 (before the poison ban) and 1973-75 (after the ban) were analyzed from 21 Texas counties, representing a cross section of operations in and adjacent to this country's most intensive sheep- and goat-raising area. A special data collection in 1975 showed that cooperative control measures protected only 40% (438,649) of the sheep and goats in the 21 counties on only 15.5% (3,441 square miles) of the total land area. Therefore, control tools were used on a far smaller land area than environmental groups had feared, although nonparticipating ranchers probably used some control methods too.

Losses of sheep and goats to coyotes and bobcats increased 47% from 1971 to 1974, then decreased in 1975 to 12% lower than in 1971. This erratic nature of livestock predation can be only partly explained by the 38% decrease in sheep and goat numbers between 1971 and 1976. Control costs averaged \$0.46 for each sheep or goat protected; the average annual loss to ranchers was 0.27%, with intensive predator control. The records indicated that large concentrations of livestock could usually be well protected, but predator control became difficult when sparse livestock populations were raised in uneven, brushy terrain. Despite this difficulty, an overall control cost-benefit ratio of 1:4.5 was calculated for 1975.

Losses reflected the availability of lambs from October to May when the weather in central Texas, unlike that in most of the West, is usually mild and allows an early lamb crop. The coyote kill may have reflected the intensive control during winter, when 36% of the 4-year total was taken. Only 13% of the coyotes were taken during the summer, when an abundance of wild food makes coyotes less susceptible to controls.

The data showed an inverse relationship between losses and weather: when precipitation was highest, losses to predators were low; during dry periods, losses to predators were high. This pattern suggests that abundant vegetation induces high populations of rodents and rabbits, which lessen predator pressure on livestock. Conversely, dry periods may support lower prey populations, thereby causing predators to turn to livestock in order to survive. Inasmuch as no specific data from the study area were available to substantiate this hypothesis, an overall intensive study is needed to unravel the complex environmental interrelationships between predators and livestock.

**Predator Response to Odor Attractants.** Steel traps and M-44 devices are widely used by the Services' Animal Damage Control (ADC) Program to control coyotes in livestock production areas. A wide variety of lures and baits are used to draw coyotes to these devices. However, few of these attractants have been systematically evaluated for effectiveness, species selectivity, and applicability to various damage control techniques. Field tests during fiscal year 1978 resulted in evaluation of 58 different odor attractants, exposure of 47,255 scent capsules yielding 8,091 coyote visits, and documentation of 9,474 behavioral responses. A modified scent-station technique was used to collect these data. Scented capsules were placed in the center of a series of 3-foot-diameter circles of sifted or raked soil located at 0.3-mile intervals along ranch roads. Scent stations were checked daily to record animal tracks, and rates of predator visitation to the different attractants were compared.

Geography, season, climate, changes in the odor properties of lures, and individual behavior are among the many factors that can cause variations in predator responses to odor attractants. In addition to determining the lures and baits most attractive to coyotes, the modified scent-station technique provided information on coyote behavioral responses to odors and on the attractants themselves. Daily coyote visitation rates indicated that the potency of lures did not diminish over a 5-day exposure period. Although the daily rates varied, coyotes paid as many visits to scent stations at the end of a 20-day period of exposure as at the beginning. Small changes in scent concentrations affected predators' responses to them. Most types of coyote behavior at stations were apparently elicited by the odors and not by the stations themselves (control stations in most tests



The toxic collar (above) designed to eliminate sheep-attacking coyotes was field-tested in Texas, Idaho, and Montana in 1978. The rubber collars contained 30 cc (about 1 ounce) of 1080 solution. When coyotes attack the collared lambs, they usually bite through the collar and receive a lethal dose of the toxicant. This collared lamb (top right) was killed by coyotes in a Montana field test of the toxic collar. The attacking coyote(s) bit through the collar and apparently received a lethal dose of the toxicant, since predation on this ranch ceased soon after the attack. This coyote (bottom right) was found 0.4 mile from the site of the attack 2 days after it attacked a lamb fitted with a collar that contained 1080 solution. Note that the animal had previously lost one front foot, presumably in a trap. Such peg-leg coyotes have a bad reputation for preying on livestock. *Photos by Guy E. Connolly.*

elicited few responses). The best lures were usually similar in rank in tests carried out in four different States. Geographical variations apparently resulted from interactions between odor properties and weather conditions. Some lures were most attractive at certain optimum temperatures. The advisability of testing lures before operational use was suggested by the results of these studies. A few of the test lures provided by ADC Program personnel ranked low when compared with other readily available attractants.

There was some evidence that specific age groups within predator populations are selectively attracted by certain lures. In one test, coyote pups were drawn to one lure, adults to another. Average monthly visitation to a base or "standard" attractant and to control capsules indicated pronounced seasonal variation. Some of the highest visitation rates occurred in the January-February mating season, even though coyote populations

are lowest at this time. Another peak occurred during June and July, when adults are trying to find sufficient food for their growing pups.

Some behavioral responses to the lures occurred more often during certain periods than during others. An apparent odor preference was detected in relation to sex in one experiment conducted in March. Adult female coyotes preferred a synthetic fetid food lure; males preferred a musky lure. These observations, as well as further analysis of our data, should prove useful to specialists in predator damage control and to research personnel.

**Toxic Collar for Selective Control of Sheep-killing Coyotes.** The toxic collar is the most selective method known for the control of coyotes that kill sheep. Coyotes that attack collared sheep usually bite the collars and receive a lethal dose of the toxicant.

In 1977 the U.S. Fish and Wildlife Service re-





ceived an Environmental Protection Agency (EPA) Experimental Use Permit to test the toxic collar with compound 1080. About 20 field tests were completed in 1978 in Texas, Idaho, and Montana. The first test in 1978 revealed design flaws in the collars, so changes were needed before field work could proceed. The redesigned collars became available in July 1978.

Although summary statistics on the 1978 field tests are not yet available, it is clear that the collar can take problem coyotes that have eluded all other means of control. In Idaho and Montana, where the collar was tested as the sole means of control, the trials often lasted for weeks or even months as collar after collar was punctured by seemingly inexhaustible numbers of sheep-killing coyotes.

It is usually not possible to find the carcasses of coyotes taken with the toxic collar, because the animals may travel considerable distances before they die. However, two poisoned coyotes were recovered in 1978. One was found some 2.5 miles, across rugged terrain, from a collar attack site in west Texas. The other, a female that had previously lost one front foot in a trap, was 0.4 mile away from the attack site on a Montana ranch. The teeth of both coyotes were stained pink by the dye (rhodamine B) from the collar solution.

We believe that the toxic collar can best be used to supplement, not replace, other means of damage prevention. If an effective, safe toxicant can be found, the collar may eventually be used to greater advantage by ranchers than by government trappers. After completion of the 1978 field tests, an application for EPA registration of the toxic collar for use in predator control will be considered.

**Conditioning Coyotes to Avoid Sheep.** Since about 1974 the use of illness-inducing chemicals, such as lithium chloride (LiCl), in sheep meat baits has sometimes been promoted as a means of reducing coyote predation on sheep. In theory, the coyotes would eat a simulated prey bait containing the aversive drug and thereafter would avoid similar baits. Moreover, the dislike of the bait is said to transfer to live prey, inhibiting future attacks on that prey.

Although this approach is an attractive concept, the evidence of its effectiveness is controversial and, in the judgment of biologists at the Denver Wildlife Research Center, unconvincing. In the hope that the aversive conditioning principle can be developed for field use, however, the Center is

studying it at both the Denver and Logan predator research stations.

Tests with LiCl at various doses produced the most effective bait avoidance at a level of 1 g LiCl per bait—far less than the 6-g dose recommended by some other workers. But later efforts to transfer bait avoidance to live prey were unsuccessful. Coyotes conditioned to avoid jack rabbit baits were each presented with another bait, a live jack rabbit, and a live chicken simultaneously. Even though these coyotes had never before killed rabbits, chickens, or other large prey, they readily killed both jack rabbits and chickens, their killing behavior seemingly unaffected by previous treatment with LiCl baits.

We hope to repeat these tests with microencapsulated LiCl. The microencapsulation is expected to mask the taste of the chemical and delay the onset of illness, thus increasing the amount of chemical absorbed by the coyote. The resulting illness should then be more severe and should induce a correspondingly stronger aversion than has developed in the animals tested thus far.

**Initial Field Test of Electric Fencing to Protect Sheep Shows Promise.** A field test to evaluate electric fencing for protecting pastured sheep from coyote predation was completed in 1977. After pen tests at the Denver Wildlife Research Center, two ranches in south-central North Dakota with a history of chronic coyote depredations were selected as test sites. Two 3- to 5-acre enclosures were constructed a few hundred yards apart at each test site. One enclosure consisted of a barbed wire fence adequate to retain lambs but not to exclude coyotes. The second enclosure was built of tightly stretched 12.5-gauge high-tensile smooth electric fencing wire. Six strands of wire were spaced 5 inches apart (total height, 30 inches) and alternate wires were grounded and charged. The fence was electrified with a 12-volt battery-operated New Zealand “energizer.” The materials and method of construction were those used by New Zealand and Australian sheep producers.

Ten lambs were placed in each of the two barbed wire enclosures and were checked every other day to determine if coyote kills had occurred. Coyote-killed lambs were replaced, as necessary, to maintain a total of 10 live lambs per enclosure. At the first ranch, 17 kills occurred in the barbed wire enclosure within a 2½ week period. The 10 live lambs were then moved into the nearby electric fence enclosure, and the fence was charged. Because nine lambs were killed by

coyotes within a 19-day period, a charged “out-rigger” or trip wire 10 inches high and 20 inches outside the test fence was erected to prevent coyotes from jumping over the electric fence. Three days later coyotes again entered the enclosure and killed four additional lambs. The trip wire was then removed and six additional wires, spaced at 6-inch intervals, were added to the initial 30-inch-high fence, resulting in a 12-wire enclosure 66 inches high. No further coyote predation occurred from the time this configuration was erected until completion of the study 60 days later.

Seventeen coyote kills were recorded on the second ranch within a 6-week period. Lambs were then moved into the adjacent electric fence enclosure. Electric fence configuration was identical with that found effective on the first study site, i.e., a 12-strand fence 66 inches high with alternating grounded and live wires. This enclosure effectively excluded coyotes; no further kills occurred during a 60-day observation period.

The electric fence described above appears to be a viable method for excluding coyotes from sheep pastures where depredations are chronic and severe. Under study is an alternate and less costly procedure that involves the addition of electric wires to existing woven-wire sheep fences. The number and spacing of electric wires are currently being tested in Kansas. Also being evaluated is the use of “Flexinet,” an electrified wire netting of lightweight polythene-stainless steel that is portable and quickly erected, to prevent coyotes from attacking sheep on the bed-grounds at night. It can also be used to confine sheep being grazed in wheat or stubble fields.

These tests will help define the potential of electric fencing and provide sheep producers with guidelines and recommendations for its use.

**Newly Developed Gas Cartridge Effectively Fumigates Coyote Dens.** For over 30 years the Service’s Pocatello Supply Depot has manufactured a gas cartridge that has been used to fumigate rodent and predator dens in agricultural areas where these animals are an economic problem. However, its current registration is only for rodents. Despite its long history of use, we know little about its efficacy for coyotes under laboratory and field conditions. As early as 1945, the Service recognized the need for a more effective cartridge and contracted with the Chemical Warfare Service (CWS) at the Army Chemical Center in Maryland to develop a better one. Studies conducted by the CWS were primarily chemical, and



A 5.5-foot electric fence field-tested in North Dakota was effective in preventing coyotes from killing sheep. *Photo by Samuel B. Linhart.*

the production of carbon monoxide from various types of pyrotechnic fumigants was compared. The CWS found that a cartridge composed of only two ingredients, sodium nitrate and charcoal, produced more carbon monoxide than did the eight-ingredient Service cartridge. These data indicated that the two-ingredient cartridge would be effective, but CWS supplied no animal data to support this finding.

Laboratory tests with coyotes at the Denver Wildlife Research Center showed that the two-ingredient cartridge was as effective as the Pocatello cartridge or a commercial cartridge known as “The Giant Destroyer,” which contains at least four ingredients. When equal amounts of each cartridge were tested, the time to death of the

coyotes was similar. In this respect, none of the three gas cartridges was superior to the others. However, as judged by animal reaction to the gasses produced by each cartridge, the CWS cartridge produced the least stress and the least irritation.

Pressurized carbon monoxide and chloropicrin were also evaluated. Carbon monoxide was less stressful to the animal than chloropicrin. It is perhaps the most humane agent to use as a fumigant, but the cost of putting this gas in a suitable pressurized cylinder is high (\$20 to \$30 for a disposable cylinder containing enough carbon monoxide for one den). Cylinders pressurized up to 1,000 pounds per square inch could also be dangerous to transport over rough terrain, and their size and weight make them impractical for field use. Chloropicrin was considered unacceptable because of the severe discomfort it causes to the animal.

These laboratory tests showed that the gas cartridge had sufficient promise to warrant field testing. Since the cartridge produces a toxic gas (carbon monoxide), tests were prohibited on public lands by Executive Order 11643. Personnel of the Denver Wildlife Research Center and Animal Damage Control cooperated in evaluating the cartridge in areas that were predominantly deeded land.

Animal Damage Control personnel routinely locate and destroy dens as a means of livestock damage control. Fumigation is normally conducted by aircraft in conjunction with aerial hunting; either the aircraft crew or a ground crew treats the dens. Animal Damage Control personnel in California, Oregon, Texas, Wyoming, and Nebraska participated in the gas cartridge tests in the spring of 1978. One county trapper in Carbon County, Wyoming, also tested the cartridge.

When a coyote den was located, the small microphone of a listening device (consisting also of a speaker and connecting electrical cable) was usually inserted as far as practical into the den to determine whether it was occupied. When a den was known to contain pups, all exit holes but one were plugged with dirt, a cartridge was attached to a metal rod, ignited, and inserted as far as possible into the den, and then the remaining hole was plugged. A half hour to an hour later, the den was opened and, when practical, was dug out to retrieve the pups. Dead pups were sometimes recovered with a wire. When dens were known to be complex and extensive, two or three cartridges

were used.

Ninety-eight dens in the five States were treated; 500 (97%) of the 521 pups in the dens were killed. Dens where all pups were not killed were usually extensive and all pups could not be retrieved. It is also possible that not all dead pups were retrieved from some of the extensive dens that could not be opened. Six adult female coyotes were also killed in the dens.

The data obtained from this study will be used to support an application to the Environmental Protection Agency for registration of the gas cartridge.

**Tranquilizer Trap Tabs.** More than 13 years ago, the Center reported the benefits of tranquilizer trap tabs for reducing trauma and injury to predators in steel traps. However, diazepam, the chemical of choice at that time, did not become commercially available. Within the past few years, research has been undertaken to find a replacement. One commercially available chemical that has given good results in both field and laboratory tests is propiopromazine hydrochloride. However, it is effective for only 24 hours. This time limit is acceptable if animals are being captured for use in the laboratory or for mark-and-release studies. But laws in several States require trap inspection only every 48 hours, a more practical interval for field work. By combining propiopromazine with chlordiazepoxide we obtained an effective duration of 42-48 hours in laboratory tests. Limited field trials indicate that the combination is also effective under field conditions. After additional field evaluations, a decision will be made about requesting the Food and Drug Administration to register these chemicals for operational use.

**Stored Sodium Monofluoroacetate (1080) Solutions Remain Toxic for 1 Year.** Statements in the literature indicate that solutions of 1080 deteriorate when stored. We have attempted to gain more information about this deterioration by conducting toxicity bioassays. In relation to the toxic collar for sheep, there are two primary reasons for wanting additional data on the stability of 1080 solutions. First, if 1080 toxic collars are used under field conditions, the instability of 1080 would limit the effectiveness of the collars to a specific period of time. Second, some of the 1080 collars could be lost by coyotes carrying away dead sheep and could be a potential hazard if found by persons unfamiliar with them.

Aqueous solutions containing 1080 (10 mg/ml



Cotton rats cause extensive damage to young corn plants in Latin America. In this laboratory experiment, the repellent activity of selected agents was evaluated when the rats were exposed to topically treated seedlings. *Photo by Stephen A. Shumake.*

active ingredient), plus 1 mg/ml rhodamine B to serve as a marker, were placed in individual rubber packets and stored under three conditions: outdoors, in the laboratory, and in a refrigerator. At five weekly intervals after formulation, an LD90 dose of 1080 held under each storage condition and a similar dose from freshly prepared 1080 were administered intraperitoneally to groups of 20 mice each. After 5 weeks the dose of 1080 was lowered to obtain 20 to 40% mortality, and bioassays were conducted monthly for 1 year. Statistical analysis of the mortality data showed that there was no difference in toxicity up to 1 year between stored and freshly prepared 1080 solutions. Thus, our data do not support statements in the literature that solutions of 1080 deteriorate. The implications of these findings are that 1080 collars remain toxic for at least 1 year and should be handled with extreme caution.

**Protecting Corn Seedlings from Cotton Rat Damage.** Cotton rats cause extensive damage to early-growth corn plants in many farming regions of Latin America. In some areas, damage is often so severe that fields must be replanted several times before adequate corn stands are raised. The Denver Wildlife Research Center, under a joint USFWS-AID agreement, has started a program to develop better methods of rodent control for these

nations. Currently, research is aimed toward the assessment of repellent chemicals that can be used to prevent damage to corn seedlings.

Several candidate repellents (Di-Syston, Furidan, methiocarb, Arasan, dimethoate, and Guthion) were evaluated in a standard bioassay. Individual cotton rats were offered a choice of 25 treated and 25 untreated whole wheat seeds. An index of repellency was obtained by comparing the numbers of seeds consumed. Both Di-Syston and Furidan treatments produced over 90% repellency in this test. However, repellency was sharply reduced when the same treatments were topically applied to young (6-inch-high) corn plants.

In later tests with cotton rats exposed to treated plants, the adhesive binder (Rhoplex AC-33), used for plant spray treatments, produced slight repellency. The addition of sweet-tasting compounds (glucose and saccharin) further increased the repellency of Di-Syston. These data suggest that treatments that alter the taste and texture of corn seedlings, used in conjunction with sublethal chemicals, may be helpful in protecting growing plants.

**Aversive Conditioning for Control of Animal Damage.** Conditioned taste aversion occurs when an animal eats a new food, receives a dose of an illness-inducing drug, and shuns the offending

food thereafter. If the taste of the food is sufficiently unlike that of the normal diet, and if the drug dosage is adequate, the aversion response can occur after only one experience.

To evaluate the feasibility of applying the concept of conditioned taste aversion to problems of animal damage control, scientists at the Center began the following studies: (1) an evaluation of conditioned taste and color aversion effects in *Quelea quelea* (an African weaver finch), with methiocarb as an aversive drug and hulled proso millet seed as bait; (2) tests of conditioned prey aversion in coyotes, with lithium chloride as an aversive drug and live lambs as prey; and (3) an assessment of conditioned aversion to growing rice, induced in ricefield rats by applying selected drugs (lithium chloride, cyclophosphamide, red squill, and copper sulfate) to rice bait.

Although results have been variable, all species tested showed conditioned aversion responses. Methiocarb, for example, can produce aversion to untreated millet in quelea for up to 14 days. Some coyotes can be conditioned to avoid live lambs as prey for up to 7 days after a lithium chloride baiting trial. Ricefield rats show aversion to the taste of sodium saccharin-flavored material for 3 weeks or more after they consume sufficient levels (150 mg/kg or more) of lithium chloride in their drinking water.

These data point to the validity and generality of the conditioned aversion process for many vertebrate pest species. However, the logistics and cost benefit ratios of bait applications and the feasibility of long-term damage reduction need to be investigated.

**New Developments in Bird-resistant Sorghums.** Bird damage to sorghums is so severe in some parts of the world that only bird-resistant varieties survive until harvest. Unfortunately, the tannins that produce astringency and thereby repellency also reduce the digestibility and palatability of the foods containing them. A worldwide campaign to discourage consumers from buying these bird-resistant varieties is now in progress. This campaign has created problems for farmers who are able to grow only these varieties. Farmers in arid regions where wheat or corn cannot be grown experience even greater hardship—they have no choice but to grow a crop with low market value.

Substantial progress is being made toward solving this dilemma. Investigations at the Center and occasional reports in the literature revealed that some high-tannin varieties differed from the more

common bird-resistant hybrids. Tannin development in these varieties was similar to the development of tannins in some fruits, such as bananas, peaches, plums, and persimmons. For example, bananas are astringent when immature but lose this property at maturity. In the immature stage, tannin molecules “grow” (polymerize) to the optimal size for cross-linking with mucoproteins in the mouth, but during ripening they become so large and bulky that they are no longer active. These fruits are not criticized as being nutritionally inferior.

These exceptional varieties also appear to have characteristics resembling those of a class of tannin-containing sorghums (“Group II”) that Purdue University distinguished as having excellent nutritional qualities. Laboratory investigation indicates that Group II sorghums have tannin properties similar to those of the fruits mentioned here. This finding means that varieties can be produced that have good astringent characteristics during the immature stage, when bird damage is greatest, but have excellent nutritional qualities when they are mature.

The recognition of these properties provides a framework for bringing relief to embattled sorghum growers around the world. The Center is collaborating directly with Purdue University and indirectly with two other agricultural schools in an intensive effort to develop varieties that have optimal Group II characteristics.

**Effects of Formulation Modifications on Coyote Response to Attractants.** A synthetic fermented egg (SFE) coyote attractant, developed at the Denver Wildlife Research Center, has been a good model for evaluating the effects of formulations in eliciting specific behavioral responses from coyotes. The odor quality of SFE can be significantly changed by altering one of the four basic odor properties. Each property is associated with a specific class of compound (i.e., fishy from amines, fruity from esters, sweaty from fatty acids, and sulfurous from sulfur compounds). Modifications were made by increasing the concentration of one class of compound to the level at which the odorant being added is first detected. These modifications, here called SFE-fruity, SFE-fishy, SFE-sweaty, and SFE-sulfurous, each elicit different behavioral responses from coyotes. In field tests, differences in such responses as digging, scratching, pulling, urinating, and rolling were observed. Intensification of certain responses is important in various control methodologies

(e.g., pulling for the M-44 cartridges and digging for trapping). Knowledge about specific modifications will make it possible to provide a greater selection of lures for control applications such as census techniques, drop baits, trapping, and use of M-44's.

In addition to the specific odor qualities of SFE, such factors as volatilization and weatherability can influence effectiveness under field conditions. By decreasing the rate of volatilization, the effective duration of SFE and other lures can be increased. This rate can be decreased by the use of controlled-release matrices. Three types of matrices (i.e., a paste, a solid, and a liquid) have been developed for use with coyote lures. One of these formulations has also been prepared as an aerosol (for convenience). Laboratory tests have shown these matrices to be effective in increasing the duration of odor qualities of SFE. Limited field tests have confirmed their usefulness.

Thus, a selection of standard formulations are available for various applications and climatic conditions. These formulations and the instructions for their use are being made available to animal damage control operators throughout the United States.

**Radio-tracking Device for Sea Turtles.** Hatching loggerhead turtles captured in September 1977 were reared in saltwater aquariums by the National Marine Fisheries Laboratory, as part of a pilot study to determine the feasibility of increasing sea turtle populations with released stock. Researchers at the Marine Fisheries Laboratory suggested that release of nursery-reared juveniles could significantly boost the dwindling populations of sea turtles. However, a monitoring technique had to be developed to determine whether nursery-reared stock can survive in the wild.

No one had ever followed a sea turtle for an extended period of time. The Marine Fisheries Laboratory therefore contacted electronics personnel of the Denver Wildlife Research Center for assistance in developing a radio frequency transmitter for attachment to juvenile turtles. Inasmuch as radio frequencies cannot be transmitted through seawater, a small transmitter was designed into a plastic bubble 1.5 inches in diameter, which was attached to a turtle's shell with a short nylon line. The transmitter would then emit radio signals whenever the turtle swam near the ocean's surface and the bubble floated.

Twelve juvenile turtles were instrumented and released offshore at Biloxi, Mississippi, in July



Releasing a Pacific Ridley turtle instrumented with a wildlife transmitter inside a plastic bubble to test the feasibility of radio-tracking sea turtles. *Photo by A. Lawrence Kolz.*

1978. These nursery turtles weighed about 1 pound and were 7 to 9 inches in diameter. The radio signals were tracked with a specially instrumented Cessna aircraft.

The tracking results are most encouraging for continuing the turtle-rearing program. Nursery turtles were located swimming in the Gulf as far as 70 miles offshore. They appeared to be healthy and swimming vigorously over a 10-day tracking period.

**Determination of Sodium Cyanide Residues in Vegetation and Soil.** A recently developed analytical method for sodium cyanide was used in a study to assess environmental residue levels resulting from use of the M-44 cartridge. Although sodium cyanide is extremely toxic, its use in the cartridge has not been considered environmentally hazardous because of the instability of the chemical and restricted use of the cartridge. However, requirements of regulatory agencies necessitated determination of sodium cyanide persistence in plants and soil.

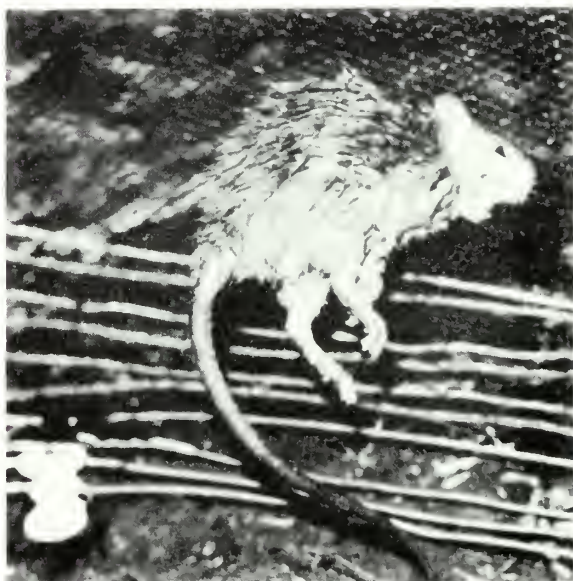
In the study, sodium cyanide from a cartridge was applied directly to randomly selected square-foot plots of vegetation or soil. The analysis of samples collected from plots at scheduled intervals showed that residue levels in vegetation decreased rapidly within 24 hours and were below detectable



These six rice-field rats are trying to escape an enclosure having a 3-wire electrode system and a nonelectrified vertical barrier designed to prevent rats from invading rice fields. *Photo by A. Lawrence Kolz.*

levels after only 2 days. Residues in soil also decreased rapidly for 2 days after application, then leveled off at a range of 0.5 to 6.0 ppm after 2 weeks, and 0.1 to 0.6 ppm after 6 weeks. These low levels indicate that environmental contamination from the M-44 cartridge is highly unlikely. Accidental discharge of sodium cyanide from a cartridge would probably be so thinly dispersed that its concentration in vegetation or soil would be considerably less than the trace amounts found in test plots. Since an average of one cartridge (containing less than 1 g of sodium cyanide) per 10 acres is the normal application rate, hazardous accumulations of sodium cyanide are not expected to occur.

**An Analytical Method for the Determination of Warfarin Residues.** Warfarin is an anticoagulant rodenticide that is being used experimentally for control of rice-field rats in the Philippines. The Agency for International Development, through cooperative agreement with the Center, is studying the occurrence of warfarin residues in rice plants, soil, and water from areas under sustained baiting programs. Hence, an analytical method to measure warfarin residue levels in these materials was required. Since warfarin is not registered for agri-



This rice-field rat has just been shocked as it attempted to escape from a high-voltage enclosure consisting of a perimeter grid of horizontal wires. *Photo by A. Lawrence Kolz.*

cultural use in the United States, a suitable analytical method was not available. However, chemists at the Center developed a technique for



such analysis, which involves treatment of warfarin with methyl alcohol and sulfuric acid to form a derivative that can be measured by gas chromatography. The derivative, which is detectable in nanogram quantities by electron capture gas chromatography, allows the detection of 0.1 ppm warfarin in plants and soil, and 0.01 ppm in water.

**Electric Barriers for Rats.** Prototype designs of high-voltage electric barriers are proving to be effective for preventing rats from invading rice fields. The success of this research will probably depend on whether the average Filipino farmer will be able to afford the barriers. Simplified barriers constructed of low-cost native materials are therefore being developed and tested. Even with cheaper materials, it will probably be necessary for several farmers to group together and fence large areas, if the method is to be cost effective.

Electric barriers inherently have a number of desirable characteristics. They can be designed to be nonlethal to humans, do not contaminate the environment, provide a stimulus to which animals cannot adapt, can be energized only when needed, and apparently can even develop avoidance behavior in animals.

**A New Wildlife Marker: Color-coded Plastic Particles.** A small plastic chip, originally developed for the explosives industry, offers a new way to mark wildlife or baits. The plastic chips, about the size of a grain of fine sand, contain colored layers that can be arranged differently in

each lot manufactured. Varying the number and combinations of the 10 colors available yields millions of usable codes. A 30X-100X magnifier is used to read the code.

Research conducted with blackbirds and starlings has shown that application of the particles in a sprayed adhesive marks birds for at least 3 months. Since one layer of the particle is fluorescent, examination under ultraviolet light immediately reveals whether a bird is marked. Theoretically, thousands of blackbirds in a single roost could be marked with an aerial spray. Field trials to test this concept are being planned. Mass marking would advance our understanding of the population dynamics of certain avian species, which previously could not readily be marked in large numbers.

Studies with marked baits have shown that mice, rats, ground squirrels, coyotes, starlings, and red-winged blackbirds readily accept baits containing these markers. Digestive tracts and fecal deposits can be quickly scanned for the particles with an ultraviolet light. Another layer of the particles is ferromagnetic. Thus, liquids, suspensions, and powders can be quickly checked by passing a magnet through or over the sample to recover particles present. The particles remained intact in all species tested.

The potential usefulness of this marker in the field of wildlife research is great. The particle's unique code, ease of detection and recovery, and durability make it a breakthrough in the field of wildlife marking.

## Environmental Contaminant Evaluation

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### COLUMBIA NATIONAL FISHERIES RESEARCH LABORATORY

**Acute Toxicity of Benomyl, Trifluralin, and Picloram to Freshwater Organisms.** Benomyl, trifluralin, and picloram are pesticides used extensively in agricultural areas throughout the United States. Benomyl is a fungicide used on rice in the South; trifluralin is one of the more widely used pre-emergent herbicides for weed control in soy-

beans and cotton; and picloram is used to control Canada thistle and larkspur in the intermountain areas of the West and multiflora rose in the Midwest and South. Benomyl was the most toxic of the three chemicals to fish and invertebrates, followed by trifluralin and picloram. Benomyl was extremely toxic to all life stages of channel catfish (96-hour LC<sub>50</sub>, 5.6-29 µg/l), and less toxic to different life stages of rainbow trout (96-hour LC<sub>50</sub>, 120-310 µg/l). The results suggest that this fungi-



Effects of acute Kepone intoxication in fathead minnows exposed to 73 mg/l for 48 hours. Fish acutely exposed to Kepone exhibited broken and dislocated vertebrae. Photo by D. R. Buckler.

cide could be particularly hazardous to catfish in natural systems or fish-farming operations adjacent to rice fields. Trifluralin was more toxic to rainbow trout than to channel catfish, and picloram was slightly more toxic to small channel catfish than to rainbow trout. These studies suggest that contamination of aquatic habitats by these chemicals during the spawning season could reduce the survival of young fish.

**Kepone-Mirex Research.** The structurally related organochlorine insecticides, Kepone and mirex, are common contaminants in aquatic habitats. Kepone is a major contaminant in the James River in Virginia, and mirex is an insecticide for fire ant control in the southeastern United States, where residues have been reported in fish from natural waters. Recently mirex residues have also been reported in fish from the eastern Great Lakes region.

Chronic exposure of fathead minnows to Kepone at concentrations of 3.1  $\mu\text{g/l}$  or higher resulted in reduced growth and survival, but mirex caused no effects at concentrations as high as 34  $\mu\text{g/l}$ . Kepone was acutely toxic to fathead minnows; mortality and dislocated vertebrae appeared at concentrations as low as 10  $\mu\text{g/l}$ . Kepone concentrations that reduced growth and survival were in the range of those reported to exist in natural waters in the Hopewell, Virginia, area.

Biochemical studies focused on backbone development after chronic exposure to the chemicals. Fry of fathead minnows were continuously exposed to Kepone (13-312 ng/l) or to mirex (1.6-34  $\mu\text{g/l}$ ) for 120 days. Neither chemical affected growth, reproduction, or survival at these concentrations, but backbone composition was significantly altered. Collagen, the protein organic matrix of bone, was decreased by Kepone concentrations as low as 70 ng/l. Kepone could alter bone integrity and mechanical properties in fish because collagen fibrils are responsible for bone structure and strength. Furthermore, both Kepone and mirex significantly altered collagen metabolism in the swim bladder; Kepone induced changes at 70 ng/l and greater and mirex at 2.6  $\mu\text{g/l}$  and greater. Because collagen is responsible for the elasticity and mechanical properties of the swim bladder, chemical-induced alteration in collagen fibrils could alter swim bladder function and adversely influence hydrostatic responses in fish. On the basis of these two studies, we believe that Kepone presents a more serious environmental problem than mirex because concentrations of Kepone that induced changes in bone composition were very low in relation to acute toxicity and water solubility—and were lower than those reported for the James River and Bailey's Creek, Virginia. It is unlikely that mirex exposure concentrations that induced biochemical responses would occur in aquatic habitats.

Although Kepone is an organochlorine insecticide, analytical procedures that should detect this insecticide in fish are inadequate. Samples of fish from the James River and from Chesapeake Bay, which were contaminated with Kepone, did not show the residues expected. Fish exposed to  $^{14}\text{C}$ -Kepone in the laboratory did accumulate residues, but 90% of these consisted of an uncharacterized metabolite. Kepone appears to be bound to some natural biochemical of fish, and therefore is not detectable by routine analyses used in monitoring of fish.

The detection of mirex in the Great Lakes, its widespread use for fire ant control in the southeastern part of the United States, and the structural similarity of mirex and Kepone prompted us to undertake detailed residue dynamics studies on mirex. We found no significant degradation products of mirex in fish, but the fish accumulated large quantities of mirex, which were excreted slowly. The half-life of mirex residues in fish maintained in untreated water was 56 days. Both Kepone and mirex appear to be resistant to degradation in hydrosol.

Kepone inhibited the metabolic activity of freshwater heterotrophic bacteria at water concentrations greater than 1.0 mg/l. We measured the dark uptake of  $^{14}\text{CO}_2$  by heterotrophic bacteria and estimated production of microbial biomass. At Kepone concentrations of 10 mg/l,  $^{14}\text{CO}_2$  fixation by heterotrophic bacteria was inhibited about 95% when compared with the control. Similar effects were observed in the  $^{14}\text{C}$ -glucose mineralization, growth curve, most-probable-number, and total viable plate count procedures.

#### **Ecological Influence of Chemicals Used in Management of Ponds and Irrigation Systems.**

Over the last 2 years, investigations in experimental ponds were directed toward three objectives: (1) evaluation of the role of rooted submersed aquatic plants in cycling of pond nutrients; (2) determination of the effects of plant growth suppression by herbicides on pond productivity; and (3) evaluation of limnological measurements that are most useful in assessing ecological changes induced by contaminants.

High densities of submergent rooted vegetation were suppressed by applying the aquatic herbicide fenac (2 mg/l) and dichlobenil (110 kg/ha) before the plants emerged, or by stocking grass carp. Heavy suppression of plant growth reduced algae, total productivity, and cycling of nutrients (nitrogen and phosphorus), and may have adversely affected fish populations. In ponds where grass carp had significantly reduced the density of rooted vegetation, the numbers of young largemouth bass were reduced, but their growth rate was increased. However, the presence of large masses of aquatic vegetation appeared to result in a reduction in the weight of adult largemouth bass.

The surface area of inland waters larger than 16.2 ha in the United States now exceeds 139,860 km<sup>2</sup>, of which 51,800 km<sup>2</sup> occur in the 17 western States. In addition, the United States has well over 300,000 linear miles of ditches and irri-

gation canals. Much of this aquatic habitat is suitable for growth of aquatic plants to nuisance proportions. Recent invasions by aggressive exotic species such as Eurasian water milfoil (*Myriophyllum spicatum*) and hydrilla (*Hydrilla verticillata*), which are difficult to control, have highlighted aquatic plant problems and greatly increased the need for control.

Herbicides have played a major role in attempts to limit aquatic plant infestations. Irrigation systems are particularly susceptible to such infestations, and herbicides are used extensively to control aquatic plants as well as terrestrial plants along irrigation ditch banks. Many irrigation canals support significant fish populations that may be exposed to toxic herbicides during plant control efforts. Since 1971, the Columbia National Fishery Research Laboratory has participated in cooperative research with the Bureau of Reclamation and the Department of Agriculture's Science and Education Administration-Federal Research, to investigate the effects of aquatic plant control in irrigation systems on fish and other aquatic organisms. This research has resulted in the formulation of management recommendations designed to reduce impacts on fish in irrigation canals, and in the development and use of less toxic and more degradable herbicides.

An innovative method for decreasing the impact of aquatic plant control on fish and other mobile organisms in irrigation canals may be to induce the animals to move out of canal sections scheduled for herbicide treatment. One possibility involves the application of copper sulfate. Earlier laboratory research showed that newly hatched rainbow trout avoided copper sulfate concentrations below 1  $\mu\text{g/l}$ . Preliminary investigations were begun in spring 1978 to determine whether rainbow trout fingerlings would avoid copper sulfate in simulated irrigation canals maintained by the Bureau of Reclamation. The source of water to the canals is irrigation water (temperature, 12° C) stored in Carter Lake, Berthoud, Colorado. Fish tended to concentrate in shaded areas in the canals, but those exposed to a metered concentration of 7  $\mu\text{g/l}$  of copper sulfate quickly moved to the furthest downstream shaded area. The copper sulfate treatment caused no fish mortalities. Background levels of copper ( $\text{Cu}^{++}$ ) in the water supply averaged 1.0  $\mu\text{g/l}$ .

Asiatic clams (*Corbicula* sp.) have become a serious problem in various freshwater systems in the United States, particularly in concrete-lined

canals. These mollusks, which were first discovered in the Columbia River in the 1930's, have become widespread and rapidly develop large populations; they clog intake screens, reduce discharge capacity in canals, and even colonize cooling system condenser tubes. Although molluscicides were believed to be a possible solution, a review of the available literature indicated that adults are highly resistant to chemicals and can isolate themselves from the environment for long periods. Promising control measures suggested from the literature include mechanical harvesting or environmental manipulation, such as changing temperature, water level, water flow, or water chemistry. Harvesting is possible because the clams are edible and considered a delicacy by some ethnic groups.

**Black Fly Control with Larvicides.** Black flies traditionally have been serious biting pests only in May and June in the upper New England States; however, multigeneration species have become prevalent and have extended the black fly season through October and advanced peak biting activity to July and August. Outdoor industries in upper New York and northern New England are said to be damaged in summer by the presence of the insects. The control of black flies by application of methoxychlor directly into streams several times per season is under consideration and has been practiced in New York.

We found that methoxychlor retarded growth and development of rainbow trout fry exposed to water concentrations of 1.2  $\mu\text{g}/\text{l}$  for 90 days. Yolk absorption was delayed at 3.1  $\mu\text{g}/\text{l}$  and halted at 6.9  $\mu\text{g}/\text{l}$ . The fry did not survive beyond 45 days at concentrations of 3.1  $\mu\text{g}/\text{l}$  and greater. Early life stages (eyed eggs and sac fry), however, were tolerant of extremely high water concentrations (50,000  $\mu\text{g}/\text{l}$ ) in 96-hour static tests.

**Crude Oil Processing—Potential Problem to Coldwater Fishes.** Underground deposits of crude oil in the western United States coexist with aquifers of fresh water, and fresh water is sometimes injected into the oil-bearing strata to force oil toward the well. In both situations, fresh water is pumped to the surface with the oil where the two are separated by treaters. The oil is transported to refineries and the water is either discharged or re-injected. An apparatus was developed to simulate an oil-treater for delivering various concentrations of organics obtained from Wyoming crude oil and dissolved in fresh water.

We determined that the organics present in dis-

charge waters from selected oil production sites in Wyoming are hazardous at concentrations below the allowable discharge limitation. Chronic exposure of cutthroat trout to the soluble phase of an oil-in-water mixture resulted in reduced growth at a total hydrocarbon level of 0.02 of the maximum allowable discharge established by Wyoming water quality standards.

**Stoneflies as Environmental Indicators.** Current knowledge of chronic toxicological impacts of contaminants on life cycles of aquatic invertebrates is mainly confined to the Crustacea and the Diptera. In view of the potential impact of energy development in the West, it is essential that we be able to assess the effects of environmental contaminants on the life cycle of important coldwater invertebrates.

*Pteronarcella badia*, a common and abundant stonefly in many western coldwater streams, is an important fish food organism. We collected large numbers of this stonefly, which has a 1-year life cycle, in the fall and held the naiads under different conditions of diet, temperature, and photoperiod through the winter and early spring. The naiads grew best on a diet of aspen leaves and detritus already colonized with bacteria and periphyton. The highest incidence of emergence was observed when the naiads were maintained under a controlled photoperiod and at a constant temperature of 10° C until June. When the water temperature was raised to 15° C in early June, emergence followed in 7 to 14 days. Although survival to emergence was only 34%, 82% of the survivors emerged. The smaller males emerged early, and mated repeatedly with more than one female. The adults lived 5 to 10 days, and several egg masses could be collected from a single female. The adults were most active at night and during the early morning; egg masses were usually deposited within the first few hours of the morning. Although we experimented with several methods for incubating stonefly eggs, none hatched.

Enough information was collected about this stonefly to enable us to measure the following events in the life cycle in a toxicological investigation: naiad growth, time of emergence, percentage emergence, number of matings, number of egg masses produced, and longevity of adults.

**Aquatic Contaminants and Hydrosol.** We developed a hydrosol biodegradation test to investigate the persistence of aquatic contaminants. Temperature, pH, dissolved oxygen, and nutritional state of the hydrosol significantly affected

the degradation of various contaminants. For example, di-2-ethylhexyl phthalate was not degraded in hydrosol at pH 5, or at 5° C, or under anaerobic conditions after 28 days incubation, whereas at higher pH's and temperatures, 70 to 80% of the phthalate was degraded. Perturbations of biogeochemical cycles in hydrosol by contaminants were also studied. At water concentrations greater than 1.0 mg/l, Kepone inhibited the metabolic activity of freshwater heterotrophic bacteria, and also blocked the degradation of Imidan, Dylox, and di-*n*-butyl phthalate in hydrosol.

**Polychlorinated Biphenyls and Related Research.** The environmental occurrence of polychlorinated biphenyls (PCB's) has been well documented. About 400 million pounds of PCB's are estimated to have already been discarded into the environment, and an additional 300 million pounds are now in use. Because many important aquatic habitats are being threatened by the presence of high concentrations of PCB's, we have begun to study the effect of PCB's on fish and aquatic invertebrates; and more importantly, we have begun to evaluate the effects of chemicals that are replacements for PCB's, to reduce the possibilities of the occurrence of similar contamination problems in the future. In partial chronic studies with rainbow trout, two PCB replacements for hydraulic fluids, Pydraul 50E and 115E, at concentrations of 10 to 50  $\mu\text{g/l}$  reduced growth, increased mortality, and caused the development of eye lens cataracts. Two components of the fluids, nonylphenyldiphenyl phosphate (NPDPP) and cumylphenyldiphenyl phosphate (CPDPP), were responsible for the chronic effects observed, whereas the other component, triphenyl phosphate, appeared to be mainly a problem under acute conditions. Formulation of phosphate ester mixtures with minimal amounts of CPDPP and possibly NPDPP would be more environmentally acceptable than the present formulations of Pydraul 50E and 115E.

**Biological Significance of PCB's in the Upper Mississippi River.** The aquatic and wetland habitats of the Upper Mississippi River support a diverse array of flora and fauna, many of significant economic and recreational value. The Fish and Wildlife Service has recognized that these important areas are being threatened by the presence of high concentrations of PCB's. However, neither the full extent of the problem nor the factors controlling the distribution of PCB's within these habitats have been adequately assessed. Although

PCB contamination poses an immediate threat to the viability of this riverine ecosystem, it also provides a unique opportunity to obtain a fundamental understanding of the dynamics of PCB's, and thus increase our ability to predict future problems prior to the crisis stage.

A multidisciplinary approach was needed to assess quantitatively the impact of PCB's on the important flora and fauna of the region. It was anticipated that a carefully planned and integrated hydrological, physicochemical, and biological data collection and analysis system would provide the information for the generation of a diagnostic model that would aid in assessing the environmental dynamics of PCB's in the Upper Mississippi River.

An intensive effort was begun to identify, compile, and document the information necessary to obtain a coherent overview of the physical and ecological dynamics of the Upper Mississippi River, and to document present sources and levels of PCB's in the River. Major areas covered include PCB transport and accumulation, hydrology and sediment transport, biology of the Upper Mississippi River, ecosystem modeling, and water quality. In addition, we are critically evaluating and synthesizing pertinent current and historical information relating to the physical characteristics, including hydrology and sediment transport, and the distribution and transport of PCB's in the study area (with emphasis on Lake Onalaska in Pool 7).

Only limited data are available for estimating the mass transport of PCB's within Lake Onalaska itself. On the basis of residue levels in carp from the main channel and from the Black River, it reasonably can be concluded that most transport is associated with the influx of water from the main channel into the lake. During the late spring, summer, and fall, wind stress probably is sufficient to keep the lake reasonably well mixed except in local areas. Under these conditions, the mean aqueous PCB level probably approaches that of the main channel, estimated earlier to be about 35 ng/l. During the winter and early spring, relatively large influxes of Black River water may occur, which would tend to decrease the available PCB residues. During summer and fall, severe thunderstorms in the watershed of the Black River may also greatly increase its relative contribution to the lake. The beds of macrophytes constitute a significant mass of material of potentially high adsorptive capacity within the



Beach seining for young-of-the-year striped bass in the Potomac River. Striped bass from four watersheds will be analyzed for contaminant residues and collagen content of their backbones; collagen is important to normal growth and development of fish and has been shown in the laboratory to be seriously affected by contaminants such as PCB's and toxaphene.

lake, and may represent a significant reservoir of PCB residues and route of transport to consumer organisms.

**Chemical Aspects of PCB's.** Polychlorinated biphenyls are widespread environmental contaminants, consisting of over 200 related chlorine-containing organic chemicals. Using an experimental activated carbon, we separated many PCB components and began studies of their respective toxicity to fish. Preliminary results indicate that some PCB components, especially 3,4,3',4'-tetrachlorobiphenyl, are more toxic than others. We suspect that its planar configuration, which is somewhat similar to that of dioxins, may be responsible for its greater biological activity. Using our most advanced analytical techniques, we have for the first time measured residues of 3,4,3',4'-tetrachlorobiphenyl in fish from the Hudson River, New York. The same analytical techniques can be used to determine whether additional PCB components similar to 3,4,3',4'-tetrachlorobiphenyl are present in fish and other aquatic organisms.

**Progress in Developing Analytical Methods for Selected Herbicides and Toxic Substances.** Analytical methods development was directed mainly toward three major groups of contaminants: (1) the herbicides trifluralin, picloram, and 2,4,5-T, because of their expanding use in soybean production, range management, and forest management,

respectively; (2) phenols, including pentachlorophenol, because of their presence in aquatic habitats and their presence on the Consent Decree list of the Environmental Protection Agency (EPA); and (3) dioxins, dibenzofurans, and planar PCB's, because they have been detected in fish and have relatively high biological activity.

Trifluralin, picloram, and 2,4,5-T are used extensively in the Nation's watersheds. Toxicological assessment of the effects of these chemicals on fishery resources has required early establishment of procedures for analysis of these chemicals in water and fish tissues. During 1978, analysts at the Columbia National Fishery Research Laboratory also worked closely with EPA to develop analytical procedures for a number of high-priority toxic chemicals known to contaminate aquatic habitats. We have developed methods for separating and analyzing 11 of the most important phenols, including pentachlorophenol, that could coexist in water, fish tissues, and sediments. In other analytical research, we have developed a complex separation procedure for analysis of dioxins and dibenzofurans that permits detection of as little as 0.01-0.1 part per billion in fish. These highly toxic chemicals are generally contaminants of other phenolic products produced during manufacture and are believed to be biologically active in trace amounts. A pooled sample of several species of fish collected by the Michigan Department of Natural Resources from the Tittabawassee River, a tributary of Lake Huron, contained a dioxin residue of 1 part per billion.

In the procedure developed for dioxins and other planar contaminants, we used gel permeation and carbon foam chromatography. We can now separate phenols and acidic herbicides from PCB's, amines, and neutral pesticide residues by using our recently developed alkali metal silicate chromatography.

**National Contaminant Monitoring Program.** Analysis of bottom feeding and predatory fish from 54 locations, representing most of the Nation's major watersheds, has continued to illustrate areas of contaminant accumulation. The most obvious problems concern the continued presence of the following contaminants: (1) DDT and related compounds, PCB's, chlordane, and a toxaphene-like substance in Lake Michigan and other Great Lakes; (2) toxaphene, chlordane, endrin, HCB, and DDT-related compounds in the lower Mississippi River; (3) PCB's and chlordane in the Interior Basin in Nevada; (4) toxaphene and

endrin in Gulf Coast streams; (5) PCB's and chlordane in the Northeast; and (6) chlordane and aldrin-dieldrin in Hawaii. DDT concentrations continue to decline, but PCB's, which are also ubiquitous, show no marked changes from recent years.

**Field Research Assessments and Activities Relating to Contaminants.** Eight field research stations were activated in fiscal year 1978 to complete the establishment of field research functions of the Columbia National Fishery Research Laboratory in eight major watershed areas across the country. All stations developed research liaison with the Service's Regional Offices and began gathering information on existing and potential sources of contaminants.

Intensive assessment of research needs was made by each Field Research Station. Sources of information on contaminants include Federal, State, and local agencies and river basin commissions, as well as academic institutions and special interest groups. Regional and area offices of the Fish and Wildlife Service were contacted first to obtain information and to establish contacts with other agencies. Other Federal agencies routinely contacted include the EPA, U.S. Geological Survey, U.S. Department of Agriculture, and U.S. Army Corps of Engineers.

Preliminary information on contaminant problems is already available from all of the Field Research Stations. Potential problems involve energy development, agriculture and forestry, industry, urban wastes, and mineral mining. Problems related to agriculture include herbicide and insecticide use and the effects of changing land-use practices—including increased grazing, increased irrigation, and the change to no-till or minimum-till cultivation. Forest management and silviculture also include the use of insecticides and herbicides, and pulp and paper production has secondary effluent wastes that can be hazardous to aquatic organisms.

Pollutants associated with energy resource development will become increasingly important as the United States strives toward energy independence. Coal mining, combustion, gasification and liquifaction, and mineral mining represent the largest potential contaminant problems on a national scale. Heavy metals in waste water from solution mining of uranium, brine wastes from petroleum wells, toxic drilling fluids, and oil seepage are all important regional problems.

Of major concern is the disposal of domestic

and industrial wastes. The chlorination and fluorination of municipal water supplies create potentially hazardous chemicals such as the trihalomethanes, which contaminate municipal water supplies. Disposal of municipal sludge (now occurring in some national forests) also poses a contaminant problem because of its heavy-metal content. Industrial pollutants enter streams from plant discharges and leakages from disposal areas.

Research initiated by the Field Research Stations included studies on toxicant effects, surveys of contaminants, and research to develop biological or biochemical indicators of contaminant effects in the field. For example, one of the stations is studying striped bass from four North Atlantic drainages that are subject to varying types and concentrations of contaminants. These studies will correlate collagen content and integrity of striped bass backbones with tissue residues, a correlation shown to exist in laboratory toxicological studies.

## **PATUXENT WILDLIFE RESEARCH CENTER**

**Evaluation of Environmental Contaminants of the Future.** New funding in late fiscal year 1977 increased consideration of the problems of the future: effects on wildlife of chemicals from mining and smelting, coal conversion, oil transport and oil spills, and effects of new chemicals used in forest, range, and agricultural insect control. In fiscal year 1978, about two-thirds of the research effort took a new direction, with the rest devoted to problems associated with hard pesticides still in use or being phased out, where current evaluations are needed for decision making. The principal effort is in population ecology, where the objectives are to predict and verify the effects of environmental contaminants on population size, trends, distribution, and on habitat use. The second effort is in physiology and behavior, where the objectives are to predict and verify the effects of environmental change on life processes pertinent to survival, reproduction, and behavior in the field.

Ecological studies were conducted in nine States, and seven cooperative research projects were initiated with Cooperative Wildlife Research Units, universities, or State Conservation Depart-

ments. These studies included research to measure the relationships between bald eagles and contaminants in the Klamath Basin in southern Oregon and northern California, the possible impact of lead shot on bald eagles in Minnesota, the potential effects of synthetic pyrethroid insecticides on wildlife in Iowa, the interactions of nutritional factors with contaminants, the relationships between herbicide use and small bird populations in Oregon, the food chain source of contaminants in endangered bats in Missouri, and the effects of pollutants on egg quality.

Ecological research of Service personnel was based from field stations on the Gulf Coast, in the Pacific Northwest, and in the Rocky Mountain area, as well as from the headquarters station in the Atlantic Coastal area. A field team worked on contaminant problems in Lake Michigan, and joint studies with the Canadian Wildlife Service dealt with problems in Lake Michigan and Lake Erie.

**Brain Cholinesterase Recovers at Same Rate from Single or Multiple Doses of Insecticide.** The newer insecticides, most of which are organophosphates, act primarily by inhibiting an enzyme, cholinesterase, in the brain. In studying effects of these chemicals on body functions, it is important to know how rapidly inhibition occurs and how long it lasts. Experiments were performed with young mallards treated with dicotophos (= Bidrin) to obtain data needed for later behavioral studies. Some groups received single doses, and others received the chemical in the diet over a 14-day period. Some were challenged with second doses after recovering from the first.

Inhibition in the brain reached a maximum in about 4 hours after a single dose. With dietary dosage, the maximum occurred in 3 days and remained level for the remaining 11 days of treatment. The amount of inhibition caused by a single dose of 2.4 mg/kg was equal to that caused by dietary intake of 16 ppm. Neither was lethal.

The rate of recovery, i.e., the rate of regeneration of cholinesterase, was the same whether the birds received one dose or dietary dosage, and was the same after second exposures as after the first. This conclusion will be tested with other chemicals. If it holds true, it will permit better interpretation of findings in the field and will allow simple dosage procedures to be used in experimental work.

**Parathion Kills Young and Adult Laughing Gulls.** Sudden heavy mortality struck a colony of

laughing gulls under study on nesting islands in Nueces Bay near Corpus Christi, Texas. On June 28, 1978, over 100 adults died in and near cotton fields that had been sprayed with parathion on that day and the day before. On the nesting islands, about 2 miles away, 116 dead chicks were found.

In all of the nine dead adults that were analyzed, cholinesterase in the brain was inhibited by 55-89%—enough to account for death. In addition, parathion was recovered from their gastrointestinal tracts and identified by mass spectroscopy. In five of the nine dead young analyzed, inhibition of brain cholinesterase ranged from 33 to 78%, and parathion was also present. The other four apparently starved because their parents died. It was estimated that 33% of all the young in the colony died. The total mortality of adults could not be judged, because many of the dead adults were probably not located.

This is believed to be the first recorded instance of an organophosphate insecticide killing young by means of insects carried to the young by the parents.

**Attwater's Prairie Chickens Have Low Pesticide Residues.** This rare bird exists only as a few scattered populations primarily on a refuge surrounded by farm- or range-land of the Texas Coastal Plain. There are only about 125 of the birds on the Attwater Prairie Chicken National Wildlife Refuge established for them. Because mortality from pesticides occurred in the past on treated cropland, a survey of pesticide use near the Refuge was made in 1978. The pesticides used were the fungicide captan; the insecticides malathion, methoxychlor, and carbaryl; and the herbicides propanil and picloram. All of these pesticides have little or no toxicity for birds, especially at the relatively low levels encountered in the field. The prairie chickens were thus not exposed to any real pesticide hazard in 1978.

A few salvaged prairie chickens were obtained for analysis, and a series of bobwhite quail were collected from prairie chicken habitat for a study of residues in a related bird with similar food habits. No residues of organochlorine pesticides or PCB's were found in the quail. The salvaged prairie chickens, found in different areas in different years, had only low levels of DDE—usually under 1 ppm and never much higher.

Pesticides are apparently not a problem for this rare species at most times and places. Most prairie chickens found dead have been hit by auto-



mobiles. Flooding of nests, which occurs in some years, is the major reproductive problem.

**Birds Killed by Fenthion.** Dead birds have been reported in several regions of the United States from areas sprayed with the insecticide fenthion (= Baytex) for mosquito control. These reports stimulated a field study of the effects of fenthion on breeding birds near Laramie, Wyoming. Field work was conducted in plots within about 100,000 acres of irrigated meadow habitat that was aerially sprayed in June 1978 with 0.05 pound of fenthion in 1 or 2 quarts of water per acre.

Effects were not uniform throughout the sprayed area. Few or no dead animals were found at three locations, but 96 dead birds of eight species were found at a fourth site. A few dead mammals were also found there. Inhibition of brain cholinesterase (ChE) in dead birds ranged from 66 to 97%, which indicated that death was due to poisoning by a cholinesterase inhibitor such as fenthion. (ChE inhibition greater than 50%, in birds found dead, is considered diagnostic of death from a ChE inhibitor.) Several sick birds showing severe signs of poisoning were collected. ChE inhibition in these birds was in the same range as that in birds found dead. Numbers of live birds counted on transects in the area of high mortality were significantly depressed for 3 weeks after spraying. Numbers also decreased in three other study areas, although the changes were not statistically significant.

In an area where few dead birds were found, a number of red-winged blackbirds, Savannah sparrows, and Wilson's phalaropes (the three most common breeding birds) were collected to measure brain ChE activity in apparent survivors. The highest brain ChE inhibition in the three species occurred 2 days after the area had been sprayed. It averaged from 50.4% in phalaropes to 74.9% in Savannah sparrows. Whether these birds would have lived or died is an open question. By 15 days after spraying, inhibition ranged from 5% in Savannah sparrows to 24% in phalaropes. About half of all birds that were alive when collected had brain ChE inhibition of 20% or more, indicating exposure to the insecticide. Ten percent had ChE inhibition within the range of that in the birds found dead.

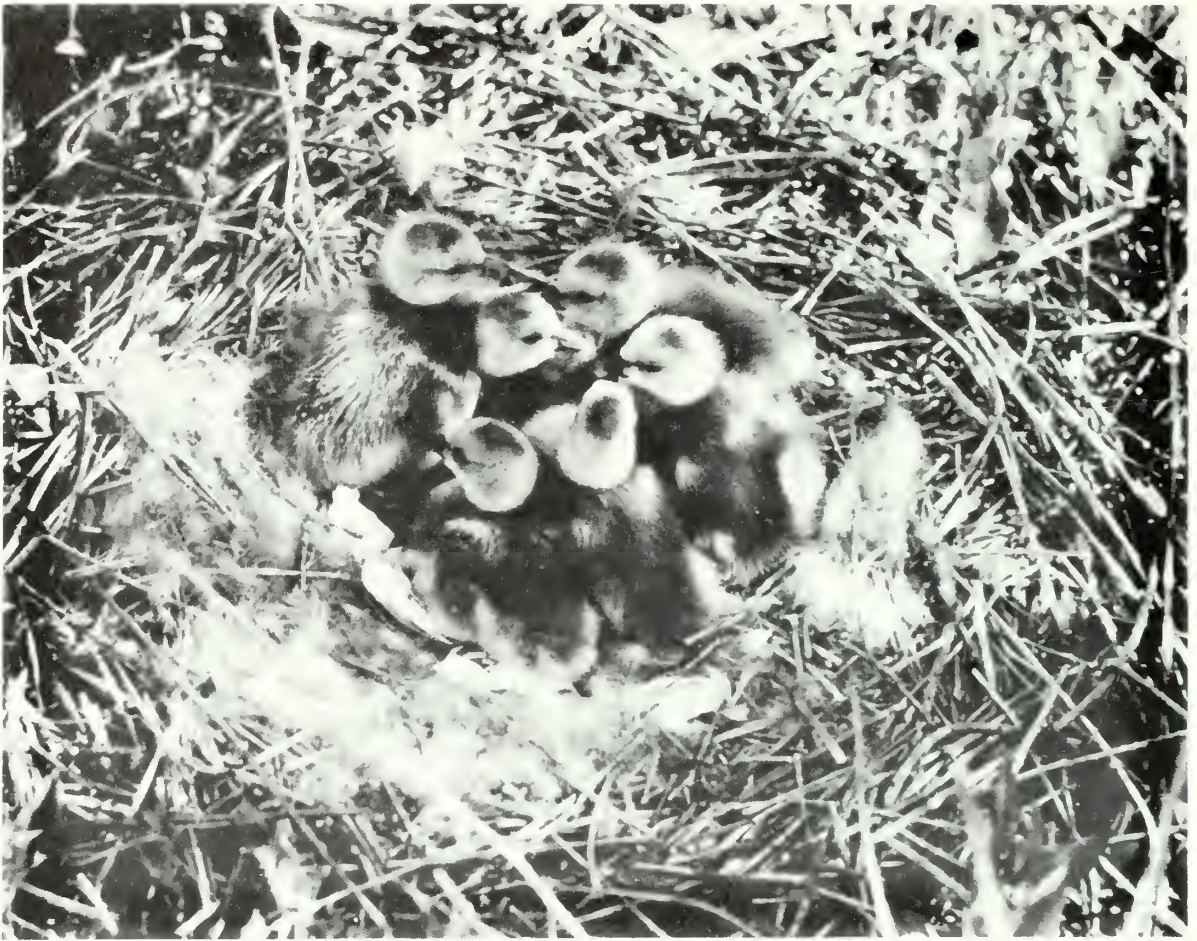
**Heavy Nickel Contamination Has Little Effect on Mallard Reproduction.** Waterfowl food plants growing in streams polluted with metals can concentrate nickel by 20,000 times and have been known to contain as much as 690 ppm. To deter-

mine the extent of the danger to waterfowl, we gave adult mallards nickel in the diet for 90 days through the breeding season. Different groups were given 0, 12½, 50, 200, or 800 ppm in the form of nickel sulfate. Many aspects of health and reproduction were measured. Chemical and physiological results cannot yet be reported, but all other data suggest that there were few effects. Birds on the two highest dosages ate slightly more than the others, and birds on the highest dosage produced black, tarry feces. The higher food intake was not reflected, however, in body weights or in ratios of organ weights. Eggshells were normal. Production and hatchability did not differ significantly among groups, and weights and survival of young were good in all groups. Relatively high concentrations of nickel sulfate are apparently tolerated by mallards.

**Mallard Reproduction Unaffected by Low Dietary Dosage of PCB.** A dietary dosage of 25 ppm Aroclor 1254 was fed to penned mallards for one season. Eggs were left with the parents to be incubated naturally. The goal was to determine whether PCB interfered with incubation behavior and thereby reduced reproductive success. The treatment had no effect on the number of ducks laying, date of first egg laid, or clutch size. Incubation behavior remained normal; hatchability of incubated eggs was actually greater among Aroclor-treated birds (70%) than among controls (49%). The Aroclor may have brought males into reproductive condition earlier than usual, because only 12% of the eggs of treated birds were infertile as compared with 27% for eggs of control birds. Hatchability of fertile eggs was nearly the same for treated and control birds.

**Heptachlor Affects Canada Geese and Other Birds in the Columbia Basin.** Die-offs of Canada geese and ring-necked pheasants were reported in 1977 on the Umatilla National Wildlife Refuge, which lies along the Columbia River in Washington and Oregon. Brains of the pheasants, a golden eagle, and a magpie contained levels of heptachlor epoxide that are diagnostic of death. Heptachlor is used as a seed treatment on wheat, some of which is spilled on the surface of the ground and eaten by birds.

Lethal levels of heptachlor epoxide were found in the brains of five of six resident Canada geese found dead on the Refuge in 1978. Residues in the sixth goose were just below the known lethal level. Although we have no firm estimates, we believe that several hundred resident geese died from



Successful nest of Canada geese on the McNary Recreation Area, Washington, which served as a control area in heptachlor studies. More than 90% of the nests produced young, in contrast to only 51% at the Umatilla National Wildlife Refuge, where eggs contained high residues of heptachlor epoxide. Heptachlor is still used for seed treatments in that area. *Photo by Larry J. Blus.*

heptachlor poisoning.

Reproductive success of geese on the Refuge was much poorer than that of geese on the McNary Recreation Area in Washington. High concentrations of heptachlor epoxide were found in most eggs from Umatilla, whereas few eggs from McNary contained detectable amounts. Reproductive success of geese was apparently impaired by high levels of heptachlor epoxide.

**Wildlife Mortality High in Texas Oil Pits.** A survey was made of wildlife mortality at petrochemical and oil field petroleum pits in southeast Texas in 1977-78. The pits contained a variety of oil wastes, ranging from crude oils to refined oils, sludge, tar, chemicals, and metals. The heaviest mortality occurred in pools of styrene tar that had seeped to the surface of large, insufficiently covered pits. Found at one pit site were 316 dead

or dying birds (including 95 killdeers and 104 other plovers and sandpipers), as well as 38 mammals, 15 reptiles, and 10 amphibians. Ducks, especially lesser scaups, were found primarily in large, open oil and sludge pits. Animals were rarely found in the numerous small, tank-battery spillage pits in the oil fields. Renovation of large, open refinery pits began in 1976 under Texas oil-pit closing orders. Much of the material from these pits was recycled into creosote, harrowed into soil for biodegradation, or burned by smokeless incineration.

**Pollutant Levels High in Eggs of Fish-eating Birds of Lake Michigan.** Eggs of fish-eating birds in Lake Michigan (including Green Bay) contained high levels of environmental contaminants in 1977. Herring gulls topped the list; their eggs contained an average of 102 ppm of PCB's, 33 ppm of

DDE, and 0.44 ppm of dieldrin. Averages for eggs of black-crowned night herons were 84 ppm of PCB's, 15 ppm of DDE, and 0.35 ppm of dieldrin. The average concentrations of contaminants in the eggs of red-breasted mergansers were 25 ppm of PCB's, 8.1 ppm of DDE, and 0.85 ppm of dieldrin. Eggs of double-crested cormorants and common terns also had substantial amounts of pollutants. Chemicals found in the eggs of some species included heptachlor epoxide, chlordane isomers, toxaphene, mirex, hexachlorobenzene, and polybrominated biphenyls.

Eggshells were 7.9% thinner in red-breasted merganser eggs collected in 1977 than in museum eggs collected before the days of DDT. DDE is believed to be the cause of thin shells. Shell thickness of the mergansers has improved since 1975, when shells were 17.7% thinner than those in museums and DDE levels were about twice as high as in 1977.

This work was performed in cooperation with personnel of the University of Wisconsin and the Wisconsin Department of Natural Resources.

**Endrin Far More Toxic than Toxaphene to Frogs.** Experiments with adult leopard frogs indicated that endrin is about 40 times more toxic than toxaphene. The amount in water that killed half of the frogs in a period of 96 hours was 0.013 ppm for endrin and about 0.54 ppm for toxaphene. These figures are based on continuous-flow aquatic toxicity tests and are believed to be more reliable than previously published data for amphibians.

**Accumulation of Methoxychlor Low in Toads.** American toads were exposed to methoxychlor, a biodegradable relative of DDT, for periods as long as 36 days. One group was exposed through contaminated food, and another group received the pesticide in the water supply. The group fed mealworms contaminated by methoxychlor had residues averaging only about 0.2 times the levels in the diet. Those exposed in water had residues averaging 3.2 times the amounts in the water, but levels of residues did not change with time, indicating that an equilibrium had been reached. Residue concentrations were higher in males than in females. No ill effects of exposure were observed.

**Toxic Residues Low in Eggs of Green and Loggerhead Turtles from Florida.** Sizable series of eggs of green and loggerhead turtles were obtained from Merritt Island National Wildlife Refuge in Florida. Green turtles are mainly herbivorous; loggerheads are mainly carnivorous and therefore

would be expected to have higher residues. Analysis revealed, however, that none of the eggs contained significant residues. The highest concentration found was 0.2 ppm of DDE. Several other pesticides and PCB's were found, but at much lower concentrations. The levels were so low that no adverse effects would be expected. How the eggs of carnivorous marine turtles from Florida can be so clean is a mystery.

**Behavior Tests Sensitive Indicators of Organophosphate Levels in Bobwhites.** Azodrin in diets of bobwhites at levels as low as 0.0067 to 0.02 ppm impaired learning ability in operant conditioning tests (tests that measure an animal's ability to learn and relearn). Loss of motor control prevented the testing of diet dosages above 0.5 ppm. At 0.18 and 0.5 ppm, effects were irreversible. Azodrin is a highly toxic organophosphate chemical, with a 5-day LC50 (the dietary dosage estimated to kill half the quail in 5 days) of 2.4 ppm. The impairment of learning began when exposure was well below the lethal levels.

Although operant tests require only a few birds, the testing period may be long, often requiring months. Birds are trained to peck at lighted translucent keys to receive food rewards. They must distinguish between two patterns, such as vertical black stripes on one key versus horizontal black stripes on the other. The position of the patterns is changed in random sequence. When a bird has learned which pattern brings the reward, as evidenced by 18 correct choices out of 20 consecutive tries, the correct pattern is changed, and the bird must relearn. In both of these processes, records are kept of the number of errors made before learning or relearning is achieved. In a test of a single dosage of a chemical, four birds receive low concentrations of a toxicant in the diet and four controls receive untreated food. Different dosage levels require new groups of birds. Comparisons of error scores showed that the performance of dosed birds was significantly poorer than that of controls in this study, as well as in previous studies with endrin and toxaphene.

**Study Begun on Effects of Diazinon on Bobwhite Reproduction.** Although organophosphate insecticides are relatively short-lived, some are highly toxic. Attention has been focused, therefore, on their lethal action. Efforts are now being made to study their effects on behavior and reproduction. Diazinon, a chemical of fairly high toxicity to birds, is being studied in bobwhites, with particular attention to breeding success and

cholinesterase inhibition. The latter gives a good measurement of one major effect of the organophosphates.

Birds were given dietary dosages of 0, 10, 40, or 160 ppm for 3 weeks during the breeding period. Some groups received the dosage continuously. Other groups received the same dosages, but at declining levels, so that they were receiving only half as much after 15 days—a simulation of natural reduction of residues in the wild. Data are now available for the portions of the study dealing with egg production and inhibition of cholinesterase in blood plasma.

In the groups receiving 10 or 40 ppm production of eggs was as good as that of controls, but production in the group receiving 160 ppm was sharply depressed. Whereas controls averaged 12.9 eggs in 3 weeks, birds that received 160 ppm averaged only 2.3 on the constant dosage and 3.3 on the declining dosage.

Plasma cholinesterase responded more sensitively than egg production. It declined strongly in the 10-ppm group and declined still further in the 40-ppm group. However, it was about the same in the 40- and 160-ppm groups. Inhibition was most severe in the 1st week; it gradually recovered while birds were on dosage but was still well below control levels after 3 weeks of exposure.

It seems clear that cholinesterase inhibition did not correlate well with egg production and cannot be used as a good index of reproductive condition. It is also apparent that high concentrations of diazinon interfere with quail reproduction but that low levels do not.

**Earthworms Accumulate Dangerous Amounts of Cadmium from Certain Sludge-treated Soils.** One of the best uses of sludge is to fertilize fields, but some sludges carry potentially dangerous amounts of metals. Cadmium is of special concern, and regulatory limits have been set on amounts that are allowable in soil. The present study indicated that even these allowable amounts may create dangerous residues in earthworms, which are eaten by many other animals.

Worms were collected from 48 plots at four sites in southern Pennsylvania, all of which had received sludge for at least 5 years. Worms from treated sites contained 3 to 32 times as much cadmium as those from untreated sites. Residues were 10% higher in limed soils than in unlimed soils. Amounts in worms were highly correlated with the amounts in soils, but the amounts were 14 to 66 times higher in worms than in the soils.

Worms from two of the sites had at least 100 ppm of cadmium (dry weight basis). Some references indicate that this much cadmium in the diet would be harmless, but numerous other studies report a variety of ill effects at concentrations well below 100 ppm. It is safe to conclude that worms containing the higher amounts of cadmium would be hazardous to the more susceptible species of animals that feed heavily on earthworms.

**Swainson's Hawks Nesting Beyond DDT Spray Area Show Residue Buildup.** Emergency use of DDT for tussock moth control was cleared by the Environmental Protection Agency in 1974. During June and July 1974, 426,000 acres of forest in northeastern Oregon, southeastern Washington, and adjacent Idaho were sprayed with 0.75 pound DDT per acre. Detailed studies were made of several raptors of the area, and in 1976 a special effort was made to collect eggs of Swainson's hawks.

Since Swainson's hawks do not nest in forests, no eggs were available from the sprayed area. Eggs collected within 14 to 27 km of the spray area contained a mean of 5.55 ppm (wet weight) DDE. Each egg also contained either DDT or DDD. Eggs collected 80 km or more away from the spray area contained a mean of 1.28 ppm DDE but had no detectable levels of DDD or DDT. The 4.3-fold greater amount of DDE near the sprayed area, combined with the presence of the parent DDT, strongly suggests that the increased residues resulted from the 1974 DDT application.

Shells of eggs collected near the spray area were 11.4% thinner than those of eggs collected before 1947, whereas those of eggs from greater distances were only 3.5% thinner than normal. However, the residues were not high enough to affect reproductive success.

**Reproduction in Screech Owls Unaffected by Low-level Dietary PCB.** Aroclor 1248 was fed to screech owls at the realistic concentration of 3 ppm (wet weight) for 2 years to study its effect on reproduction of a raptorial bird. This particular form of PCB was chosen because it is one of the most active against reproduction in chickens, where it causes reduced egg production, lower hatchability, and malformations in chicks.

No effects on screech owl reproduction were noted in the 2 years of work although several factors were measured. This lack of effect suggests that the usual environmental levels of PCB's are not likely to affect reproduction of raptorial birds. The dosage employed was well calculated to make



Two avocets and (center) a willet, Texas coast. Heavy industrial development in the Corpus Christi and Nueces Bay areas of Texas may expose feeding water birds to a wide array of contaminants. Accumulation of heavy metals and other chemicals is being measured in several species. *Photo by Kirke A. King.*

this determination, for the residues in the eggs and in the bodies of the breeders were at levels commonly found in wild flesh-eating birds.

**Osprey Nesting Population in Baja and the Gulf of California, Mexico.** An estimated  $774 \pm 55$  pairs (minimum) of ospreys were nesting in the Baja and Gulf of California region during a survey conducted from March 24 to April 1, 1977. The actual population may be larger, since the species tends to have a prolonged breeding season in Mexico. About 174 pairs nested along the Pacific side of Baja California, 255 pairs along the gulf side, 187 pairs on the Midriff Islands, and 158 pairs in coastal Sonora and Sinaloa. Most (62%) nested on sea cliffs and moderately high numbers



Juvenile white-faced ibis, Texas. Reproductive success has improved since aldrin is no longer applied to the rice fields where the ibis feed. *Photo by Kirke A. King.*

(23%) on cactus in flat terrain; 8% nested on the ground, 3% in mangroves and other trees in the southern portion of the study area, and 4% on man-made structures.

The population in extreme northwestern Baja California, which was extirpated early in this century (before the era of modern pesticides), has never been replaced. However, populations immediately to the south along the Pacific Coast (Scammons Lagoon, Natividad Island, and Cedros Island) appear to have been stable over the last 25 years. Pesticide residues were present in osprey eggs from Mexico, but concentrations were among the lowest reported for the species in North America.

Although substantial numbers of ospreys remain in Baja California and the Gulf of California, the loss of the population in the extreme northwest portion of Baja California carries a warning that ospreys require protection if they are to be maintained as a part of the fauna of the region. It is known from experience in other parts of the species' range that man and ospreys can survive together. In Chesapeake Bay (which has the largest osprey population in North America) about two-thirds of the birds nest on man-made structures—some near human dwellings.

**Offspring of Captive Bald Eagles Increase Wild Populations.** The bald eagles of the captive breeding colony at the Patuxent Wildlife Research Center regularly lay a second clutch of eggs if the first clutch is removed. The first clutch is artificially incubated and the young are reared by hand; the parents rear the young of the second clutch. Thus the number of young available for restocking is substantially increased. In 1978 this procedure resulted in the production of seven young from three pairs that bred.

Four young that were reared by their parents until they were 8 weeks old were sent to New York. There, the State Department of Environmental Conservation released them at the Montezuma National Wildlife Refuge by means of the falconer's technique of hacking. One of the three eaglets reared by hand for 3 weeks was placed in the only known active eagle nest in the State of New York, in place of a nonviable egg. The adults shifted from incubation to feeding and brooding and succeeded in fledging the young. The other two 3-week-old eaglets were placed in an active nest in Virginia, where they were cared for by the adults and are believed to have fledged successfully.

**Residues of DDE Increase Effects of Food Shortage on Bird Reproduction.** Field studies with brown pelicans in the Gulf of California suggested that reproductive success was reduced when birds that carried body burdens of DDE underwent periods of food scarcity. This hypothesis was tested in a series of experiments with ringed turtle doves. Birds were fed 100 ppm DDE for 3 weeks to build up residues. Later, after uncontaminated feed was restored to them, performance was studied. Equal numbers of clean birds and DDE birds were tested. Success was compared for groups of birds on full feed and for groups receiving 90, 80, and 70% of the normal diet.

Food restriction itself decreased the number of pairs that attempted to breed and also reduced the success of those that tried. But the results were about twice as severe when food restrictions were applied to birds that carried DDE burdens. In one series of trials, birds that had been fed DDE laid only 41% as many eggs as did clean birds. The doves that carried DDE also lost more weight than did control doves fed the same amounts of food. A considerable part of this weight loss was from muscle, not simply from fat—which indicates that mobilization of DDE caused catabolism of proteinaceous tissues. Analysis of the birds after the tests revealed that their DDE burdens varied widely but averaged around 70 ppm, wet weight. Such concentrations occur in heavily contaminated populations in the wild.

**Organochlorines Depress Neurotransmitters in Brains of Ringed Turtle Doves.** Two of the most important neurotransmitters (chemicals in the brain that mediate behavior) are norepinephrine and dopamine. A test was conducted to determine whether common organochlorine pollutants change the level of these chemicals in the brains of ringed turtle doves. Birds were fed diets containing 0, 2, 20, or 200 ppm of DDE; 1, 4, or 16 ppm of dieldrin; or 1, 10, or 100 ppm of Aroclor 1254 (a PCB mixture).

All of the treated diets depressed both norepinephrine and dopamine. The depression became greater as the level of contaminant in the diet increased.

More work is required to determine whether other species of birds are similarly affected and whether the depression of neurotransmitters influences reproductive behavior.

**Ferrets Not Killed by Secondary Poisoning with Zinc Phosphide.** There are fears that black-footed ferrets, an exceedingly rare species, might be

poisoned by eating prairie dogs killed by zinc phosphide, a rodenticide. This possibility was tested by killing rats with the chemical and feeding them to Siberian ferrets, which closely resemble black-footed ferrets. All of the ferrets ate the rats, but none died. Instead, they seemed to regurgitate the entrails of the poisoned rats. This reaction has been reported for other nonrodent mammals given zinc phosphide. The protective emesis undoubtedly reduces the potential hazard of secondary poisoning of mustelids by this chemical.

**Anticoagulant Rodenticides Differ Sharply in Secondary Poisoning of Barn Owls.** An Executive Order restricts the use of poisons that may kill animals that eat directly poisoned ones. Consequently, the anticoagulant rodenticides, most of which are new, are being tested to determine which ones are most likely to cause this secondary poisoning. In a cooperative study conducted by the Patuxent Wildlife Research Center and the Hawaii substation of the Denver Wildlife Research Center, a series of tests was made with barn owls that were bred in the Patuxent colony. Six anticoagulants were compared: fumarin, diphacinone, chlorphacinone, difenacoum, LM-637, and PP-581. For 10 days rats were given feed treated with low concentrations of one of the six chemicals, but at the same time they had their choice of clean food, as in the wild. Rats that died were fed to the owls for 1, 3, 6, or 10 days. Six owls were used to test each chemical. Amounts eaten were recorded, coagulation times of the blood were measured, and all birds were necropsied to search for internal hemorrhages.

Fumarin, diphacinone, and chlorphacinone caused no mortality among the barn owls. Difenacoum caused no deaths but did cause hemorrhages in three birds (severe in one). LM-637 killed one owl. PP-581 was the most dangerous: it killed five of the six test birds. It is clear that these chemicals differ widely in their ability to cause secondary poisoning of raptorial birds.

**Resistance to Pesticides Increases with Age in Young Birds.** One of the questions related to testing chemicals on young birds concerns the need for using birds of standardized ages. (Testing is simpler and more economical if birds of various ages can be used.) It is acknowledged that sensitivity usually—but not always—declines with age. There is also debate about the effect of an age difference of 1 or 2 weeks. New light was thrown on the question by tests of nine chemicals with Japanese quail chicks. The standard 5-day dietary dos-

age system was used. This system gives the short-term LC50, the median lethal dose.

For every chemical tested, the amount required to kill a chick increased from 1 week of age to 2 weeks, and again to 3 weeks. The rise in the LC50 from week 1 to week 3 was often large and important: from 74 to 155 ppm (109%) for prothos; from 355 to 786 ppm (121%) for aldicarb; from 1,237 to 1,746 ppm (41%) for dicofol; and from 51 to 109 ppm (114%) for Ceresan M. Differences were only a little less for the five other chemicals. These results definitely indicate that birds of the same age should always be tested when lethal dietary toxicities are to be compared.

**Bats Exceed Other Mammals in Accumulation of Lead Near Highway.** Levels of lead were determined for small mammals living near the heavily traveled Baltimore-Washington Parkway. Meadow voles, white-footed mice, and short-tailed shrews were taken from land along the Parkway. Big brown bats and little brown bats were captured in a barn 0.6 km northwest of the Parkway.

Bodies of male big brown bats, female big brown bats, and female little brown bats contained 47, 32, and 17 ppm (wet weight) of lead, respectively. Residues were also high in shrews (26 ppm), but were considerably lower in voles and mice. Carnivorous mammals were apparently accumulating much more lead than herbivorous ones.

Stomach contents were also analyzed. The estimated dosages of lead received by little brown bats, shrews, and voles equaled or exceeded levels that have been reported to cause mortality or reproductive impairment in domestic mammals. Furthermore, lead concentrations in the bats and shrews equaled or exceeded those found in voles and mice that were collected at old mine sites in Wales, and which had lead-induced inclusions in the kidneys or edema of the kidneys.

**Endangered Gray Bats Continue to Die of Dieldrin; Heptachlor Adds to the Problem.** In each of 3 years, dead gray bats (an endangered species) were found beneath one of the three principal maternity roosts of this species in the area of the proposed Meramec Park Lake, Missouri; 74 were found dead at the same roost on July 8, 1977, and 103 in July 1978.

Analyses of bats from both 1976 and 1977 revealed lethal levels of dieldrin in the brains of some individuals. Investigators believe that bats obtained this dieldrin by eating flying insects pro-

duced in cornfields treated with the parent compound, aldrin. Aldrin was banned by the Environmental Protection Agency in 1974. Unfortunately, however, dieldrin residues in gray bats did not decrease by 1978. When heptachlor replaced aldrin for use in corn, residues of heptachlor immediately began to increase in gray bats while dieldrin residues remained high. The predicament of the gray bat appears to be worsening.

**Embryotoxic Components of Crude Oil Identified.** Crude oils that contained the highest levels of aromatic hydrocarbons proved to be the most toxic to embryos exposed by surface applications to eggshells. The aliphatic hydrocarbon fractions were virtually nontoxic. Additions of specific classes of compounds to aromatic mixtures showed that tetracyclic (or greater) compounds significantly increased the toxicity of the mixture, killing embryos, stunting growth, and producing abnormalities. Additions of vanadium or nickel aromatic-porphyrin compounds to crude oil also increased the detrimental effects, as was shown earlier for mercury. These metals occur as components of some types of crude oil.

**Petroleum Hydrocarbons Accumulate in Bird Tissues.** Claims that birds did not absorb petroleum from their digestive tracts and so were in no hazard from petroleum, except as a result of feather oiling, were tested in a series of experimental and field studies.

Chemical analysis of environmental contaminants in warm-blooded animals is greatly complicated by the production of metabolites, whose identity may not even be known. Analysis for petroleum hydrocarbons is especially difficult because hundreds of different compounds make up the mixture known as petroleum. Furthermore, certain hydrocarbons occur naturally in the animal body and may be difficult to distinguish. These difficulties were overcome in a series of chemical studies.

Finally, in 1978, concentrations of petroleum hydrocarbons were measured in mallard ducks that had been fed four dosages of South Louisiana crude oil. Fifty-five specific saturated and aromatic oil hydrocarbons were identified and quantified. Total oil saturates, total oil aromatics, and total oil hydrocarbons were also measured. There was a clear relationship between levels of oil in the diet and the concentrations accumulated in the tissues, showing that petroleum hydrocarbons followed patterns similar to those of other environmental contaminants. The data also suggested

metabolic change of some of the components.

After the development of this methodology, petroleum components were measured in tissues of four birds that were killed in the *Amoco Cadiz* oil spill on the coast of France: common cormorant, herring gull, razorbill, and common murre.

The methodology, however, is still so complex that it permits analysis of only a small number of critical samples and not large-scale environmental surveillance of low-level exposure.



Laughing gulls carrying nest material, Matagorda Bay, Texas. Birds were trapped on their nests and small quantities of oil were applied to their breast feathers to determine the effects on hatching success of the eggs they incubated. Birds usually washed and preened the oil from their feathers before returning to their nests. Nevertheless, enough oil remained to cause some mortality: after 5 days of incubation dead embryos were found in 41% of the oil-treated group compared with only 2% in the control group. *Photo by Kirke A. King.*

**Embryos Killed by Oil Droplets Carried to Eggs by Parent Birds.** Early experiments with oil showed that mallard and eider duck embryos were killed by minute traces of crude oil applied to their eggs in early stages of development. In 1977, results were duplicated in field experiments with five species of birds: common eider, great black-backed gull, laughing gull, Louisiana heron, and Sandwich tern. Oil was applied directly to the eggs, which the parents continued to incubate.

In 1978, the chain of evidence was essentially completed by two sets of experiments in which oil on the feathers of the parent birds was transferred to the eggs. In the first experiment, the water baths of nesting captive mallards received 100 ml of crude oil per square meter of water surface for



2 days early in incubation, after which the baths were cleaned and provided with fresh water. Oil was visible on the plumage of both hens and drakes and on the eggs of 10 of 18 pairs of exposed birds.

Only 47% of the eggs of the oil-exposed ducks hatched, compared with 96% for the controls. Other pairs that were exposed to a smaller amount of oil (5 ml per square meter) hatched 80% of their eggs—a lower percentage than that of the controls but not different statistically. Although oil was not visible on the eggs at the lower level of exposure, it was recovered chemically from the shell surfaces.

In the second set of experiments, conducted in the field in Texas, a small amount (2.5 ml) of No. 2 fuel oil was applied to the breast feathers of 42 laughing gulls trapped at nest sites early in the breeding season; water was applied to 20 controls. Dead embryos were found in 41% of the eggs in nests of oiled birds compared with 2% in nests of control birds.

Oil spills commonly result in mortality of adult

birds through feather oiling. The present experiments demonstrated that egg oiling, by reducing hatching success of local populations, may well be a serious secondary hazard of oil spills.

**Weathering Reduces Toxicity of Oil to Eggs.** Toxicities of both Prudhoe Bay crude oil and No. 2 fuel oil were significantly reduced by weathering. The toxicity of Prudhoe Bay oil decreased significantly after 3 weeks of weathering and that of fuel oil after 1 week. In one set of tests made with 59 lots of 50 mallard eggs each, oil was weathered by exposure of a 5% mixture in water in open steel troughs for 10 days, both indoors and out. Hatching generally remained poorer for oil-treated eggs than for controls. Hatching success of eggs treated with different amounts of No. 2 fuel oil on the 8th day of incubation was as follows: fresh oil—64% (1 microliter), 42% (5 microliters), 12% (10 microliters), 0 (20 or 50 microliters); oil weathered outdoors—78% (1 microliter), 46% (5 microliters), 42% (10 microliters), 24% (20 microliters), 0 (50 microliters).

## Coastal and Anadromous Fish

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### LA CROSSE NATIONAL FISHERY RESEARCH LABORATORY

**Registrations and Classifications of Fishery Compounds.** The National Fishery Research Laboratory attempted to clarify the status of several compounds and to determine what studies, if any, are needed to establish labels for fishery use. The Environmental Protection Agency (EPA) responded to our official request by stating that rhodamine B and fluorescein sodium dyes do not require registration when used to determine water flows, distribution patterns, and dilution rates for applying fish toxicants. In addition, potassium permanganate was cleared for use as an oxidizing agent to alleviate oxygen depletion and to terminate the piscicidal activity of rotenone and antimycin.

The Fish and Wildlife Service requested a ruling

from the Food and Drug Administration (FDA) regarding the registration status of sodium bicarbonate, carbon dioxide, and acetic acid. These chemicals are “generally recognized as safe” when used in accordance with good manufacturing or feeding practice as feed additives. They are freely available on the market not only for feed, but as general chemical reagents. They are used in fish culture and research for various therapeutic purposes, but no claims are made as to their effectiveness.

**Chemical Screening for Selective Control Agents.** The National Fishery Research Laboratory, by request from the Utah Cooperative Fishery Research Unit, initiated a screening program for a possible selective toxicant to be used against Utah chubs in some western reservoirs. The Utah chub is a direct competitor of the rainbow trout. Thirteen chemical control agents were



Chemist operating atomic absorption spectrophotometer as part of project to increase salmon returns by improving the health and quality of the smolts released. *Photo by William T. Yasutake.*

screened against Utah chubs and rainbow trout, but none showed sufficient selectivity to safely control chubs without causing significant losses of rainbow trout.

## SEATTLE NATIONAL FISHERIES RESEARCH CENTER

Over the past several fiscal years the program at the Seattle National Fisheries Research Center has been broadening from a hatchery research orientation to one that examines all factors that limit the survival of fish. This change is reflected in the following restatement of the mission of the Center:

To identify and quantify factors limiting the distribution and abundance of fish populations in freshwater and estuarine environments of the western U.S. (west of the Continental Divide, including Alaska and Hawaii) and the Pacific Trust Terri-

ories, and the development of methods to increase efficiency in the use of artificially propagated juveniles to supplement populations of anadromous fishes.

**Standard Stress-Physiological Characteristics of Rainbow Trout Strains.** This study, conducted in cooperation with the Service's Fish Genetics Laboratory, is directed toward the development of standardized test procedures to determine the ability of fish to withstand temperature stress, crowding, and oxygen depletion.

Laboratory tests of the ability of coho salmon and rainbow and steelhead trout to respond adequately to adrenalin showed that marked differences occur among strains.

Physiological characterization will assist in the selective breeding program to produce trout that meet specific management needs.

**Stress Mitigation for Smolt Hauling.** Key elements of information needed to reduce the stress imposed by procedures for transporting smolts

were identified. Efforts were concentrated on hypermagnesemia and hyperkalemia as a function of scale loss, and on the amount of recovery time in fresh water required before the fish can be safely transferred to sea water. Coho salmon were able to maintain homeostasis, in terms of blood electrolytes, if scale loss was 12% or less and the water in which the fish were transported was maintained at 10 parts per thousand sea water.

**Identification of Hatchery Practices that Diminish Saltwater Tolerance or Preference Among Smolts of Pacific Salmon.** We used smolts of steelhead trout and coho salmon to test 10 medication protocols for possible adverse side effects. At 0, 1, 2, 4, 8, and 16 days after treatment, samples of smolts were placed in full-strength sea water and mortality was observed for 10 days. Posttreatment mortality ranged from 10 to 80% above control levels when the fish were transferred directly into salt water at a salinity of 28 parts per thousand.

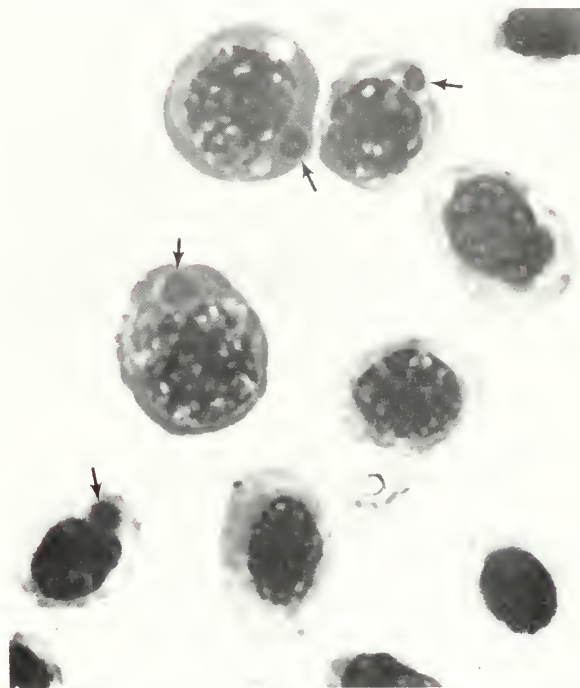
Mortality thereafter was usually inversely proportional to the time lapse between medication and exposure to salt water. On the basis of mortality alone, impairment of saltwater tolerance lasted for at least 1 week. Additional damage to migration behavior and preference for salt water may have occurred, and the effects could persist for a longer period.

Salmonid smolts apparently are easily damaged by medicines. When stressed with otherwise acceptable levels of medication, smolts reverted from a high to a low salinity tolerance—which may also extend to saltwater preference. Recovery of gross survival is possible if the fish are given adequate time before entering the ocean. However, it is not clear what physiological systems are attacked by the medicines.

These results clearly demonstrate the need for alternative methods of disease management among smolts. In some circumstances medication may be highly counter-productive, and the ultimate effect may not be evident in fresh water. Likewise, other environmental stresses may repress “successful” smolt production, both in hatcheries and in streams.

**Bacterial Kidney Disease.** In rainbow trout or chinook salmon, bacterial kidney disease can be transmitted through the eggs to the progeny. This transmission occurs even when the adult fish have only a subclinical infection, and show no overt signs of disease. Iodophor treatment of the eggs did not prevent transmission of the pathogen.

**Alaska IHN Virus.** Injections of follicle stimulating hormone into spawning adult carriers of infectious hematopoietic necrosis (IHN) virus reduced the amount of virus produced by 1,000-fold. Half of the female sockeye salmon tested after they spawned had IHN virus in their blood, indicating an acute infection in the adults.



Viral inclusions (arrows) of piscine erythrocytic necrosis in red blood cells of salmonids. Magnified 2700 X. Photo by John R. MacMillan.

**PEN Virus in Salmon and Herring.** Most populations of chum salmon in the Puget Sound area were found to be infected with the virus of piscine erythrocytic necrosis (PEN). The incidence of the disease was high in some Pacific herring populations. The virus can be experimentally transmitted to almost all salmon and trout species, but has been found naturally only in pink and chum salmon. Fish infected with PEN are 2½ times more sensitive than healthy fish to a common bacterial disease (vibriosis) and, when subjected to low oxygen levels, died at much higher dissolved oxygen concentrations than those lethal to uninfected fish.

**Holding Density Versus Disease Susceptibility.** In studies of the effects of fish-holding density on susceptibility to disease, triplicated results with rainbow trout indicated that increasing loading densities from 0.5 to 4 pounds per cubic foot sig-

nificantly increased susceptibility to a standard Type I *Vibrio anguillarum* challenge. Challenges were carried out in brackish water (Cl<sup>-</sup> = 20 parts per thousand), at temperatures of 14.5° to 7° C. As the temperature decreased, the average time to death increased.

**Genetic Studies of Freshwater Fishes on National Petroleum Reserve Number Four, Alaska.** Populations of least cisco and Arctic grayling were surveyed by enzyme electrophoresis to determine

whether genetic differences exist between populations in the waters of National Petroleum Reserve Number Four. Three enzyme systems in the least cisco and two in the grayling were found to be polymorphic. Variation between populations of least cisco was not statistically significant. However, one population of grayling was determined to be unique for one enzyme system. Both species exhibited a high degree of apparent selection for either the homozygotes or the heterozygotes.

## Endangered Species

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### NATIONAL FISH AND WILDLIFE LABORATORY

**Mexican Duck Study.** This study was designed to assess in detail the geographic variation in characteristics of ducks in the Mexican portion of the intergrade zone between the common mallard and the Mexican duck. Ninety-nine specimens were taken between Lake Chapala, Jalisco, and the United States-Chihuahua border. These specimens have been scored according to a hybrid index developed by John Hubbard of the New Mexico Department of Game and Fish.

Mexican ducks compose most of the population at the southernmost collecting sites, and mallard characteristics become progressively more common toward the north.

Data were taken on the weights, breeding biology, food habits, and parasites of the specimens.

**Vertebrates of the World.** The Laboratory has recently completed a first draft of a complete taxonomic list of all vertebrate species in the world. More than 37,000 species are arranged phylogenetically and alphabetically in a computer printout. The preliminary listing is being distributed to specialists in systematics for comment and review. In addition to its significance to the taxonomic community, the list will be useful to those responsible for regulatory control over trafficking in wildlife, because it provides the latest taxonomic placement and correct nomenclature for the world's vertebrate fauna. The list was prepared at the request of the Taxonomic Com-

mittee of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and has met with nearly unanimous approval from the scientific community. As specialist input is received, the list will be updated and refined.

**Kirtland's Warbler Presented to the U.S. National Museum of Natural History.** In January 1978 the body of the only banded Kirtland's warbler ever found outside of Michigan was presented to the Laboratory by the Assistant Area Manager for Wildlife, East Lansing, Michigan. Kirtland's warbler is listed as an endangered species by the U.S. Fish and Wildlife Service. This bird died when it flew into a windowpane in Cincinnati, Ohio; it was taken to the Cincinnati Museum of Natural History, where the partially decomposed body was preserved. The Service subsequently presented the specimen to the U.S. National Museum of Natural History. Other than an immature female, this specimen is the only Kirtland's warbler in fall plumage at the National Museum.

### DENVER WILDLIFE RESEARCH CENTER

**Status of Peregrine Falcons in Baja California, Mexico.** The peregrine falcon survey initiated in 1976 was completed in 1978. The islands and peninsular sea cliffs in the Gulf of California were surveyed in 1978 from the midriff section to near the southern end of the Baja California peninsula.



A portion of the rugged Mexican coastline along the Gulf of California. Such areas were searched for nesting peregrine falcons during a 3-year study of the peregrine's population and reproductive health in Baja California. *Photo by M. Alan Jenkins.*

A total of 44 pairs of peregrines were located in the 3 years of study. If several historic and probable sites that were not checked were added, the number of active pairs would probably approach 50. Peregrine falcon populations in the Gulf of California, unlike other North American populations, apparently have not declined appreciably during the past several decades, judging from the historical data available.

The Gulf peregrines prey on at least 25 species of birds and at least 2 species of bats. They rely heavily on warblers that migrate across the Gulf. Eared grebes, Craveri's murrelets, least and black storm-petrels, Bonaparte's and Heermann's gulls, northern phalaropes, and fish bats are other principal food species.

Samples of breast muscle tissue were taken from seven species of avian prey and the fish bat for pesticide and heavy metal determinations. Results of these analyses should give a clearer picture of the future reproductive health of peregrines in the Gulf of California. Inasmuch as fragments of eggshells from two successful eyries were of normal thickness, the Baja population appears to be reproductively healthy, and neither the peregrine nor its prey appears to be highly contaminated with pesticides. This indication is confirmed by normal productivity, which exceeds two young per pair at successful sites. However, not all sites are successful at producing young, and the ratio of successful to unsuccessful pairs was not determined in this study.



Two winter-plumaged Bonaparte's gulls on the Gulf of California, Mexico. This gull and other species of marine birds and fish bats are important parts of the diet of the peregrine falcon in this area. Analyses of chlorinated hydrocarbon pesticide and heavy metal residues are being carried out to determine the level of pollution in the food base of peregrines in the Gulf. *Photo by M. Alan Jenkins.*

## PATUXENT WILDLIFE RESEARCH CENTER

**Breeding of Captive Black-footed Ferrets.** Artificial insemination developed for use with a female black-footed ferret was not required during the 1978 breeding season because this female never entered estrus, despite hormonal therapy. Another female, however, reached full estrus on April 11 and was placed with a male for 3 consecutive nights. Pre- and post-copulatory behavior were observed each night and a few sperm were present on the vaginal smear obtained after breeding occurred.

After a 42-day gestation period, we decided that a caesarian should be performed on this female to prevent the birth of stillborn young as in previous years. Caesarian techniques used with captive mustelids are similar to those used on the domestic cat. Although only one of the numerous births that have occurred at Patuxent required a caesarian, this surgery was performed successfully on several experimental European ferrets. After a midline incision and retraction of the uterine horns, neonatal European ferrets were successfully obtained and subsequently placed on surrogate females to ensure their safety while their natural mothers were recovering from the anesthetic and surgery. Although the surgery on the female black-footed ferret was successful and she recovered, she had a false pregnancy and contained no young.



Wildlife Research biologists training observers who participated in the Hawaii forest bird surveys. *Photo by Mark Collins.*

**Neoplasia in Black-footed Ferrets.** Between 1976 and 1978, all five of the black-footed ferrets maintained at Patuxent developed adenocarcinomas of sweat or sebaceous glands. Despite intensive care and supportive treatment, two ferrets died; prognosis for the three remaining ferrets is probably fair. Although viral inclusion bodies have not yet been identified in the neoplastic tissues, viral isolation will be attempted upon death of the remaining ferrets. It should be noted that the husbandry and the nutrition of these animals are similar to those of the Eurasian ferrets maintained in a separate facility, but these pathological conditions have not been observed in these 200 or more surrogates. It is speculated that the black-footed ferret might have a genetic predisposition to these tumors, possibly a result of inbreeding.

**Ferret Surveys Find Evidence of Remnant Populations.** An accelerated search for black-footed ferrets has produced evidence that remnant

populations occur in scattered areas throughout the northern Great Plains. Personnel of the Montana Department of Fish and Game observed a ferret on a prairie dog town in southeastern Montana in fall 1977 and again in 1978. These observations represent the first verified ferret sightings in Montana since 1953. Easements are being sought to protect prairie dog towns in the vicinity of the sightings.

Intensive ferret surveys were conducted on public lands in Wyoming before the lands were leased for mineral exploration and mining. Two black-footed ferret skulls were found on white-tailed prairie dog towns in the south-central and southwestern regions. Also, reports of ferret sightings were received from throughout Wyoming's prairie dog range. In addition, a ferret skull was found during prairie dog-ferret surveys in northeastern Colorado.

These findings have engendered a more positive



Camp at 4,900 ft (msl) on Mt. Hualalai, Hawaii, during the 1978 forest bird survey on the Kona Coast. Photo by C. B. Kepler.

attitude toward the ferret's current status and have revealed the need for more extensive surveys throughout the ferret's original range.

**Nutrition Believed To Be an Important Factor in Regulation of Wolf Populations.** Although social factors have long been thought to have an overriding influence in regulation of wolf populations, a recent review of Fish and Wildlife Service data and the literature indicates that food supply is much more important than was previously recognized. Both social and nutritional factors interact in wolf populations, with each factor having a different relative population-regulating influence, depending on whether wolves are increasing or decreasing and whether food is abundant or scarce. This view implies that reduced productivity and outright starvation in wolf populations will not necessarily be prevented by social factors—a view consistent with data available from the Superior National Forest study area.

**Nutritional and Population Status Differences in Wolves.** Preliminary analyses of 28 blood variables from the blood of large samples of wolves from northeastern and northwestern Minnesota confirm that wolves from the northeast are nutritionally inferior. They also indicate that the nutritional condition of wolves in the Superior National Forest deteriorates markedly in August and September, probably as a result of the decreased fawn supply at that time. Blood results from more intensive analyses will provide considerably more information about the health and condition of both wolf populations.

**Wolf's Primary Prey (Deer) Limited by Weather, Hunting, and Predation.** An analysis of deer productivity, fawn and yearling survival, and population trends in the Superior National Forest study area indicates that the low-density deer herd is being severely limited by a combination of factors. Annual production and survival of fawns to

9 months of age since 1974 has been about 10 females and 32 males per 100 does. Survival of male yearlings to 2 years of age has been about 14%. Severe winter weather appears to be the primary cause of low productivity and survival of female fawns, whereas hunting and wolf predation are the major restrictive factors in yearling male survival. The net result is a stable or declining herd of less than one deer per square mile over an area of about 2,000 square miles.

**California Condor Population Continues to Decline.** No California condors are known to have been produced in 1978, and only one was reared in 1977. An average of 6.37 hours of observation were required to see a condor in 1976-78; in comparable studies in 1970-71, there was one sighting every 3.37 hours. Numbers of condors per sighting have also decreased markedly. In 1970-71, 55% of the sightings involved more than one condor and 11% involved five or more. In the current study, corresponding percentages were only 45 and 1.

**Reproduction in Captive Andean Condors.** Eight adult and six immature Andean condors were maintained during the past year. The four breeding pairs produced six eggs, three of which hatched. The hatchlings (two females, one male) were successfully reared. The incubation periods of these three eggs were 57 (partly artificially incubated), 59, and 60 days.

**Responses of Cranes to Diets Differ.** Whooping crane chicks reared in captivity appear to have an unusually high incidence of leg abnormalities when compared with their counterparts in the wild. These abnormalities are believed to be related to rapid growth occurring during the 1st month of life. Studies have been in progress with Florida and greater sandhill cranes to determine whether a diet can be formulated that will slow growth and reduce or eliminate leg disorders.

In earlier studies, when chicks of Florida sandhill cranes and whooping cranes were fed the same dry rations of known nutrient composition, only the whooping crane chicks developed leg disorders. Later work with greater sandhill crane chicks indicated that they grew about 25% faster than Florida sandhill crane chicks, and some of the fastest growing chicks developed leg disorders. Work during the past year with Florida sandhill crane chicks has confirmed that the growth of this subspecies is much slower than that of the greater sandhill cranes and that the Florida chicks do not develop leg disorders on a ration that appears to cause leg abnormalities among some greater sand-

hill crane chicks.

These findings suggest that cranes of the northern latitudes, such as greater sandhill cranes and whooping cranes, are genetically capable of very rapid growth when food supplies are readily available. Conversely, cranes of the southern latitudes, such as the Florida sandhill crane, appear to lack the genetic potential for growing as fast as their counterparts from the north. This growth difference seems logical from an evolutionary standpoint, since rapid growth probably offers cranes of the southern latitudes no particular advantage in a temperate climate where adequate food is normally available for lengthy periods. In the northern latitudes where the growing season is short, chicks with the capacity for more rapid growth may have a greater risk of developing leg disorders. This interpretation could explain why whooping crane chicks from stock that has become adapted to climatic conditions in the Far North have been subject to leg disorders and have been more difficult to raise in captivity than other species of cranes that breed farther south.

**Frozen Semen Used to Produce Sandhill Cranes at Patuxent.** For the first time (1977-78), artificial insemination with frozen-thawed greater sandhill crane semen produced fertile eggs and chicks. During the 2-year study, 5 of 27 eggs were fertile and three chicks hatched. Frozen semen samples stored in liquid nitrogen for 2 months or less were thawed and used for insemination.

Of nine pairs of greater sandhill cranes, all of which had produced eggs during at least 2 years before this trial, only six were productive. The low production resulted from separation of the birds in adjoining enclosures to prevent copulation. Three hens that were inseminated with large numbers of live sperm before oviposition laid eight eggs, five of which were fertile, and three chicks hatched. Recent improvements in laboratory procedures should yield semen samples with larger concentrations of live sperm after freezing and thawing, and greater fertility rates can be expected.

**Released Masked Bobwhites Surviving Well in Arizona.** The 1977 release of 900 masked bobwhites in the Altar Valley has resulted in the establishment of a relatively large, well-distributed population. Numerous observations were made throughout the year by Fish and Wildlife Service biologists and personnel from the Buenos Aires Ranch.

During August 1978, a minimum of 54 calling



males (21 calling males in 1977) were located. Five of the six birds identified as to race were masked bobwhites and one was a Texas bobwhite. If this ratio is projected and equal male:female survival rates are assumed, the estimated population is 90 masked bobwhites. This population is 3 times that estimated in 1977. The field survey for calling males did not begin until August 2, and standardized call routes were run in Arizona and Mexico for 10 days. Calling in Arizona peaked during August 8-18 and then declined rapidly. Thus, many areas in Arizona where concentrations of bobwhites were suspected were not surveyed until well after the peak in calling. In addition, personnel from the Buenos Aires Ranch reported bobwhites calling in several areas where the surveys revealed none. Therefore, the 54 calling males and the population estimate of 90 birds are both extremely conservative figures.

#### **Bell's Vireo Shows Major Decline in California.**

During extensive surveys in central California in 1978, Bell's vireos were observed in only three localities. The species was formerly considered abundant and conspicuous in most of the areas surveyed. Loss of preferred riparian habitat accounts for part of the decline, but much apparently suitable habitat is unoccupied. The spread of the nest-parasitizing brown-headed cowbird has been suggested as an important cause of vireo decline, but concrete evidence is still lacking. In California south of Los Angeles, Bell's vireos are rarer than formerly but are still locally common.

**Effects of Low-flying Jet Aircraft on Wild Everglade Kites.** From April 4 through 13, 1978, a unique 10-day experiment on the effects of low-elevation flights by 727 jet aircraft on wild Everglade kites was conducted in the southern Everglades of Florida. The experiment attempted to simulate as closely as possible the actual levels of disturbance expected in the vicinity of the proposed Miami Training Jetport in northwestern Dade County. The proposed jetport lies just 2.5 miles east of a major nesting colony of kites on a willow island. This colony served as the study colony for the experiment.

On 5 days in the experimental period, jet aircraft flew at altitudes of about 750 feet in the vicinity of the nesting colony at frequencies and noise levels expected for the operational airport. Periods of overflights lasted between 1 and 2 hours on the test days, and the frequency of flights averaged one flight every 4 minutes. On the other



First greater sandhill crane, about 2 months old, produced at the Patuxent Wildlife Research Center by artificial insemination with cryogenically stored semen. Photo by George F. Gee.

5 days of the experiment, generally alternate days to the overflight days, there were no low passes by aircraft—these days served as controls.

At the time of the experiment there were 30-40 kites nesting and roosting on the willow island and about 12 active nests. On all 10 days, full morning periods of observations were made of various aspects of kite behavior and ecology. Observers in



Forty-one Everglade kites in flight and two perched at nesting-roosting site located in a willow stand in the southeastern corner of Conservation Area 3A, Dade County, Florida. There are also 12 anhingas in flight among the kites. *Photo by Paul W. Sykes, Jr.*

two blinds within the island monitored nesting biology, while those in two airboats exterior to the island monitored general colony behavior, such as feeding rates and nest-building rates. Overall, 19 different quantitative measures of kite behavior were followed, and in none of these measures were there significant differences between control and test days. Aside from watching the aircraft on occasion, the kites gave no signs of abnormal behavior caused by the aircraft.

Between April 26 and May 7 a supplementary assessment of the impacts of jet aircraft on kite populations was made in Barranquilla, Colombia. There, a long-standing airport is situated immediately adjacent to marshes containing Everglade kites. There were several kite colonies in the marshes, and it was significant that the largest and most vigorous colony was located only 400 m from the end of the main airport runway. The kites could not have nested more than a few meters closer to the runway, and there appeared to be ample suitable habitat for them to have nested farther away. They appeared to be unperturbed by jet aircraft flying low overhead and carried on what appeared to be normal nest-building and copulation behavior throughout the disturbance. Thirteen pairs were nesting in the colony, making it about twice the size of the next largest colony in the region.

Combined, the overflight experiment in Florida

and the observations near the Barranquilla, Colombia, airport strongly suggest that kites can easily accommodate to the noise and disturbance associated with low-flying jet aircraft. Jetports have other impacts than noise and disturbance, however, and these effects were not assessed in the studies. The principal concerns with regard to the proposed Training Jetport in Dade County are the threats of ancillary developments in areas around the jetport and increased human use of these areas.

**Everglade Kite Population in Florida Continues to Increase.** Annual censuses of the Everglade kite in Florida have been conducted since 1969. The population showed an increase in 1970 but declined significantly after the drought of 1971. Since 1974 the number of kites has steadily increased. On the latest census (November 1977), 152 birds were counted. At that time the population was estimated to be about 165 to 170 individuals. The long breeding season of 1978 was highly successful, as were the two preceding ones. Most of the kites and the nesting in 1978 were in eastern and southeastern Conservation Area 3A (Dade County). There were somewhat more than 60 nests in that area. The next census may reveal more than 200 kites in Florida. The current population level is probably the highest in nearly 50 years. The population may never have been as low as some workers have believed but may have

dropped to 20-25 birds in the late 1950's and early 1960's. The steady increase over the last 5 years is attributed to favorable water levels at Lake Okechobee, Conservation Area 3A, and several other localities. Nesting success for the last 10+ years has averaged just under 50%; the mean number of young fledged per successful nest was 1.9. If planned management procedures can be implemented for the kite before the next severe drought, we should be able to maintain the population at this high level and avoid a repetition of the rapid decline observed in 1971.

**Puerto Rican Parrot Studies.** In 1978 the status of the Puerto Rican parrot was perhaps the most encouraging since the U.S. Fish and Wildlife Service parrot program began in 1968, and hopes that the wild population may yet recover appear justified. The total wild population of Puerto Rican parrots increased from 19 to 26 (maximum, 28) with the fledging of a record 9 chicks in 1978. The number of captive parrots increased by 1 to 15 birds, all housed at the Puerto Rico Field Station aviary.

Certainly the most significant event of the year was the increase in number of breeding pairs in the wild. For the first time in the 11 breeding seasons since the start of the parrot program, there was a gain in the number of active nests. Although the population has been building since it reached a low point of just 13 birds in 1975, it has, until this year, consisted of immature and nonbreeding birds; in fact, the number of breeding pairs had steadily declined to only 3 pairs during 1976 and 1977. In 1978 there were four active pairs, all of which laid eggs. The new pair adopted a nest site they had been inspecting in 1977. Additional pairs were observed inspecting new nest sites during 1978 and could breed during the next 2 years.

Three of the nesting pairs, including the new pair, were successful in fledging young. However, without emergency treatment, one brood probably would not have fledged, because their feathers became thoroughly matted with muck that accumulated on the inner surface of the nest cavity after a leak occurred late in the season. After a scrubbing (and feather transplant for one chick that had severely damaged feathers), all three chicks fledged.

One of the four nests failed during the incubation stage. The female laid three eggs; two were broken in the nest and one was a "runt" egg. All three eggs were taken into the Puerto Rico Field Station aviary for artificial incubation and

dummy eggs were substituted in the wild nest. One egg was too badly crushed to repair and the embryo soon died from moisture loss; the other broken egg was repaired and hatched. This chick was placed in a foster nest (its own nest had already been deserted by the adults) and it fledged with its foster siblings. The runt egg hatched but the chick lacked vigor and soon died. The pair laid a second clutch but again deserted their nest. This re-nesting attempt is the second documented instance of Puerto Rican parrots laying replacement clutches, which suggests that repeat clutching may prove to be a useful management tool.

All nesting pairs used artificial or improved natural sites, which were completely effective in preventing predation of parrot nests by the pearly-eyed thrasher. None of the nests was seriously threatened by this predator, which in previous years had been the major cause of egg and chick losses.

For the first time, fertile eggs were produced by a captive pair of Puerto Rican parrots. Two of the four eggs laid at the Puerto Rico aviary developed well but the embryos died just before hatching. The third embryo came to the pipping stage but died the day after the first pip was made. The fourth egg was infertile.

**Yellow-shouldered Blackbird Studies.** For the second time the yellow-shouldered blackbird has been recorded from Vieques Island, 12 km east of Puerto Rico. A single bird was observed there on March 11, 1978. The only other known record of the species on Vieques was a small flock seen in April 1974. A 2-day survey of the Mona Island yellow-shoulder race resulted in a total count of 135 blackbirds, most of them along the northeastern edge of the island.

Shiny cowbird parasitism of yellow-shouldered blackbird nests occurred at 97% of the nests examined in the study areas in southwestern Puerto Rico. Two of 33 yellow-shoulder nests fledged young there. None of the six yellow-shouldered blackbird nests monitored at Roosevelt Roads Naval Station in eastern Puerto Rico was successful in fledging young.

Observations of color-marked female cowbirds at yellow-shouldered blackbird nests revealed that multiple parasitism was common. Two female cowbirds were seen laying eggs in the same blackbird nest, and two cowbirds were noted visiting the same yellow-shoulder nest several times during the breeding season. Puncturing of yellow-shouldered blackbird eggs by female cowbirds was

observed for the first time, confirming the cowbird's responsibility for this type of egg loss. Formerly observed only in cowbird populations in eastern Puerto Rico, this behavior is now also occurring in southwestern Puerto Rico.

Cowbirds laid more eggs (average, 3.3 eggs per blackbird nest) in yellow-shouldered blackbird nests than did their hosts (yellow-shoulders averaged 2.3 eggs per nest). Many times cowbirds parasitized the nests even before the blackbirds laid their eggs. Cowbirds are now using other species (e.g., yellow warbler and greater Antillean grackle) as hosts more than in the past, probably because yellow-shouldered blackbirds have decreased in number and cowbird numbers have increased.

Studies of yellow-shoulder habitat requirements show that the species prefers young mangrove stands, particularly those interspersed with open areas. Habitat management for the yellow-shouldered blackbird should include thinning of some of the denser stands of mangrove and maintaining nesting areas in several stages of development.

A satisfactory trap for shiny cowbirds was developed, and in experimental trapping at Roosevelt Roads, 228 cowbirds were caught during 1978. Yellow-shouldered blackbirds are not attracted to the trap and none have yet been captured.

Nest boxes were installed at Roosevelt Roads and in southwestern Puerto Rico to test the acceptability of different structures to blackbirds and cowbirds and the effects of the structures on

overall yellow-shoulder breeding success. Blackbirds have not used the boxes at Roosevelt Roads, but at the southwestern area they built nests in several of the boxes (four new styles) installed in 1978. Yellow-shoulders apparently prefer boxes with a ramp-like entry to the bottom rather than those with initial drops to the floor. A nest box designed to exclude cowbirds has not yet been developed; boxes and open nests of yellow-shouldered blackbirds were parasitized to the same degree.

**Determination of a Dosage Schedule for Gentamycin.** The evaluation, including dosage schedules, of medications for use on endangered birds is generally an ongoing project. However, the evaluation of gentamycin, a broad-spectrum antibiotic used to treat bacterial infections and to prevent infection in newly hatched chicks or incubating eggs, was conducted in three avian species in cooperation with researchers at the National Zoological Park.

The dosage and frequency of administration of gentamycin to quail and cranes were determined on the basis of data collected in this study. However, a marked variation in plasma levels was noted in individuals of the same species after administration of identical doses. Such variations in plasma concentration from individual to individual, the large variations in the half-life of gentamycin from species to species, and the narrow range between toxic and therapeutic gentamycin levels, combine to make further study necessary before the clinical use of gentamycin will be safe and effective.

## Great Lakes Fisheries

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### GREAT LAKES FISHERY LABORATORY

The Great Lakes Fishery Laboratory, Ann Arbor, Michigan—which now includes field stations at Ashland, Wisconsin; Hammond Bay, Michigan; Sandusky, Ohio; and Oswego, New York; and the research vessels *Cisco*, *Kaho*, *Siscowet*, *Musky II*, and *Grayling*—completed its 50th year of fishery research on the Great Lakes in fis-

cal year 1978. A staff of over 100 professional and support personnel addressed a wide variety of Great Lakes problems, including the incomplete restoration of lake trout populations in Lakes Michigan and Superior; the status of heavily preyed-upon forage fishes such as alewives and smelt in Lakes Michigan, Huron, Erie, and Ontario; the continued decline of yellow perch in Lake Erie; the potentially adverse effects of fish-



The Great Lakes Fishery Laboratory's new research vessel, *Grayling*, arrived at its home port of Cheboygan, Michigan, in October 1977. It will operate on Lake Huron, eastern Lake Superior, and northern Lake Michigan. *Photo by Bender Shipbuilding Co., Mobile, Alabama.*

habitat impairment in the ecologically important St. Clair-Detroit River system; the possibility that contaminants have lowered the reproductive capacity of deep-water coregonids (principally bloaters) in Lake Michigan; and the extent to which contaminants in sediments resuspended by dredging are absorbed or ingested by Great Lakes fishes.

A continuing feature of the Laboratory's program is an ever-increasing degree of interagency and international coordination and cooperation on common problems concerning fishery resources and their essential habitats.

**Restoration of Lake Trout in Lake Superior.** Populations of lake trout, an important commercial and sport species in Lake Superior, were greatly reduced in the 1950's by intense exploitation and by sea lamprey predation. Partial control of the sea lamprey, protective fishery restrictions, and intense stocking resulted in a great increase in trout abundance in much of the lake by 1971. Present trout populations, however, are not only affected by large variations in annual plants of hatchery-reared fish, but are subjected to an ex-

panding sport fishery, continued sea lamprey predation, and increased commercial fishing by Indians in Wisconsin and in Whitefish Bay, Michigan.

We derive various indices of population status and trend from technical data obtained annually by contract fishing, surveys with research vessels, and fishery censuses. They reveal that most lake trout stocks in Michigan waters of Lake Superior continue to show general improvement. For example, the abundance of all lake trout above the "legal" length of 17 inches increased sharply in 1977 on the west side of the Keweenaw Peninsula and in the area from Keweenaw Point east to Grand Marais. The largest increases were among the largest sizes of lake trout: 29.0- to 32.9-inch fish increased 2.7-fold and fish longer than 32.9 inches increased 4-fold. Abundance of fish in these two size groups appears to be substantially higher than in any other inshore area of U.S. waters.

Prospects for rehabilitating naturally reproducing stocks are also brightened by increases in both the abundance and proportion of native fish in



An adult lake trout, just removed from a gill net set overnight in southeastern Lake Michigan, is measured and its finclip pattern tallied. Despite massive plantings of hatchery-reared yearlings, the goal of establishing self-sustaining populations of lake trout in Lake Michigan has not yet been achieved. *Photo by Neal R. Foster.*

most Michigan waters except Whitefish Bay. The percentage of native fish in the undersize (<17-inch) portion of the spring assessment catch increased from 6% in 1976 to 56% in 1977. Of the legal-size fish, 15% of those taken in 1977 were native.

In contrast to conditions in other Michigan waters, the drastic decline of lake trout that began in Whitefish Bay in 1975 continued. Numerical abundance in the spring of 1977 was only 7% of that in 1975 and was even lower in the spring of 1978. Abundance has declined 96% since 1974, and is the lowest observed since surveys began there in 1962. Unless mortality among the older components can be greatly reduced, the prospect of rehabilitating the stock of lake trout in Whitefish Bay is virtually nil.

The number of lake trout in Wisconsin waters

continues to decline from levels achieved in 1974 by the restoration program. Assessment fishing with gill nets at 14 traditional lake trout spawning sites in the Apostle Islands area in October 1977 indicated, for example, that the number of spawners had further declined there since 1976. The average catch at stations within the island complex was about one lake trout in 1977 compared with about three in 1976. Abundance increased slightly in 1978, but was still less than 50% of that in 1970, and well below the 9-year (1970-78) average. Another index of lake trout abundance, the annual catch per unit of effort (CPE) in the Wisconsin DNR's contract assessment fishery, declined from 367 fish per 10,000 linear feet of gill net in 1970 to 153 in 1975, 182 in 1976, and 159 in 1977.

Although adult fish are experiencing heavy mortality in Wisconsin's waters from a variety of causes, lake trout less than 17 inches long seem to be increasing in abundance. Experimental trawling during 1978 indicated the presence of substantial numbers of native yearlings, confirming observations of the previous fall that the 1977 year class was the strongest we have seen there since sampling began in 1965. The 1978 catch of young-of-the-year native lake trout was smaller than that in 1977, but nevertheless surpassed the 1974 catch as the second-highest on record. Two young-of-the-year and several yearling native lake trout were caught off Manitou Island at a station that has not yielded native juveniles in past years. One further hopeful sign of the lake trout's return to self-sustainability is that even with the abundance of adult lake trout sharply down, sea lamprey wounding rates also remain low; 4.6% of the fish showed wounds in 1978, which is near the annual average for the period 1970-78.

**Interaction of Alewife and Lake Trout in Lake Michigan.** The buildup of lake trout and Pacific salmon populations in Lake Michigan through annual stockings of hatchery-reared fish may become limited by the availability of forage fish (mainly alewives). As part of a continuing examination of salmonid predator-prey relations in Lake Michigan, we have derived first-order biomass estimates and projections for alewives and lake trout.

Point and interval biomass estimates for alewives, derived from surveys conducted throughout Lake Michigan each fall over the past 10 years, ranged from 114,000 metric tons (range, 98,000-131,000) in 1973 to 45,000 (37,000-53,000)

in 1977 for adults, and from 31,000 metric tons (range, 19,000-42,000) in 1974 to 3 (0-6) in 1971 for young of the year. The adult population has declined markedly since 1975, and appears to be oscillating about a lower average level than before. The amplitude of the oscillations is being dampened to an unknown extent by what we believe to be increased predation by lake trout, Pacific salmon, and other salmonids. Abiotic factors, including two unusually cold winters in succession (1976-77 and 1977-78), may have disturbed the system and increased the amplitude as reflected in the recent decline. If temperatures lower than those in the recent past become frequent, the alewife population could fall below the average of recent years because of the species' limited tolerance to low temperature (in effect, Lake Michigan would become thermally more like Lake Superior, where the alewife has been only marginally successful).

For lake trout, we have made preliminary projections of the standing stocks of adults and juveniles in Lake Michigan in January 1979. These projections were derived from estimates of the survival and of the mean weights at successive ages for each cohort stocked throughout the lake since 1965:

Life stage	Number (thousands)	Weight (metric tons)
Juveniles	2,180	1,077
Adults	150	473
Total	2,330	1,550

An average annual mortality of 50%, derived from catch curves of intensive sampling off Saugatuck in 1976-78, was assumed to be representative of Lake Michigan's entire stock of lake trout. This assumption is supported by the results of lakewide sampling by the States and the Laboratory during the same period. (Because the assumption of 50% annual mortality for the total population is based on data for lake trout of age V or older, our projections of the weight of younger trout are too conservative, if in fact the loss rate among the younger fish is lower.) Continuing interagency analysis of available and forthcoming catch data should provide more precise estimates of age-specific mortality rates.

Our next step is to combine the alewife and trout biomass estimates with data on seasonal feeding activity and food-conversion efficiency to determine the lake trout's rate of predation on the alewife, and its effect.

**Measurement of Forage Fish Populations in Lake Huron.** Success of the intensive program by United States and Canadian fishery managers to reestablish self-sustaining lake trout populations and introduce Pacific and Atlantic salmon, splake, and other salmonids in Lake Huron relies heavily on the adequacy of the forage base to support large populations of predator species. Systematic sampling with mid-water and bottom trawls at permanent index stations in western Lake Huron (off De Tour, Hammond Bay, Alpena, Harbor Beach, and AuSable Point) during 1978 provided the 6th year of base-line data on the distribution, abundance, and biology of alewives, rainbow smelt, and other forage fishes.

In fall 1977, we estimated the combined pelagic and demersal standing stocks of alewives and smelt to be in excess of 52,000 metric tons in the U.S. waters of Lake Huron. About 10% of the total biomass was distributed mid-water; alewives made up about 40% of that on or near the bottom, and less than 50% of that in mid-water.

The CPE data collected during the 1978 spring assessment of forage fish populations in Lake Huron showed a small decline in abundance of adult and yearling alewives. The decline in numbers of adults reflects expected year-to-year attrition of the weak 1974 year class, compounded by increased predator pressure. The CPE of yearlings, like that of young-of-the-year fish observed in fall 1977, was relatively high, confirming that the 1977 year class is strong and that the alewife population should be fairly stable for the next few years. Few dead alewives were noted in bottom-trawl catches, suggesting that overwinter mortality was not unusually heavy.

Growth of alewives in Lake Michigan and Lake Huron appears to be similar. The mean back-calculated lengths of alewives in age groups I to VII were 110, 148, 165, 176, 187, 190, and 213 mm, respectively. Several years ago, mean back-calculated lengths for alewives from Lake Michigan in the same age groups were 98, 144, 162, 172, 180, 189, and 196 mm. These results are surprisingly similar, in view of the far greater densities of alewives in Lake Michigan, and the potential there for growth depression through intraspecific competition for food.

The substantial increase in abundance of rainbow smelt in Lake Huron in 1977 (due primarily to recruitment of the strong 1975 year class) persisted into 1978. The CPE of adult smelt in spring 1978 was even larger than that in spring 1977.

Additional strong year classes produced in 1976 and 1977 should provide the recruitment necessary to maintain the smelt population at moderately high levels for the next several years.

Other forage species have declined noticeably over the past several years. By 1978, the ninespine stickleback, an important food of lake trout, had decreased in abundance for the 5th consecutive year, particularly in the northern part of the lake where trout are most abundant. The decline in abundance of slimy sculpins, as well as a decline in their average size at capture, was also most pronounced in the northern part of the lake. Such reductions in the abundance of sticklebacks and slimy sculpins could be a result of predation by expanding populations of lake trout.

**Management of Walleye and Yellow Perch in Western Lake Erie.** The walleye population of western Lake Erie is now larger than at any time during the last 25 years. Moreover, six or more year classes contributing to the fishery indicate a more balanced age structure than formerly existed. In 1977, the species produced the strongest year class observed since surveys began in western Lake Erie in 1958. This strong recovery of the walleye is gratifying to the agencies cooperating in resource-wide quota management, although there is some concern now that the stock may be at or near the western basin's carrying capacity for this species. Also, growth rate has steadily declined since 1974, and the age of sexual maturity for females has increased. The year class produced in 1978 was very weak, probably because the spawning and incubation period was prolonged by low water temperatures.

The Scientific Technical Committee of the Lake Erie Lake Committee, sponsored by the Great Lakes Fishery Commission, analyzed the walleye fishery statistics and biological data collected during 1977. It projected the 1978 standing stock of "catchable-size" walleyes (age II and older) at 9.5 million fish; forecast the stock's expected surplus production at 827,000 fish weighing 2,350,000 pounds; and recommended 1978 catch quotas of 73,000 fish for Michigan, 321,000 for Ontario, and 433,000 for Ohio. A provisional combined quota of 5.6 million pounds was forecast for 1979, reflecting recruitment of the exceptionally strong 1977 year class into the fishable stock.

The yellow perch resource of western Lake Erie has deteriorated further since 1976. In that year, the Yellow Perch Technical Committee recommended to the Great Lakes Fishery Commission's

Lake Erie Lake Committee that the minimum length limit in all fisheries be increased from the existing 8.0 inches to at least 8.5 inches. Theoretically, this change would increase the average stock weight by 36%, the potential egg deposition by 44%, and the average spawning opportunity per adult from 0.6 to about 1.2—with essentially no decrease in yield. Although the technical report and recommendation were accepted in 1976 by all fishery agencies sharing jurisdiction over the yellow perch resource in western Lake Erie, the recommended increase in minimum size limit had not been imposed by late 1978. Stricter enforcement of the existing minimum size limit of 8.0 inches for commercial catches since 1976 has resulted in a smaller percentage of sublegal fish in the catch and a higher average size. The resource remains depressed, however, and surveys in 1978 indicated that the 1978 year class of yellow perch was poor, compared with the strong year classes produced in the 1950's and 1960's.

**Assessment of Alewife and Rainbow Smelt Stocks in Lake Ontario.** Alewives and rainbow smelt are the major prey for trout (lake, brown, and rainbow) and salmon (coho and chinook) in Lake Ontario. Hatchery-reared trout and salmon, stocked in the lake by U.S. and Canadian fishery agencies each year since 1969, are being planted in increasing numbers as hatchery capacity expands and major fisheries for these introduced fish develop. Survival has been enhanced by a program begun in 1971-72 to control the parasitic sea lamprey. Continuing success of the evolving fisheries depends on the ability of the forage stocks to support the predators. Current knowledge of the status of the forage fish stocks is essential to formulate management decisions designed to perpetuate vigorous stocks of both predator and prey species.

We obtained our first comprehensive data on alewives and smelt in 1972, when we participated in an interagency cooperative survey of Lake Ontario fishery resources as part of the International Field Year on the Great Lakes. Data were next collected in 1978, when we began a fish-stock assessment program in cooperation with the New York Department of Environmental Conservation and Ontario Ministry of Natural Resources, to provide continuing information on status of the major fish stocks.

Alewives were the most abundant forage fish in both years of observation, but their numbers in 1978 were only about half those in 1972. Scale



analyses showed that most fish grew rapidly during 1977, the faster growth being mainly responsible for an increase in mean size at capture of adults from 150 mm in 1972 to 171 mm in 1978. The sudden increased growth most likely resulted from a substantial reduction in alewife abundance—probably during the severe winter of 1976-77. The improved physical condition of alewives may also be attributed to the lower population density; fish collected in the spring of 1978 averaged 10 to 50% heavier than fish of the same lengths taken in 1972. The combination of better condition and faster growth held the loss in estimated biomass between 1972 and 1978 to only 22%, despite the 50% reduction in numbers.

Rainbow smelt made up a much greater portion of the forage-fish community in 1978 than in 1972, due to the decline in alewife abundance and a 14-fold increase in the smelt population. During this period the ratio of alewives to smelt changed from 75:1 to 6:1. In 1978, the estimated biomass of alewives and smelt combined was only about 75% as great as that in 1972.

such wastes on these larvae in natural waters, including the St. Clair-Detroit River Ecosystem (which links Lakes Huron and Erie), have not been demonstrated. One sensitive, measurable effect of exposure of fish larvae to these wastes may be a change in the feeding activity of the larvae, as reflected in the contents of their alimentary canals. To test this hypothesis, we examined the alimentary tracts of 113 larval yellow perch from samples collected in mid-May in the Detroit River. One group of samples was collected in relatively unpolluted water near Belle Isle, and another downstream near Grosse Ile, in an area impacted by major industrial and municipal waste discharges. Microscopic examination showed that all larvae were in yolk-sac or early post-yolk-sac stages. About 83% of the perch (4.6-7.8 mm long) from the Belle Isle area had food in their alimentary canals, compared with 30% of the perch (5.5-7.8 mm long) from the Grosse Ile area. The Belle Isle perch had ingested an average of five organisms each, and the Grosse Ile perch two organisms each. Because larvae at both transects were in the same life stage and probably from a common population in Lake St. Clair, the data suggest that impaired water quality in the lower Detroit River had a detrimental effect on the food supply and feeding activity of the larvae. Gut contents of additional specimens are to be examined to further evaluate these preliminary results.

**Base-line Habitat Characterization of the St. Clair-Detroit River Ecosystem: Distribution, Abundance, and Productivity of Aquatic Plants.** Aquatic plants were a prominent biological feature of the extensive wetlands that once bordered the U.S. shores of Lake St. Clair. Over the past century, however, about 85% of these wetlands have been dredged, filled, and bulkheaded and the rest face a similar threat. In 1977, we observed that about 25% of the lake's open waters still support stands of aquatic plants, parts of which are also threatened by such factors as pollution, increased turbidity, dredging, and dredge-spoil disposal. Because aquatic macrophytes (and their periphyton) are known to provide food, oxygen, and other habitat requirements for fish in marine and brackish waters, the loss of additional wetland or open-lake habitat may reduce fish productivity. Research is needed to document the contribution of the remaining plant communities to the fish productivity of Lake St. Clair, so that encroachment by man on the essential elements of their remaining habitat in this important ecosys-



Sampling fish larvae with 0.5-m plankton net to determine locations of spawning and nursery areas in the St. Clair-Detroit River system. *Photo by Roann Ogawa.*

**Effect of Water-use Practices on Food and Feeding of Larval Fish in the St. Clair-Detroit River Ecosystem.** Fish larvae are sensitive and vulnerable to many substances present in industrial and municipal waste discharges, yet the effects of

tem can perhaps be prevented.

Samples of submersed plants collected at eight locations of Anchor Bay and the St. Clair Flats (Lake St. Clair) in June, July, and August revealed that *Chara* was widely distributed and the dominant taxon in open waters of Anchor, Fisher, and Goose, and Little and Big Muscamoot bays. Water milfoil and wild celery were characteristic of more shallow nearshore waters in Anchor Bay, Little Muscamoot Bay, and around Sand Island. Pondweeds were also abundant east of Sand Island in water 2-5 m deep. Waterweed was found primarily in Little Muscamoot Bay, sparingly along the western side of Anchor Bay, and in dense, isolated mats covering the bottom in shallow, narrow, connecting channels in St. Clair Flats.

Mean total surface area of plants (determined by measuring the surface area of the individual plants in each sample with a photoelectric "leaf-area meter") increased in all locations from June to August. These values were consistently high in Little Muscamoot Bay; relatively low in northern Anchor, Fisher, and Big Muscamoot bays; and intermediate in the open water and along the western shore of Anchor Bay. The highest macrophyte surface area value, and the greatest seasonal increase, were recorded at Sand Island.

**Alternative Methods of Sea Lamprey Control: Velocity Barriers.** The Great Lakes Fishery Commission is committed to a continuing program of assessing the impact of residual sea lamprey populations on Great Lakes fish stocks. Its main charge is to develop an integrated, cost-effective lamprey control program that will include the continued use of chemical toxicants where appropriate, but that will also include the use of attractants, repellents, sterilants, physical barriers, and other methods that may prove useful and economical.

The installation of barrier dams on certain streams as part of an integrated sea lamprey control program has long been endorsed by the Commission. Consideration is being given to the design of low-head dams that would prevent the upstream movement of spawning-run lampreys during low and normal conditions of streamflow, and that would create velocity barriers when high streamflow reduces the necessary head. To develop reliable design criteria for these velocity barriers, engineers need information on the burst swimming speed of spawning-run sea lampreys.

In providing this information, biologists at the Hammond Bay Biological Station performed tests

designed to yield data on maximum swimming speeds attainable by spawning-run sea lampreys. Water velocities in the flow-through test flume (1 x 1 x 8 feet) on the Ocqueoc River (which has an annual run of sea lampreys) ranged from 5 to 13 feet per second; water temperature ranged from 16 to 25° C. Migrating sea lampreys, captured in an electro-mechanical trap at the site of the swimming-test apparatus, were able to swim distances from 1 to 8 feet against the maximum current (13 feet per second) that could be generated in the test apparatus. From the tests we concluded that the ability of adult sea lampreys to swim at speeds in excess of this value over distances of up to 8 feet probably precludes the development of velocity barriers against lampreys in most fish-passage facilities.

**Uptake of PCB's by Lake Trout Fry.** The apparent failure of lake trout to reproduce in Lake Michigan has prompted considerable research to identify the factors influencing reproduction of stocked lake trout. One factor under investigation is the effect of organic contaminants on the survival, growth, and performance of lake trout fry. In preparation for a field evaluation of the effects of organic contaminants such as PCB's and DDE on survival and growth of lake trout fry, we conducted two laboratory exposures of fry to PCB's (Aroclor 1254). The first exposure was to describe PCB uptake patterns through critical life stages, including yolk absorption and onset of feeding, and the second was to evaluate the effect that use of a carrier solvent (acetone) has on uptake of PCB's by lake trout during low-level exposures simulating environmental conditions.

Fry hatched from eggs of Lake Michigan lake trout were exposed to 50 ng/l PCB's in water and 0.8 µg/g in food through the first 48 days after hatching. During this period samples of lake trout fry were taken seven times and analyzed for PCB's. Results of these analyses were expressed in three ways: concentration (µg/g) based on wet weight of fish, concentration (µg/g) based on dry weight of fish, and body burden (µg PCB's per fish). Wet-weight concentrations of PCB's in the fish ultimately decreased by the 48th day of exposure, but dry-weight concentrations increased 65% and body burden increased 67%. These apparently contradictory results are believed to be caused by substantial physiological changes, including rapid growth and associated changes in water and lipid content known to occur during early life stages of fish. Thus, conclusions drawn

about the uptake patterns of contaminants by these young fish differ dramatically, depending on how the results are expressed. We conclude that when studies are conducted to measure rate and extent of contaminant uptake, the data should be reported as body burdens (e.g.,  $\mu\text{g}$  PCB's per fish).

In the second study, we exposed lake trout (from hatchery stocks) to low levels of PCB's in water (50 ng/l) for 52 days with and without the addition of acetone (10 mg/l). Fry exposed to PCB's with acetone accumulated 43% more PCB's than did fry exposed to the same concentration of PCB's without acetone. The use of a carrier solvent such as acetone is a common bioassay practice for maintaining low-polarity organic compounds in water solution. The results of this study indicate, however, that the use of acetone in such studies may result in an overestimation of PCB uptake by the fish, particularly under exposures intended to simulate environmental conditions. We therefore recommend that studies intended to evaluate the uptake or hazards of compounds such as PCB's under simulated field conditions be performed without the use of carrier solvents.

**Acute Toxicity of Arsenic and PCB's to Fry of Bloaters.** As the initial step in evaluating the potential role of arsenic and PCB's in the decline of Lake Michigan bloaters, static acute-toxicity tests (96-hour) were performed on fry, the most sensitive life stage. Levels of contaminants used in these tests were as follows: in adults, 0.43 to 0.98  $\mu\text{g}$  arsenic/g, 0.8 to 2.7  $\mu\text{g}$  PCB's/g, and 0.4 to 2.0  $\mu\text{g}$  DDE/g (saponified DDT plus DDE); and in the eggs, 0.26  $\mu\text{g}$  arsenic/g, 0.5  $\mu\text{g}$  PCB's/g, and 0.2  $\mu\text{g}$  DDE/g.

Statistical analysis of 96-hour acute toxicity tests with arsenic ( $\text{As}_2\text{O}_3$ ) when the fry were 15 to 19 days old resulted in an LC50 of 26  $\mu\text{g}$  arsenic/ml. Arsenic and PCB's (Aroclor 1254), singly and in combination at doses of 3.2 to 32  $\mu\text{g}$  arsenic/l and 1.0 to 10  $\mu\text{g}$  PCB's/l, tested on 22- to 26-day-old fry, yielded the following LC50 values: arsenic alone, 17  $\mu\text{g}$ /ml; arsenic with PCB's, 11  $\mu\text{g}$ /ml; and PCB's with arsenic, 3.5  $\mu\text{g}$ /ml. Only 20% of the fry died in the highest dose of 10  $\mu\text{g}$  PCB's/ml. Estimation of the additive index indicated simple additive toxicity for arsenic and PCB's.

Because additive toxicity was indicated, the "safe" concentrations were calculated by multiplying an application factor of 0.01 (recom-

mended by the National Academy of Sciences) by the LC50 values of the mixtures. The estimated safe concentrations of 35  $\mu\text{g}$  PCB's/l and 110  $\mu\text{g}$  arsenic/l are well above the reported levels of less than 10 ng PCB's/l and 1  $\mu\text{g}$  arsenic/l for Lake Michigan waters. Hence, the water-quality criteria and objectives for PCB's (1.0 ng/l) and arsenic (50  $\mu\text{g}$ /l) recommended by the Environmental Protection Agency and the International Joint Commission appear to be adequate to protect bloater populations in Lake Michigan.

**Energetics of Great Lakes Fishes.** Information on the caloric (energy) content and proximate composition of fishes is needed to help understand the flow of energy through Great Lakes food webs and to evaluate laboratory-derived energy budgets. Such information can also be used to indicate the general condition of stocks, including the level of feeding by, or forage available to, a particular stock. Because of the recently increased stocking of salmonids in the upper Great Lakes and the potentially unstable nature of the alewife stocks (now the principal prey of most of these salmonids), forage availability will be a major concern in future fishery management in the Great Lakes.

We measured the proximate composition (percentage fat, water, fat-free dry material, and ash) and caloric content of eight species of Lake Michigan fishes: lake trout, coho salmon, lake whitefish, bloater, alewife, rainbow smelt, and deep-water and slimy sculpins. Caloric content of all species varied directly with fat content and inversely with water content. No significant difference in proximate composition or caloric content was observed between males and females or between fish collected in different years. Fat and caloric content of lake trout increased directly with age. Small, presumably immature, fish of the other seven species were significantly lower in fat and caloric content than larger, older fish. Age was not determined, however, for the other species analyzed. Fat content of lake trout, whitefish, and bloaters (range of means, 16-22%) was nearly 3 times higher than that of coho salmon, sculpins, smelt, and alewives (range of means, 5.2 to 7.0%). The caloric content ranged from 3.9 to 7.1 kcal/l for lake trout, whitefish, and bloaters and from 5.8 to 6.3 kcal/g for coho salmon, sculpins, smelt, and alewives. Since the decrease in caloric content was not proportional to the decrease in fat content, and other components of fish composition were essentially unchanged, energy content of fat appears to vary among these

fish species.

We also conducted experiments to develop a working knowledge of the bioenergetics of lake trout that would enable us to better understand this species' forage requirements as well as its impact on the forage stocks. A preliminary energy budget was constructed for yearling lake trout fed various rations of alewives while held at temperatures ranging from 3 to 20° C. The energy content of the alewives consumed, as well as that used for standard metabolism and growth, was measured directly, but the energy required for active metabolism and specific dynamic action, together with that lost as waste, had to be estimated.

The relative amount of energy assigned to each of the various components of the budget for yearling lake trout varied with temperature; the largest increase in food intake and growth occurred between 10 and 12° C. The largest portion of ingested energy, 31 to 34%, was lost as waste; the smallest portion, 18 to 33%, was added as growth; and the remaining 30 to 45% was used for respiration. The respiration component of the budget could be further subdivided into the energy required for standard metabolism (26 to 45%) and that used for activity and assimilating food (55 to 74%).

Lack of information on the thermal experience, activity level, feeding behavior, and diet of lake trout in the lake environment makes a meaningful comparison of growth rates between field and laboratory fish difficult. Nevertheless, the estimated daily growth rates for lake trout of ages I and II collected in Lake Michigan are within the ranges of growth rates observed for laboratory fish fed restricted rations at temperatures similar to those in the lake. The growth rate of 19 calories per gram per day obtained for laboratory fish fed alewives ad libitum (at 7° C), was nearly 3 times that estimated for lake fish.

**New Research Vessel.** The Laboratory's new research vessel *Grayling* arrived at its home port of Cheboygan, Michigan, in October 1977, after a 2,200-mile voyage from its construction site in Mobile, Alabama. It joins four other research vessels operated by the Laboratory in support of fishing and environmental research across the Great Lakes: the *Cisco* on Lake Michigan at Saugatuck, the *Siscowet* on Lake Superior at Bayfield, the *Musky II* in Lake Erie at Sandusky, and the *Kaho* on Lake Ontario at Oswego. The *Grayling*, operating mainly on Lake Huron, eastern Lake Superior, and northern Lake Michigan, en-

gages primarily in surveys associated with the assessment of stocks of forage fishes such as alewives and smelt, as well as stocks of sport and food fishes such as lake trout, bloaters, yellow perch, and walleyes. As required, it also facilitates investigation of the effects on fishery resources of habitat alterations that result from contamination, water withdrawal, maintenance dredging, and shoreline modification.

The *Grayling*, a modified stock-model Gulf-of-Mexico trawler, is of all-welded steel construction with an overall length of 75 feet, a beam of 22 feet, and a loaded draft of 9.8 feet. Displacement is 189 long tons. It has a cruising speed of 9.1 knots and a range of 4,000 miles, and can sustain continuous operation for up to 40 days. Its hull is reinforced for winter (ice) operations and is equipped with bilge keels to reduce roll.

The vessel features a raised forecastle bow that houses two fully equipped laboratories, galley and mess area, quarters for two scientists, and a combination washroom and shower on the main deck. Below deck forward are separate quarters for two scientists and two crew members, a combination washroom and shower, and dry-storage compartment. Quarters for the vessel's captain are directly aft of the pilot house on the upper deck. Scientist and crew quarters, galley space, washrooms, and laboratories are heated for cold-weather operation; scientist and crew quarters, and galley space, are also air-conditioned.

The vessel is propelled by two diesel engines rated at 275 shaft horsepower each and located below aft. Each engine is equipped with a special marine gear that allows separate, variable-speed control with constant engine speed. Electrical power is supplied by two diesel-powered generators, each rated at 75 kW.

Deck machinery located on the after main deck, in the forward laboratory, and on the upper deck forward are all hydraulically operated with power from the main engines. The machinery includes split, automatic level-wind trawl winches; split trawl-net reels (one reel to accommodate a bottom trawl, the other a mid-water trawl); articulated crane; gill net lifter; anchor windlass; and two bathythermograph winches with boom.

The *Grayling's* navigation-communication equipment includes a magnetic compass/automatic pilot, 64-mile-range radar, two VHF-FM transceivers, Loran-C navigation system, wind velocity/direction indicator, depth sounder, and sophisticated acoustical fish-detection equipment.

## LA CROSSE NATIONAL FISHERY RESEARCH LABORATORY

**Registration of Lampricides.** In concert with the Fish and Wildlife Service Registration Liaison Officer, supplemental labels were developed to cover the use of the lampricides 3-trifluoromethyl-4-nitrophenol (TFM) and TFM:Bayer 73 as used by the Great Lakes Fishery Commission's sea lamprey control crews. The new labels received the approval of the Environmental Protection Agency (EPA) on May 5, 1978, and instructions for affixing them to containers of chemicals on hand were mailed to the field crews.

This approval means that all current uses of TFM as a lampricide are now covered by adequate labels. Although EPA has not formally responded to our February 1976 submissions for amended registration and exemption from a requirement of a tolerance (ERT), the granted supplemental labels provide the needed legal coverage. Thus, no further concerns related to the registration of lampricidal uses of TFM are anticipated until EPA calls for reregistration of the compound.

After reviewing the Pesticide Petition and Food Additive Petition for TFM, EPA recommended that the Service extend the request for an ERT to include meat, milk, and eggs. In addition, EPA suggested that the Service petition for an ERT on dimethylformamide when used as a solvent for TFM. The Laboratory prepared draft letters regarding both matters and provided additional data on safety and residue concerns of dimethylformamide.

**Interaction of the Lampricide TFM and Nitrite Nitrogen.** A recent chemical treatment of the Muskegon River (Michigan) with TFM for larval sea lamprey control resulted in a fish kill—primarily of northern pike and white suckers. A spot check of selected water quality characteristics of the River indicated relatively high nitrite nitrogen levels (0.02-0.3 mg/l). It was postulated that an interaction between the nitrite and TFM may have resulted in increased toxicity. The La Crosse National Fishery Research Laboratory was asked to evaluate the possibility of this interaction under laboratory conditions. We exposed northern pike and white suckers to TFM, nitrite, and a combination of the two and analyzed the data for the individual toxicities and the combined toxicities. For both species the toxicity of the combination was greater than that of the individual compounds, indicating that synergism may have been a factor in

the fish kill. The development of a program to evaluate the effects of contaminants on the toxicity of the lampricides should be considered, since contaminants may have been a factor in previous unexplained fish kills.

**Uptake and Elimination of TFM.** Largemouth bass exposed to a 1-mg/l solution of  $^{14}\text{C}$ -TFM for up to 24 hours were analyzed for residues of TFM during the period of uptake and for 72 hours of withdrawal in lampricide-free water. Uptake of the lampricide in largemouth bass muscle was rapid. The muscle contained 0.375  $\mu\text{g/g}$  after 2 hours of exposure and 0.653  $\mu\text{g/g}$  after 24 hours. The head and viscera contained higher concentrations of lampricide after exposures of both 2 hours (0.553  $\mu\text{g/g}$ ) and 24 hours (2.50  $\mu\text{g/g}$ ). During withdrawal in lampricide-free water, the concentration of TFM in muscle declined to less than the detectable limit (0.001  $\mu\text{g/g}$ ) within 48 hours. The concentration also declined in the head and viscera; however, after 72 hours of withdrawal the head and viscera still contained 0.418  $\mu\text{g/g}$ . Most of the  $^{14}\text{C}$ -material found in largemouth bass after exposure to  $^{14}\text{C}$ -TFM occurs as either the parent compound or the glucuronide conjugate. A small amount of unidentified  $^{14}\text{C}$ -material was also found. Largemouth bass apparently detoxify TFM by glucuronide conjugation similar to that demonstrated in salmonids. Since the lampricide is readily metabolized and eliminated by fish, there is little chance that tissue residues could ever become harmful to humans.

**Residues of Bayer 73.** A method for analysis of residues of the lampricide Bayer 73 in fish muscle tissue was recently improved by the development of a solvent partitioning cleanup procedure. Further refinement of the procedure by eliminating unnecessary steps and optimizing the cleanup and recovery of Bayer 73 is under way. Steps involving incubation of tissue extracts and the use of potassium permanganate and lead acetate as oxidizing agents are being evaluated. The presence of 30%  $\text{H}_2\text{O}_2$  during hydrolysis of Bayer 73 to form 2-chloro-4-nitroaniline is essential for good recoveries, especially in the presence of interfering lipid material. The use of gas chromatographic columns containing 6% OV-3 on Gas Chrom Q or 5% OV-17 on Chromasorb W-HP seems to be most effective for Bayer 73 analysis.

Residues of Bayer 73 in plasma and gallbladder bile of rainbow trout exposed to 0.05 mg/l of Bayer 73 increased with time; after 24 hours of exposure the concentrations were 5.30  $\mu\text{g/l}$  in

plasma and 473  $\mu\text{g}/\text{ml}$  in bile. In rainbow trout exposed to 0.05 mg/l of Bayer 73 for 12 hours and then placed in lampricide-free water, Bayer 73 residues in the blood plasma decreased to less than 0.01  $\mu\text{g}/\text{ml}$  after 3 weeks of withdrawal. Some Bayer 73 residues (0.76  $\mu\text{g}/\text{ml}$ ) were still detected in the gallbladder bile.

Blood plasma and bile from coho salmon exposed to 0.05 mg/l of Bayer 73 were analyzed for residues of that material. Bile contained 3,040  $\mu\text{g}/\text{ml}$  in the 0-hour samples and 880  $\mu\text{g}/\text{ml}$  after 14 days of withdrawal; plasma contained 5.2  $\mu\text{g}/\text{ml}$  at 0-hour and 0.24  $\mu\text{g}/\text{ml}$  after 7 days of

withdrawal. No Bayer 73 residues were detected in plasma of fish withdrawn from the lampricide for 14 days. The fish were not fed during the experiment, and thus accumulated the conjugated Bayer 73 in gallbladder bile.

Muscle of largemouth bass exposed to 0.05 mg/l of Bayer 73 for 24 hours contained 0.035  $\mu\text{g}/\text{ml}$  immediately after the exposure; after 14 days in lampricide-free water the residue concentration had decreased to 0.008  $\mu\text{g}/\text{ml}$ . Fish apparently have the ability to eliminate Bayer 73 over a short period of time.

## Inland Fisheries and Reservoir Management

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### GAINESVILLE NATIONAL FISHERY RESEARCH LABORATORY

**Laboratory for Study of Exotic Fishes.** In August 1977 Director Lynn Greenwalt announced the establishment of a National Fishery Research Laboratory at Gainesville, Florida, to conduct research on exotic and non-native fish species that have become established, or are likely to become established, in the Nation's waters.

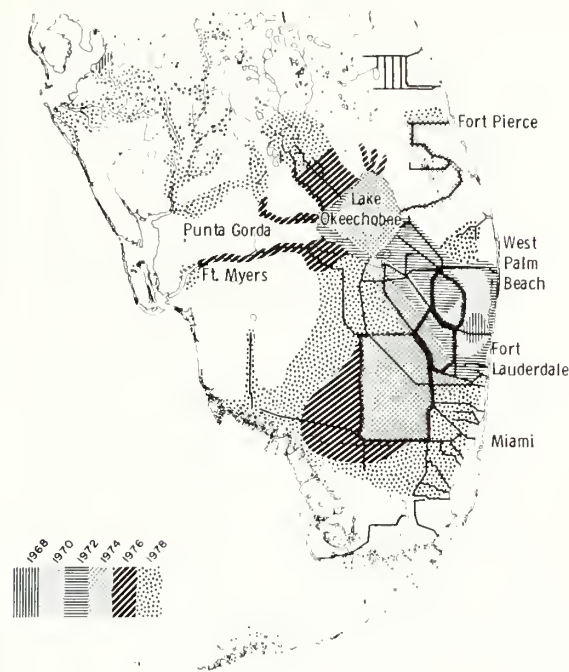
Large numbers of exotic fish species are being introduced into the United States each year by the tropical fish industry for the home aquarium trade or by Federal and State agencies to provide better sport fishing or as possible agents to control aquatic weeds. Many of the species have been either intentionally or accidentally released into natural waters and have established breeding populations. Many compete successfully with native fish populations and are potentially capable of causing severe damage to aquatic ecosystems. Knowledge of the potential damage that an exotic fish could cause if it became established would assist managers and law enforcement agencies in stopping the introduction and spread of harmful species.

The Laboratory's activities will be part of the

Service's increased efforts to stop this introduction and establishment of harmful exotic fishes. At present 43 species are known to occur in U.S. waters, of which 25 are found in Florida. Some exotic species, such as the carp and goldfish, have been widely established for many years and are clearly undesirable. Others, such as those belonging to the genus *Tilapia*, various tropical aquarium fishes, and grass carp are relatively new additions whose potential impacts are not fully known. The Laboratory will be responsible for determining the distribution, status, and effects of the exotic fishes that are already established, for supporting regulations to prevent further introductions of undesirable species, and for development of protocols and studies which must be completed before a new exotic species can be purposely released into the open waters of the Nation.

An Environmental Assessment on the Laboratory and a Cooperative Agreement with the University of Florida have been completed. The agreement includes a 99-year lease on 25 acres of University property for the site of the Laboratory and associated experimental ponds. The final planning and design of the Laboratory will take place in 1979 and construction will begin soon thereafter.

One of the first projects of the Laboratory is



Distribution of the South Asian walking catfish *Clarias batrachus* in south and central Florida showing the rapid uncontrolled expansion of its range. (Interim contract report—Walter R. Courtenay, Jr. [From Am. Men Sci.], Florida Atlantic University.)

that of supporting a program to monitor the status of all fish populations in the United States and provide an early warning if changes in their abundance or distribution takes place. Land development activities and man-made contaminants, both chemical and biological, have been gradually increasing the stress on native fish species and their habitats. This stress has caused major changes in fish populations and has caused a reduction in numbers or in distribution of many of the more sensitive species. Some species under extreme stress are reaching threatened or endangered status. Under these conditions, the introduction of exotic fish can have major impacts.

A contract with the North Carolina State Museum was developed that would support the compilation of a distributional atlas of all freshwater and brackish water fish found in North America north of Mexico. The atlas would contain an illustration or photo for about 700 species and a brief summary and references outlining their systematics, geographical and ecological distributions, status, and biology. In addition, either a dot distribution or area distribution range map would be shown for each species. The atlas is scheduled

to be published in 1980 in loose-leaf form to allow updating as new material becomes available. The resulting publication should be of major assistance to Federal and State agencies, land developers, and utility companies in assessment of the ecological consequences of any new project before it is undertaken.

Ichthyologists, researchers, managers, students, and sportsmen alike should find the volume interesting and a valuable source of basic information, and provide a base for a future catalogue summarizing systematic and life history information. Lists of major fish identification and life history references for each State or region of the United States and a current list of the species considered threatened or endangered by Federal or State conservation agencies would be included.

## LA CROSSE NATIONAL FISHERY RESEARCH LABORATORY

**Laboratory Construction.** The new National Fishery Research Laboratory, La Crosse, Wisconsin, was dedicated on September 16, 1978. Assistant Secretary Robert L. Herbst delivered a challenging and informative dedicatory address. After the ceremonies, the new facilities were toured by over 1,000 visitors and guests.

Two of three main structures have been completed, and the third is scheduled for completion in October 1979. Also completed are three wells for supplying all needed water, a toxic treatment facility for waste water, concrete pools and raceways for culturing fish and testing chemicals, and earthen ponds for fish culture and chemical exposures.

Development of the new facility will permit an accelerated program of research, will provide the latest innovations in technical facilities and capabilities, and will provide an opportunity to begin studies of the effects of resource management activities, pollutants, and navigational development on river ecosystems.

Fishery chemical registration activities will continue at the new facility to ensure the availability of chemicals for fish management and culture. This research relates to the effects of fishery chemicals on nontarget organisms, and persistence of these compounds and their degradation products in animal tissues and in soil, water, and



Dedication of the La Crosse National Fishery Research Laboratory was keynoted by Assistant Secretary Robert L. Herbst on September 16, 1978. *Photo by L. L. Marking.*

plants. Interrelations between chemical and biological variations and fishery chemicals are explored to determine potential neutralizing effects or possible synergistic reactions that might increase toxic effects. Mammalian safety is investigated by contracting studies with laboratories that specialize in such work.

**Progress Toward Registration of Fishery Chemicals.** Communications continued with Food and Drug Administration (FDA) officials concerning evaluation of the submission for registration of formalin. Information was provided on a recent rat study involving formalin-treated meat that showed no deleterious effects. Data that showed no residues in fish after applications at double the use-pattern levels were also provided.

The National Fishery Research Laboratory provided additional information on formaldehyde to FDA and developed the proposed use label and package insert along with relevant reprints that support the efficacy claims. The Laboratory also prepared briefing material on formalin at the request of the Service Registration Liaison Officer.

The information was used in a meeting of solicitors from FDA and the Environmental Protection Agency (EPA), who discussed the registration for the use of formalin in fisheries.

Formalin has now been reviewed and passed on by all divisions within FDA, except the Environmental Impact Group.

Betadine is very effective in disinfecting fish eggs for bacterial and viral pathogens. Inasmuch as the Purdue-Frederick Company has the human-use registration for the compound, all the mammalian safety and residue work has been completed.

Communications with Purdue-Frederick Co. and Tavolek Inc. concerning possible submission of a "new animal drug application" to cover use of Betadine in fisheries led to an arrangement under which Tavolek will assume sponsorship of the application. All of the Laboratory's data relating to Betadine were forwarded to Tavolek.

It was recommended that the Service abandon further efforts to have malachite green registered for fishery uses. Recent results from a rabbit tera-





The National Fishery Research Laboratory, La Crosse, Wisconsin, provides space and flexibility to meet future research needs. *Photo by L. L. Marking.*

tology study yielded evidence of significant developmental defects at all treatment levels. Discussions with FDA officials indicated a low likelihood of success, and greatly increased research requirements and costs.

**Aids in Registration.** The National Fishery Research Laboratory received word from the Fish and Wildlife Service Registration Liaison Officer that FDA had accepted the definitions developed by the Laboratory that excluded the designation of food fish to eggs, sac fry, fingerlings (as defined), and brood fish of cultured species. The definitions were to be published in the Federal Register in October, and a 1- to 2-month period was to be allotted for comments or hearing before the acceptance of the definitions becomes official. This ruling will allow registration of fishery chemicals for these categories of fishes without the necessity for performing all the tests required for a food use registration—thus providing substantial savings in funds and manpower.

The Laboratory developed a list of what were considered to be the priority chemicals currently

used by hatcheries and in other fishery work, in an attempt to gain support for additional funds needed for registration-oriented research. The priority needs were as follows:

- A fungicide to replace malachite green
- Registration of a quaternary ammonium compound
- A broad spectrum antibiotic
- A bacterial gill disease control agent
- Reregistration of rotenone
- Extension of the label for Furanace to allow use on food fish
- Further research on GD-174, a selective piscicide
- Extension of the label for Masoten to allow use on food fish
- Reregistration of antimycin
- Completion of registration of quinaldine sulfate
- Registration of erythromycin

Using the list of priority chemicals, the Laboratory determined what essential contract studies could be funded as funds become available. In

order of priority the chemicals and studies are as follows:

- Quinaldine sulfate—90-day subacute oral (rat)
- Hyamine 1622—teratology (rabbit)
- Hyamine 3500—2-year oncogenicity (rat)
- Ames mutagenicity tests on new candidate compounds
- Furanace—2-year oncogenicity (rat)
- Hyamine 1622—metabolism (rat)
- Hyamine 1622—2-year oncogenicity (rat)
- Hyamine 3500—2-year oncogenicity (hamster)
- Hyamine 1622—2-year oncogenicity (hamster)

**Toxicity of the Piscicide GD-174.** Rotenone and antimycin are currently the only two piscicides registered for use in the United States. Through an intensive screening program for selective chemicals for the control of undesirable fish populations, Laboratory studies in 1974 had shown that a terpine derivative, 2-(digeranylamino)-ethanol (GD-174) was more toxic to carp than to other warmwater species.

Although the chemical has shown great promise in laboratory studies as a general toxicant and potential for the selective control of carp, results in field applications have been inconsistent. Consequently, we designed laboratory toxicity tests to weigh the individual effects of photodegradation, turbidity, aquatic vegetation, pH, and temperature. We found that the activity of the compound was reduced in cold water, in acid water, and in turbid water where bentonite or Crowley silt loam were the major components, and in water containing the waterweed *Elodea* sp. The activity was not affected by exposure to ultraviolet light or duckweed (*Lemna* sp.), or in turbid waters where turbidities were produced by kaolin or barium sulfate. The factors affecting activity may preclude the use of this compound as a general or selective fish toxicant; however, the identification of a compound which carp cannot metabolize as well as other warmwater fish is extremely important, because it may lead to the discovery of a related compound or analogue that is better suited for use as a general fish toxicant.

**Development of GD-174 in Field Tests.** In pond tests, routine on-site bioassays in plastic bags have failed to predict the effective concentration of GD-174 in 50 to 75% of the experiments. Tests were conducted to determine whether differences in water chemistry develop between water inside

the bags and that in the pond from which they were filled. Temperature, pH, dissolved oxygen, CO<sub>2</sub>, total hardness, and alkalinity were monitored inside and outside the bags. There was little variation in any of the factors between water in the bags and water in the pond. The only factor known to be different between bag and pond was intensity of ultraviolet light, and laboratory tests indicated no significant effect of ultraviolet light on activity or degradation rate of the chemical.

Further testing, in which fish were used as indicators of toxicity, was done to determine degradation rates of GD-174 in bioassay bags and in ponds. In one test the chemical degraded substantially faster in the pond (3 hours) than in the bags (19 hours). Three other tests showed about equal degradation rates in bags and in ponds. These tests showed the degradation rates to be short (12 hours maximum in ponds) and also variable. The rapid and variable degradation rate was considered a very significant factor in the erratic activity of this toxicant. The multiple factors that affect the toxicity of GD-174, some additive and some antagonistic, will make it difficult to use this toxicant selectively in the field.

Four pond treatments were designed to be selective against carp, and a fifth was intended to eradicate all species. The first selective test was done in winter in two small, acidic ponds. A treatment of the first pond at 0.875  $\mu\text{l/l}$  (pH 5.86) killed all rainbow trout and some spotted suckers (33%) and carp (20%), but none of the remaining 12 species. A 0.625- $\mu\text{l/l}$  treatment in the second pond (pH 6.56) eliminated the rainbow trout, two species of suckers, and carp, but killed few fish of the other 10 species except for about 17% of the brown bullheads.

The second selective test was done in a farm pond that contained an indigenous population of largemouth bass and bluegills and 12 other species stocked several days before exposure. A 0.9- $\mu\text{l/l}$  treatment applied to a pond with a pH of 8.1 killed all spotted suckers and various percentages of other species—carp, nearly 99; white bass, 32; yellow perch, 10; white crappie, 5; and brown bullheads, 3. Some phytoplankton was killed, but not enough to depress dissolved oxygen concentrations.

The third test was done in the same two ponds as the first trial, but for this test both ponds were fertilized and limed to produce fairly dense plankton blooms and a high pH (about 9.5). A selective treatment (0.75  $\mu\text{l/l}$ ) in the pond containing 12

species removed spotted suckers (80%), carp (74%), brown bullheads (5%), and a number of fathead minnows. The attempted total treatment of the other pond (1.75  $\mu\text{l/l}$ ) eliminated 15 of 18 species, but failed to kill about 3% of the largemouth bass, 8% of the green sunfish, and 56% of the bowfins. A marked reduction of the plankton population strongly depressed dissolved oxygen concentrations, but not to lethal levels.

Separate experiments demonstrated that largemouth bass and bluegills exposed to GD-174 applications in three consecutive tests in 1977 produced normal crops of young in 1978. Still another test in four ponds showed that benthic invertebrates and zooplankters were only slightly affected by 0.09- $\mu\text{l/l}$  treatments that eradicated adult carp.

**Detection of GD-174.** A gas chromatographic method for the analysis of the candidate toxicant GD-174 in fish has been developed. Muscle tissue of largemouth bass and channel catfish exposed to 0.3 mg/l of GD-174 for 4 hours contained 0.97 and 2.30  $\mu\text{g/g}$ , respectively, immediately after the exposure. However, after 14 days in water free of GD-174 the concentration had declined to less than 0.01  $\mu\text{g/g}$  in largemouth bass and 0.05  $\mu\text{g/g}$  in channel catfish, indicating that the chemical is eliminated by fish after their withdrawal from contact with the chemical.

In two ponds treated with GD-174, the compound was mixed by circulating the water with an outboard motor. Both ponds were sampled at the deepest point. The pond treated at a concentration of 1.5 mg/l contained 1.34 mg/l at the top and 1.44 mg/l at the bottom. The pond treated at 0.5 mg/l contained 0.5 mg/l at the top and 0.35 mg/l at the bottom. Four days after treatment the pond treated at 1.5 mg/l contained 0.6 mg/l, and the one treated at 0.5 mg/l contained 0.1 mg/l. These studies verify that the distribution of the chemical in the ponds was fairly uniform, and that its concentration was decreasing due to degradation or binding.

**Metabolism of Thanite.** Residues of a Thanite metabolite (isobornyl- $\alpha$ -[methylthio]acetate) in carp exposed to 1 mg/l of Thanite for 8 hours at 12° C in well water were measured in muscle plasma and gallbladder bile. No parent compound was detected in any of the samples. The highest concentration of metabolite (0.734  $\mu\text{g/g}$ ) was found in muscle samples taken immediately after exposure. After 48 hours of withdrawal in fresh water, muscle residues had declined to 0.028  $\mu\text{g/g}$ .

Plasma and bile contained 0.185 and 0.210  $\mu\text{g/ml}$ , respectively, at 0 hour. No residues of Thanite were detected after 48 hours of withdrawal.



Largemouth bass commonly survive exposures to GD-174 that are lethal to carp and suckers. Photo by L. L. Marking.

**Toxicity of Nitrate, Nitrite, and Ammonia Nitrogen.** Among these nitrogen forms, nitrite was the most toxic to aquatic invertebrates. The 48-hour LC50 for *Daphnia* was 2.95 mg/l for nitrite, 30.8 mg/l for ammonia, and 125 mg/l for nitrate nitrogen. The glass shrimp was the most sensitive invertebrate exposed to the nitrogen compounds; however, its sensitivity was not affected by changes in water hardness, temperature, or pH. As with other fishery compounds, the exotic clam *Corbicula* was more resistant than native clams or fish to nitrite nitrogen.

The blood of nitrite-poisoned vertebrates is reported to turn brown due to a reaction between nitrite and hemoglobin that produces methemoglobin. We found that a similar effect was produced by exposing larvae of the bloodworm midge to nitrite nitrogen. These midges are one of only a few invertebrates that have a hemoglobin-like respiratory pigment. About 60% of the larvae exposed to 5.0 mg/l of nitrite nitrogen lost their normal red body coloration within 3 hours.



Some clams emerged from overlays of 6 to 10 inches of silt or sand. *Photo by L. L. Marking.*



Mature female pocketbook clam displaying siphons and mantle. It is suspected that this behavior attracts host fish. *Photo by L. L. Marking.*

#### **Effects of Silt and Sand Sedimentation on Freshwater Mussels.**

Considerable attention has been given in recent years to the preservation of aquatic organisms, especially those bottom-dwelling species that cannot evade the adverse effects of man's activities on aquatic ecosystems. The Mississippi River is continually subjected to intensive commercial and recreational uses that have included major alteration, such as the construction of wingdams and navigation structures. Environmentalists have recognized the biological and ecological implications of some of these alterations and have tried to reduce or restrict environmental changes by resorting to legal actions based on requirements established in environmental impact statements, government permits, or the Endangered Species Act of 1973. Although the Mississippi River system has stabilized somewhat since the navigation system was developed, maintenance dredging will always be required to ensure a 9-foot navigation channel because sand and silt are constantly shifting. Erosion of silt and sand have been reported to be the most outstanding factors producing changes throughout the Mississippi River system and may be responsible for the decimation of mussel populations. The Corps of Engineers, which is responsible for maintaining the

navigation channel, has expressed concern about the effects of burying clams under river sediments at varying rates and depths. Because of these concerns, the Corps issued a contract to the Laboratory to determine the acute effects of dredge spoils on three species of mussels: pig-toe (*Fusconaia flava*), fat mucket (*Lampsilis radiata luteola*), and pocketbook (*L. ventricosa*). Our results showed that over 50% of the fat mucket and pocketbook clams were able to emerge from about 7 inches of sand or silt overlays, but that pig-toe clams were unable to negotiate 4 inches of silt.

The ability of clams to emerge from soil overlays is perhaps related to variations among species. Pocketbook clams are large and have a broad, strong foot with which to gain traction for movement in sand or silt. They also demonstrated their mobility characteristics by traveling up to 6 feet on the sand substrates before burial. On the other hand, pig-toe clams are much smaller and demonstrated less ability to move laterally on top of the substrate or vertically through the soil overlays.

Our studies showed that the type of soil overlay made little difference in the emergence of fat mucket and pocketbook clams. Emergence is actually a first step in survival; later steps involve the adaptation to new substrates or migration to a suitable substrate. Our studies also showed that most emergence occurred within 6 hours after the animals were covered. If clams are able to emerge from 6 inches of overlay within 6 hours, perhaps they could emerge from greater depths if the sediments were applied over a longer period of time.

## LEETOWN NATIONAL FISHERIES CENTER

The National Fisheries Center—Leetown was established in October 1977 by combining all fish husbandry research, development, and training activities into a comprehensive unit to focus on national fishery needs and objectives. The Center now comprises the Fish Health Research Laboratory, Leetown, West Virginia; the Tunison Laboratory of Fish Nutrition, Cortland, New York; the Fishery Research and Development Laboratory, Wellsboro, Pennsylvania; the Fish Farming Experimental Station, Stuttgart, Arkansas; the Southeastern Fish Cultural Laboratory, Marion, Alabama; the Fish Genetics Laboratory, Beulah, Wyoming; the Fisheries

Academy, Leetown, West Virginia; and the Experimental Hatchery, Leetown, West Virginia. The Center serves as an international focal point for these functions, to keep Service and national fishery interests abreast of worldwide fishery activities. The Fisheries Center complex arrangement is designed to efficiently serve the needs of management and of the fishery resource. The Center is situated on approximately 150 acres in West Virginia's Eastern Panhandle; the modern facilities and rural environment provide an excellent setting for research, training, and developmental programs.

Highlights include the expansion of the library formerly at the Fish Health Research Laboratory and its elevation to the status of a Center Library, complete with modern ADP storage and retrieval capabilities through the Department of the Interior Library and other contract sources.

The Library will now be able to provide users ready access to national and international literature related to fish husbandry research. Not only can users search our data base from anywhere in the United States, but users can submit searches to us for processing in related data bases as well. Through Lockheed, Systems Development Corporation, Bibliographic Retrieval Services, and the National Library of Medicine, we have access to more than 100 data bases. Searches can be by author, genus or species names, corporate body names, geographic names, journal name, date, keywords or descriptors, or significant words in the title and abstract.

## NATIONAL FISH HEALTH RESEARCH LABORATORY

**Diagnostic Methods for the Major Bacterial Diseases of Fishes.** Rapid and accurate diagnostic procedures are essential for effective control of diseases. Accordingly, we have concentrated on adaptation of serological procedures for diagnosis of bacterial kidney disease, furunculosis, and enteric redmouth disease. The indirect fluorescent antibody test (IFAT) has proved rapid and accurate in diagnosis of all three of these diseases. The IFAT is carried out in two steps and consists of treating test material from fish with a specific antiserum, followed by the addition of a second serum that is coupled with a fluorescent dye. Bacteria that retain the dye fluoresce brilliantly when

viewed with a microscope equipped with an ultraviolet light source. Although the IFAT is more rapid than methods previously used, 1½ to 2 hours are required to perform the test. Therefore, a direct fluorescent antibody test (FAT) was developed for the three bacterial diseases. The direct FAT can be completed in 7 minutes and is a one-step test in which the fluorescent dye is coupled directly to specific antisera. The direct FAT for diagnosis of kidney disease, furunculosis, and enteric redmouth disease is now being evaluated under field conditions.

**Transmission of Bacterial Kidney Disease and Detection of Carrier Fish.** Last year we reported that the bacterium causing kidney disease (KD) in salmon and trout is vertically transmitted (passed from parent to offspring with eggs or sperm), and that disinfection of fertilized eggs with organic iodine solution does not prevent transmission. Vertical transmission is one way in which kidney disease is perpetuated—sometimes by infected fish that simply carry the kidney disease bacterium but do not become clinically sick. Such carriers pose a threat to healthy salmon and trout and it is important they be detected to avoid infection of healthy stocks. The direct FAT, described earlier, is used to detect KD bacteria in carriers. Results of examination of several hundred carrier trout have shown that feces may provide the best material for such detection. This sampling procedure is desirable for use on valuable brood stock because it is nondestructive. Evaluation of the direct FAT with fecal material is being continued.

**Clearance of an Additional Antibacterial Drug for Treatment of Bacterial Fish Diseases.** Only sulfamerazine and terramycin have as yet been cleared by the Food and Drug Administration (FDA) for use on food and sport fishes. Often these drugs fail to control bacterial diseases, principally because the causative bacteria have become resistant to them. Therefore we have been testing a potentiated sulfonamide for FDA clearance. The drug contains a sulfonamide (sulfadimethoxine) and a potentiator (ormetoprim). The potentiator increases antibacterial activity and we have found that furunculosis can be controlled with much less of the potentiated sulfonamide than with sulfa alone. We have been cooperating with the manufacturer, Hoffman La Roche, Inc., to obtain data for FDA clearance of the drug, which is now referred to as RO5-0037. We hope to obtain clearance for treatment of furunculosis, enteric redmouth disease, and vibriosis. Initial data have

been submitted to FDA.

**Fish Virus Isolation: an Evaluation of Decontamination Procedures.** Wild and propagated fishes are susceptible to a number of diseases caused by viruses. Infection with the more serious viruses usually results in the death of young fish, particularly those less than 6 months old. Infected adults and some of the infected young survive and become lifelong carriers of the virus. These carriers are a source of virus for later disease outbreaks. A necessary step in controlling the spread of viral diseases is the detection and identification of the viral agent.

Conventional cell culture methods are currently used for virus isolation. However, tissues, body fluids, and solids used as samples in a virological examination may contain bacteria, fungi, and parasites. The growth of these contaminants must be suppressed so that virus-specific effects can be detected in infected cell cultures. Two methods are currently used to control such contamination—membrane filtration by which microbial contaminants and larger particulate matter are retained on a cellulose filter and thereby removed from the sample, and antibiotic treatment by which the growth of microbial contaminants is inhibited by the use of concentrations of antibiotics. Both methods are effective, but are expensive or require prolonged treatment before cell culture inoculation. Improvements in the antibiotic treatment method have yielded an effective cost- and time-efficient procedure. The antibiotic gentamicin, a mixture of penicillin, streptomycin, and nystatin, was found to be effective at conventional levels and, in addition, required no pretreatment period before cell culture inoculation. This improved procedure reduced sample preparation time by 2 to 6 hours and greatly reduced the cost per sample.

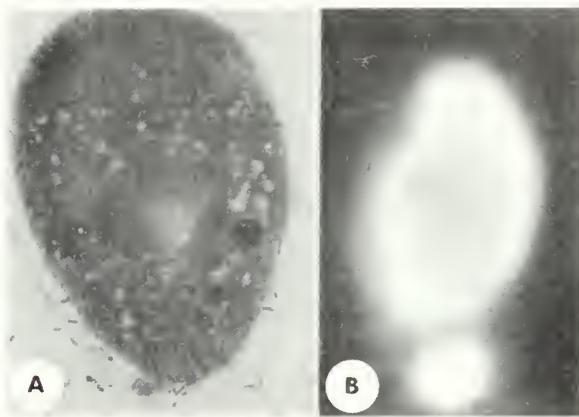
**Establishment of a Cell Culture Repository.** Unlike bacteria and fungi, which can grow on inanimate materials, viruses require living cells in which to multiply and indeed are generally detected by observing changes in the appearance of infected cells. Research and diagnostic laboratories maintain cells in single-layer cultures in glass or plastic bottles or as cells in suspension. The growth requirements of the cells are supplied by a liquid nutrient medium, and the cultures are subdivided to ensure a continuing supply. Cell culture stocks are periodically replaced, either as a requisite of good management practice or as the result of microbial contamination or some other unfortunate incident. Replacement cultures

should be of high quality and free of detectable microbial contaminants. To assist in the replacement of fish cell cultures, the National Fish Health Research Laboratory has established a repository of selected fish cell lines. The cell cultures have been tested for quality and are certifiable as free of detectable contaminants, including mycoplasmas. The cells are stored under liquid nitrogen and should remain viable for at least 10 to 15 years. The following five cell lines are now available for distribution: bluegill fry (BF-2), brown bullhead (BB), chinook salmon embryo (CHSE), fathead minnow (FHM), and rainbow trout gonad (RTG-2).

#### Detection of Mycoplasma in Fish Cell Cultures.

The growth requirements of cells in culture are supplied by a liquid nutrient medium which, unfortunately, also provides an ideal environment for the multiplication of bacteria, fungi, and other microbial entities. The detection of these contaminants is of preeminent concern in cell cultivation. The effects of bacterial and fungal contamination are generally dramatic—the cells may be killed and the media may become cloudy or contain visible clumps of the contaminant. Another of the cell culture contaminants are the mycoplasmas, which are bacteria-like organisms. Mycoplasmas have rather strict growth requirements and are usually difficult to detect; however, their detection is important because they can affect the properties of the cell culture. Mycoplasma infection may kill the cells or produce no visible effects; may mimic the effects of or decrease the sensitivity to viruses; or may interfere with cell metabolic functions. Although many methods have been proposed for mycoplasma detection in mammalian cell culture, applications to fish cell cultures have been limited. We evaluated two detection methods for their efficacy in fish cell culture systems. A bisbenzamide staining method, which reveals chromosomal nucleic acid as a fluorescent lime green color, was found to be sensitive and rapid. A second method commonly used in mammalian cell culture, in which radioactive materials are included in the chromosomal nucleic acid, was unsatisfactory because the fish cells, unlike some mammalian cells, included the radioactive material into the cellular chromosomes, giving false positive results. The bisbenzamide staining method reduces by 7 days or more the time required to evaluate cell cultures for mycoplasma contamination.

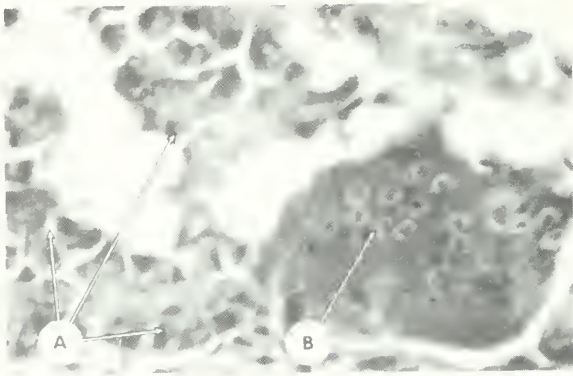
**Suspension Cultures of Fish Cells.** The establishment of suspension cultures of fish cells has



Fluorescent stains provide identification tag for life stages of fish parasites. The most troublesome fish parasite is a ciliated protozoan known as "Ich." (A) The invasive stage stained with traditional dyes shows complex interior features. (B) The invasive stage treated with bisbenzamide, a specific dye for DNA, shows only the small micronucleus and the larger macronucleus. Nuclear changes presage development of adults. *Photo by M. Markiw.*

several applications. Such cultures have found routine use in virus and vaccine production as well as in toxicology. Therefore we initiated studies with four fish cell lines to evaluate the potential for developing suspension cultures. Ultimately, the fathead minnow (FHM) and rainbow trout gonad (RTG-2) cell lines proved most adaptable. A program of adaptation to suspension culture was begun with both lines. This approach resulted in the establishment of FHM cells as the first continuous suspension culture of a fish cell line. The culture has demonstrated a rapid growth rate and the cell densities developed have been higher than those in conventional monolayer cultures. Viable cultures require complete renewal of the medium every 7 to 10 days and may offer excellent potential in a perfusion system. After 6 months in suspension culture the FHM cells retain the ability to grow as a monolayer. The RTG-2 cell line has not yet made the transition to high-density growth. However, a pattern of growth response similar to that seen with FHM cells has developed and the cultures are being continued.

**Development of Reduced-serum and Serum-free Media for Use with Fish Cells.** Studies have been conducted on the development of reduced-serum and serum-free (synthetic) media for use with cells of cold-blooded vertebrates. Such media make possible more detailed cellular studies, reduce the cost of cell culturing, and limit problems



A new and pathogenic fish herpesvirus produces specific tissue damage in fish. (A) Normal fish pancreas consists of well-defined enzyme secreting cells. (B) Herpesvirus infection causes cells of the pancreas to fuse—a specific change known only for this virus. Photo by K. Wolf.

of contamination. The ability of various synthetic and reduced serum media to support the growth of the brown bullhead (BB), bluegill fry (BF-2), fat-head minnow (FHM), and rainbow trout gonad (RTG-2) cell lines was evaluated. These cell lines are commercially available, represent both fibroblastic and epithelial cell types, and are routinely cultured in media with 10% fetal bovine serum. Cultures initiated in media in which serum concentration had been reduced 50, 80, and 90% exhibited growth proportional to the serum level. After a year in reduced serum culture, none of the cell lines had growth rates equivalent to that in the 10% serum medium. However, the quality of the cells grown in media in which the serum concentration was reduced 50 and 80% was good.

Other cell cultures were placed directly in serum-free media. However, with two exceptions, none of these commercially available media were able to maintain viable fish cells. An evaluation of serum substitutes, media supplements, and components showed that many substitutes and supplements supported or even stimulated the growth of fish cells in a low-serum medium. However, no combination produced growth equal to that of the 10% serum medium. Increased concentrations of many components, found in nearly all culture media, had no stimulative effects. Although current combinations of supplements and substitutes can maintain growing cultures of fish cells with low levels of serum, many refinements in media formulations are still necessary before rapid rates of cell growth can be developed.

**Culture and Immunization of *Ichthyophthirius multifiliis*.** The pathogenic protozoan with the tongue-twisting name *Ichthyophthirius multifiliis* is better known by its nickname, "Ich." Experimental infections are being maintained as a reli-

able and convenient source of the adult organism. Adults are harvested as needed and manipulated by temperature to divide repeatedly to produce the invasive stage known as the tomite. A variety of culture media are being tested for ability to support the development of adults in vitro. Early results with several media are promising, but the work has also emphasized the need to be able to identify serologically transformed tomites and to distinguish them from free-living ciliates. Methods of deciliation have been found in the literature, and purified cilia will be used for their highly antigenic qualities. A number of antibiotics are also being tested—the purpose being to develop a reliable method of decontaminating tomites without disabling their mechanism for penetrating nutrient media. Our long-range goal is the large-scale culture of avirulent tomites that can be used to immunize fish.

**Fish Health News.** *Fish Health News* is a compilation of abstracts of world literature on topics related to fish health. Printing of the quarterly for 5 years has been approved by the President's Office of Management and Budget. The authorization also provides for sale of yearly subscriptions at cost by the Government Printing Office. The Laboratory is authorized to distribute 300 free copies to the scientific community; 200 of these go to agencies in the United States, and the rest to 38 foreign countries. Work is under way to computerize the storage, retrieval, and ultimately the regular print-out of *Fish Health News*.

**Life Cycle and Control of Trout Whirling Disease.** Waterborne infectivity was concentrated on filters and assayed in susceptible trout fry by several routes of inoculation. Only the positive control fish exposed by immersion developed disease. The results clearly showed that waterborne



infectivity was trapped on a 25-micron filter, thus sizing the infectivity at nearly twice that reported by other researchers. Special stainless steel screens of suitable sizes are being used in attempts to concentrate the infectivity and identify its form or its carrier.

**Pathology of Rainbow Trout Herpesvirus in Fish.** The virulence of the salmonid herpesvirus was confirmed during the 2nd year of work, and specificity was again shown for rainbow trout. Kokanee fingerlings proved to be refractory under conditions that resulted in total mortality of rainbow trout. Moribund victims were fixed and sent to the Armed Forces Institute of Pathology for embedding, sectioning, and staining. Major pathological changes were found in the blood-forming and excretory tissues of the kidneys, and secondarily in the liver, spleen, and pancreas. The most noteworthy findings are fusion of cells of the pancreas and liver, resulting in the production of giant cells, a distinctive change that permits diagnosis where viral isolation capability is lacking.

A direct fluorescent antibody test has been developed for the salmonid herpesvirus. The test is applied to monolayer cultures of cells and results are available in about 1 hour. Because the first antiserum tested has a low titer, a revised schedule of immunization will be tried.

**Development of Fish Cell Lines.** Cell lines initiated from American shad, striped bass, and kokanee are all more than a year old, and have been subcultured from 11 to 20 times. All lines have been used in diagnostic services or research, or both. A world survey of literature and research laboratories has been made to compile information on existing fish cell lines. There are now 50 different fish cell lines representing 14 families of fish. The compilation is available to scientists and diagnosticians who need the information.

**Biologics: Antisera and Antigens for Serodiagnosis.** The Biologics section produces antisera and antigens for use in serodiagnosis of fish diseases. Over the last year more than 450 vials of lyophilized antisera were distributed upon request, mainly to Federal biologists and the in-house research staff. When Biologics supplies were sufficient, requests were also filled for State, university, private, and foreign agencies. These standardized biologics help to bring uniformity to the highly complex and diversified field of fish disease serodiagnosis.

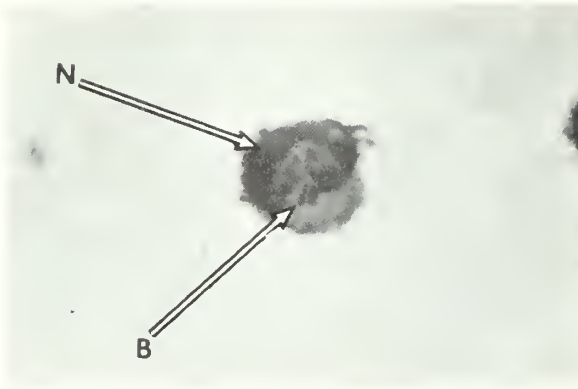
The production of biologics is regulated by the number of requests. For instance, antisera to *Yer-*

*sinia ruckeri*, the causative agent of enteric redmouth disease of trout, and *Aeromonas salmonicida*, the agent of furunculosis, are the two antisera in most demand; therefore, more rabbits are immunized with these fish disease agents than with others. In each case, the antiserum is carefully defined as to antibody titer and specificity before being placed in the Biologics file. When possible, the homologous antigen is distributed, along with the antiserum. Questionnaires enclosed with the biologics distributed to the field enable us to evaluate their quality and use.

**Cellular Antibody in Immunized Trout.** The passive hemolytic plaque assay (Jerne technique) has been adapted for the first time to the study of the immune response in rainbow trout exposed by injection or immersion to antigens extracted from fish pathogens. This technique enables the demonstration of the lymphocytes producing specific antibody in spleen and kidney samples. Specific antibody-producing cells were first found 7 days after exposure; maximum numbers occurred at day 11; and by 21 days none were detected. Circulatory antibody, presumably resulting from the functioning cellular system, was not demonstrated in the 7-day sample. In trout held at 17° C the maximum antibody titers were reached 21 days after antigen exposure.

Dosage studies demonstrating the smallest amount of bacterin that could be used to stimulate splenic lymphocytes to produce antibody were done with the bacterins from *Yersinia ruckeri* and *Aeromonas salmonicida*. The minimal dose of *Y. ruckeri* O-antigen bacterin required by injection was 0.5 µg, whereas fish immersed in the antigen preparations for 2 minutes required a concentration of 5.0 µg/ml to stimulate the specific antibody response. Doses for induction of a response to O-antigen preparations of *A. salmonicida* were much higher: 100 µg for injection and 500 µg/ml for immunization by immersion.

**Cellular Activities in Disease Resistance.** Fish combat infectious bacteria by bringing into play certain blood cells that literally "eat" and kill the invading bacteria. Studies of this process have revealed a dramatic difference between cell activities related to the presence or absence of antibody. When fish blood serum contains antibody against a particular bacterium, the blood cells are more aggressive in capturing and killing those particular bacteria. This can be interpreted to mean that a fish with antibody against a pathogen will be more resistant to the pathogen than a fish without anti-



A trout blood cell which has "eaten" bacteria. The darkened area indicated by the "N" is the cell nucleus. Bacteria "B" are seen as small rods within the cytoplasm of the cell. Photo by B. Griffin.

body. Studies are now under way to determine the most effective way of inducing antibody production to protect fish from pathogenic diseases.

## EXPERIMENTAL FISH HATCHERY

As of October 1, 1977, the Leetown National Fish Hatchery became part of the National Fisheries Center—Leetown and was converted into the Experimental Fish Hatchery. Along with the change in name came a change in function. For the past several years the hatchery produced 50,000 pounds of trout annually. This number was greatly reduced and the hatchery began a wide variety of projects. We became involved in the evaluation of rainbow trout strains, the development of brown trout strains, and the administration of a fishing area for the handicapped. This change has given more depth to the hatchery program, in that it now produces not only salmonids but also warm- and cool-water fish in a program directed toward providing fishing for the handicapped.

The program designed to provide fishing for the physically handicapped in the surrounding area, begun in August 1978, was initially successful. The fish for the program were collected by seining or electrofishing in various lakes and streams, purchased, or reared at the station; some were donated by other Federal and State facilities. The fishing area was built through the efforts of the Young Adult Conservation Corps, along with the Youth Conservation Corps and the Center staff.

During the first 1½ months of operation, 59 persons fished in the ponds at the Experimental Hatchery, for a total of 92 angler-hours. They caught 90 fish, of which 45 were largemouth bass and 21 were rainbow trout.

Newly hatched brown trout fry and hatching eggs were received from the Bowden National Fish Hatchery for rearing at the Experimental Hatchery. Past experience had shown this particular strain of brown trout to be one of the best in the country, and we hope to provide a reliable source of brood stock. However, Bowden has had a history of disease problems. Once at the station the fish were kept in isolation, first in the warmwater holding house and later on the tank pad of the new Laboratory complex.

The fish were carefully monitored for signs of disease. With the assistance of the staff of the National Fish Health Laboratory, we checked the fish early in their development for both viral and bacterial infection but none could be detected. During the course of a 9-month period, no disease-causing agents were found. Particular emphasis was placed on the *Corynebacterium* causing kidney disease, but none was found.

## FISHERIES ACADEMY

The Fisheries Academy was created on October 1, 1977, as a functional element of the National Fisheries Center. Its purpose is to provide technical training to operating biologists of government organizations and, to a limited extent, private practitioners. The continuing education and development of fishery managers is vital to the perpetuation of the resource. Plans are well advanced for the construction of a new 8,000-square-foot building to house the Academy, and for major extensions of the training program.

The traditional long course in fish health, which has long been conducted at the former National Fish Health Research Laboratory, began in early September and will continue until mid-March. The students include representatives of the Fish and Wildlife Service, Food and Drug Administration, Territory of Guam, the government of India, the State of Maine, and several universities.

Planning for development and delivery of a long course in fish husbandry was started. The new program will include training in the culture of warmwater, coolwater, and coldwater fish, along



Handicapped persons from a local Veterans Administration Center enjoy a leisurely afternoon of fishing at the recently opened fishing area located at the Leetown National Fisheries Center. They are aided by station employees. *Photo by H. M. Stuckey.*

with intensive work in administration and management science.

### **TUNISON LABORATORY OF FISH NUTRITION**

**Progress in Nutritional Energetics Research.** Studies of energy metabolism that have been done with aquatic animals are mostly by indirect oxygen-consumption methods. The heat equivalent of oxygen has not been measured for fish. Many phases of nutritional energetics have not been investigated because of the lack of suitable equipment. Preliminary work with a manually controlled adiabatic calorimeter indicated that direct

calorimetry of fish was feasible and that much could be learned regarding energetic efficiency of fish.

An automated respiration calorimeter for fish was constructed that measures and records the oxygen consumption and heat production of groups of fish with a total mass of 2 kg and of single fish that weigh up to 500 g. The measurement of ammonia and carbon dioxide has not yet been automated but samples can be removed periodically for the determination of these waste products. Fish can be held in the calorimeter for extended periods. Physical activity of the fish can be monitored and recorded. The fish can be fed while in the calorimeter and the heat increment of feeding can be measured.

The instrument has been calibrated by adding known amounts of heat with an electric current and has given accurate and reproducible results. It is expected that many valuable data concerning energy metabolism can be obtained with this instrument.

**Progress in Water Reuse Research.** We successfully cultured salmonids in a pilot-scale, nearly 100% closed-water reuse system, incorporating advanced waste water treatments. Growth rates and feed conversions were similar to those for fish in flow-through systems. Clarity of the culture water was excellent; transparencies (compared with distilled water) were 93% to 98%. As loadings of the system were increased, a stable, air-generated foam was produced from suspended solid wastes, permitting their easy removal from the system. This removal, along with ozone-generated froth removal of refractory dissolved wastes, contributed to the purity of the water.

In the first trial we used 31 6-quart jars to raise over 70 pounds of rainbow trout at an average food conversion of 1.3 on a standard pelleted food. We calculated hatchery constants for each jar and varied them from 12 to 14 to equalize and maximize the growth of the fish, based on their length increase per fish per jar per day. These calculations proved to be effective and practical in ensuring economical closed-system aquaculture through circumventing fouling problems caused by excess, unneeded food in any individual culture unit. No disease or health problems were observed, but the fish grew too large for the small jars before the rated filtering capacity of the system (100 pounds) was reached. Body analyses showed no differences among fish fed at different hatchery constants, but the flesh of fish in the reuse system contained considerably more fat and less water than the flesh of those cultured in normal, flowing water.

In a second trial we used 20 5-gallon jars to try to reach the full capacity of the system at a water flow of 16 gallons per minute. Insufficient water changes took place, and plumbing changes will be required to ensure sanitary conditions at loadings of over 70 pounds of fish. Information from these trials has been applied to the construction of a larger, practical closed-culture system with a projected capacity of 300 pounds of fish, housed in a 29- by 16-foot enclosure in our experimental hatchery.

**Progress in Research on Dietary Protein and Amino Acid Requirements.** Research with diets

containing corn gluten meal or herring meal as sole sources of protein showed that trout fed corn gluten meal without amino acid supplements grew only 6% as much as the control trout fed herring meal. The addition of a mixture of essential amino acids to the diets with corn protein yielded growth and feed conversion fully as good as that for the herring meal controls. The mixture supplied seven essential amino acids, including lysine, arginine, tryptophan, and others. Lysine was the major essential component of the mixture for optimum nutrition, and also prevented caudal fin erosion. Some, but probably not much, arginine was shown to be needed. Tryptophan was not needed, even though corn protein contains little tryptophan. Feed-grade lysine is commercially available, economical, and is practical for use in fish diets. Low levels of arginine may be supplied by additions of other protein feedstuffs rich in this amino acid. Since supplemental tryptophan is not needed, and fish require much less tryptophan than do domestic animals, fish may thrive on diets containing protein supplied mainly by corn gluten. If so, the ingredient costs of trout diets may be substantially reduced.

**Progress in Diet-related Cataract Research.** Rainbow trout and lake trout fed a commercial whitefish meal as the major source of protein develop bilateral lens cataracts. In earlier work, a new mixture of supplemental minerals prevented these cataracts and improved growth and feed conversions. Results of recent work showed that the addition of only zinc to the same diet prevented cataracts and improved fish growth.

This type of cataract is also prevented by replacing the whitefish meal with herring meal. Inasmuch as levels of zinc are similar in these two meals, the existence of simply a low level of total dietary zinc is apparently not the key problem; something in the whitefish meal apparently interferes with either the intestinal absorption or the metabolism of zinc.

Results of these and other experiments show that salmonids are highly susceptible to eye lesions caused by deficiencies of at least four different nutrients. Feeding of a supplemental amino acid (methionine) prevents lens cataract in trout fed a diet containing a commercial isolated soybean protein as the sole protein. Trout fed a diet sufficient in protein, but lacking a water-soluble vitamin (riboflavin), developed ocular lesions including lens cataracts, and other degenerative changes in both the lens and cornea. Exophthalmos, an

ocular lesion involving a markedly expanded, thin cornea, and fluid-filled chambers, developed in the eyes of trout fed a diet deficient in the fat-soluble vitamin A. The lenses of these fish were normal, but the retina degenerated.

## SOUTHEASTERN FISH CULTURAL LABORATORY

**Disease Control.** The development of vaccines for disease control is one of the more significant advances of fish health research in recent years. Some vaccines are commercially available for diseases of salmon and trout, but warmwater fish diseases have received much less attention. Studies were begun at the Southeastern Fish Culture Laboratory to develop a bacterin for immunizing channel catfish against the fish pathogen *Aeromonas hydrophila*. Tests conducted thus far show that immunization occurs—i.e., bacterin-injected fish formed agglutinating antibodies and developed protection against the disease. However, various dosing methods used effectively for administering other vaccines to large groups of fish have not produced desired results. More work is needed to perfect methods for administering the bacterin and to broaden protection with a bacterin of several *A. hydrophila* serotypes.

**Fish Diets.** In further studies to help develop low-cost artificial diets, striped bass-white bass hybrids and yellow perch were fed various amounts of animal (casein) and plant (soya bean) proteins. Ratios of animal to plant proteins were 3:1, 1:1, 1:3, 1:7, and 4:0 in experimental diets having 38% total protein. The diets were tested in replicate groups.

Hybrids averaging about 4 g at stocking gained 2.0, 2.7, 3.5, 6.5, and 8.0 g on diets in which the percentages of protein as casein were 12.5, 25, 50, 75, and 100, respectively. On the same diets yellow perch averaging about 5.5 g at stocking gained only 0.2, 0.3, 0.8, 1.2, and 1.2 g after 12 weeks. Growth of both species correlated positively with increasing casein percentage. Heat-treated whole soya bean meal was not an adequate replacement for even 25% of the casein.

**Biologic Control of Alligatorweed.** We initiated a field evaluation of the stem-boring moth, *Vogtia malloi*, to control alligatorweed in fish ponds. Moth larvae provided by the U.S. Department of Agriculture, Stoneville, Mississippi, were used to



The paddlefish, *Polyodon spathula*, a primitive relict of the past provides base-line physiological data against which more advanced fish may be measured. Photo by N. C. Parker.

establish a breeding colony to supply additional moths to be released at our test site. This moth was originally brought to the United States from South America but is now found throughout the southern States. It overwinters only in the more southern regions of Florida and Louisiana and moves northward to Alabama in late summer. Studies by the U.S. Department of Agriculture have shown its diet to be restricted solely to alligatorweed.

We released the first moths in late June 1978, and others throughout July and August. Examination of the alligatorweed mat in September revealed that 19% of the stems were either wilted or showed signs of earlier moth damage. The alligatorweed mat did not develop to the extent it did in 1977, before the moths were introduced. Our *Vogtia* culture being overwintered in the laboratory will be released in April 1979, in an attempt to establish control earlier in the season.

**Pond Aeration.** A 2-inch air-lift pump having a 4-foot vertical entrainment pipe moved water and air at the rates of 30 and 15 gallons per minute, respectively, and added about 1 ppm of oxygen to water containing 3-4 ppm oxygen and 0.3 ppm of oxygen to water containing 5-6 ppm dissolved oxygen. Water movement from the bottom and across

the surface helped prevent stratification and promoted oxygen transfer with the atmosphere. To empirically establish the carrying capacity of ponds equipped with air-lift pumps, we stocked 10 1/20-acre ponds with fingerling channel catfish in mid-April. Ponds were stocked in duplicate with 100, 200, 400, and 800 fish per pond; two control ponds without air-lift pumps were stocked with 100 fish each. A sample of 50 fish taken at the time of stocking averaged 15.2 g in weight and 128 mm in length. The fish were fed at the rate of 3% body weight per day.

In ponds stocked with 800 fingerlings, the fish attained a density equivalent to 10,940 pounds per acre after 128 days in one pond and 11,900 pounds per acre after 142 days in the other. When loading densities reached about 10,000 pounds per acre, air-lift pumps could not maintain sufficient dissolved oxygen at night, so Aqualators were used from evenings to mornings. In early September, half of the fish in the ponds stocked with 800 fish were harvested. The fish removed weighed 274 and 297 pounds (individual weights averaged 0.68 and 0.74 pound, respectively)—a per-acre production equal to 5,480 and 5,940 pounds, respectively. In mid-October, 184 days after stocking, the fish remaining in each of these ponds weighed 423 and 494 pounds—equal to a further production of 8,466 and 9,877 pounds per acre. Thus the total production for the season was 13,946 and 15,817 per acre.

These production estimates agree with others that have been developed where efficient aeration devices were used to increase production and protect against losses from temporary low dissolved oxygen in heavily loaded production units.

**Larval Food for Striped Bass.** Continued efforts in 1978 to define a better diet and feeding regimen for larval striped bass included our evaluation of four types of postlarva culture units receiving fresh water or salt water at controlled temperature. Additional parts of this work were contracted to Auburn University's Fisheries and Allied Aquacultures group, whose studies evaluated the most promising dry diets tested in 1977, along with several new formulations, combinations of dry and natural foods, and freshwater forage organisms that might be substituted for brine shrimp nauplii.

Survival of striped bass fry fed several dry foods or dry food plus brine shrimp was similar to that of fry fed only brine shrimp. Fry growth was reasonably encouraging in feeding trials that started

with brine shrimp, then combined brine shrimp and dry food, and ended with only dry food. For example, the following estimates of increase in length (mm) were recorded: brine shrimp alone, 7.2; brine shrimp plus salmon starter, 3.6; brine shrimp plus "W-7" starter, 2.7; brine shrimp plus Tetra-Min "E," 2.7; and salmon starter alone, 1.2. Fry that fed on freshwater zooplankton had satisfactory growth and survival; they chose cladocera over copepods and other organisms. Growth and survival were also satisfactory in fish fed a diet of rotifers grown on *Chlorella*.

Survival of striped bass fry in culture systems of 5 parts per thousand salt water (Instant Ocean) was as high as 27 times that of fry in fresh water. The best designed culture unit for fry, which included provisions to help keep food particles suspended in the water column, had air-lift pumps to circulate, aerate, and give the water a slow laminar flow in an oval 20-gallon tank having a partial, vertical partition centered in the tank's long axis.

Problems with intensive culture of striped bass fry are common to most "small-egg" fishes. Though much work has been done in developing an acceptable artificial diet and a suitable artificial environment, we still cannot recommend guidelines for production use that are better than or equal to nursery ponds that have rich zooplankton blooms.

**Cryopreservation of Sperm.** A problem occurs in attempts at sperm preservation when diluents containing "extenders" are added to fresh sperm before it is frozen in liquid nitrogen vapor. Extenders such as dimethylsulfoxide must be added to prevent ice crystal damage to cells. But motility is lost when diluents are added in the first step of the process. Loss of motility is irreversible, although freezing and subsequent thawing does not detectably alter cell structure. We have attempted to solve this problem by isolating and characterizing a natural constituent of seminal fluid that suppresses motility until sperm are released in water during spawning, and motility discharges naturally with dilution of the suppressor. When isolated and identified, the natural constituent can be included in the diluent so that sperm cells are kept immotile. Accordingly, we fractionated seminal fluid by gel filtration (Sephadex G10 and G15), a method that separates dissolved constituents on the basis of their molecular dimensions. Fractions of striped bass seminal fluid, dried and reconstituted to original volumes of starting material preserved motility of whole sperm. Only the fraction

having major electrolytes Na<sup>+</sup>, K<sup>+</sup>, Cl<sup>-</sup>, and osmolalities near whole seminal fluid were effective. Apparently, no larger constituent such as a small organic molecule is responsible for motility suppression. Electrolytes in specific relative and total amounts apparently maintain spermatozoa imotile.

Chorionic gonadotropin injections, commonly used to stimulate seminal fluid production to increase milt volume, altered major electrolytes in seminal fluid, and presumably its quality as a sperm carrier; fresh sperm held in cold storage for short periods lost motility potential more rapidly than did that from noninjected striped bass. More research is required on these and other characteristics of the sperm carrier, spermiation, and artificial extenders for sperm preservation.

**Stress Physiology.** A competitive protein binding assay was developed and used to measure adrenal steroid hormones in fish. Resting plasma levels of such hormones in channel catfish appear to be below 0.5 µg/dl with no evidence of a diurnal rhythm. Handling stress (holding in a net for 30 minutes) resulted in elevation of the hormone levels to about 4.5 µg/dl. These hormone levels are much lower than those reported for salmon, trout, and goldfish. Methods are being developed for extraction and identification of plasma and urinary metabolites of adrenal steroids by high-performance liquid chromatography. Separation of the hormones suspected of being present has been completed and several extraction methods are being compared for efficiency of recovery. Methods for extracting steroid metabolites from water by adsorption on amberlite beads are being tested. Such extraction will enable us to estimate stress on the fish by sampling the water without handling the fish.

## FISH FARMING EXPERIMENTAL STATION

**Comparison of Feeds Containing Full Fat Soybeans with Feeds Containing Fish Meal and Typically Available Feed Ingredients for Catfish and Minnows.** Catfish and minnow producers desire feed formulations that result in low total food costs. Plant proteins supplemented with fish meal or other animal proteins have been in general use. However, fish meal continues to increase in price, and often the better quality meals are not obtain-

able. Ideally, the industry should have feeds available that contain only locally available low-priced ingredients and produce fish at an acceptable cost.

The attractiveness of full-fat soybeans (FFSB) as food lies in the fact that it contains 38% protein, which is high in lysine, and 18% fat. The problem encountered in the past with FFSB is that certain growth inhibitors—ureases and trypsin inhibitors in particular—are present in raw soybeans. Heat treatment of the beans destroys these growth inhibitors. Unfortunately the heat required to destroy the trypsin and the urease also decreases the availability of lysine. The temperature at which lysine availability starts decreasing and total trypsin inhibitor and urease destruction occurs is between 325° and 410° F.

Six feeds were formulated that contained different amounts of fish meal, and FFSB meal was prepared at different temperatures up to 405° F. These feeds were fed to channel catfish in 0.25-acre ponds, and the ponds were stocked and managed according to currently recommended practices.

Essentially, the performance of feed that contained 50% FFSB and no fish meal was nearly identical with that of feed that contained 10% fish meal and typical feed ingredients. Production of catfish exceeded 2,000 pounds per acre. Little difference could be detected in performance of fish fed FFSB prepared at 345°, 375°, or 405° F.

In a related experiment we compared the performance of golden shiners fed the typically available minnow meal, which contains 10% fish meal, with shiners fed FFSB meal supplemented with only a vitamin premix. The fish were held in ponds for 75 days and managed according to current commercial practices.

The average food conversion factor (amount of feed fed/fish weight gained) of golden shiners fed the typical commercial minnow meal was 2.98:1, whereas that of fish fed the vitamin-supplemented FFSB was 2.01:1. Standing crop harvested at the end of the 75 days averaged 502 pounds per acre for the group fed minnow meal and 624 pounds for the group fed FFSB. Survival was similar for all fish and averaged about 75%.

It appears that feeds prepared from heat-treated FFSB could be used, in place of the currently fed feeds containing 10% fish meal, for production of marketable-size channel catfish, as well as minnows, in ponds. Since large amounts of soybeans are readily available, and the development of the technology for their heat-treating appears

feasible, a high demand for feeds containing FFBS may evolve among commercial producers of warmwater fishes and State and Federal producers of sport fishes.

**Effect of Food Pellet Size on Variation in Growth of Channel Catfish.** Channel catfish must often be graded before they are marketed to remove fish that are too large or too small for sale. Methods of increasing size uniformity would decrease grading time and increase production efficiency. Choice of feed pellet size may be one method of reducing size variation. A comparison of channel catfish fed identical quantities of either large (0.10 g) or small (0.04 g) pellets showed that fish offered the smaller pellets grew more uniformly. Apparently, under test conditions, the use of numerous small pellets provided a more nearly equal opportunity for all fish to obtain a portion of the rations, and consequently growth was more uniform.

**Evaluation of Tube-type Filters for Removing Particulate Matter in Discharge Water from Ponds.** Discharge of silt-laden effluent into receiving streams, from earthen ponds used in intensive fish production, can be detrimental to native fishes. The Environmental Protection Agency (EPA) has recommended that the maximum amount of settleable solids not exceed 3.3 ml/l. Filter systems and draining techniques that require low capital investment and little energy would be of great value to the fish-producing industry and the various State and Federal installations in meeting the EPA pond-discharge criteria.

In previous studies, tube-type settlers have been shown to reduce uneaten feed, feces, and other waste metabolites in fish production systems to an acceptable level. Possibly this technique, with modifications, could be used to reduce soil particles in pond discharge waters to 3.3 ml/l or less, and thus meet this EPA criterion.

A filter system of tube filters was designed to cause the waste water to flow upward and be discharged through a 90° weir. The height of the filter ranged up to 3 feet. Hydraulic loads, which are expressed as gallons per minute that pass through a square foot of filter surface, varied from 0.2 to 11.3.

When the level of settleable solids entering the filter system was varied from 40 to less than 1 ml/l, the maximum level of settleable solids in the effluent leaving the filter was 14 ml/l. Removal efficiency ranged from 100% to negative values. Negative efficiency resulted when water, as

it passed through the filter, picked up solids that had been deposited earlier. Thus the system tended to average the particulate load, but did not appreciably reduce the total amount of settleable solids exhausted into the environment. We speculate that for the tube filters to reduce the level of settleable solids below the 3.3 ml/l maximum recommended by EPA, the system would have to be too large and deep to be practical.

**Effect of Solids Removal on Growth of Fish in Reuse Systems.** In water reuse systems, solids such as uneaten feed and feces, and particulate matter resulting from metabolic waste, should (in theory) be removed from the system and not segregated in one area such as in the filter. Some systems are designed for such removal, but little is known about the volume and frequency of removal required.

Our studies showed that biweekly drainages of water at the rate of 1.5 to 3% of the total water volume in the system neither increased fish production nor improved water quality during the 128-day testing period. However, differences in feeding rate (1 and 2% of body weight per day) did have a significant effect on growth rate and water quality factors, though not on feed conversion efficiency. Growth increased at the rate of 1.3 g per fish per day at the 1% feeding rate, and at 2.3 g per day at the 2% feeding rate. Feed efficiency values were near 1:1 for all groups of fish. Standing crops of fish in tanks that were fed the largest allowances were about 1.2 pounds per cubic foot.

Growth rate, standing crop, feeding efficiency, and health do not appear to be related to water characteristics. The values of many of these characteristics appeared to be in excess of those reported to be detrimental and even lethal to fish. Possibly the values reported in the scientific literature are lethal or detrimental to fish due to unknown interrelationships among the water quality factors and not necessarily to the magnitude of any single factor. Further research on water quality criteria should be encouraged.

**Evaluation of Different Pump Duty Cycles on Fish Growth in Recycled Tank Water.** Water requirements of commercial fish farms, State and Federal fish hatcheries, and wildlife refuges are expected to increase in Arkansas by more than 60% within the next 10 years. Since this water use in fish and wildlife production will be in direct competition with municipal, agricultural, and industrial uses, sound management necessitates that water used for fish production be reused.



Water reuse systems for fish culture consist of two main sections: (1) a fish chamber where the fish are grown and (2) a filter chamber where by-products detrimental to fish growth—primarily ammonia-nitrogen—are removed. Water is circulated from the fish chamber through the filter and pumped back into the fish chamber. Turbulence, created by the pumping process, aerates the water as it is jetted back into the fish chamber.

In water reuse systems studied at this Station, pumping added 22% to the cost of fish production. To determine whether pumping expenses could be reduced by varying the duty cycle, we tested three pumping rates: continuous, 6 minutes on and 4 minutes off, and 2 minutes on and 8 minutes off.

Fish growth tended to decrease slightly as pumping time was reduced to 20% (2 minutes on, 8 minutes off), but weight gain, feed conversion, and survival were not significantly different from those of fish in ponds where pumps were operated 40 or 100% of the time during the 82-day test period. However, on the basis of the low coefficients of variation, which suggest that the data are reliable, we speculate that, if the test period had been longer, significantly less growth would have occurred in the systems with the 20% duty cycle.

Water analysis indicated a lower nitrification rate when the pumps operated on the 20% cycle; larger amounts of ammonia- and nitrite-nitrogen and smaller amounts of nitrate-nitrogen were measured in the 20% systems. A high nitrification rate is mandatory in successful reuse systems to transform the more toxic ammonia- and nitrite-nitrogen to the less toxic nitrate-nitrogen.

Biological filter systems are known to require 4.5 mg of oxygen for each 1.0 mg of ammonia-nitrogen transformed to nitrate-nitrogen. This is in addition to the oxygen required for respiration of fish, plankton, and other organisms (as measured by biological oxygen demand). Obviously, oxygen requirements of reuse systems are high.

In the oxidation of ammonia with biological filters, alkalinity is reduced at the rate of 7.14 mg of alkalinity for each milligram of ammonia-nitrogen oxidized. In our study, alkalinity was lower in the systems with the greater pumping rates, indicating differences in nitrification rates. Loss of alkalinity can have a detrimental effect on fish. Waters low in alkalinity (less than 100 mg/l as CaCO<sub>3</sub>) permit rapid changes in pH, which may result in fish becoming more sensitive to heavy metals and physiological stress. Though alkalinity was lost in the re-

use systems at the higher pumping rates, it did not decrease to a level that could have adversely affected the fish.

**Evaluation of Therapeutants for the Control of *Gyrodactylus* in Goldfish and Channel Catfish.** Flubendazole, supplied by Tavolek, has been suggested as a possible therapeutant for the control of Monogenea of fish. Recommended trial concentration is 0.01 ppm. This chemical at the recommended concentration eliminated all *Gyrodactylus* on goldfish within a 3-day period.

In studies of the effectiveness of Flubendazole, Mebendazole, formalin, Masoten, and malachite green for the control of *G. ictaluri* of channel catfish at 12° to 15° C, Flubendazole and formalin at 0.01 and 25 ppm, respectively, were effective. However, Flubendazole required 5-6 days to completely eliminate the parasite from catfish. Mebendazole at 0.01 ppm, Masoten at 0.25 ppm, and malachite green at 0.1 ppm were not effective chemicals for the control of the parasite.

**Identification and Verification of Previously Unknown Parasites in the United States.** As a function of the National Fish Parasite Referral Service component of this Station, identifications and verifications of several dangerous fish parasites have been completed. Identification of *Chilodonella hexasticha*, the "warmwater chilo" was completed with the collaboration of S. Kuzubski of Poland. Verification specimens of two parasites that had never been reported in North America were obtained from the paddlefish: *Polypodium hydriforme*, the coelenterate parasite of Eurasian sturgeon eggs; and the microsporidian, *Pleistophora sulci*. Another new parasite of the paddlefish, *Eimeria* sp., which appears to be a serious pathogen in the liver and kidney, has been submitted to us for study. In goldfish, *Cryptobia branchialis*, which is an important European gill parasite, has been identified; however, the North American strain appears to differ somewhat from the European strain.

**Evaluation of Chemicals for the Control of *Ichthyophthirius multifiliis* on Warmwater Fishes.** *Ichthyophthirius multifiliis* or "Ich" is one of the most destructive parasitic organisms in warmwater fish culture. Because of the discontinuation of the use of malachite green (not registered for fishery use), which was an effective Ich control chemical, a replacement chemical is much needed by commercial fish farmers, State and Federal fish hatchery workers, and fish hobbyists.

Because Ich trophozoites leave the infected fish

as free-swimming forms, and normally develop into infective tomites in 10-12 hours, it was logical to test candidate therapeutants *in vivo*. Furanace at 0.1 ppm has been recommended for Ich control, but in our tests this dosage was not effective. However, 0.2 ppm did suppress Ich development in six of seven tests, and at higher concentrations there was no development.

Levamisole has been considered for use in fish culture, but in our laboratory tests Ich developed normally in concentrations as high as 7 ppm. It is probably not a likely candidate for Ich control. We found it to be toxic to channel catfish fingerlings and golden shiners at 14 ppm but not at 12 ppm.

## FISH GENETICS LABORATORY

### Characterization of Rainbow Trout Strains.

The objective of this work is to characterize different strains of rainbow trout genetically and evaluate their suitability for various environments and management uses. Studies of 18 strains—12 from hatchery brood stock and 6 from wild sources—are under way. Results of laboratory tests under controlled conditions show significant differences between strains, especially in survival, growth rate, feed conversion, and frequency of vertebral deformities. For the 10 strains evaluated to 1 year of age or older, the average weight attained at the end of 1 year ranged from 85 to 202 g. The frequency of vertebral deformities, measured in six strains, ranged from 7 to 34%. Frequencies of deformities were higher in strains that had been retained in hatchery environments for the largest number of generations. These results, coupled with findings from studies of inbred lines, suggest that inbreeding may account for many of the deformities found in some hatchery strains.

Early results from studies of performance of different strains in production hatchery and field environments indicate large differences between strains in general hatchery performance, and in growth, survival, and catchability in field situations.

These differences, measured in laboratory, hatchery, and field environments, clearly indicate the potential for effectively matching strains to a variety of specific management uses.

**Effects of Inbreeding Rainbow Trout.** Studies

designed to measure the effects of different levels of inbreeding have demonstrated significant depression in a number of traits. After three generations of brother-sister matings, the effects on reproduction traits were substantial. In females, the weight, egg production, and frequency of occurrence of maturity at age II declined 29, 33, and 25%, respectively. The performance of inbred fish was clearly inferior to that of their outbred half-sibs in terms of growth, survival, and frequency of deformities.

A 1-year field test of inbred fish and outbred half-sibs planted as fingerlings in a 2-acre pond also showed the adverse effects of inbreeding. One generation of brother-sister matings resulted in a 17% reduction in fish weight and a 29% reduction in numbers of fish recovered from the pond.

These results, coupled with the findings of earlier studies at this Laboratory, clearly show that inbreeding produces serious adverse effects on the general vigor and performance of rainbow trout. Present inbreeding levels in hatchery stocks are largely unknown; however, past breeding practices have undoubtedly produced significant inbreeding in some hatchery brood stocks. Further inbreeding accumulation in hatchery stocks can be reduced by the use of mating techniques that have been defined by this Laboratory.

**Crossbreeding Rainbow Trout Strains and Inbred Lines.** Studies were begun to evaluate the utility of crosses of different strains and inbred lines in combating the effects of inbreeding and improving overall performance of rainbow trout strains. The first phase of the study deals with performance in our standard Laboratory rearing environment. The progeny of seven strains mated in all combinations and six inbred lines mated in all combinations showed large differences in growth at 1 year of age. Strain crosses tended to be intermediate to the two parental strains; only 8% of the crosses were larger than the best parental strain. The best strain cross was 15% heavier than the best parental strain. Inbred line crosses, on the other hand, tended to be heavier than either parent line. Since all parent lines suffer measurable inbreeding depression, we compared the performance of inbred line crosses with those of strain crosses. At 1 year of age, 52% of the inbred line crosses were heavier than the best strain, and 48% were heavier than the best strain cross. The best inbred line cross was 50% heavier than the best strain, and 40% heavier than the best strain cross. No significant differences between strain

crosses and inbred line crosses were found in egg hatchability, fry survival, or feed conversion.

These results suggest that both strain and inbred line crossing can be used to improve hatchery growth performance, but that inbred line crosses were clearly superior in these initial tests.

**Information Transfer.** Formal publication of results of technical journals remains a continuing activity of this Laboratory. However, this means of disseminating information is not timely and does not offer a readily usable format in many instances. Therefore, during the past year we have initiated efforts designed to provide more effective and rapid means for transferring the results of our research and development to fishery resource managers. The first annual Fish Genetics Short-course was presented at the Laboratory in September 1978. Material covered in the course included an introduction to basic genetics, strain characteristics, inbreeding effects, and methods for strain maintenance and improvement. This material was summarized and given to each student in the form of a reference manual.

We also began work on the preparation of a catalog of strain characteristics of rainbow trout and a breeding and selection methods manual.

## **NATIONAL RESERVOIR RESEARCH PROGRAM**

The National Reservoir Research Program (NRRP) continued intensive efforts to describe and quantify the environmental factors that determine sport fish production in 1,500 large reservoirs (over 500 acres in area). These waters now provide about 30% of all freshwater fishing in the United States. By synthesizing the data produced by its several field research units and that from other Federal and State fishery agencies, an integrated body of information is produced, upon which to base improved management techniques and measures designed to protect or enhance fishery resources in water projects.

During fiscal year 1978, a staff of 32 professional and support personnel addressed problems ranging from heated water effluents in reservoirs to minimum flow requirements in tailwaters below dams. The studies have yielded answers to immediate management problems, as well as broad findings concerning reservoir ecology. The find-

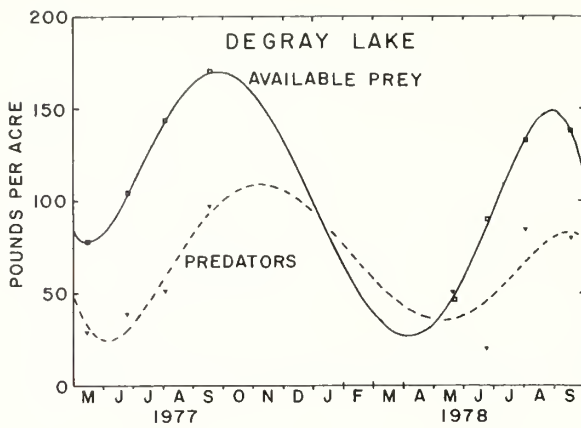
ings have been communicated to managers and other users by the publication of technical papers; by illustrated talks at workshops, seminars, and regional and national meetings; by correspondence and telephone; by personal visits; and by field demonstrations of equipment and techniques.

Long-term base-line studies designed to describe variations in fish population composition and structure in selected reservoir types have been the backbone of the reservoir research program. Studies on impoundments of the Missouri River in the Dakotas and on the White River in Arkansas-Missouri have resulted in the development of extensive data bases, which have provided invaluable information concerning the effects of variations in reservoir operational procedures on reservoir ecology. Upon completion, this effort should provide a long-term record of the ecology and productivity of reservoirs and a broad understanding of the sport fishing potential of these waters.

Widespread concern over possible adverse effects of heated water additions and pump-back operations in reservoirs prompted an extensive field investigation of Lakes Keowee and Jocassee in South Carolina. Studies of the fish populations and related trophic levels began in 1972, 2 years before start-up of Duke Power Company's Oconee nuclear generating and pump-storage facilities on the two lakes.

In 1974, NRRP and the Environmental Effects Laboratory, U.S. Army Engineers, Waterways Experiment Station, began a cooperative study on the effects of varying the outlet depth of the dam on the ecology of DeGray Lake and its tailwater. Coordinated field studies are under way to test and provide verification for elaborate ecological simulation models currently being developed by the Environmental Effects Laboratory. Research for 4 years during which water was released from the epilimnion have been completed, and 4 years of study during which water is released from the hypolimnion will begin in 1979.

In a broad approach to reservoir operation as related to aquatic resources, NRRP and the Waterways Experiment Station have recently entered into a 6-year coordinated research effort designed to locate and define conditions that optimize both coldwater and warmwater tailwater fisheries, the limits within which they can operate, and the immediate and long-term biological effects of varied operational procedures. The program includes a synthesis of existing published



Estimated biomass of total available prey and predators in DeGray Lake, Arkansas, based on samples collected in May, June, August, and September, 1977 and 1978, fitted with a fifth-degree polynomial. Decreases in 1978 may be attributable to a severe winter and to a midsummer drawdown in that year.

and unpublished information on biological relations in tailwaters, and field studies on nine selected tailwaters which exhibit widely used operational modes. Studies will incorporate operational modification of reservoirs on an experimental basis. They will include such objectives as determining criteria for establishing optimal minimum release, downstream effects of different depths of release of water from the reservoir, and effects of different hydropower operational modes on the tailwater biota. The effects of various operational modes on the reservoir fisheries will also be evaluated.

**Standing Crop and Harvest Predictions.** The NRRP has been engaged in the collection, collation, and analysis of biological information on reservoirs obtained by fishery agencies and institutions for 15 years. Standing crop information is now available from 221 reservoirs, with a total of about 950 years of record. Harvest data are available for 285 reservoirs and more than 900 years of record. Environmental variables, which are often a function of reservoir design and operation, have also been measured in most of these reservoirs. This information has been analyzed to derive simplified regression models for predicting fish standing crop and harvest on the basis of environmental variables. The regression formulas were updated with new information obtained in 1978, and a revised list of 52 formulas was distributed to U.S. Fish and Wildlife Service Ecological Services field offices and other agencies for use in reservoir impact assessment and fishery management evalua-

tions. Current analyses are also providing Ecological Services with criteria for evaluating reservoir animal and plant communities in its aquatic Habitat Evaluation Procedures Program.

Studies are under way to evaluate the effects of short-term variations in the physical environment on reservoir fish assemblages. Seventy reservoirs from which data on standing crop of fish have been collected for 5 or more years are being studied to assess the effects of short-term variations in the reservoir environment on these standing crops. Variations in reservoir releases, volume, and water level fluctuation occurring within a single growing season are being related to changes in total reservoir fish production and, more specifically, to changes in the production of important sport and prey fishes. When completed, these studies will provide resource managers with a better understanding of the importance of short-term environmental fluctuations to management, particularly with respect to the development of seasonal reservoir operational modes that will ensure optimal sport or prey fish production.

Tapes of programs have been developed for use by operators of Hewlett-Packard 9830 desk-top computers in calculating fish standing crop and harvest and available prey-predator ratios, and in completing 20 other statistical procedures related to common fishery research problems.

**Predator-Prey Relations.** Predatory fishes (black basses, crappies, white bass, striped bass, catfishes, walleye, pikes, and others) make up 70% of the average sport fish harvest from reservoirs, and are therefore of primary concern to fishery managers. Management goals have been directed toward improving the variety and harvest of predatory fish by introductions of predatory and prey species.

To aid in evaluating the technique, we have developed an "available prey-predator (AP/P) ratio," based on fish samples collected after the application of the fish toxicant rotenone to blocked-off coves (here termed cove sampling or cove-rotenone sampling). This ratio describes the adequacy of the prey crop to sustain the existing predator crop, and thus enables the fishery manager to estimate the additional biomass of predators that could be supported, or, conversely, to estimate the loss of predators due to natural mortality that results from inadequate prey.

Analysis of data from many southern reservoirs indicates that predator crops tend to exceed food resources when reservoir environments are per-

turbed (e.g., by high water levels), but return to equilibrium conditions within 1 year under more stable conditions. Prey crops, however, decline more slowly, requiring up to 4 years to return to a minimum stable level.

A seasonal examination of the AP/P ratio provides a quantitative approximation of annual cycles of fish biomass and surplus production estimates. Plots of seasonal prey and predator crops in DeGray Lake, Arkansas, and annual estimates of predator harvest lead to the conclusion that natural mortality is the major factor causing fluctuations in predator populations. Periodic cove sampling during the growing season provides surplus production estimates that can be used by managers to determine optimum regulations, stocking needs, and the range of production values to be expected under various environmental conditions in reservoirs.

**Reservoir Ecosystem Modeling.** After completion of the fishery portion of a reservoir ecosystem model currently being developed by the U.S. Army Engineers, Waterways Experiment Station, work began on the development of the zooplankton and benthos portions of the model. About 1,500 relevant references were catalogued, and extensive effort was directed toward the development of model conceptualization and state-of-the-art assessment of existing zooplankton and benthos models. Some 10 subjects are being analyzed: (1) description of species composition, abundance, biomass, and distribution of zooplankton and benthos in reservoirs of the temperate zone; (2) habitat preference; (3) seasonal population dynamics; (4) consumption, grazing rates, and food preference—including the role of detritus in nutrition; (5) half-saturation constants for growth; (6) assimilation efficiency; (7) respiration rates; (8) nonpredatory mortality; (9) chemical composition, and (10) temperature influences. The work, which is scheduled for completion in 1979, will provide information vital to the development of a complex ecological model for use in exploring various reservoir operational manipulations.

The zooplankton and benthos models will be used in conjunction with the existing fish model, which defines fish standing crop in terms of five food compartments: zooplankton, benthos, detritus, fish, and nutrients from terrestrial sources.

## SOUTHEAST RESERVOIR INVESTIGATIONS

**Purpose of the Studies.** Increasing numbers of electrical generating plants are being constructed to meet the ever-increasing demands for electric power throughout the world. In many areas of the United States, coal-burning steam-generating plants now provide most of the electric power produced. However, electric power shortages may come as soon as the 1980's, and rapid expansion of other nonfossil fuel energy sources is needed. To help meet estimated needs in the southeastern United States, power companies are altering the Savannah River and its tributaries into a continuous chain of power reservoirs. Power is being produced by conventional hydroelectric plants, pumped-storage hydroelectric systems, and nuclear-fueled steam generation plants. Power plants typically release water at temperatures different from those of the receiving waters. Hydroelectric plants usually use cold water taken from considerable depths in the reservoir and release it into shallow, warm tailwaters; steam-generating plants generally heat water above the temperatures normal for a particular area. Pumped-storage hydroelectric plants sometimes cause rapid and frequent changes in water levels. Many power plants pass (entrain) plankton and fish through their penstocks or cooling systems. All power plants could alter the water quality and aquatic communities of the rivers and reservoirs on which they are located.

Southeast Reservoir Investigations was established at Clemson, South Carolina, to develop knowledge on the impact of power development on the aquatic ecosystems in the Southeast and to provide the information to power companies, State resource agencies, and Federal agencies concerned with power plant problems. This Laboratory has collected water quality and biological information from the upper impoundment of the 610-MW Jocassee Pumped Storage Station (Jocassee Reservoir) and the lower impoundment (Keowee Reservoir) since 1973. Keowee Reservoir also supplies water for cooling a 2,600-MW nuclear power station and for a 140-MW hydroelectric plant. The cooling water is returned to Keowee Reservoir, and the hydroelectric plant discharges water into Hartwell Reservoir. Most research to date has been concerned with the thermal effects of the nuclear power plant. We have

collected physicochemical data, as well as information on the relative abundance of plankton and benthos, and on fish population dynamics. Pumped storage research has included studies of water quality alteration and of the passage of larval fish through the station during both pumping and generation. In general, the research is designed to determine the long-term effects of habitat alteration on fish and other aquatic life.

**Zooplankton Entrainment.** Entrainment in power plant water intake systems and impingement on intake screens sometimes cause substantial losses of plankton and fish. Wide variations in the magnitude and causes of these losses, however, prevent the reliable prediction of the effects of planned power plants. Knowledge of zooplankton distributional patterns could facilitate the placement and design of water intake structures to control or reduce entrainment. We studied the vertical distribution of zooplankton in 7,400-ha Keowee Reservoir, South Carolina. The nuclear plant withdraws cold water from depths of 20-27 m beneath a surface skimmer wall for once-through condenser cooling. Daily and seasonal variations in vertical distributions of zooplankton influenced the degree of entrainment at the power plant. For about 9 months, most zooplankton was near the surface, and only relatively small amounts were entrained. During July, August, and September, however, most zooplankters were in deeper water near the bottom during the day, and large numbers were entrained; at night most moved to or near the surface, and few were entrained. The danger of entrainment during these 3 months was thus restricted largely to the 12 to 13 daylight hours. Although entrainment was reduced by the use of a skimmer wall, dilution of zooplankton in the outfall area may have resulted in a scarcity of food for higher aquatic animals. Dilution diminished with increased distance from the discharge structure.

**Life History Studies.** Habitat alterations usually result in changes in the feeding, growth, and reproduction of fishes. Consequently we examined segments of the life history of three species—yellow perch, largemouth bass, and threadfin shad—in Keowee Reservoir. Yellow perch spawned about 2 months earlier in Keowee Reservoir than in northern States, but at about the same water temperature (10° C). Maturity indexes for gravid females, the number of eggs produced by a female of a given length, and the age of maturity also were similar to those characteristics of perch in the

North. Although yellow perch in South Carolina appeared to have a longer growing season than fish in the North, southern fish did not grow significantly faster. Young of the year grew from a length of 7 mm in early March to about 40 mm in early June. Average lengths of yellow perch at the end of each of the first 6 years of life in Keowee Reservoir were 77, 132, 184, 217, 250, and 252 mm. Standing crops of yellow perch from 1972 through 1976 varied from less than 0.7 to 3.1 kg/ha in Keowee Reservoir—considerably lower than the standing crops in many northern small ponds and lakes that have been studied.

Food of 141 largemouth bass collected in 1973 and 1974, before nuclear power production and before the presence of threadfin shad in Keowee Reservoir, was compared with the food of 149 bass collected in 1976, after power production began and after the stocking and reproduction of threadfin shad. Sunfishes (mostly bluegills) were the most important food during all years. Threadfin shad ranked second in 1976. Other fish in the diet were yellow perch, largemouth bass, whitefin shiners, and black crappies. There was no significant difference between bass growth in 1973-74 and that in 1976.

Survival of threadfin shad in Keowee and Jocassee reservoirs was examined after the severe winter of 1976-77. Winter water temperatures throughout Jocassee Reservoir and most of Keowee Reservoir fell below 9.0° C, the reported minimum temperature for survival of threadfin shad. However, winter water temperatures in the vicinity of the Oconee Nuclear Station discharge never fell below 11.0° C, providing a refuge area for winter survival of breeding stock in Keowee Reservoir. Catches of larvae in trawls, and rotenone samples of threadfin shad during the following spring and summer, showed successful spawning and production of young of the year; adults through age III were collected in Keowee Reservoir. Larval threadfin shad were lacking in trawl catches in Jocassee Reservoir until late spring, and numbers were noticeably reduced from those of the previous year. Only young-of-the-year threadfin shad were present in August rotenone samples. It appears that threadfin shad breeding stock survived in Keowee Reservoir and that either adults or larvae, or both, were pumped through the Jocassee Pumped Storage Station and into Jocassee Reservoir, mitigating the apparent winterkill in that reservoir.

**Population Dynamics.** Three sampling methods



Placing block-net across mouth of cove to prevent loss of fish during the collection of cove-rotenone samples in Jocassee Reservoir, South Carolina. *Photo by R. A. Hansen.*



Sorting fish from cove-rotenone samples in Jocassee Reservoir, South Carolina. Net across mouth of cove prevents movement of fish from the area. *Photo by J. P. Clugston.*

have been used to assess changes in the adult fish populations in Keowee and Jocassee reservoirs since 1973: seines have been used in nearshore areas, gill nets in off-shore areas, and rotenone in coves. A bag seine 30.5 m long was used to sample nearshore fish populations from areas affected and unaffected by power production in Keowee Reservoir from 1973 through 1977. A total of 22 species of fish were captured. There was a significant reduction in the total numbers of all fishes from most areas during this period. The sample site nearest the nuclear plant's heated discharge was the only area where the abundance of fishes was not reduced over the sampling period—primarily because populations of spottail shiners remained high in this area. Other species that were reduced in other parts of the reservoir were also reduced in the heated discharge. Spottail shiners, not seined in the reservoir until 1975 (the peak year of power production), superseded whitefin shiners as the most abundant species found in the heated area. The nearshore fish populations appeared to be affected more by the operation of the Oconee Nuclear Station than by the pumped-storage or hydroelectric power production.

Gill-net samples and cove rotenone samples in Keowee Reservoir have shown a decline in the relative abundance of chain pickerel, carp, quillback, silver redhorse, brown bullhead, bluegill, and yellow perch from 1972 to 1978. However, trends in abundance for the flat bullhead, largemouth bass, and black crappie differed for these two sampling methods: gill-net catches suggested an increase in numbers and rotenone samples suggested a decline. The inconsistent results apparently resulted from a change in vertical distribution of these three species in summer. The addition of heated water from the nuclear plant changed the reservoir's temperature profiles throughout the year. Generally, summer water temperatures at a depth of 6 to 26 m ranged from 3° to 10° C higher in 1975-78 than in 1973. Consequently, to live in water at their preferred temperature, these three species probably moved to water deeper than that sampled with rotenone.

## **SOUTH CENTRAL RESERVOIR INVESTIGATIONS**

### **White River Reservoir Studies.** Long-term field

studies on Beaver and Bull Shoals lakes, which are impoundments on the White River in Missouri and Arkansas, have provided valuable insight into the dynamics of reservoir fish communities and the role of the physical environment in determining the structure and production of important sport fishes. Relations involving fluctuations in the reservoir elevation and flow-through patterns have proved to be of paramount importance, as they reflect climatic variation.

**Regrowth of Peripheral Vegetation.** Long-term fishery studies on White River impoundments have indicated a strong relation between seasonal flooding of peripheral vegetation and year-class strength of certain fish species. Generally receding pool levels from 1973 through 1977 produced conditions favorable for the regrowth of peripheral vegetation. Low, stable water levels during 1977 enabled us to conduct a study of these regrowth patterns in the fluctuation zones of Beaver and Bull Shoals lakes that provided information on the types and rates of vegetation regrowth on both a seasonal and annual basis.

Five vegetative zones were identified around Beaver Lake, and six around Bull Shoals Lake. The zones generally corresponded to the time in months since the last inundation.

Effects of slope, orientation, and nearby vegetation were evaluated. Reflooding of these vegetative associations in 1978 has prompted study of relations between vegetative assemblages and fish production in White River impoundments.

**Effects of Flooding Peripheral Vegetation on Reservoir Fish Populations.** A water-level management plan carried out by cooperative efforts of the U.S. Army Corps of Engineers and the Arkansas Game and Fish Commission during 1977 and 1978 enabled us to observe the effects of flooding peripheral vegetation in Beaver Lake in 1978. Due to drought conditions in 1977, the water level of Beaver Lake was drawn down nearly 30 feet, and a low level was maintained throughout the year. As a result, a dense growth of terrestrial vegetation developed in the dewatered zone. The lake was refilled early in 1978, inundating the vegetation. Preliminary results indicate record levels of black bass reproduction and survival to September 1978.

**Underwater Observations of Black Bass Reproduction.** Underwater observations of black bass reproduction in Bull Shoals Lake began on April 17 and continued weekly through June 6, in five standard study areas representing bluff and cove



habitats. Largemouth bass spawning was already under way on April 17 (judging by the condition of nests at that time, it probably began on about April 14). A drop in water temperature within a few days after spawning began apparently interrupted nesting activity for a period of nearly 2 weeks. On May 1, fresh largemouth bass nests were about as numerous as at the beginning of the spawning season, and spotted and smallmouth bass nests were at peak densities.

Nest densities (numbers per 100 m of shoreline) were relatively low throughout the season: in coves the values were 1.8 for largemouth bass, 1.5 for spotted bass, and 0.6 for smallmouth bass. The bluff habitat produced a total of only one spotted bass nest and two smallmouth bass nests (no largemouth bass nests). This light use of the bluff habitat has occurred previously only during years of very high water.

Although water level in Bull Shoals Lake during spring was only about 1 m above conservation pool elevation, regrowth of shoreline vegetation during the previous year, when water levels were extremely low, produced near high-water conditions of abundant underwater cover. Vegetation was flooded to depths of about 5 m, and provided good nest cover and concealment for young bass. Despite heavy mortalities in early nests, due to the water temperature decline shortly after spawning began, total nesting success was higher than in 1977. The rates of survival to fry emergence from the nests were 57% for largemouth, 42% for spotted, and 33% for smallmouth bass. The survival rates of fry schools that reached fry-dispersal stages were 81% for largemouth bass, 85% for spotted bass, and 50% for smallmouth bass. These fry-school survival rates for largemouth and spotted bass are about 3 times greater than those

School of largemouth bass fry in cover afforded by flooded willows in Bull Shoals Lake. Survival of young bass in reservoirs is greatly increased during years of high water levels. *Photo by L. E. Voegelé.*



for 1977 and reflect the benefits afforded by flooded vegetation during the nesting season.

**Production of Young-of-the-year Shad.** Numbers of young-of-the-year threadfin shad caught in midwater trawls in 1978 were extremely low, as they were in 1977. Two successive severe winters lowered lake water temperatures to lethal levels for the species. Although threadfin shad were restocked in 1977, apparently none survived the winter of 1977-78. The population of gizzard shad was much lower than usual.

**Cove Population Sampling.** Standing crops of fish in both Beaver and Bull Shoals lakes increased in 1978. At the time of sampling, water elevation in Beaver Lake was 20 feet higher than in 1977, and that in Bull Shoals Lake was 15 feet higher. Drought conditions in 1977 caused the lowered lake elevations in that year. Increased rainfall in 1978 brought elevations up to above normal during the spring. Improved habitat provided for greater reproduction, survival of young fish, and growth of older fish.

**Black Bass Population Estimates by Electro-fishing.** Mark and recapture population estimates, based on collections by electrofishing, showed that early-spring bass populations in both Beaver and Bull Shoals lakes decreased this year. Largemouth bass fell from 61 to 54 per km of shoreline, spotted bass from 26 to 15 per km, and smallmouth bass from 39 to 11 per km. These results continue to confirm preliminary conclusions that bass populations respond directly to the amount of rainfall and lake elevations.

**Estimates of Angler Use and Harvest, Beaver Lake.** Fish harvest from Beaver Lake increased from 8.8 pounds per acre in calendar year 1976 to 12.6 pounds in 1977. In 1976 crappies were dominant in the catch, providing 3.1 pounds per acre and 35% of the total catch by weight; the black basses provided 2.9 pounds per acre and 33% of the catch. The black bass catch in 1977 doubled to 6 pounds per acre and 48% of the catch, whereas the crappie catch declined slightly to 2.8 pounds per acre and 22% of the catch. White bass contributed the only other important share of the catch—22% in 1976 and 14% in 1977.

**Multi-Outlet Reservoir Studies.** The objectives of the Multi-Outlet Reservoir Studies are to assess changes in the biota of DeGray Lake and tailwater that result from different outlet release levels. In addition, data are being collected for the development and verification of ecosystem simulations. From impoundment in 1969 to the present, all

water has been released from the epilimnial outlet. Releases from the hypolimnion will begin in 1979, and will continue for four seasons. The DeGray Lake studies are part of a cooperative effort by several State and Federal agencies and universities, and are designed to yield information on physical and biological interactions in multi-outlet reservoirs.

**Population Dynamics.** Fluctuations in the abundance and production of black bass and shad populations are studied to provide indexes of environmental and operational effects on fish stocks in DeGray Lake. During the 4 years of epilimnial release, the abundance of largemouth bass has varied substantially. Numbers have generally declined, but there has been evidence of large year-to-year variation in recruitment. Numbers of gizzard and threadfin shad have also varied widely. Unusually cold winters in 1977 and 1978 resulted in extremely heavy mortality of threadfin shad, and thereby created major restructuring of the clupeid population. These large annual variations in abundance and production of important predator and prey species have occurred within the period of epilimnial release.

August cove rotenone samples have been used to index year-to-year changes in crops of fish in DeGray Lake. During the 4 years of study under epilimnial release, the total estimated standing crop of fish in August has varied from about 130 to 230 pounds per acre. Ratios of predator to prey species have remained relatively stable throughout the period.

Field studies begun in 1977 to measure carrying capacity of DeGray Lake and annual production of fishes continued. Cove rotenone samples conducted from May to September have indicated a repeatable pattern of seasonal production, where total crops are smallest in late March or April, and largest in late summer.

**Loss of Larval Fish and Zooplankton.** Larval fish and zooplankton losses through DeGray Dam are measured each spring and summer to compare losses under epilimnial and hypolimnial releases. These studies have indicated a strong correlation between total volume of water released and loss of larval fish. Downstream losses are greatest during the early stages of larval development, in May and June of each year. Total annual losses therefore vary with the May-June rates of water release, and the abundance of larval fish in the reservoir. Shad, crappies, and sunfishes are the most abundant forms in the release water.

Total zooplankton losses are also closely related to reservoir discharge and, because of the seasonal pattern of zooplankton abundance in the reservoir, the greatest losses typically occur in April and May. Vertical distribution patterns of zooplankton and larval fish in the lake are such that the change from epilimnial to hypolimnial discharge is expected to result in a marked reduction in the loss of both.

**Tailwater Studies.** Sampling of the Caddo River downstream from DeGray Lake, and a 40-mile reach of the Ouachita River, was intensified in the spring of 1978, to define base-line conditions prior to the change to hypolimnial release. In addition to information on fish species composition and relative abundance that has been collected since 1975, age and growth data were collected for largemouth bass, golden redhorse, and channel catfish. These three species represent different trophic levels of feeding and will be used to index possible changes in the productivity of the tailwater associated with temperature changes resulting from the change to hypolimnial release.

Studies of zooplankton, benthos, and water quality, also begun in the spring of 1978, have indicated little production of zooplankton in the tailwater and a rapid decline in zooplankton abundance downstream from DeGray Dam. Studies of the benthos should provide a better index of changes associated with an altered reservoir release level.

The Multi-Outlet Reservoir Studies station was selected as a base of operations for tailwater studies on Greeson, Gillham, and Pine Creek lakes, under the NRRP-Waterways Experiment Station Cooperative Agreement. Cove-rotenone sampling in Greeson Lake has indicated that the standing crop of fish in that reservoir is only about two-thirds that in DeGray Lake. Reservoir and tailwater studies in Gillham and Pine Creek lakes are scheduled to begin in April 1979.

## **NORTH CENTRAL RESERVOIR INVESTIGATIONS<sup>1</sup>**

**Changes in Reservoir Water Levels Affect Abundance of Young Fish and Zooplankton.** The effects of spring and early summer water levels on

<sup>1</sup>Investigations terminated in June 1978. Staff moved to Bowling Green, Kentucky, to establish East Central Reservoir Investigations.

fish spawning success in Lake Francis Case, a main stem Missouri River reservoir, were studied by comparing the abundance, growth, diet, and food supply of commonly collected young-of-the-year fish in a low-water year (1974) and a high-water year (1975). Yellow perch and buffalofishes, which spawn near shore, were several times more abundant during the high-water year because the spawning substrate was more suitable and the nursery habitat more protected. The abundance of pelagic and tributary spawners such as white bass and freshwater drum, which migrate into shore areas as juveniles, was also greater during the high-water year, presumably because nursery conditions were more favorable.

Food supply was also more abundant during the high-water year, but growth of the three most common fishes (white bass, yellow perch, buffaloes) did not change. The diet of white bass and yellow perch differed between the two years: yellow perch ate more zooplankton during the high-water year and about the same number of insects in both years; white bass ate more insects during the low-water year and about the same amount of zooplankton in both years. The proportion of cladocerans in the diet of both species increased during the high-water year, but calanoid copepods were the preferred food. The standing crop of major zooplankton groups decreased during the high-water year, perhaps because of fish predation. Standing crops of minor zooplankton species increased during the high-water year, as did overall species diversity. We conclude that management of water levels in Lake Francis Case, to include one high-water year out of every three, would greatly enhance the lake's fishery resources.

**Populations of Zooplankton Changed as Reservoir Aged.** Zooplankton standing crops in the discharge of Lewis and Clark Lake, the lowermost reservoir in the Missouri River main stem system, were sampled from 1964 to 1973 to monitor long-term changes in abundance and species composition. Samples were taken and preserved with an automatic sampler four times daily, and weekly composite collections were analyzed throughout the period.

Zooplankton abundance decreased during the 10 years, from 18.5 organisms per liter in 1964 to 3.8 in 1971, and averaged 9.8 for the entire period. The three major groups of zooplankton collected and percentage composition were as follows: cyclopoid copepods, 68; calanoid copepods, 20; and daphnid cladocerans, 9. Densities of cyclo-

poïd copepods were highest during the first 6 years and lowest during the final 4 years. Densities of calanoid copepods were lowest during the early years of sampling and increased slightly during the later years. The abundance of daphnids fluctuated slightly over the entire period but showed no long-term change. The most common zooplankton species was *Cyclops bicuspidatus thomasi*, which contributed an average of 46% of the total number of adults collected.

Abundance and species composition of zooplankton in the discharge from Lewis and Clark Lake were highly correlated with those in the discharge of Lake Francis Case, 60 km upstream. In addition, zooplankton in Lewis and Clark Lake discharges appeared to be influenced by perturbations in the reservoirs farther upstream (lakes Oahe and Sharpe), during the final filling stages and the attainment of operating pool levels in the entire reservoir system.

**Use of Reservoir Water for Irrigation Affects Fish.** The use of water from Missouri River reservoirs to irrigate adjacent croplands has increased during recent years. Before 1976, the Corps of Engineers had issued one permit for taking water from Lake Oahe for irrigation. An aerial survey conducted in July 1978 revealed that 162 irrigation pumps were operating. In addition, 35 systems for which permits had been issued were either not operating or were still under construction at the time of the survey.

To reduce entrainment of larval fish, the Fish and Wildlife Service requests that irrigation intakes be blocked with ¼-inch-mesh screens, be placed in water at least 20 feet deep, and have a water approach velocity of not more than 0.05 foot per second. To evaluate the effectiveness of these guidelines, we conducted a study to determine the number and species of larvae entrained by intakes installed in shallow (5 feet) and deep (20 feet) water and with pumps operating at 2 and 3 cfs. Biologists used a 1,400-gpm pump and a single-screened intake pipe. Water from the outlet pipe was sampled with a small-mesh plankton net.

Larval fish were entrained throughout the period of study from May through mid-August. The maximum number of larvae (1,450 per day) was entrained in late May, and the number remained large until late June; few larvae were taken during July and August. Fishes entrained included yellow perch, buffalos, carp, smelt, suckers, sunfishes, shiners, and white bass. Egg entrainment peaked in mid-May at about 9,600 per day, de-

clined rapidly, and ceased after June. Placing the intake structure in deep rather than shallow water (20 feet vs. 5 feet) significantly reduced the number of larvae entrained. Increasing pump volume from 2 to 3 cfs did not significantly increase the catch.

These studies show that the guidelines suggested by the Fish and Wildlife Service for removal of irrigation water from Missouri River reservoirs are necessary to protect young fish.

**Biology of the Walleye in Lake Sharpe.** A study of the walleye population in Lake Sharpe was conducted during 1964-75. The abundance of yearling or older fish doubled during the first 3 years after impoundment, continued to rise during the following 4 years, and remained high thereafter. Walleyes are currently the most abundant and valuable game fish in this 56,000-acre reservoir.

The largest year classes of walleyes were produced in 1964 and 1968. Year-class strength was associated with the abundance of mature females. Growth of yearling and older fish declined after the first 2 years of impoundment. The decline was associated with a drop of about 75% in the abundance of young-of-the-year forage fishes. Female walleyes were increasingly larger than males after age IV. Mortality appeared to be higher in the first several postimpoundment year classes than in later year classes. The lower mortality rates for later year classes may indicate that the stock had reached equilibrium. Peak stock size of harvestable fish apparently occurred in 1971, when the 1968 year class entered the fishery.

## SEATTLE NATIONAL FISHERIES RESEARCH CENTER

**Ozone Toxicity to Salmonids.** The acute toxicity of ozone is high. Under the conditions tested, the average 96-hour LC50 was 9.3 (range, 8.1-10.6) µg/l for rainbow trout 10-13 cm long. Death during acute exposures is most likely due to severe destruction of gill lamellar epithelial tissue, accompanied by massive hydromineral imbalances. The resulting hypertrophy and hyperplasia probably also seriously impair respiration because of the increased diffusion distance for gas exchange, and there is also a potential for reduced erythrocytic oxygen binding and transport capacity.

Short-term chronic testing revealed that ozone

exposure at 2  $\mu\text{g}/\text{l}$  for 3 months caused few physiological changes, none of which would be expected to compromise biological function. Thus, as a guideline, a provisional maximum safe exposure level of 2  $\mu\text{g}/\text{l}$  is recommended for salmonids, pending completion of life cycle studies.

If ozone is used as a replacement for chlorine in water treatment systems or for disinfecting hatchery water supplies, it should be removed or diluted to about the 2- $\mu\text{g}/\text{l}$  level, before it is allowed to come into contact with salmonids.

**Blood Enzyme Response to Exsanguination and Salinity.** Blood equal to 5, 10, or 15% of estimated total blood volume (0.3, 0.6, or 0.9% of total body weight) was drawn from individual rainbow trout each week for 6 weeks. Analyses included hematocrits, hemoglobin, plasma proteins, three plasma enzymes (phosphocreatine kinase, lactate dehydrogenase, and leucyl aminonaphylamidase), plasma chlorides, glucose, and blood counts from peripheral blood smears. Significant changes were induced in virtually all of the blood characteristics of fish bled more than once or twice. The intensity of change and mortalities increased in direct proportion to the number of samplings.

A similar study was conducted on rainbow trout challenged with full-strength sea water. The only significant change was a rise in plasma chlorides; plasma enzymes and other characteristics remained within normal limits over a period of 1 month.

These results demonstrate that bleeding previously considered acceptable can induce significant changes in cellular and noncellular blood characteristics. Thus, repeated blood sampling would tend to mask the impact of environmental stress to an as yet undetermined degree.

**Clinical Monitoring: Development of Leucocrit as a Useful Diagnostic Tool.** The differential separation of blood leucocytes by centrifugation (leucocrit) was evaluated as a method of detecting stress and incipient infection in salmonids.

The leucocrit values of coho salmon infected with furunculosis and steelhead trout infected with enteric redmouth disease were significantly lower than those of uninfected fish. However, no significant change in the leucocrit preceded an epizootic of either disease. The leucocrit value can thus be used to quantify the degree of infection and perhaps detect the carrier state, but may not

be a useful diagnostic method for detecting incipient epizootics of acute disease.

Handling and crowding stress significantly lowered leucocrit values in coho salmon. Similarly, leucopenia occurred when there were extreme temperature changes ( $\pm 20^\circ\text{F}$ ). Coho salmon were more sensitive to a drop in temperature than to a rise.

**Clinical Monitoring: Blood Sodium-Sea Water Challenge.** Laboratory testing of the blood sodium-sea water challenge test for predicting the optimum release time of smolts, in terms of their ability to survive and continue to grow in the ocean, was continued. After steelhead trout, transported to a saltwater field station in January, were transferred to sea water, blood sodium tests were carried out on four dates, before, during, and after maximum ATPase development. Hypernatremia, due to poor osmoregulation, was measured over a 4-day period in 28 parts per thousand sea water. Optimum blood sodium regulation occurred during the 3rd week of April. Later sea-water testing resulted in high blood sodium levels and mortality.

**Clinical Monitoring.** The health and smolt functionality of steelheads reared in three water reuse systems was evaluated by a series of clinical tests, and the physiological condition of each group was characterized. A protocol was developed for assessing the degree of chronic stress due to hatchery practices by measuring interrenal cell nuclei and cell size. Significant differences in interrenal hypertrophy were found for the three reuse systems, and these differences were correlated with the severity of stress as determined by clinical tests.

Recently, abnormally high body burdens of copper and cadmium were measured in the early rearing stage of steelhead trout at the Dworshak National Fish Hatchery. The concentrations decreased as the fish grew, indicating that a single exposure had probably occurred. Throughout the past year, monthly water and fish samples were taken to monitor seasonal fluctuations in copper, zinc, and cadmium levels at the hatchery. Steelheads in the reuse system at the Seattle National Fishery Research Center were used as a control. Heavy-metal concentrations in the water were less than 0.01 ppm for each sample (determinations of the body burden of these metals are incomplete).



Rivera Flowage, Bradford, Maine. Beaver flowages 3-5 years in age that contain dense, emergent herbaceous vegetation produce abundant macroinvertebrates important to black duck hens, especially during the laying season, and to growing ducklings. *Photo by J. R. Longcore.*

## Migratory Birds

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### MIGRATORY BIRD AND HABITAT RESEARCH LABORATORY

**Research on Black Duck Breeding Habitat in Maine.** A contract study with the University of Maine at Orono investigated the importance of aquatic invertebrates as food for black ducks on their breeding ground, compared the energy and nutrient content of plant and invertebrate foods, and related the seasonal physical condition of female black ducks to the stresses of nesting and winter weather. Natural foods consumed by nesting black ducks and their young contained levels

of important nutrients well above estimated minimum requirements. On the basis of field sampling, the following wetland cover types were ranked in decreasing order of importance according to invertebrate abundance and potential value for feeding waterfowl: dense herbaceous (marsh) emergents, sparse herbaceous emergents, dense ericaceous (heathlike) emergents, sparse ericaceous emergents, floating-leaved plants, and flooded timber. This preliminary research suggests that maintenance of stands of herbaceous emergents should be an important objective in wetland habitat management in Maine.



Klimavicz Flowage, Dover-Foxcroft, Maine. Beaver flowages 20-30 years old produce fewer macroinvertebrates (important foods of black ducks and other waterfowl) than do flowages 3-5 years old. *Photo by J. R. Longcore.*

**Canvasback Banding Records Analyzed.** Recent concern for the apparent decline of North American canvasback populations has emphasized the need for recent estimates of critical population characteristics for this prized waterfowl species. Winter banding and recovery data from three populations of canvasbacks were therefore analyzed, and survival and recovery rates were estimated. Mean annual survival rates for males ranged from about 70 to 75% for the three populations; survival rates for females ranged from about 0.55 to 75%. In two of the populations, female canvasbacks had significantly lower survival rates than males. Survival rates were also shown to vary geographically, suggesting that canvasbacks should not be managed on a continental basis. Evidence of year-to-year variation in both survival and recovery rates was found in studied populations. Although lower recovery rates were noted during periods of restrictive hunting regulations, confirming that hunting pressure is influenced by changes in regulations, the relationship

was not clear-cut. (It appears that winter banding programs can provide a means of estimating some key population variables for canvasbacks.) The feasibility of using data from recaptured banded birds to estimate adult survival rates rather than relying entirely on band-recovery information submitted by hunters is now being evaluated. This approach might be especially useful for monitoring canvasback survival because the restrictive hunting regulations for this species result in relatively few band recoveries.

**Shore and Upland Game Bird Contract Research Continues.** The Laboratory annually awards \$175,000 in contracts to State Fish and Game Departments and to universities for research on migratory shore and upland game birds. Species studied include woodcock, mourning doves, snipe, rails, gallinules, sandhill cranes, the American coot, white-winged doves, and band-tailed pigeons. Funds are administered through the Laboratory's Accelerated Research Program for Migratory Shore and Upland Game Birds.



Black ducks trapped in early spring are fitted with transmitters to monitor habitat usage in south-central Maine.  
*Photo by J. K. Ringelman.*

Twenty-six projects in 17 States received these special funds in fiscal year 1978. Six of the projects are being conducted by State Fish and Game Departments and 20 by universities, which include four Cooperative Wildlife Research Units (Louisiana, Missouri, Oklahoma, and Pennsylvania). The purpose of the program is to gain information needed for more effective management of this important resource.

The nature of the research varies. For the more heavily hunted species, studies often focus on specific problems of management. For example, during fiscal year 1978, contract research on mourning doves increased our understanding of crop gland activity in relation to breeding activity. This research is especially timely because of concern over the possible impact that September hunting may have on mourning dove recruitment. A variable percentage of hunter-harvested adult doves across the country each year shows indications of crop gland activity, suggesting that adult birds may still be feeding young when hunting seasons begin. This study indicated that in captive pairs, crop development began by the 9th day of egg incubation and then greatly accelerated from hatching at 14 days until the nestlings were 5 days old. Crop glands became inactive earlier in

females than in males, but by 18 to 20 days after hatching, all crop glands were inactive. The impact of September hunting on late-season nesting is the subject of a major cooperative study being conducted by State Fish and Wildlife Agencies and the U.S. Fish and Wildlife Service.

Research on some species of shore and upland game birds is fundamental in its approach because of the need for basic information. For instance, a study of the common snipe in Montana provided information on snipe distribution, migration chronology, breeding biology, and harvest in the State. The study indicated that 84% of the harvest and 80% of the hunting pressure for snipe occurred in the Rocky Mountain highlands in the western half (Pacific Flyway portion) of the State. This area coincides with the snipe breeding habitat located and mapped during the study. The moist intermountain valleys with sedge bogs, meadows, and stream edges provide the best snipe breeding habitat. Peak fall migration occurred in October and resulted in a threefold increase in birds. This study showed that snipe harvest in Montana is small, with estimates of 450 hunters harvesting 1,350 snipe. By comparison, Florida hunters harvest 197,000. All available information suggests that hunting removes only a small fraction of the



overall snipe population and that this species offers much additional hunting opportunity.

**Technical Literature Compiled on the American Woodcock.** A bibliography has been compiled of scientific references published between 1927 and 1978 on the woodcock. The cutoff date of 1927 was chosen for early literature because of the importance of Arthur Cleveland Bent's work in that year. Most articles before 1927 are descriptive and do not add appreciably to the scientific literature on the species. An excellent listing of the early literature may be found in the 1936 monograph by Olin Sewall Pettingill, Jr. No previously published bibliography devoted solely to woodcock is available.

This compilation of technical literature on the woodcock is primarily intended as an aid to wildlife researchers and managers. Many important references on woodcock are not found in scientific journals but occur in Pittman-Robertson Reports, Woodcock Workshop Proceedings, university theses, and in the proceedings of regional wildlife conferences. Each of these sources was searched for relevant reports. *Wildlife Review*, *Biological Abstracts*, *Zoological Record*, and the Fish and Wildlife Reference Service (an information retrieval service) were the additional sources consulted.

**Timing of Adult Primary Molt in Mourning Doves.** The timing of the adult primary molt in mourning doves, the earliest dates of its completion, and the variability in molt rate among years and between sexes were studied in North and South Carolina. Recaptures of 8,047 banded adult mourning doves were used to document the timing of the molt and to predict the earliest dates of completion. Variability of molt rate was based on 403 recaptures. Substantial numbers of adult doves in the Carolinas had completed their primary feather molt in September. Comparison of this study with a similar Missouri study showed that northern doves complete their primary molt later than southern doves.

The onset and completion of the primary molt are concerns of management because of the importance of accurate age determination in doves captured for banding, especially in deriving recruitment indices from dove wings submitted by hunters. Both young doves and adults shed their wing feathers in summer. Complete replacement requires about 4.5 months. Before molt is complete, young and adult doves can be identified by characteristic differences in feather coloration. It

has generally been believed that molt is completed first by young doves, that most birds that complete the molt in September are young, and that adult birds can be identified because they are still molting at that time.

Results of this study indicate that many adults that have completed molting will be erroneously classified in September as young birds. Consequently, recruitment indices based on wings collected in September are likely to be biased, and recruitment rates are probably lower than past estimations.

**Pennsylvania Woodcock Hunters and Woodcock Harvest Characteristics.** A statewide wing survey (1971-73) and hunter questionnaire (1974) were used to examine woodcock harvest and hunter characteristics in Pennsylvania. A yearly average of 292 respondents made 3.9 hunting trips per hunter per season, flushing 15.1 and harvesting 5.1 woodcock. Bird dogs were used on 73% of the hunting trips, and 91% of all trips were on private land. The average respondent was a male, between 31 and 40 years of age. He traveled less than 20 miles to his favorite hunting cover and usually hunted with a partner. The most frequent choices among a number of possible reasons for hunting were: to enjoy the scenery, to be outdoors, and to work with bird dogs.

**Synthesis and Evaluation of Avian Population and Habitat Data for Alabama and West Virginia.** An evaluation of the bird populations of West Virginia and Alabama included a compilation of data on specific habitat requirements. Results from the Breeding Bird Survey (BBS), the Breeding Bird Census (BBC), and other published and unpublished material available at the Laboratory were used as references.

Figures obtained from the BBS were used to prepare graphs that showed population trends of birds in the two States. Populations of Cooper's hawks had been declining until about 1970 and then significantly increased. The red-tailed hawk population also increased in the eastern section of the United States, including Alabama. In contrast, the severe winter of 1976-77 produced a sharp decline in the bobwhite population in both West Virginia and the eastern part of the United States in general. The killdeer, which had increased in both West Virginia and the eastern region, also suffered a decline. The final report contains graphs of population trends for all other species for which there are adequate BBS data.

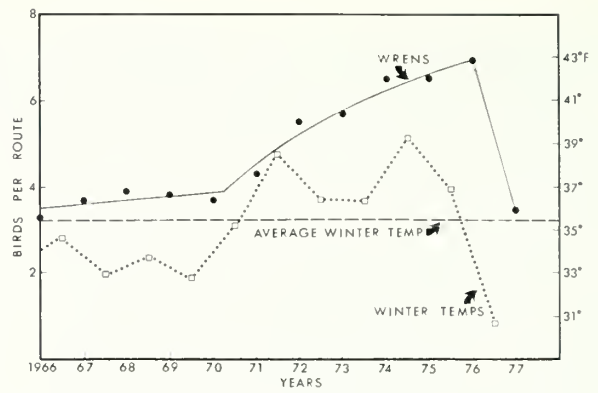
Information from the BBC was used primarily

to construct tables that show the breeding bird density of different habitat types in the two States, including disturbed as well as undisturbed areas. Disturbed habitats included strip mines, edge, logged-over tracts, and areas in different stages of succession following disturbance. Relating habitat type to bird composition and abundance aids planners in predicting the probable effects of proposed habitat alterations on bird populations.

All the information for each bird species is on computer tape in the "Runwild" format and can be easily extracted by potential users. Specific information can be obtained by calling or writing the Laboratory.

**Close Correlation Between Habitat and Breeding Bird Populations.** Height and density of forest canopy, percentage of conifers, annual precipitation, and extent of contiguous similar habitat were some of the variables found by statistical tests to have the greatest influence on density of several species of forest- and edge-inhabiting birds during the nesting season. These habitat characteristics and others that could be measured numerically were compared singly and in combination with densities of several common species of breeding birds in 80 census plots. Computer-generated formulas based on correlations found in these 80 plots were then used to predict population densities of the same bird species in other census plots for which densities had not yet been determined. The observed populations in the new plots were significantly correlated with the predicted populations for seven common species: Acadian flycatcher, tufted titmouse, blue-gray gnatcatcher, red-eyed vireo, Kentucky warbler, hooded warbler, and cardinal. Correlations were not as high for the few other species tested, suggesting that some key habitat factors had not been included in the initial analysis. This method, however, provides a means of using detailed habitat descriptions, obtainable at any time during the summer (and to some degree even in winter), to evaluate the impact of habitat changes on breeding bird populations.

**Harsh Winter Causes High Mortality Among Nongame Birds in East.** For the first time in the history of the Breeding Bird Survey (BBS), the eastern United States experienced an unusually severe winter (1976-77). The BBS detected effects of the prolonged cold weather. Declines of 20 to 50% were noted in many bird species in the 1977 BBS. The semihardy species that winter in the eastern interior suffered the greatest losses.



Index of the Carolina wren population in the eastern States, based on the Breeding Bird Survey, in relation to winter temperatures (December-February) at Baltimore, Maryland. The long-term average temperature is shown as a dashed line.

Species with the most severe declines were winter, Carolina, and house wrens, golden- and ruby-crowned kinglets, bobwhite, ring-necked pheasant, eastern phoebe, pine warbler, eastern bluebird, and swamp sparrow. Despite the extreme cold, populations of certain hardy species that have been expanding their ranges northward, such as the mockingbird, cardinal, and tufted titmouse, remained stable.

Survey coverage continued to improve and the number of requests for survey data increased. The number of 50-stop roadside transects run in 1977 reached a new high, with 1,820 routes covering the 49 continental United States and all 10 Canadian Provinces.

**Transmission-line Corridor Causes Changes in Forest Bird Species Composition.** During the spring of 1973, four breeding bird census transects were established along the proposed Sequoyah-Franklin transmission-line corridor in Tennessee. Ten sample points were censused eight times on each transect. The vegetation was also sampled. The corridor was cut through this deciduous forest habitat the following February and March. From 1974 through 1977, the four breeding bird transects were run four times each spring. Because the corridor was 45 m wide, birds were censused on the entire corridor, its edge areas, and 7.5 m into the forest on each side.

In the spring of 1974, after the corridor was cut, the ground was covered with short grasses and sedge. Bird species diversity in this new grassland habitat declined from 1.92 (1973) to 1.78 (1974).

Seven species of breeding birds that held territories in the forest before the cut were not ob-

served in the open areas of the corridor. Those species were the yellow-billed cuckoo, red-eyed vireo, Kentucky warbler, scarlet tanager, and summer tanager, which winter in Latin America; the blue-gray gnatcatcher, which winters in the southern United States and along the Gulf Coast; and the pine warbler, which winters on the coastal plain.

Six species (field sparrow, bobwhite, brown thrasher, eastern kingbird, indigo bunting, and blue grosbeak) that were not observed in the deciduous forest before the cut were later seen in the open area of the transmission-line corridor.

Although transmission-line corridors through large tracts of deciduous forests can increase total diversity, there appear to be fewer species in the new grassland habitat than in the forest. Disturbances in deciduous forest reduce habitat for some species of migratory birds and increase it for others. The greatest adverse impact is on species that winter elsewhere. The positive impact is greatest on species that favor grasslands and forest edge.

**Handbook Prepared on Statistical Inference from Band-recovery Data.** Banding of birds has long been recognized as an important research and management tool, especially for hunted species. Well-designed banding programs provide information on a wide variety of subjects, including survival rates, shooting pressure (recovery rates), and the geographic and temporal distribution of harvest. A recently published handbook should prove useful to anyone engaged in detailed analysis of band-recovery records. It was prepared by Service personnel in cooperation with statisticians at Cornell University.

The handbook includes descriptions of a number of stochastic models for band-recovery data. Band recoveries are modeled as random variables that can be described in terms of recovery and survival probabilities and of number of bandings. Actual banding and recovery data can then be used, in conjunction with these models, to estimate survival and recovery probabilities and their sampling variances and covariances. The models differ in their inclusion of one, two, or three distinguishable age categories and in assumptions about the degree of year-to-year variation in survival and recovery probabilities. Comprehensive FORTRAN computer programs were written to implement the estimation methods and to provide test statistics to be used in choosing appropriate models for specific data sets. Instructions on the

use of the computer programs and the interpretation of output are included in the handbook. The handbook also contains suggestions on the computation of statistics to test hypotheses about variation in survival and recovery probabilities. Finally, the handbook contains a chapter on the planning of banding studies, which includes guidelines for determining appropriate sample sizes.

## NATIONAL WILDLIFE HEALTH LABORATORY

**Causes of Nonhunting Mortality of Migratory Birds.** The diagnosis and control of diseases of migratory birds is a primary concern of the U.S. Fish and Wildlife Service. Effective disease control resulting in reduced losses depends on early detection of the problem, rapid and proper identification of its cause, and timely application of appropriate control measures. In 1978, the Laboratory processed 3,866 diagnostic specimens in field and laboratory investigations. In addition to identifying the causes of mortality, these diagnostic findings are invaluable in establishing research priorities for more comprehensive investigations.

In 1978, avian botulism was a major cause of migratory bird losses due to bacterial microorganisms. Die-offs from this cause were documented from New York, New Jersey, Pennsylvania, Maryland, Wisconsin, Iowa, Nebraska, North and South Dakota, Montana, Texas, Arizona, Nevada, Oregon, and California. The largest single loss was estimated to be about 50,000 birds in the vicinity of Billings, Montana.

Avian cholera was identified as the cause of bird losses in California, Nebraska, Texas, Iowa, Missouri, Wisconsin, New York, and Maryland. The isolation of *Pasteurella multocida* from a white pelican represents the first report of avian cholera in this species and extends the known range of host susceptibility.

Isolations of *Salmonella enteritidis* (various serotypes) were also made from a variety of avian species across the country. Songbirds using backyard feeders in Minnesota, Wisconsin, and Florida were the source of many of these specimens; other isolations were made from an albatross on Midway Islands (central Pacific), pheasants in Nebraska, black and turkey vultures in Florida, and a variety of species of captive

Migratory bird losses from avian botulism. Extensive losses from this disease occur periodically throughout the United States. This die-off near Billings, Montana, resulted in a loss of about 50,000 birds. *Photo by Jim Runningen.*



Airboats, plastic bags, and people power—common ingredients necessary to combat migratory bird die-offs and to prevent their spread over large areas. *Photo by Jim Runningen*



National Wildlife Health Laboratory personnel conducting on-site field necropsies to evaluate the cause of mortality in birds picked up during disease control activities. The causes of mortality must be monitored throughout the course of disease control so that appropriate adjustments in control measures can be quickly made if any new problems erupt. *Photo by Jim Runningen.*



Administering antitoxin to birds suffering from avian botulism. A very high percentage of birds treated in this manner survive. *Photo by Jim Runningen.*



A coot and a Canada goose recuperating from avian botulism in a "hospital pen" at the Horicon National Wildlife Refuge. When they recover the birds can fly out of the open-top pens. *Photo by Jim Runningen.*



Burning is the preferred method for disposing of carcasses collected during disease control activities. This method prevents environmental concentration of large amounts of contaminated materials at burial sites. *Photo by Jim Runningen.*

cranes in Wisconsin, including some newly hatched Siberian crane chicks. Other bacterial agents identified in diagnostic specimens included *Mycobacterium avium*, the causative agent of avian tuberculosis, and *Aeromonas hydrophila*, a known pathogen of fish that is commonly isolated from birds that appear to have drowned.

During the year 1,166 virus isolation attempts were carried out for five viral diseases: avian influenza, Newcastle disease, avian pox, duck plague, and inclusion body disease of cranes (IBDC).

The role of migratory birds in the distribution of influenza viruses is slowly being determined by the combined findings of these studies and those of other investigators. Isolation of the viruses of both avian influenza and Newcastle disease continues at a low rate. No evidence of duck plague virus activity has been detected in the wild waterfowl populations examined during these investigations. These findings do not support the contention that duck plague is enzootic among North American waterfowl.

The isolation from cranes of a herpes virus (IBDC) that also causes mortality in young ducks and adult coots was a significant biological finding. The broad spectrum of species susceptibility already evident for this virus indicates that it may be a greater threat to the well-being of our migratory bird populations than duck plague.

When the causes of migratory bird losses are identified rapidly, proper control measures can be initiated in time to reduce significantly the on-site losses and to minimize the potential spread of the problem to other areas. Procedures used to combat one type of disease are often ineffective for another. Laboratory evaluations are necessary to confirm subjective field judgments, thus avoiding mistakes that could result in rapid dissemination of diseases because of mobility and gregariousness of many migratory bird species. The wildlife health program of the Service has resulted in the annual savings of thousands of birds that would otherwise be lost to disease. The continued finding of lead poisoning in a significant number of the waterfowl received for necropsy and the continued loss of bald eagles and other raptors to poaching demonstrate that we must deal just as much with relevant social and political issues as with the biological factors involved in infectious disease.

**Discovery of New Herpes Virus Infection of Cranes.** A spontaneous die-off of seven sandhill, five Japanese, four Stanley, and two hooded

cranes at the International Crane Foundation in Baraboo, Wisconsin, prompted a request for assistance in determining the cause of this mortality. Investigations disclosed that the die-off was confined to a large pen containing a mixed population of nonbreeding juveniles and adults. Attempts to isolate the causative virus resulted in isolation of an unknown viral agent from three sandhill cranes and two Japanese cranes.

Identification and characterization studies of this virus showed it was capable of forming intranuclear inclusion bodies, was ether sensitive, was heat labile after 10 minutes at 56° C, and contained DNA nucleic acid. These characteristics and morphological findings clearly identified the virus as belonging to the herpes group, and the illness induced by the virus was termed inclusion body disease of cranes (IBDC).

Studies were then undertaken to determine the range of host susceptibility to this previously unknown virus. Of the species tested, 3-day-old white Pekin ducklings were the most susceptible; 16-day-old Pekin ducklings and adult American coots were susceptible when exposed to concentrated doses of the virus, but 64-day-old Muscovy ducks and 17-day-old white Leghorn chickens were not susceptible.

Serum samples from 11 surviving cranes in the affected pen and sera from 95 wild sandhill cranes trapped in Wisconsin and Indiana were tested for neutralizing antibodies against this virus. Nine of the 11 captive cranes tested had high neutralizing antibody titers, whereas none of the sera from the wild sandhill cranes had the specific antibody against this virus. These findings confirm that IBDC virus is a new pathogen for sandhill cranes.

The origin of IBDC virus is unknown; however, the captive crane population at risk represents all but one of the world's species of cranes. These birds were obtained from a variety of sources, including their native lands. Because viruses of the herpes group can produce latent infections during which the virus apparently disappears from infected individuals for months or years, the virus may have been imported with the birds. This latency can also aid the spread of the virus to new locations. The longevity of cranes, the nature of herpes virus infections, and the lack of species specificity of the IBDC virus combine to create a potentially hazardous situation. These cranes and their progeny must be continually monitored and must be maintained in isolation from free-living North American avifauna until more is known



Albatross habits provided a mechanism for pox virus transmission on Midway Islands. The soft bill of the chick became abraded by the sharp edges of the hard bill of the adult during the feeding process. These abrasions provided points of entry for the virus. *Photo by Milton Friend.*

about the pathogenicity and distribution of this virus in nature.

**Control of Avian Pox Among Albatross Chicks on Midway Islands.** Notification of mortality among albatross chicks on Midway Islands in the central Pacific Ocean resulted in a joint endeavor involving personnel from the Laboratory, the Hawaiian Islands National Wildlife Refuge, and the U.S. Navy. The large number of endangered species in the Hawaiian Islands chain and the potential for the spread of the disease to other islands by migratory birds made it necessary to identify the cause of the problem and to apply control measures, if possible.

A field investigation at Midway Islands disclosed that the problem was confined to Sand Island and had not crossed the channel to nearby Eastern Island. It was determined that avian pox (a viral disease) caused the mortalities and that differential rates of infection occurred among species, age-classes, and locations on Sand Island. Only albatross chicks were infected and the incidence of infection was not density dependent. Pox viruses cannot penetrate intact skin surfaces, lesions are generally confined to unfeathered parts of the body, and transmission is generally accomplished by insect vectors.

Further investigation revealed that the green



Avian pox lesions on the bill and eye of a Laysan albatross chick. Sight has been lost in the right eye as a result of infection with this virus. *Photo by Milton Friend.*

blowfly was the most probable vector and that transmission was mechanical (contaminated foot and mouth parts of the flies). Parental feeding of albatross chicks causes abrasions in the soft bills of the chicks as they remove regurgitated squid

and other food items from the hard, sharp bills of the parent birds. These abrasions provide suitable points of entry for the virus, and the soiling of feathers around the face with squid oil and food items attracts flies to this vulnerable area. Dead birds that became flyblown, thus producing more flies, contributed to the already ample fly population on Sand Island.

In addition to the suitable vector population, certain habitat conditions contributed to the problem. Wind conditions in the open areas kept the flies away from albatross chicks and thereby reduced the potential for transmission of the virus. As the height and density of herbaceous vegetation increased, infection rates in the birds also increased. Maximum rates of infection (nearly 100%) occurred in areas that had a dense woody overstory as well as dense herbaceous cover. The dense cover moderated the wind, thus enabling flies to cling to the faces of the chicks. Numerous observations were made of flies feeding and walking on pox lesions on the faces of infected birds.

The problem was controlled by a combination of activities including fly control, increased sanitation (removal and disposal of dead carcasses), selective destruction of heavily infected birds, and hand-cutting of vegetation to allow stronger winds to reach albatross chicks. Enrollees of the Young Adult Conservation Corps took part in the control effort and materially contributed to its success. As a result of the control measures, the problem was confined to Sand Island, losses of albatross chicks from avian pox at that location were reduced, the potential spread of the disease to other bird species on the Island was decreased, and a better understanding of the ecological relations involved in the transmission of this disease among nesting birds was obtained.

**Cryogenics Aid Studies of Interactions Between Viral Agents and Environmental Pollutants in Migratory Birds.** Wildlife organisms are often exposed within a short period to multiple biological insults such as environmental pollutants, parasitic burdens, and microbial agents. Despite this common occurrence, studies of possible interactions between these pollutants and microbial agents have been hampered by the lack of adequate biological assay systems that are flexible, sensitive, and relatively inexpensive. Cell lines developed from various groups of wildlife species represent a potentially suitable model system for detecting important interactions between environmental pollutants and viral agents, thereby providing a

mechanism for preliminary evaluation of this type of sublethal impact.

Research is being conducted by scientists of the U.S. Fish and Wildlife Service to develop tissue culture stocks from a variety of avian species representing a broad spectrum of native avifauna. Cell culture techniques developed or modified from existing methods for harvesting, growing, maintaining, and storing viable cells are being used to prepare and store cells from embryos collected at the Bear River National Wildlife Refuge in Utah. Eggs from 18 avian species representing five genera were collected during 1978 and frozen stocks were prepared from 12 of these species.

Maintenance of viable avian cells in a frozen state requires the development of satisfactory cryoprotectant concentrations and freezing rates to prevent cell damage during the freezing process. In addition, a recovery rate greater than 50% for the frozen cells is desired. Our preliminary studies with cells prepared from mallard and white Pekin embryos indicated that cell culture media containing 10% dimethyl sulfoxide as a cryoprotectant and a controlled freezing rate of from 1 to 5 Celsius degrees per minute were best for cell survival. Recovery rates of 70% (mallard) and 74% (white Pekin) were obtained from these embryos.

Storage temperature is an important factor to ensure good cell culture stocks of similar quality for future use. Mallard cells stored at  $-76^{\circ}\text{C}$  underwent an 80 to 99% reduction of cell viability over a period of 3 to 4 months. However, storage in liquid nitrogen tanks at  $-196^{\circ}\text{C}$  resulted in decreased cell viability counts of only 0 to 30% during 2.5 months of evaluation.

Optimal laboratory growth and maintenance procedures for cell cultures vary greatly with the different species and these variations are under intensive study. They appear to be the final hurdle to be negotiated before interaction studies can be initiated with this system. Recovery rates of viable frozen cells from nine avian species tested have ranged from 37 to 100%. Six of those species have yielded recovery rates greater than 63%.

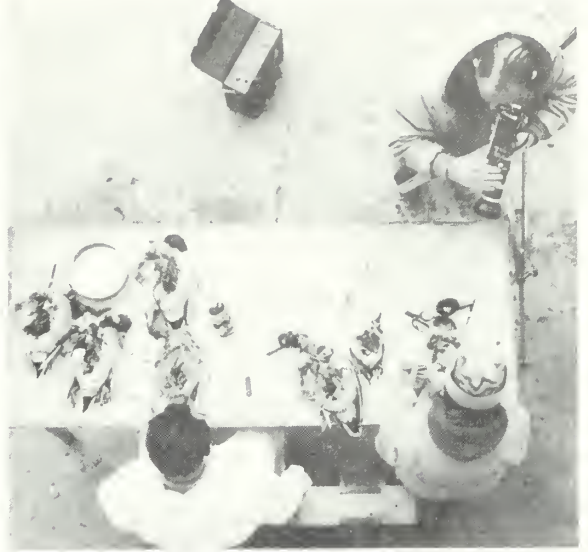
**Streptococcosis in Eared Grebes.** Between mid-November and mid-December 1977, agents of the U.S. Fish and Wildlife Service and the Utah Division of Wildlife Resources observed the deaths of about 7,500 eared grebes on the Great Salt Lake in northern Utah. The total number of grebes using the lake was not reported.

About 10,000 ducks (roughly 75% northern shovelers and 25% green-winged teal) inter-





Each year an estimated 1.6 to 2.4 million waterfowl die from lead poisoning. The majority of this mortality goes unnoticed or undetected because it occurs after the hunting season. This late winter die-off in central Nebraska resulted in a loss of more than 1,500 mallards. Photo by Jim Runningen.



News coverage of wildlife die-offs often results in on-site visitation by the press. This field operation is being filmed during the early diagnostic stages of a lead poisoning die-off in Nebraska. Photo by Jim Runningen.

mingled with the grebes, and hundreds of gulls (species not reported) fed on grebe carcasses, but these species showed no signs of illness.

The body cavities of many of the grebe carcasses had been opened by scavengers, making them unsuitable for microbiological examination, but 12 in good condition were submitted to the Bear River Research Station for necropsy. Heavy layers of subcutaneous fat suggested that the illness was acute. Buff-colored livers were enlarged and friable; lungs were congested and filled with fluid.

Stain preparations of liver, lung, spleen, and heart blood disclosed the presence of numerous cocci in pairs and short chains. This bacterium, isolated on laboratory culture media, was identified as *Streptococcus zooepidemicus*.

This outbreak has two noteworthy aspects: It is the first reported instance of epizootic streptococcosis in wild birds, and it occurred at the same site where, in late 1975, an outbreak of erysipelas also selectively affected eared grebes.

## NATIONAL FISH AND WILDLIFE LABORATORY

**Habitat Use and Breeding Biology of Willets.** In this 2nd year of the study of willets, refined techniques for trapping and marking enabled us to mark 70 breeding adults on the Wallops Island

(Maryland) study area and 25 at a secondary site. Both areas are situated in barrier island/salt marsh systems. Because of the high mortality suffered by birds marked with patagial tags in 1977, dyes and color-bands were used this year instead of the tags. Habitat use varied in the population as a whole but was predictable for individual birds. Tidal creeks and low (wet) *Spartina alterniflora* were the primary feeding habitats, although some individuals also fed on the outer beach. Feeding territories of various sizes were defended; territories on the beach were probably larger than those in the marsh (measurement of marsh territories was more subjective) and there was much overlap during intermediate tidal stages. Some birds maintained two feeding territories and defended a separate nesting area.

This year, the extremely high tides prevailing late into the spring and the frequent rains apparently somewhat delayed the onset of nesting. Much of the preferred nesting habitat was so wet that many willets selected atypically high and dry sites for nest placement. Site selection accounted in part for increased hatching success, because the selected areas harbored fewer raccoons. Seventy-seven nests were found and basic data on eggs and nest microhabitat were taken. All eggs were reweighed and refloated periodically during incubation, and an index to stage of incubation was developed from the flotation data. This index may

be precise enough to permit determination of breeding phenology of local populations on the basis of one-time sampling.

**Studies of the Biology of Terns and Related Species.** More extensive data now available on the age composition of breeding royal terns in Virginia and North Carolina confirm that the age of first breeding is 3 years, that only a comparatively small number of 3-year-olds breed, and that this number fluctuates widely from year to year. Whether one sex is more liable than the other to nest at this age is not known. Breeding appears to become general among 4-year-old birds; individuals of this age usually form the largest year class of the breeding populations. Royal terns are long-lived, and individuals a decade old are not unusual. The longevity record is 17, and it seems probable that older birds occur but cannot be identified because their bands have worn through and have been lost.

The royal tern and its smaller close relative, the Sandwich tern, nest in joint colonies in the southeastern United States. Along the Atlantic Coast, royal terns far outnumber Sandwich terns, but the population of Sandwich terns has been increasing steadily and now exceeds 1,000 pairs in North Carolina. Evidence indicates that the increase was due in part to immigration: a Sandwich tern banded as a chick on the Gulf Coast of Mississippi was found nesting in North Carolina.

Unlike most terns, which have little sexual dimorphism, black skimmers show a considerable sex-based size difference. Criteria based on measurements and weight data will enable field researchers to determine the sex of essentially all live adult skimmers encountered. Why skimmers are more dimorphic than their close relatives the terns and gulls is unclear, but the answer seems more likely to be related to their unique feeding behavior than to courtship display or other social behavior.

## **NORTHERN PRAIRIE WILDLIFE RESEARCH CENTER**

**Age-related Aspects of Mallard Reproduction.** Several factors that are potentially important to recruitment in mallard populations were compared for yearling and adult hens in North Dakota during two 4-year periods (1968-72, 1974-77). Status of the reproductive tracts of autopsied

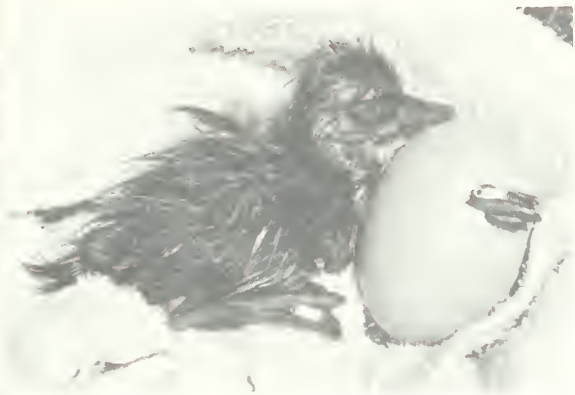
birds indicated that the level of nesting activity among adult breeding hens was 28% higher (although not statistically significant) than among yearling breeders. Most yearling hens will nest at least once under optimum conditions. In experimental studies, 27 of 28 yearling hens (96%) nested when food was provided ad libitum.

Physical condition of wild hens varied with age. Adult hens were heavier and had larger lipid reserves throughout the nesting season. Average weights were  $1,121.2 \pm 121.5$  g for 106 adults and  $1,070.2 \pm 121.3$  g for 44 yearlings. Lipid content in carcasses of 42 adult breeding hens averaged 24% higher than among 16 yearlings. On average, adults began nesting activity 5 days earlier than yearlings (April 28 vs. May 3), and initial clutches averaged  $10.3 \pm 1.1$  eggs (46 nests) for adult hens and  $9.3 \pm 1.7$  eggs (7 nests) for yearlings. Clutches of some (but not all) hens gradually increased in size over several years. For example, one hen laid clutches of 9, 8, 9, 10, 10, 11, and 11 eggs in years 1, 2, 3, 4, 5, 8, and 9. Weather conditions during April varied markedly among years, influencing timing of nest initiation and clutch size.

The results of the study show that certain reproductive factors exhibit subtle age-related differences that may cause recruitment rates to vary between yearling and adult hens breeding in the Prairie Pothole Region, particularly during years when unfavorable habitat conditions are widespread.

**Reproductive Potential of Mallards Under Drought Conditions.** Nesting activity by mallards on the Medina Study Area in south-central North Dakota was light under drought conditions during the spring of 1977. By May 10, only 76 of 783 wetland basins on the 36-square-mile area held any water, and nearly all temporary and seasonal wetlands were dry. Of eight mallard hens captured on the study area in late April that were radio-marked and monitored daily, only one is known to have made a nesting attempt (0.1 nest per pair). Pairs generally abandoned the area as the nesting season progressed and water conditions deteriorated. In comparison, eight radio-marked hens monitored on the area during years of favorable water conditions made 14 known nesting attempts (1.8 nests per pair). Nine mallard nests were found on the area in 1977, whereas 46 nests were found in 1976 under favorable water conditions.

Aquatic foods are less plentiful in drought years, a factor that undoubtedly contributes to reproductive failure. Experimental studies of



Gadwall ducklings in hatching eggs are marked with small aluminum tags to facilitate their identification in the future when captured on brood-rearing marshes or at nest sites. *Photo by Harold F. Duebbert.*

mallards have indicated that when hens have little access to animal foods, reproductive potential is adversely affected. Mallard hens with access only to wheat (14% protein) and a supplemental source of calcium laid 48% fewer eggs than did controls fed a diet containing 29% protein, the approximate level of protein in the natural diet under normal conditions. Egg composition was also af-

ected by diet content. Mean weight of eggs declined from 55.9 to 49.0 g (12%,  $P < 0.001$ ) and mean yolk weight (dry) from  $11.9 \pm 1.3$  to  $10.2 \pm 1.0$  g (14%). The change in yolk weight represents a substantial decrease in nutrient reserves for developing embryos and newly hatched young. The addition of 10 g of live earthworms daily to the wheat diet of mallard hens during the nesting season markedly improved egg hatchability but had no effect on egg production, presumably because of a deficiency of total protein or of one or more essential amino acids. Mallard hens under the nutrient stress of a plant diet ovulated at irregular intervals. For example, hens on the plant diet failed to ovulate an average of 1 day for every 2 eggs laid, whereas hens on the control diet failed to ovulate 1 day for every 4.6 eggs. (Lengthening of the laying interval because of marginal food resources increases the probability of nest destruction.) Inadequate access to nutrients can inhibit hens from reneating when initial nests are destroyed.

These data indicate that mallard reproduction is sensitive to habitat conditions that affect the status of food resources. Favorable water condi-

Gadwall duckling about 22 days old that was marked in a hatching egg with a numbered aluminum tag and later captured on a brood-rearing marsh one mile from the nest in a field of planted nesting cover. *Photo by Harold F. Duebbert.*



tions provide access to food sources of high quality; when shallow wetlands go dry, the supply of animal foods becomes scarce, intraspecific strife increases, and nesting activity declines.

**Mate Preference in Wild and Game Farm Mallards.** Experiments were designed to determine whether assortative mating occurs in wild and game farm mallards. Males raised with females of the same strain courted these females more than females of the opposite strain and paired successfully only with females of their own strain. Males raised with females of the opposite strain courted wild and game farm females with equal intensity and were successful in pairing with females of either strain. Although this study does not settle the question of possible gene flow between these two mallard populations, it indicates that there may be some barrier to panmixis.

**A Model of Sandhill Crane Population Dynamics.** The impact of sport hunting on the Central Flyway population of sandhill cranes has been a subject of controversy for several years. A recent study yielded some important information on sandhill crane population dynamics that has been incorporated into a mathematical model to assess the long-range impact of hunting on the sandhill crane population.

The model is a simple deterministic system that embodies density-dependent rates of survival and recruitment and employs four kinds of data. The first is the size of the spring population of sandhill cranes, estimated from aerial surveys to be between 250,000 and 400,000 birds. The second is the age ratio in fall, used as a measure of productivity; the proportion of young in the fall population averaged 11.3% in 1974-76. Third is the harvest of cranes, estimated from a variety of sources and believed to be about 18,000 birds annually, or about 5 to 6% of the spring population. The fourth is the age ratio of harvested cranes; this ratio is not definitely determined, but immature birds are apparently 2 to 4 times as vulnerable to hunting as adults.

Because sandhill crane population dynamics are poorly understood, it was necessary to try numerous (768 in all) combinations of survival and recruitment functions, and to focus on the relatively few (37) that yielded population sizes and age ratios comparable to those of the real population. Hunting pressure was then applied to those simulated populations. In all instances, hunting resulted in a lower asymptotic crane population with a median decline of 22% (range, 5

to 54%). The results from this model suggest that a hunted sandhill crane population might be about 78% as large as it would be if left unhunted.

**Fall Foods of Migrating Common Snipe in North Dakota.** Fall foods consumed by 68 common snipe during years of different hydrological conditions were investigated. Dipteran larvae (mainly Tipulidae, Chironomidae, and Syrphidae) made up more than 80% of the diet in 1969 and 1970, when semipermanent marshes provided the principal aquatic habitat. In 1977, when abundant precipitation in September filled dry wetland basins, snipe fed mainly on earthworms.

**A Remote-control System for Capturing Nesting Waterfowl.** The capture of breeding waterfowl for research purposes is often a tedious and inefficient operation. Findings of research undertaken in North Dakota during the 1976 field season indicated that many difficult trapping situations are simplified when trap closure is triggered by a radio signal sent from a hand-held transmitter to a receiver attached to the trap. A remote-control system developed for guiding model airplanes was used for this purpose. The principal components of the system are a transmitter, receiver, and servo; power is provided by 1.5-V alkaline batteries.

During a 2-month period, 31 incubating mallard hens were captured with the remote-control system. None were injured. Two hens were missed when the net was accidentally released before the hens returned to their nests, but trapping failures caused by premature departures of hens were eliminated. Hens were captured on the nest at upland sites (7), in nest baskets (17), and over water in natural vegetation (7). Hens at nest sites that were difficult to approach were captured by field personnel operating transmitters from a moving car or boat several hundred meters from the trap site. The unit was successfully test-fired at distances up to 1,700 m, but most trap closures were triggered within 200 m of the nest site.

This system, with minor modification, can be adapted for use with any spring-released or drop-door trap. Although we used the system only for trapping mallards, it is potentially useful for capturing other species.

**Evaluation of Waterfowl Habitat with Satellite Sensors and Computer-aided Analysis Techniques.** Landsat and Skylab multispectral scanner (MSS) data collected between 1972 and 1976 were analyzed with computer-aided analysis techniques to evaluate waterfowl habitat conditions in study

sites in east-central North Dakota. The use of selected data from a single near infrared waveband was determined to be the most practical and easily implemented means of mapping surface water areas. Maps and statistical tabulations of surface water conditions in May and July were produced for each year. Landsat pond counts averaged only about 19% of the counts obtained by Fish and Wildlife Service aerial surveys of the same area, largely because most prairie ponds were smaller than the resolution capability of the Landsat. Landsat estimates were improved by using correction factors derived from a comparison of high-resolution aircraft MSS data with satellite data. The use of certain multispectral analysis techniques also greatly improved pond number estimates. Land-use analysis was achieved with a pattern-recognition processing technique in which seven terrain categories were identified. Analysis of selected areas indicated an overall classification accuracy of about 75%. Results of Skylab and Landsat data analyses were generally comparable. Data from Landsat and other satellite systems offer great potential for monitoring changes in general habitat conditions over large areas.

**Management of Grassland for Upland-nesting Birds.** Abundant residual grassland vegetation offers the most favorable nesting habitat for upland game birds and upland-nesting ducks. More nesting occurs and a greater proportion of the eggs hatch in tall, dense vegetation than in sparser cover. Cover management programs that remove all or part of the vegetation annually adversely affect nesting upland birds.

In the Northern Great Plains of the United States, the goal of grassland habitat management for upland-nesting ducks and upland game birds should be to provide abundant residual vegetation. In most areas, manipulation to disrupt vegetative succession and restore vigor will be needed to maintain prime cover. Periodic treatments by prescribed burning, short-term heavy grazing, or mowing should be carried out whenever needed to restore maximum height and density of residual vegetation. These treatments should be accomplished in as short a time as possible to reduce disruptive effects on nesting birds and other wildlife.

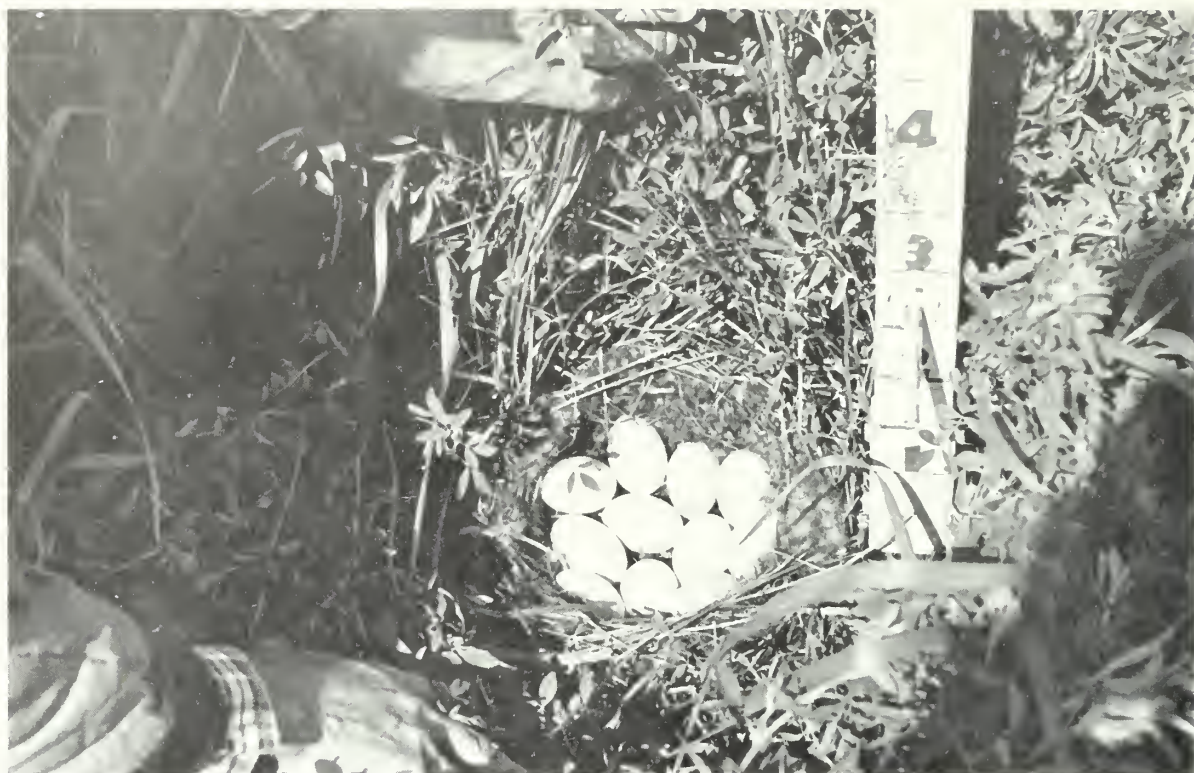
**Evaluation of Waterfowl Habitat by Computer Analysis of Landsat Classified Data.** Maps produced from Landsat data have proved useful as base-line records of prevailing habitat conditions in the Prairie Pothole Region. These classification

maps provide a geographic data base that permits classified terrain features to be combined, mapped, and manipulated in a variety of ways for different management tasks and management decisions. They also permit analysis of spatial relationships among various classes of terrain.

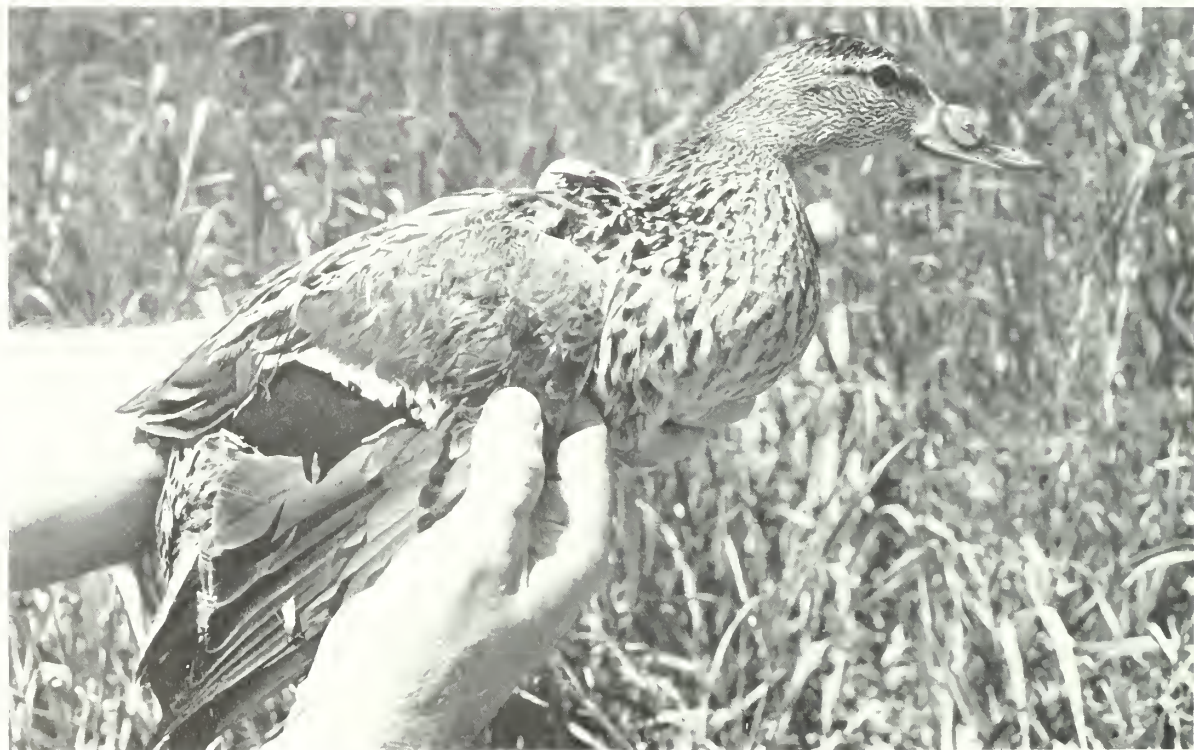
The quality of waterfowl habitat was assessed on a section-by-section basis (the approximate home ranges of several species of waterfowl), and these ratings were then superimposed on a map of the study site to indicate the relative habitat quality of the various areas within the site. Preliminary results suggest that these ratings are valid indicators of good, poor, and intermediate habitat. Such ratings should enable a waterfowl manager to specify those portions of a management district that should be preserved as waterfowl habitat, those that could become good habitat through management action, and areas of such poor quality that disturbing them would have little effect on the waterfowl population. These ratings also provide a useful basis for quantitatively and objectively analyzing the effects of various environmental impacts (e.g., fire, overgrazing, drought, cultivation) by comparing the values before and after the event.

## PATUXENT WILDLIFE RESEARCH CENTER

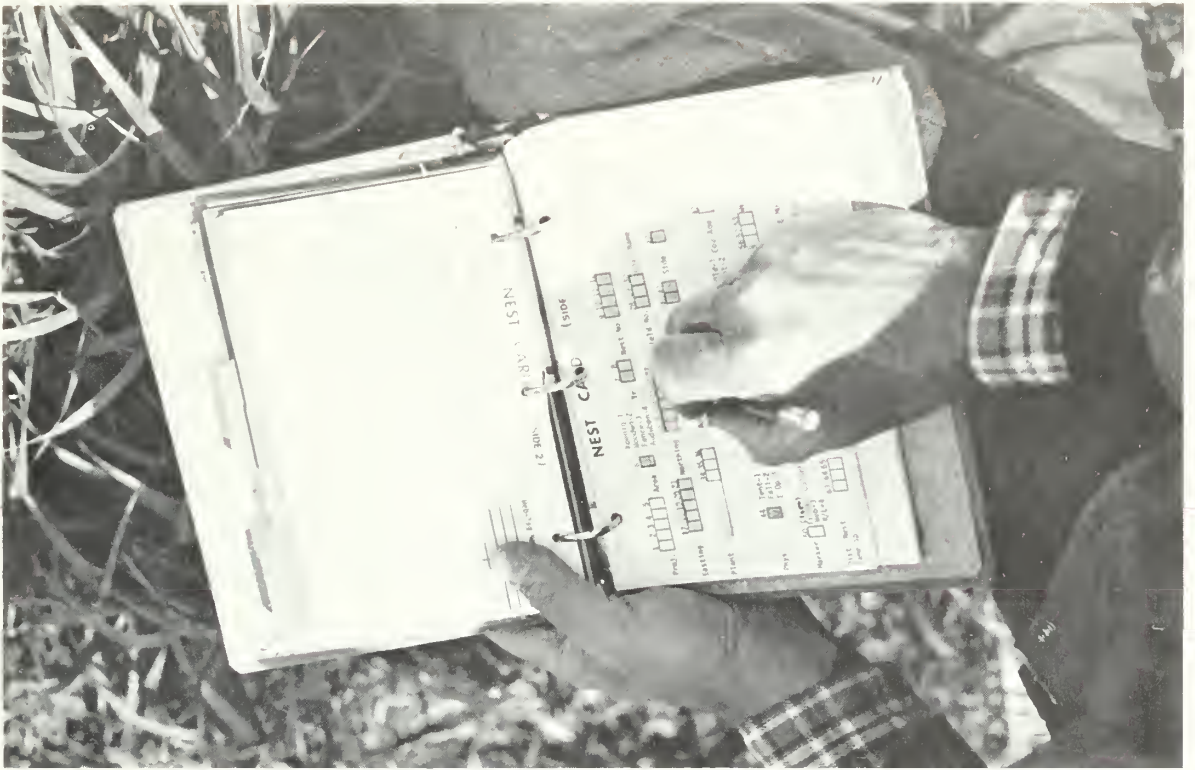
**Urban Wildlife Studies.** A new field procedure for measuring bird habitat was extensively tested in an ongoing effort to achieve a better understanding of the factors that define bird populations in the urban environment. The objective of the study was to find a more efficient method of quantifying habitat characteristics in urban areas and relating these characteristics to bird population density. The new procedure, for example, emphasizes the ratios of the areas of open lawn and pavement to the areas with shrub and tree cover. Such ratios can be more meaningfully correlated with bird populations than can absolute measures of the habitat variables being considered, and habitat data can be collected relatively quickly because private property can be "sampled" without having to obtain the permission of property owners. The species diversity of trees and shrubs and the structure of vegetation are also examined. The habitat characteristics of 79 2-acre study plots distributed in nine residential developments near Washington, D. C., were measured. These char-



Gadwall nest in field of planted nesting cover composed of intermediate wheatgrass and alfalfa. The pole, marked in decimeters, is used to obtain information on height and density of vegetation at nest sites. *Photo by Kenneth F. Higgins.*



Migrational homing, nest site fidelity, and brood movements of mallards in relation to fields of planted nesting cover are being studied by observation of hens marked with colored nasal discs. *Photo by Harold F. Duebbert.*



Research biologists record data on several hundred duck nests each year to obtain information on cover selection, hatching success, and population ecology of upland nesting ducks. *Photo by Kenneth F. Higgins.*



Young short-eared owls on a nest in a field of planted duck nesting cover. Several species of birds other than ducks nest in this type of cover, including American bitterns, marsh hawks, sharp-tailed grouse, and ring-necked pheasants. *Photo by Harold F. Duebbert.*

acteristics are being related to wintering and breeding bird counts that have been conducted in these areas for the past 3 years. The study areas were all located in residential developments that had been built on open farmland; they represent a wide variety of landscaping and lot sizes. The densest bird populations occurred on relatively small lots rather than on large lots in ruralized areas.

In other studies, the most cost-effective materials for use in feeding birds were determined. Preliminary results indicate that seeds of the oil sunflower are superior to those of the striped sunflower, which are commonly used to feed birds. The smaller, darker seeds of the oil sunflower are more attractive to American goldfinches and mourning doves than are the larger striped sunflower seeds. Cardinals showed little preference for sunflower types, but blue jays preferred

striped sunflower seeds. The two sunflower types attracted more birds of a wider variety of species than did the popular, expensive "thistle" seeds, and the oil sunflower was even more effective than thistle in attracting goldfinches, a primary species for which thistle is purchased. Most of the common ingredients in wild bird feed mixes, such as wheat, milo, cracked corn, whole peanuts, peanut hearts, canary seed, rice, and hulled oats, were less attractive to most species of birds than either sunflower or proso millet. This finding suggests that if the sole objective is to attract birds, the mixes could be less complex. People seem to prefer a mix that has a wide variety of ingredients. Therefore, until the public is better informed, inexpensive heavy materials such as wheat and milo will probably continue to be included in mixes, even though they are less attractive to birds than sunflower or proso millet.

## Mammals and Nonmigratory Birds

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### DENVER WILDLIFE RESEARCH CENTER

**Pronghorn Response to Coal Mine Construction.** In spring 1977, construction began on the East Decker mine in Montana, about 20 miles north of Sheridan, Wyoming. Surveys conducted in 1975 and 1976 indicated that this low-lying area on the east shore of the Tongue River Reservoir was important pronghorn habitat. Pronghorns had been frequently observed in the area during spring and summer, and numerous fawns were observed on lands to be mined.

In the winter of 1976-77, the Sheridan Field Station of the Denver Wildlife Research Center continued the study of the importance of the East Decker area to pronghorns. As part of our evaluation of the impacts of coal development on wildlife, we captured and marked 27 pronghorns near the East Decker mine site between January and May 1977. Nine of these pronghorns were fitted with radio transmitters to enable us to relocate them at will. Six more were instrumented during the winter of 1977-78.

Relocation of marked animals verified spring and early summer use of the East Decker area in 1977. However, all marked pronghorns (and presumably all others) left the area by early July, at a time when mine development noticeably intensified. This movement appeared to be an avoidance reaction, and pronghorns were not observed in the area again until March 1, 1978. At that time, an entire herd (some of which were marked) moved from their established winter range 4-6 km southeast of the mine to the area bordering the coal pit. The whole herd spent the entire month of March 1978 very close to the pit.

Why the pronghorns chose to move to the edge of the mine at that particular time remains a mystery, but the reason they stayed was obvious. The winter of 1977-78 in this area was one of the most severe in history. The established winter range of these pronghorns was covered with over 20 inches of hard, crusted snow in early March. In contrast, land adjacent to the mine was nearly free of snow, and vegetation was already greening. Dust raised by mine machinery had settled on the snow, result-





Red-tailed hawk (left) and rough-legged hawk (right), raptors under study in research on effects of surface mining in the western United States. *Photos by Dean E. Biggins.*

ing in increased insulation and hence greater warmth. The pronghorns apparently gave up solitude in favor of more accessible food and a warmer microclimate.

Since spring, pronghorns have remained in the East Decker area. In fact, more pronghorns used the area in summer in 1978 than in 1977, when construction activities were less noticeable. Since our work in nearby areas revealed annual shifts in pronghorn seasonal ranges, their presence near the mine in 1978 may be only a coincidence. The presence of pronghorns near the mine does not imply that mining will benefit them in the long run or that it does them no harm. However, it does indi-

cate that mining will not necessarily cause pronghorns to abandon the area.

The pronghorn's tolerance of mining activities will become important as more mines develop and as the prairies are rebuilt after mining. A favorable outlook for this species, which will have much of its present range disturbed by coal mining, is that pronghorns will probably be available to repopulate reclaimed lands.

**Surface Mining May Threaten Breeding Raptors.** Widespread effects of surface mining on breeding birds of prey are a growing concern of the U.S. Fish and Wildlife Service. Vast deposits of strippable coal underlie suitable nesting habi-



The white-tailed jack rabbit is an inhabitant of sagebrush rangeland. This cover type was sprayed with 2,4-D to increase grassland and water yield. Photo by Max H. Schroeder.

tats for a variety of raptor species in large areas of the western United States. Local populations of uncommon or sensitive birds of prey may be seriously threatened by mining developments and associated disturbances.

To determine the potential magnitude of this problem, we began aerial and ground surveys of nesting raptors in 1978. About 680 square miles of land in Campbell and Sweetwater counties, Wyoming, were surveyed for raptor nest sites and the reproductive status of breeding pairs.

In Sweetwater County, 118 nest sites believed to represent 68 territories of red-tailed hawks, ferruginous hawks, great horned owls, prairie falcons, and golden eagles were examined. Ferruginous hawks were the most common large raptor nesting on mine lands in this county. Impacts on ferruginous hawks nesting on a mine site and surrounding areas were believed to be widespread and severe. Ferruginous hawks, which were nesting on small hills and rocky outcrops, are extremely sus-

ceptible to even subtle disturbances during the early stages of their breeding cycles. At least 11 of 37 territories were occupied by adult ferruginous hawks, but young were produced in only 4. Although mining was not under way at the time of the raptor survey, exploration activities were extensive and undoubtedly adversely affected the nesting success of this raptor.

The nest sites of ferruginous hawks were largely in the open and exposed to disturbance, but the cliff nest sites of eagles, red-tailed hawks, and prairie falcons seemed more secure. Future mining activities will be conducted mostly above and behind the larger cliffs where most of these birds nest, reducing direct impacts on nest sites. However, the effects of habitat alterations and increased development on foraging areas are largely unknown and may prove to be equally important limiting factors for breeding raptor populations.

Raptor nesting habitats in Campbell County, in contrast to most of those in Sweetwater County, were relatively few, exposed, and particularly susceptible to mining disturbances. Only 66 nest sites could be located in an area encompassing some 550 square miles. Other than those of ground-nesting ferruginous hawks, raptor nest sites were restricted to scattered stands of cottonwoods that were found only on intermittent or small perennial streams.

The situation for nesting eagles is especially precarious. Only eight golden eagle nests could be located in the entire survey area, and at least six could be, or already are, seriously threatened by mining developments. From this hasty assessment of conflicts between a population of nesting eagles and industry in Wyoming, the Campbell County situation is viewed as potentially one of the worst examples of mining impact that could exist. The very existence of this small breeding population of eagles on the coal lands of Campbell County is imperiled by expanding developments. It is imperative that this population be preserved as a nucleus of breeders for expansion into habitats created by future reclamation.

**White-tailed Jack Rabbit Numbers Continue Decline on Experimental Area 2 Years After Aerial Application of Herbicide.** Two years after a big sagebrush-covered watershed in south-central Wyoming was sprayed with 2,4-D herbicide to increase herbaceous vegetation and water yield, white-tailed jack rabbit numbers were lower than those on a control watershed. In 1977, 1 year after treatment, eight jack rabbits per mile were

counted on the control area during night surveys from a moving automobile; three rabbits per mile were counted on the sprayed area. In 1978, six jack rabbits per mile were counted on the control site and only two per mile on the treated watershed.

Development of a thick, herbaceous ground cover, which restricted the movements of jack rabbits, and loss of the protective cover afforded by big sagebrush are considered important factors in the decline of jack rabbit numbers on the altered watershed. Measurements of vegetation before treatment showed 8.6% dead sagebrush on the watershed. After treatment, 67% of the sagebrush plants were dead and an additional 15% were nearly dead, having leafy cover on fewer than half of their stems.

During pretreatment years, 1968-75, measurements of vegetative production indicated similarity between watersheds; differences of only 5 to 10 pounds of herbaceous vegetation per acre were recorded. Since treatment, measurements indicate that grass cover on the treated area has increased. Vegetative production on the altered area in 1977 was 3 times as great as on the control area, and when production was compared between watersheds for the 3 years since treatment, total production had doubled. Studies have shown that where growth of grasses and weeds has increased because of greater moisture or reduced grazing, the carrying capacity for black-tailed jack rabbits was lowered. We believe that the white-tailed jack rabbits on the altered watershed in south-central Wyoming were similarly affected.

**Yellowstone Grizzly Bear Study.** The Inter-agency Grizzly Bear Study Team is conducting studies on the population dynamics, behavior, and habitat of grizzly bears within the Yellowstone system. The Team is made up of a representative from each of six agencies: U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. National Park Service, and the Fish and Game Departments of the States of Idaho, Montana, and Wyoming.

One part of the study that is nearing completion is the determination of den requirements and some aspects of denning activities in Yellowstone. Most of the dens examined during the study were located in subalpine fir-whitebark pine habitat types. All dens were on hillsides of various degrees of steepness (range of slope, 20° to 75°). Northern aspects were more often selected for den sites, although all aspects were used. Most bears dug their dens through natural caves, but one bear



The Clark's nutcracker is a resident of subalpine habitats in the Rocky Mountain West. Photo by Max H. Schroeder.

used a hollow tree.

Over a 3-year period (fall 1975 through spring 1978), data were collected on the cold-weather denning of 26 grizzly bears. The amount of time an individual bear spent in its den during the denning season ranged from 81 to 200 days.

**Snags Used by Cavity-nesting Birds in the Subalpine Zone of Colorado.** In 1977 the U.S. Forest Service adopted a snag management policy to provide habitat needed to maintain viable, self-sustaining populations of cavity-nesting and snag-dependent wildlife species on the national forests. Snags serve a variety of purposes in natural timber stands. Many hole-nesting birds and mammals nest in snags, and ospreys generally use snags for nest structures. Snags are favorite perches of band-tailed pigeons and are used by raptors and fly-catching birds for hunting, feeding, and roosting. Red squirrels and some birds store food in snags, and woodpeckers feed on insect larvae in trunks of dead trees. Recent emphasis on the use

of logging slash and standing dead trees for wood fiber could conflict with snag management goals. Since not all snags are suitable for both wildlife nesting sites and wood fiber, some trade-offs should be possible. However, if forest managers are to develop beneficial snag-management programs, they must acquire much additional information on snag use in relation to timber types.

To gain some insight into the characteristics of snags used in the subalpine zone, we surveyed 1,722 lodgepole pine, subalpine fir, and Englemann spruce snags for evidence of use by cavity-nesting birds. Snags of all three species of trees were used by cavity nesters. The factors evaluated included snag height, tree diameter, bark cover, top condition, slope, and aspect. Most snags used by cavity-nesting birds were more than 8 inches in diameter (at breast height) and had broken tops. None of the other characteristics examined seemed to be important in nest site selection.

Ten nest holes were in live trees and all but one were in dead tops or in scars. One nest was in the live wood of a broken-top lodgepole pine tree.

In the subalpine zone, about one snag per acre showed evidence of use by cavity-nesting birds. Snags are subject to windfall, and it is recommended that all broken-top snags and broken-top live trees over 8 inches in diameter be left uncut during timber harvest to provide present and future homes for wildlife dependent on snags.

**Nongame Animals Counted on Sheldon National Wildlife Refuge, Nevada.** Sampling was conducted on six ecological sites in Sheldon National Wildlife Refuge, northeastern Nevada, in summer 1978, to identify nongame bird and mammal species, estimate their relative abundance, and develop base-line population records. Base-line information will help managers to interpret and predict the changes in diversity and numbers of nongame species resulting from specific management activities.

Passerine birds were counted, either by sight or by sound, along paired transect lines 1 km long in each habitat type. Surveys for small birds were started in early May, conducted in early morning on each of 3 consecutive days, and repeated in four separate survey periods ending July 15. Diversity of species and relative occurrence of each species in each vegetation type were determined. Small mammals were caught by snap traps placed at 15-m intervals along 20 paired 285-m transect lines in each habitat on 3 consecutive days in August.

Results showed that 71 species of birds used the sampled areas during the breeding period. Areas having greatest diversity of habitat (mixed trees and shrubs or water) were richer in numbers of species than those that tended to have monotypic stands of vegetation. Sites having the most bird species were curleaf mountainmahogany (39), meadow (37), and juniper (31). The next most prolific were black greasewood (26), big sagebrush (19), and low sagebrush (10). Ranking of sites by density of birds differed. Low sagebrush habitat had the greatest bird density (2.27 birds per hectare), followed by meadow (2.04), big sagebrush (1.86), black greasewood (1.73), curleaf mountainmahogany (1.69), and juniper (1.62).

Diversity of species of small mammals important to avian and mammalian predators was greatest in black greasewood (six species) and lowest in low sagebrush (two). Numbers caught by snap traps showed that deer mice were relatively abundant and common to all habitats. Populations of deer mice ranged from two to five per hectare except in black greasewood and juniper, where the estimate was one. Total numbers of mice of all species was largest in curleaf mountainmahogany and smallest in black greasewood.

Other species of mammals caught were few and population estimates were low. Numbers captured, by habitat, included the pinyon mouse in juniper (1), the northern grasshopper mouse in meadow (1), and the desert woodrat in black greasewood (5). The sagebrush vole, the only microtine captured, was caught in low sagebrush (1), big sagebrush (2), and juniper (1). Great Basin pocket mice were taken in black greasewood (2), big sagebrush (1), curleaf mountainmahogany (10), and juniper (2). Ord's kangaroo rats were caught in meadow (6) and dark kangaroo mice in black greasewood (2).

Sciurids captured were least chipmunks (27), taken in all habitats except low sagebrush; white-tailed antelope ground squirrels (3), caught only in black greasewood; and Belding's ground squirrel (1), taken in meadow.

**Research on Moose Carrying Capacity in Alaska.** A cooperative research project to determine the capacity of the Kenai National Moose Range to support moose is being conducted by the Center, the Alaska Department of Fish and Game, and the Kenai National Moose Range. This ambitious research effort has two phases: (1) to measure the amount and quality of moose forage on the Range, and (2) to determine the requirements



Tame moose calf used in carrying capacity research on the Kenai National Moose Range in Alaska. *Photo by Mary Ford.*

of moose for various nutrients. These data will be incorporated into a mathematical model to help Range personnel to determine the optimum population of moose that the Range can support without deleterious effects on the habitat.

The vegetation on the 1.7-million-acre Kenai Range is being categorized into several types by analysis of aerial photographs. The amount of moose forage produced in each vegetation type is determined by clipping and weighing the vegetation on representative sample plots. Tame moose now being raised and trained for use as experimental animals for determination of their requirements for energy and essential nutrients will be subject to various testing procedures.

#### **NATIONAL FISH AND WILDLIFE LABORATORY**

**Biological Surveys in Baja California and Contiguous Areas.** Baja California, including the Sea

of Cortez and associated islands, is probably unique among the biotic provinces of North America. The impact on the area's biotic integrity that is created by establishment of highways, development of tourism and recreational facilities, exploration and exploitation of natural resources, and development of ancillary facilities is of mutual concern to the governments of Mexico and the United States. Additional concerns relate to agricultural development, potential energy development, and the introduction of exotic species. Protection of natural areas, threatened and endangered environments, and habitats of migratory species, of fragile mountain, desert, and seashore areas, and of sites of national and international archeological and historic significance is involved. Because U.S. citizens will play a leading role in total environment of the area, the U.S. Fish and Wildlife Service has grave responsibilities in this area.

In recognition of these responsibilities the National Fish and Wildlife Laboratory, in cooperation with personnel of the Dirección General de la

Fauna Silvestre, has conducted biological surveys on Isla Tiburon in the Sea of Cortez, and in the Cape Region of Baja California Sur. Preliminary efforts have focused on the composition of the herptiles, birds, and mammals and on a basic inventory of the associated plant communities. The results for mammals are typical of this ongoing effort.

Tiburon, the largest island in the Sea of Cortez, also possesses the largest mammalian fauna of any of the islands—20 species, 14 of them terrestrial. In contrast, the adjacent Sonoran mainland has about 40 species of terrestrial mammals. The island mammals all show closest affinity to species on the Sonoran side of the Sea of Cortez. About half of the mammals on Tiburon represent endemic subspecies of mammals found on the mainland. The remainder are either identical to mainland species or are unstudied; taxonomic studies under way will elucidate their status. In general, the mammalian fauna appears healthy and shows few effects of man's limited presence, thus reflecting the generally pristine nature of the island itself.

Conversely, the Cape Region of Baja California Sur is subjected to increasing human pressure now that the peninsular highway is complete. Studies here have focused on the status of vertebrates endemic to this unique area. A faunal inventory of the Sierra Laguna was started in November and December 1977 to obtain data for comparison with earlier studies.

**Fossil Bat Remains Suggest Climatic Changes.** Fossil bat remains uncovered more than 50 years ago have recently been identified as the California big-eared bat by scientists from the Laboratory and the Smithsonian Institution. The fossils were recovered from an abandoned cinnabar mine near Terlingua, Brewster County, in the Big Bend region of western Texas. This find is the only fossil record for the species, and it lies in a geographically interesting position, about 450 km from the closest modern sites on record, in southwestern Chihuahua, Mexico.

Recent taxonomic studies of California big-eared bats revealed the existence of two closely related species that look very much alike externally. With the use of correctly identified reference samples of the two species, the fossils were assigned to the species *Macrotus californicus* by a multivariate statistical computer program.

The occurrence of the California big-eared bat in the Big Bend region some 10,000-15,000 years

ago supports the hypothesis that the area was once warmer and more humid than it is today. It now seems likely that this bat was once distributed all across the Mexican Plateau to a line somewhat north of the present United States-Mexico border. The present distribution of this species in the United States is limited to the warmer parts of California and Arizona.

**Off-road Vehicles Affect Wildlife.** Extensive use of the California desert by off-road vehicles (ORV) is detrimentally affecting wildlife and their habitat. Research results from creosote shrub flatlands in the Mojave Desert clearly demonstrated that ORV's severely damaged the vegetation. ORV activities also significantly decreased the abundance of terrestrial vertebrates and birds. The abundance and species diversity of the desert wildlife was inversely related to the level of ORV usage—there were few animals in areas of intense ORV activities. Wildlife in ORV staging areas was diminished by as much as 80% on the basis of wildlife abundance in undisturbed desert, and areas used heavily by ORV's had losses of 65%. Because creosote shrubs are slow-growing perennials (some shrubs may be hundreds of years old), the impact of ORV's is long-lasting. Certain wildlife species have low recruitment levels and late maturation; for example, the desert tortoise has highly vulnerable young and does not reach sexual maturity until about 10-15 years of age. Thus, recovery of the desert biota from ORV disruptions may require decades. This estimate of recovery time is only conjectural, however, because ORV activities are intensifying in scope and habitat degradation is continuing at an accelerating rate.

Recently, we examined the Imperial Sand Dunes of southeastern California and found significant decreases in vegetation and wildlife in areas used by ORV's. The abundance of plants in undisturbed dunes was about 25 times greater than that in ORV areas. We found an average of 37 small vertebrates (15 lizards, 22 mammals) per hectare in undisturbed sites but only about 13 (2 lizards, 11 mammals) per hectare in the ORV areas. Several plants and animals that are restricted to dune habitat were especially sensitive to ORV activities. The integrity and survival of these unique dune communities are jeopardized by intensive ORV activity.

The present data indicate that continued ORV activity will be increasingly detrimental to the wildlife resources of arid lands. The need to determine ways to minimize the impact of ORV's on

desert ecosystems is urgent.

**Grazing Adversely Affects Wildlife of the Kofa National Game Range.** A study was initiated to assess the effects of cattle grazing on habitats and populations of wildlife in the Kofa National Game Range, Arizona. The grazing areas are generally Sonoran desert arroyos and washes in an area receiving an average of about 4 inches of rain annually. Amphibians, reptiles, and mammals were collected by hand or by trapping, birds were visually censused, and vegetation was measured in various ways.

Results of the study show that grazing dramatically changes the composition of the vegetation. The most noticeable difference between grazed and ungrazed plots was the relative density of the vegetative cover of jojoba and the sizes of its seed crops. This species is heavily browsed by livestock and its fruits are important food for deer and rodents. On the grazed plots, the relative coverage of jojoba was 1.5% and each plant produced an average of 75 fruits; in the ungrazed areas, coverage was 15% and the average crop was 766 fruits.

The density and composition of rodent populations differed in grazed and ungrazed habitats. The distribution of pocket mice is highly correlated with healthy jojoba bushes. These mice were present in the ungrazed areas but only one was taken in the grazed plots. Other rodent species that attain highest population densities in the thick vegetation found most commonly in ungrazed arroyos are the cactus mouse, white-throated woodrat, and Harris' antelope squirrel.

At Kofa, unprecedented winter rains had produced an unusually lush growth of vegetation. Censuses of birds conducted in early April revealed large numbers of Gambel's white-crowned sparrows (winterers) and phainopeplas (breeders). Mockingbirds and blue-gray gnatcatchers were also breeding in unusual densities because of the luxuriant vegetation. Differences in species composition and abundance in grazed versus ungrazed habitats showed that crissal thrasher and brown towhee populations were adversely affected by cattle browsing jojoba thickets.

**Forestry Management and Nongame Wildlife.** Studies of nongame vertebrate populations under differing regimes of forestry management in the St. Marks National Wildlife Refuge, Florida, indicate that populations of many amphibians, reptiles, and small mammals vary among treatment areas in a typical natural-succession fashion. Early successional stages of sand pine scrub and longleaf

pine sandhill habitats may be important for the success of certain species, including several that are largely restricted to these habitat types. Studies of community succession in these habitats are continuing.

Surveys of nongame birds, initiated at the St. Marks National Wildlife Refuge, included a census of winter birds conducted in late January and early February. Habitats to be censused were purposely selected to maximize the relevance of the data to the evaluation of habitat management practices. Where possible, recently burned areas were paired with comparable unburned sites, and stands of pine monocultures were compared at various natural (except for prescribed quadrennial burns) successional stages. The census technique was a modified Emlen line transect. Of nine habitats censused, the mixed 70- to 80-year-old longleaf pine-wiregrass association was found to have the largest number of bird species and the highest density of individuals. A recently clear-cut and burned habitat had the smallest number of species and the lowest density of individuals.

**Manatee Research.** West Indian manatees return annually to the headwaters of Crystal River, which is about 120 km north of Tampa, Florida. The river empties into the Gulf of Mexico, 8 km from its source in Kings Bay. The "main" spring, at the southern terminus of the Bay, is the focus of manatee congregations during the cold winter months. The status of manatees at Crystal River has been monitored since 1974. Aerial and surface surveys, conducted weekly during 1977-78, were supplemented by several hours of underwater observation.

The arrival of manatees in Crystal River was correlated with lowered air and water temperatures along the coast of the Gulf of Mexico in the fall. The number of manatees counted in Crystal River increased (maximum, 72) as the season progressed, stabilizing near mid-January. The sex ratio of identified animals was about 1:1, and calves composed 12.5% of the identified manatees. The manatees left Crystal River in late March 1978 and were seen only occasionally in the area during the summer.

Individual manatees have been observed using Crystal River for several consecutive winters. Twenty-one of the manatees observed during the winter of 1977-78 were identified from the previous year, and 6 of these 21 were known from the 1973-74 winter.

In late June 1978, a 9-day survey was conducted

in Puerto Rico that included aerial censuses and interviews with fishermen. During a 2-day flight along the coastline, from San Juan on the north coast clockwise to Rio Guajataca on the northwest coast, 38 manatees were sighted. The average size of groups was 2.2 animals, with a range of 1 to 6. Three main areas of manatee concentration were identified: the northeast coast, the east coast around Roosevelt Roads Naval Station, and the south coast around Bahía de Jobos. The count from this aerial census was nearly twice as great as any previous count and indicates that there may be 40 to 65 manatees in Puerto Rican waters.

Visits to fishing villages along the coast confirmed the aerial census data on the distribution of manatees around Puerto Rico. Interviews also indicated that manatees are sometimes entangled and drowned in fishermen's nets. However, the absence of scars on manatees, noted during the aerial survey, suggests that boat collisions are not as serious a problem for manatees in Puerto Rico as they are in Florida.

**Pacific Walrus Research.** Recent studies have shown that walrus population estimates based on aerial survey data are unacceptably inexact. The data indicate that variation over time in the proportion of the population hauled out is an important source of bias and imprecision in abundance estimates.

In 1976, the Laboratory and the Alaska Department of Fish and Game began a cooperative study of walrus at Round Island in Bristol Bay. Large numbers of male walrus occupy Round Island from spring to late fall, apparently in response to the absence of pack ice in northern Bristol Bay. It is the only location in North America where large numbers of walrus predictably haul out on land. Research objectives of the program were (1) to develop a reliable technique for marking or tagging walrus and (2) to determine the ecological and behavioral mechanisms of formation, maintenance, and dispersal of groups of walrus on land.

A number of paints, dyes, and tags have been tested. Several of these are recognizable for short periods after application; however, the maximum duration between application and the last sighting of a tagged or marked animal was about 6 weeks. Furthermore, because walrus congregate in large groups, tagged or marked individuals often could not be identified. In 1978 a radiotelemetry system was developed in which a small transmitter was affixed to the animal's tusk. All of the instru-

mented animals were sighted again at various intervals for about 3 months, after which the batteries ran down.

The number of walrus hauled out on the beaches at Round Island cycles over a 10-day period from several hundred to as many as 15,000. These cycles appear to be intrinsically controlled. They are not correlated with any obvious environmental character, and although disturbances such as human activity or heavy seas may temporarily drive the animals into the water, they do not affect the overall pattern of the cycle.

After the low period in a cycle, walrus return to one of several "preferred" beaches. As the numbers increase, individuals disperse to peripheral beaches only after available space on a preferred beach has been entirely occupied. Competition, by means of agonistic interactions, appears to be the principal factor in determining the size of walrus concentrations on the various beaches during increase phases of the cycle. Groups on the preferred beaches consist mainly of large animals with large tusks; peripheral beaches have a higher proportion of small animals. The peak of the cycle usually lasts about a day; dispersal to the sea then occurs haphazardly by spontaneous stampeding of all or most of the animals on a particular beach. Preliminary results of the telemetry study indicate that individual walrus



Florida black bear in the Osceola National Forest. Radiotelemetry studies conducted by the Laboratory's Gainesville Field Station help to delineate the habitat use patterns of black bears in northern Florida. *Photo by C. R. Smith.*



remain at Round Island only briefly (several days at most) during any cycle and that there is a continuous and high turnover of individuals.

**Annotated Bibliography of the Ecology of Galveston Bay, Texas.** The Laboratory has recently completed a bibliography of over 1,600 references dealing with the fish and wildlife resources and environmental features of the area surrounding Galveston Bay. Soon to be released by the Office of Biological Services, the bibliography includes a taxonomic index, author index, and subject index, as well as abstracts for about 90% of the citations.

**Phosphate Strip Mining in the Osceola National Forest.** A study on the anticipated effects of phosphate mining on endangered species in northern Florida's Osceola National Forest was completed and released in 1978. Although strip mining results in extensive environmental degradation, the

long-term effects may be less disastrous than first impressions suggest. The report concluded that most wildlife will be destroyed during actual mining operations but that reclamation and eventual revegetation, coupled with the creation of wetlands (a typical result of phosphate mining in Florida), may lead to improved wildlife habitat for those species capable of colonizing new habitats. Among federally listed endangered and threatened species indigenous to northern Florida, the bald eagle and the American alligator will in the long term be benefited (or at least be unaffected) by strip mining and the associated reclamation. On the other hand, 10 to 20 red-cockaded woodpeckers (whose habitat requirements include mature pine trees) will be eliminated. Impacts on the only other federally listed species (gray bat and eastern indigo snake) are undetermined.

## Cooperative Research Unit Program

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### COOPERATIVE RESEARCH UNIT PROGRAM

The Cooperative Research Unit Program is supported by the U.S. Fish and Wildlife Service and by the game and fish agency and land grant university in the State where each Unit is located. The Wildlife Management Institute is an additional co-operator for Wildlife Units. The Program began with the activation of the Iowa Cooperative Wildlife Research Unit in September 1935. The first Fishery Unit was activated in 1962 at Utah State University. In 1973 the two Unit programs were merged into one, administered by the Division of Cooperative Research. Twenty-five Fishery Units and 20 Wildlife Units are currently in operation. During fiscal year 1978, negotiations were initiated and funding was allocated to establish two new combined wildlife-fishery Units in Mississippi and Florida.

The objectives of the Cooperative Research Units are fish and wildlife research, training at the graduate level, and extension service. Unit direction is provided by a Coordinating Committee

composed of representatives from each cooperating agency. The Committee provides counsel and plans the long-term program to serve the mutual needs of the cooperators. Day-to-day operation is the responsibility of the Unit Leaders and the Assistant Unit Leaders, who are employees of the U.S. Fish and Wildlife Service. The Units are headquartered on the campuses of the cooperating universities, which provide expertise in related scientific fields; office, laboratory, and storage space; secretarial services; and utilities. All cooperators contribute funds and equipment to the Units, and additional research funds are obtained from various sources as grants and contracts. The Leaders and Assistant Leaders are granted full faculty status by the cooperating universities and thus they are qualified to advise and direct graduate students and to teach formal courses. In the field of extension service, Unit personnel organize and participate in workshops and training meetings and provide technical fish and wildlife expertise as needed. Each year, Unit personnel publish many technical and general papers on fish, wildlife, and related subjects.

During fiscal year 1978, personnel of the Fish and Wildlife Units conducted 446 research projects; 176 graduate professionals completed training through the Unit Program and 90% are employed in Federal, State, or private conservation agencies, or are continuing their education. In addition, 19 short-courses and workshops were conducted in fiscal year 1978 for the continued retraining of State and Federal biologists. One hundred forty-one seminars were provided for conservation education of the general public.

	Fishery		Wildlife	
	M.S.	Ph.D.	M.S.	Ph.D.
Students on program	246	46	240	59
Degrees granted	75	13	76	12
Employment <sup>1</sup>				
Fish and wildlife biology	59	12	56	10
Other biology	0	0	4	0
Education continued	11	4	6	2
Peace Corps	0	0	1	0
Miscellaneous and unemployed	5	0	9	2

<sup>1</sup>Includes students who accepted employment before completing all degree requirements.

## COOPERATIVE FISHERY RESEARCH UNITS

**Alabama.** The capacity to control the reproduction of fishes is limited. Manipulation of environmental factors such as light and temperature are used to effect off-season gonadal development, and spawning may be induced by injection of various gonadotropic substances. But because the need has increased for a more continuous supply of young fish for bioassay or for commercial purposes, alternate means of reproductive control are desirable.

The human fertility drug clomiphene citrate was considered as a promising means of control because it is orally active and can thus be administered with food. Long-term exposure might control seasonal gonadal development, and spawning might be controlled by adjustments in the terminal delivery rate, all without handling and stressing the fish. The channel catfish was selected as a test species, and experiments were designed to measure the effect on gonads of several dosage levels in various seasons.

Clomiphene citrate did not advance gonadal development in adult catfish during any season; it did not accelerate gonadal development imme-

diately before the normal spawning period, either when orally administered or when injected. Neither ovulation nor spawning was increased in aquaria over that in control fish.

Although encouraging responses to clomiphene citrate as a terminal ovulatory agent have been reported for other fish species, we found no positive results with channel catfish at the levels of administration used in our experiments.

**Arizona.** The feeding of brown trout and Arizona trout (*Salmo apache*) was studied at various light levels. Brown trout fed on brine shrimp in the equivalent of starlight, but Arizona trout required light equal to or exceeding that of moonlight. Brown trout (presumably using chemosenses) fed more effectively than Arizona trout in total darkness. The greater visual and possibly chemosensory capabilities of brown trout would enable them to feed later in the evening and earlier in the morning than Arizona trout.

In high light, brown trout appeared more inhibited from feeding, and used cover to a much greater degree, than did Arizona trout, suggesting that Arizona trout are the more active daytime feeders. Stomach analyses and catch rates by fly-fishing supported this suggestion. Although these differences suggest the partitioning of food and habitat between brown trout and Arizona trout, the partitioning is insufficient for the coexistence of these two species in many areas.

**California.** Research emphasized the ecology of northern coastal streams and reservoirs, and estuarine and coastal marine biology. Northern California streams are located largely in redwood forests which are in various stages of timber harvest and management; most of the streams are important salmonid producers. Humboldt Bay, the most important aquatic habitat in the immediate area, is relatively undeveloped and is an important spawning and rearing area for many species of marine fishes.

The relative abundance and spatial distribution of zooplankton in Clair Engle Reservoir and its association with environmental variables were studied for 1 year at seven monitoring stations. Zooplankton abundance and distribution varied significantly by season and reservoir area. Cladocerans accounted for 93% of the year's catch, and copepods for 6%. Zooplankton densities were generally higher at shallow littoral stations than at deep open-water stations. Water temperature, station depth, reservoir discharge, and conductivity were considered the most important variables re-



Youth Conservation Corps enrollees excavating fish trap construction site for California Cooperative Fishery Research Unit. Photo by Roger A. Barnhart.

lated to zooplankton abundance.

The biology of the redbtail surfperch, the most important of the surfperches harvested commercially along the northern California coast, was studied to provide life history information to the State fishery management agency and sport and commercial fishermen. Age-growth relationships, reproductive biology, and food of the species in Humboldt Bay, river estuaries, and the surf zone were determined. Female redbtail surfperch did not mature until age IV and averaged 14 embryos per ovary. Females were much more numerous than males in Humboldt Bay and river estuaries, whereas the sex ratio of fish in the surf zone was 1:1, indicating a separate distribution by sex among maturing fish. From gonad examination and redbtail surfperch distribution, it appears that mating takes place near the surf zone during November and December and that gravid females enter estuaries and Humboldt Bay to give birth in the spring and early summer. The diet of surfperch consisted of decapods, amphipods, mollusks, polychaetes, isopods, cirripedia, and bryozoans (in decreasing order of importance).

**Colorado.** The base of the fish food chain, photosynthesis by aquatic plants, in Pyramid Lake, Nevada, has been measured for 2 years to enable us to estimate the potential yield of fish under various proposed management strategies. Because of low angling pressure in this 172-square-mile water, the actual harvest is probably only a small part of the potential harvest. Pyramid Lake is of particular interest to the Fish and Wildlife Service because of the presence of the rela-

tively rare Lahontan cutthroat trout and the endangered cui-ui (a sucker). The cui-ui has special cultural significance to the Pyramid Lake Paiute Indian Tribe, which owns the entire lake and its immediate watershed. The Lahontan cutthroat trout is the basis for a sport fishery of financial importance to the tribe.

Previously reported work by the Unit has demonstrated a promising relation between aquatic photosynthesis and harvests of fish in ponds and small lakes. However, this work also suggested that differences in food preferences of different kinds of fish was one of the chief elements in reducing the harvest prediction value of aquatic photosynthesis measurements. Fish that accepted a wide range of vegetable and animal food appeared to produce much greater harvests for a given rate of photosynthesis than did fish that ate only animal foods. Although this difference in production has long been accepted, no experimental evidence existed to confirm the relation. Recently completed controlled experiments by the Unit have demonstrated that carp fingerlings produced crops 3 to 4 times greater than those produced by smallmouth bass fingerlings and young adult pumpkinseeds, at equal rates of aquatic photosynthesis. Thus the use of aquatic photosynthesis as an estimator of potential fish production must be qualified, according to the kinds of fish desired.

**Georgia.** The shortnose sturgeon is listed as endangered throughout its range, which extends from New Brunswick, Canada, to Florida. Efforts to promote recovery of the species are hampered by lack of knowledge about its abundance, distribution, and biology. Recent collections along the eastern seaboard of the United States suggest that this species is more abundant than previously believed. Sturgeons from southern populations appear to grow faster and mature at a younger age than do those from more northern populations. Preliminary catch and radio-tracking data indicate that in the Altamaha River, Georgia, shortnose sturgeons tend to remain near the mouth of the river from late spring until early winter; they then move upstream to spawn.

An extensive die-off of trout at a hatchery recently constructed on the Chattahoochee River prompted the initiation of a study of the movements of fishes in relation to seasonal changes in selected water quality characteristics in the tailrace of Buford Dam. From August through December 1977, over 5,000 rainbow trout, brook trout,

brown trout, and yellow perch were tagged with color-coded numbered tags. Fish were sampled every 2 weeks at each of four sampling stations. Of the fish recaptured, 92% were taken at the station at which they were tagged. Trout were most abundant just below the dam when dissolved oxygen concentrations were lowest (less than 2.0 ppm). There were no obvious correlations of abundance or movements with metal concentrations, pH, conductivity, or water temperature. The examination of gills by scanning electron microscopy shows promise as a method for early detection of stress in fishes.



Radio transmitters are used to study movements of the shortnose sturgeon, an endangered species, in the Altamaha River, Georgia. Photo by R. J. Gilbert.

**Hawaii.** Streams in Hawaii have been subjected to water diversion, introductions of exotic fishes, and several forms of channelization, including realignment, clearing of riparian vegetation, and construction of artificial bank and bed structures. The Unit performed a 3-year study, completed in 1978, to inventory and characterize channelization statewide and determine its effects on the environment and natural communities.

Channel modification was correlated with increases in physicochemical variability and reductions in numbers of several endemic gobiid fishes. Communities in channelized areas were dominated by introduced species of poeciliids and *Sarotherodon* [= *Tilapia*]. The diadromous migratory behavior of the native fauna prevents the isolation of any species from the effects of channelization on water quality. Native species were reduced or

absent in heavily channelized streams.

Daytime values of conductivity, pH, and dissolved oxygen were considerably higher in altered streams than in unaltered streams. We monitored temperature weekly at 20 stations for 1 year to assess the relative effects of different channel types on thermal fluctuations. Diurnal peak water temperatures were higher at stations downstream from channel modifications than at stations upstream and in unaltered stream stations. Temperature extremes of 36.2° and 17.8° C were recorded at the downstream end of a concrete-lined channel. Diel changes in temperature of 12° C were not uncommon at this site. High illumination due to clearing of the vegetative canopy, and shallowness of the water in lined channels, appeared to be responsible for the excessive heating.

Tolerances of native species and key exotics to elevated temperatures were determined by using a gradual heating method designed to simulate in situ diurnal heating. Growth of post-larval migrating forms of several gobiids was measured after 1-month exposures to different fluctuating thermal regimes. Upper lethal temperatures correlated with altitudinal distributions of adult fishes and crustaceans. Lethal limits of the species absent or rare in altered streams fell within the range of temperatures recorded in such degraded habitats. Dominant introduced fishes showed greater resistance to high temperatures than did native animals. Maximum growth rates occurred in streams with fluctuating temperatures whose diel maxima were 7 to 8 Celsius degrees below upper lethal limits. The study led to recommendations for mitigation of the effects of channelization.

**Idaho.** Salmonid ecology and management continues to be a major area of research of the Idaho Unit. To assess the impact of fish predators on early mortality of salmonid fishes, we recently evaluated data collected in 1975-76 on survival, density, and behavior of cutthroat and steelhead trout fry and chinook salmon fingerlings in two streams and in laboratory channels, with and without predators.

In 1975, cutthroat trout fry that we released into a fertile stream were preyed upon primarily by rainbow trout, brook trout, and sculpins; however, fry made up less than 4% of the stomach contents by volume of all fish sampled. By the end of the summer, only 7.3% of the fry survived.

In 1976, predacious fish were removed from about 30% of the test stream before steelhead fry were released. Most fry remained in the section



Crew electrofishing on Big Springs Creek, Idaho, removing fish predators in a study to assess their impact on early mortality of salmonids. *Photo by Theodore C. Bjornn.*

without predators throughout the summer. Fry occupied more diverse habitat and had different feeding habits in the absence of predators. Fry made up 28% of the stomach contents of predators that reinvaded the section from which predators had been removed. Steelhead fry survival was 25%, compared with an average of 11% in previous years.

Density of cutthroat trout fry released into pools of an infertile stream in 1975 decreased to 1% of the stocking density within 2 weeks. Predation by Dolly Varden may have been a major factor in decreasing fry densities. In 1976, chinook salmon fingerlings and steelhead and cutthroat trout fry were released into sections of this test stream with and without predators. Densities remained higher in sections without predators and all prey species occupied more diverse habitat.

In laboratory stream channels, predators reduced the density of chinook salmon fry more than that of cutthroat trout fry. Dolly Varden and brook trout were more active predators than cutthroat and rainbow trout. Fry used less habitat and feeding was more inhibited in the presence of predators. In other tests, predators reduced the densities of cutthroat trout fry more than those of steelhead fry; the Dolly Varden was the most active predator.

**Iowa.** In the intensive agricultural areas of the United States, pesticide contamination of non-target organisms continues to be a problem. Most concern in Iowa during the past 3 or 4 years has centered on dieldrin residues in fish from four

reservoirs constructed by the U.S. Army Corps of Engineers. Current research on one of these—Saylorville Reservoir, which was impounded in 1977 on the Des Moines River, downstream from a long-term pesticide monitoring site—is directed toward better understanding the movement of pesticides through the reservoir. Pesticides in water, suspended sediments, bottom muds, and fish are monitored regularly above, in, and below the reservoir to determine how water-level fluctuations and impoundment affect concentrations of pesticides in fish flesh.

Concentrations of dieldrin, the only chlorinated hydrocarbon insecticide detected in river water, never exceeded 18 parts per trillion in 1977 or 1978. Herbicides were present in higher concentrations. Atrazine reached 1.36 parts per billion in water samples collected in spring 1978. One sample of large crappies collected below Saylorville Dam in April 1978 contained dieldrin in excess of the U.S. Food and Drug Administration allowable level (300 parts per billion) in fish used for human consumption. All other fish samples contained relatively low concentrations of chlorinated hydrocarbon insecticides. Channel catfish consistently contained greater concentrations of dieldrin than did carp, and carp contained greater concentrations than did white crappies. In most fish species dieldrin concentration was a function of how far downstream the fish were collected, rather than their presence in or outside the reservoir. The farther downstream the collection site (and thus the larger the watershed above it), the



Notches have been cut in rock dikes along the Missouri River to increase diversity of fish habitat and connect backwater areas to the main river channel. Researchers at Iowa Cooperative Fishery Research Unit are conducting a study to determine benefits to the fishery from notch construction. *Photo by Ross V. Bulkley.*



Separating larval fishes to compare their abundance and diets in backwater lakes connected by notched dikes with fishes from lakes isolated from the Missouri River. *Photo by Ross V. Bulkley.*

greater the dieldrin concentration in fish.

**Louisiana.** An intensive limnological survey of Baton Rouge City-Parish lakes was begun to gain insight into the underlying causes of recurring fish kills. We found that nearly the entire water column was in the photic zone and that circulation occurred almost nightly; thus the sediments supplied a virtually constant nutrient source to support the enormous primary production. However, nitrate nitrogen was often limiting during extended periods of dry weather, when blue-green algae predominated in the phytoplankton. The survey was funded by the City-Parish government and the information became part of a successful application to the U.S. Environmental Protection Agency for matching funds to restore the lakes. The work is scheduled to begin in 1979.

The young of most important sport and commercial fishes of the Gulf of Mexico use the coastal marshes as nurseries. A survey is under way to determine how far inland these young fish move in the Barataria Basin drainage. Samples are being taken along a 40-mile north-south transect with trawls, a high-speed sampler, and a plankton net. The young of "saltwater" species have been captured in completely fresh water more than 50 miles from the Gulf. Thus, human degradation of the environment, even this far inland, may directly affect saltwater fish populations.

**Maine.** Hydrographic monitoring of water quality in the Penobscot River (a model river for Atlantic salmon restoration) that began in 1963 has been completed. During this time water quality has gradually improved, and the low dissolved oxygen concentrations that once blocked salmon migration no longer exist. This research

showed that the pollution abatement program resulted in a dramatic improvement of the habitat. In a related study, zooplankton populations in the Penobscot River estuary displayed zonation from fresh to salt water, and abundance was not related to the concentrations of wood fibers originating from pulp mills. Other contaminants of aquatic environments were also found to be benign. Operational spraying of forests with acephate had little effect on the ecology of small streams, whereas carbaryl killed some aquatic insects (stoneflies) and temporarily affected the physiology of fish. One result of spraying was that brook trout were gorged with terrestrial arthropods. Further study showed that spiders were killed by both acephate and carbaryl, suggesting that the spraying of a forest to kill insect pests may also kill predators that would normally help keep the insects in check.

Hatchery procedures for raising Atlantic salmon at Craig Brook National Fish Hatchery (Maine) were compared (on the basis of later returns of adults to the Penobscot River) to attempt to identify reasons for variability in the survival rate. Water flow and amount of living space during the last few months of life in the hatchery and the relative water level in the receiving rivers were decisive factors in determining the percent return of salmon as adults.

Reproductive sterilization of fish has potential for increasing production because energy ordinarily used for gonadal development could be used for growth instead. Further, sterile animals would be useful in preventing dilution of the gene pools of wild populations caused by stocking of hatchery fish. Analysis of sterile brook trout re-

vealed polyploid cells in the body. An identical condition was induced in Atlantic salmon by treating the eggs with a minute amount of an antibiotic. These "sex-engineered" fish are now being produced at a hatchery for field testing.

**Massachusetts.** Factors affecting the abundance of soft-shell clams, an important commercial fishery resource along New England's coast, are poorly understood. Although the importance of predation on young clams by invertebrates has been established, predation of fish on clams has not been extensively studied. Research conducted along the Massachusetts coast has disclosed that the common mummichog eats large quantities of young clams. Predation is heaviest in spring and fall, corresponding to the March-April and June-July spawning periods of the clams. Among fish longer than 55 mm, 38% of the males and 53% of the females contained clams—an average of about seven per stomach. The densities of mummichogs varied from 0.4 to 6.0 fish/m<sup>2</sup>. Application of the densities to predation rates yielded an estimated maximum consumption of 546,000 clams per 1,000 m of shoreline per day during the peak predation periods. In marsh-estuary systems in the Gulf of Maine, where mummichogs are abundant, these fish are an important predator of young soft-shell clams and may significantly affect the year-class strength of the clams.

**Missouri.** Our research projects are aimed at developing conceptual and practical approaches for sustaining or improving the value of fishery resources and the quality of fishing. Recent emphasis has been on efforts to develop quantitative indices that will facilitate the evaluation of fish populations and fishing.

Proportional Stock Density (PSD) is an index of the percentage of fish of quality size (length) in a stock. Unsatisfactory values of PSD for a population reflect problems in reproduction, growth, or mortality that may be related to poor habitat or ineffective management. Advantages of the index are that length frequency is relatively easy to measure and the index reflects what anglers "see" in a population. The index, first developed for largemouth bass and bluegills, has been proposed as a method for evaluating stocks of yellow perch, walleyes, smallmouth bass, northern pike, and muskellunge. Models of length-frequency distribution indicate that balanced populations of these coolwater fishes may have PSD values of 30 to 60%.

In a project to evaluate electrofishing efficiency

for largemouth bass and bluegills, we failed to develop a satisfactory model for direct estimates of population density. However, we have proposed correction factors that should improve the assessment of population length-frequency and the PSD index.

Fish communities and habitat conditions were assessed in side channels of the upper Mississippi River. Average current velocity between side channels ranged from 0.03 to 0.15 m/s. Temperature and oxygen stratification were observed only in slough-type habitats. Most of the 44 species of fish collected by electrofishing and hoop nets were taken in all side channels. Carp and gizzard shad were common in most samples. Centrarchids made up a high proportion of the catch in the sloughs and catfishes in the riverine habitat. Side channels appear to be important fish habitats in the Mississippi River.

**Montana.** Measurements of the mercury concentrations in game fish of various sizes and species from the Tongue River Reservoir indicated that mercury content increased with size and age. The average lengths at which fish of different species began to exceed the FDA guideline (0.5 µg Hg/g) were as follows: walleyes and saugers, 500 mm; black crappies and white crappies, 350 mm; male northern pike, 725 mm; and female northern pike, 900 mm. Northern pike reared in mine effluent water accumulated mercury at a faster rate than did fish in the reservoir. Other metals, including arsenic, lead, selenium, and zinc were detected at low levels in fish reared in the mine effluent.

A study of the temperature changes caused by Ennis Reservoir and their effects on the fish and macroinvertebrates in the Madison River below the reservoir indicated that summer water temperatures in the river increased and growth rates of trout decreased. The average increase of about 3.5° C in summer water temperatures in the river caused important differences in the species composition, abundance, standing crop, and time of emergence of macroinvertebrates. Ways to reduce the thermal impact of the reservoir and reinstate the quality of the fishery are being explored.

**New York.** Large quantities of *Daphnia magna* can be reared in flow-through systems. Our studies have shown that as much as 30 kg/m<sup>2</sup> (live weight) of *D. magna* can be produced annually in flow-through systems receiving the algae-laden effluent of a simulated sewage oxidation pond. A water exchange rate of about three per hour and

an algal concentration of about 3 mg/l produced the highest growth rates. The daphnid culture system can also function as a biological treatment system for waste-water effluents by reducing the concentration of suspended organic solids (primarily algae), total phosphorus, and total nitrogen. Concentrations of ammonia-nitrogen and dissolved phosphorus were increased, however, by passage through the daphnid culturing system, probably through metabolic processes. The culture system may have potential as a component of an effluent treatment system for fish hatcheries and fish farms, since the daphnid production from it could be recycled back into the system as a feed or feed component.

Descriptions of eggs, larvae, and juveniles of five species of suckers from northeastern United States were developed. Keys for the identification of larvae and juveniles are expected to be useful to scientists conducting environmental impact studies in this region and in other areas where these species occur.

Methods for the intensive culture of walleye fingerlings were improved; however, problems with fry culture remain to be solved. Walleye fingerlings survive and grow significantly better in vertical-flow rearing units (i.e., jars, mini-silos) than in horizontal-flow units (troughs). Feed particles apparently remain in suspension longer in the vertical units, thus establishing better feeding conditions. Fingerlings survived and grew better in dimly lighted units (less than 5 lux) than in well-lighted units. Diets based on the nutrient concentrations in walleye eggs proved to be marginally acceptable for walleye fry and fingerling culture; however, adjustments in specific ingredients seem desirable to obtain better acceptance and growth.

**North Carolina.** Primary subjects of research were studies of the effects of Eurasian watermilfoil on fish populations in Currituck Sound and studies of spermatozoa from warmwater fish.

Currituck Sound, which is nationally famous for its largemouth bass fishing, became infested with watermilfoil during the mid-1960's and dense growths now occur in 60 to 75% of its area. Data collected from rotenone samples of fish from three coves before and after milfoil infestation indicated that weight and numbers of fish (all species combined) per hectare were higher after the infestation. However, the average weight of the fish decreased. Catfishes and yellow perch showed the greatest proportionate increases in numbers per hectare and largemouth bass and

white perch the greatest decreases.

Striped bass spermatozoa were successfully preserved by using freezing procedures and media similar to those used in salmonid research. In several trials, fertilization ranged as high as 56%.

**Ohio.** The effects of stream channelization on warmwater fish and macroinvertebrate populations were studied in five streams by comparing the biota in natural areas with that in nearby channelized areas. Study streams were the Olentangy, Sandusky, Hocking, and Little Auglaize rivers in Ohio, and Rock Creek in northeastern Indiana. The sport fishery at the study sites of the Olentangy, Sandusky, and Hocking rivers was documented and an additional channelized study site, which had large artificial riffle-pool stream improvement structures, was selected in the Olentangy. In general, channelization reduced the diversity and abundance or biomass of macrobenthos, and caused a shift in species composition from riffle species to less desirable standing-water burrowing forms. An exception occurred in the Sandusky River, where both channelized and unchannelized areas had riffle areas and bedrock substrates. Game fish were less abundant in channelized areas, and some channelized areas harbored only large numbers of small fish of non-game species. The sport fishery reflected the fish population in the area; channelized areas generally supported little fishing, except during short seasonal spawning runs of game fish in the Sandusky River. The biota in the mitigated area of the Olentangy River approximated that of the natural area. The channelized area of the Little Auglaize became dewatered during drought, but the area was repopulated from downstream within a year. Rock Creek was repopulated within a year after channel construction, but with less desirable species than had previously occurred there.

**Oklahoma.** When northern and Florida largemouth bass were introduced into a reservoir in which the water was warmed slightly by a power plant effluent, the mortality of the Florida bass was greater than that of northern bass, but was not correlated with winter severity. Both subspecies inhabited the heated effluent, but laboratory simulations of cold shocks encountered by bass moving out of the effluent during winter more adversely affected Florida bass than northern bass.

A computer simulation model based on 12 consecutive years of field data showed that about 88% of the variability in year-class strength, and



in mortality of largemouth bass from egg to age I, could be attributed to water levels during spawning and water level fluctuations since the end of the previous growing season. A refined model indicated that production, yield, and catch are most sensitive to mortality from egg to age I and growth rate of the younger age groups.

Phagocytosis has been theorized to function as a host response to infection by microsporidan parasites such as *Pleistophora ovariae*, a parasite of the ovaries of golden shiner. Spores of this parasite were actively attacked by blood cells from four types of cell cultures, but not all parasites were destroyed. Even so, it appears that phagocytosis serves as a defense mechanism for the golden shiner in combating infections of *P. ovariae*.

**Oregon.** Pathogens play a major role in lowering production of hatchery-reared anadromous salmonids. Selective breeding for disease resistance has been proposed. In evaluating the resistance of fish of different stocks and transferrin genotypes to bacterial kidney disease and vibriosis, we found that differences in resistance to kidney disease among coho salmon stocks have a genetic basis, whereas susceptibility to vibriosis is more strongly influenced by environmental factors. Coho salmon or steelheads of a given stock may be resistant to one disease but susceptible to another. The importance of transferrin genotypes to resistance of coho salmon to kidney disease is stock-specific, but no differences in resistance to vibriosis among transferrin genotypes were observed. We also examined differences between meristic characters of steelhead stocks to determine whether the stock of an individual could be determined if it were caught in the ocean. We found that the Alosea, Siletz, Rogue, and North Santiam stocks were genetically different from each other in numbers of vertebrae and scales, but that the differences were not great enough to allow positive identification of fish caught in the wild.

We completed a taxonomic investigation of juvenile chinook salmon and steelhead trout races collected from the Rogue River basin, Oregon, involving scale and vertebral numbers, otolith characteristics, quantity and fatty acid constituents of mesenteric fat, and electrophoretic isozyme identification. Although significant morphological differences between fall and spring chinook and summer and winter steelheads were found, none of these differences were sufficient to allow racial identification of individual fish with 90% ac-



Removing pituitary glands from the carcasses of spawned-out fall Chinook salmon. The glands will be used to prepare a hormonal compound to induce spawning in hatchery brood stock. Photo by C. B. Schreck.

curacy.

Inasmuch as juvenile salmonids are subjected to a variety of stresses encountered in nature or due to management or research practices, we attempted to find a general indicator of stress by determining corticoid hormone dynamics in salmonids subjected to various crowding and handling procedures. Handling and close confinement markedly stressed the chinook salmon and cutthroat trout tested. Heat, although stressing, may modify this response. Crowding of smolts may reduce gill ATPase, an enzyme implicated in migratory disposition and saltwater adaptation. Use of a proper dose of anesthetic for 1 hour or less could reduce stress and increase survival during a handling procedure. We believe that plasma cortisol concentration should not be used as an index of stress in general.

Catch and streamflow data were analyzed to determine factors affecting coho salmon production in Oregon. Scale characteristics were used to distinguish wild from hatchery-produced adult coho salmon caught in the ocean sport fishery. Of the adult coho salmon caught in the ocean, 75% originated in hatcheries. The catch of coho salmon in the Oregon trolling fishery correlated positively with streamflow experienced by the fish as smolts. Upwelling in the ocean correlated significantly with catch by the trollers.

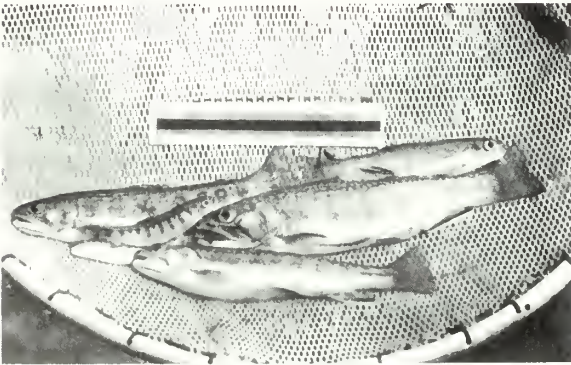
**Pennsylvania.** In a population of adult wild brown trout being studied by the Unit, the fish rarely use cover; individuals feed more than 300 times per hour during midday; and territoriality is not as well defined as has generally been assumed in adult trout. Many individual fish have been fol-

lowed for two summers. None have been handled for identification, but are instantly recognized by their distinct and unique body markings.

"Trout Tracker," a field microcomputer, has been developed specifically for behavioral studies by the Unit. Its 8,000-byte memory per standard cassette tape makes it ideal for recording a large variety of behaviors of the population. The information on each cassette may be transferred to any larger computer for manipulation. It eliminates hand-written records and errors in transcription.

Studies of unproductive, naturally acidic trout streams of the Allegheny Plateau showed that acidity affects species composition of attached algae (the base of the aquatic food chain) but not the number or diversity of species. Neither the biomass nor the growth rate of the algae is limited by acidity, in comparison with similar but neutral streams. However, biomass of aquatic insects (especially the species that feed on algae) was considerably greater in the neutral stream. Carnivorous species were about equally abundant in the two streams.

Investigations of freshwater mussels disclosed that the average filtration rate of the species studied decreased as food concentration increased. Mussels did not decrease the amount of time spent feeding at higher food concentrations, but did decrease the amount of filtration effort.



Brook trout in the infertile, often acidic streams of the Allegheny Plateau reach maturity at a small size, and their length seldom exceeds 6 or 7 inches. Studies by the Pennsylvania Cooperative Fishery Research Unit may lead to management techniques for producing more and larger trout in these streams. Photo by Dean E. Arnold.

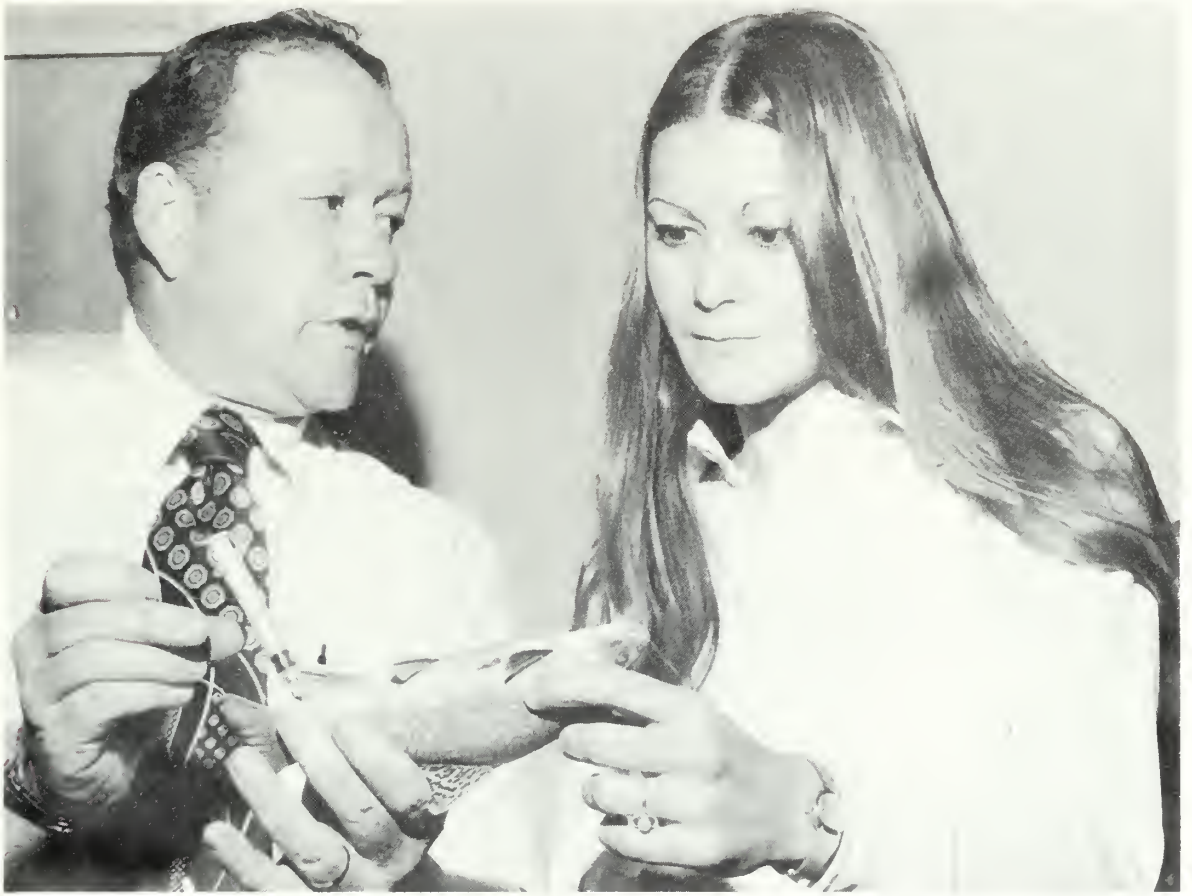
**South Dakota.** A source of brood fish for obtaining eggs and a source of food for the young are major problems in the propagation and introduction of muskellunge outside their range. The

first phase of a long-term project designed to introduce muskellunge into South Dakota was completed. Muskellunge eggs were obtained from the Pennsylvania Fish Commission and hatched at the Gavins Point National Fish Hatchery. Muskellunge fry were fed invertebrates—primarily chironomid larvae and the cladocerans *Moina affinis* and *Daphnia magna*—obtained with dip nets and drift nets from the Brookings, South Dakota, sewage lagoon. *Moina affinis* (less than 1 mm long) appeared to be of ideal size for fry of lengths up to 38 mm. (The fish did not eat chironomid larvae or the large juvenile instars and adults of *D. magna*.) After 20 days, the fry were transferred to ponds stocked with fathead minnows. Here they attained a mean total length of about 205 mm in 69 days.

The muskellunge are now part of a research project designed to evaluate and develop a power plant cooling reservoir as a rearing and holding area for brood fish. If they grow and develop in the heated water of the power plant, they may provide the eggs for producing and stocking muskellunge in other waters of the Dakotas.

**Tennessee.** A study has been completed to determine whether brook trout in the southeastern United States are different from those in other parts of the country, or more specifically to determine whether they are a distinct subspecies. Since brook trout populations have been declining in recent years in the South, particularly in Great Smoky Mountains National Park, it was vital to management to know whether southern fish were unique, as believed by many fishery biologists. We compared fish from four southern states (Tennessee, North Carolina, Georgia, and Virginia) with fish from West Virginia, Pennsylvania, New York, Utah, and Michigan, using both traditional taxonomic techniques and biochemical techniques. We concluded that there is not a separate subspecies of brook trout among the populations sampled.

In a study of angler exploitation of largemouth, smallmouth, and spotted bass in Center Hill Reservoir, Tennessee, numbered tags with various reward values were attached to large numbers of bass in May 1975 and April 1976. Returns from fishermen indicated that 15 to 20% of all bass over 8 inches long were caught in each of the two years. Comparisons between the number of tags returned and estimated monthly catches by anglers indicated that increased angling vulnerability, increased mortality, or tag loss seriously affected the



Dr. Raymond C. Simon, U.S. Fish and Wildlife Service biologist from Leetown, West Virginia, demonstrates blood sampling techniques to a graduate student who is studying the feasibility of live-sampling techniques in electrophoretic studies of brook trout. *Photo by Tennessee Tech University Photographic Services.*

reliability of the annual exploitation estimates. Assuming that tag loss was significant, exploitation rates for all three species were about 30%. We concluded that bass in the reservoir were not being overharvested.

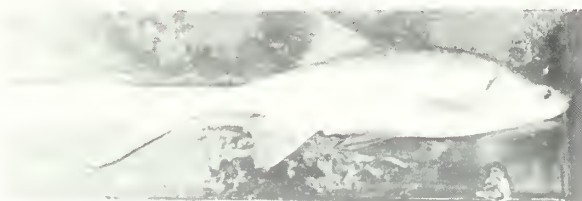
A study in Watts Bar and Chickamauga reservoirs, Tennessee, indicated that a commercial fishery in these waters had only a low or negligible influence on striped bass and other game fishes. There has been concern that the commercial fishery, which has operated in these two reservoirs since the early 1960's, was adversely affecting the striped bass population. In our study, experimental trammel nets that were identical with commercial gear were set at times and places identical with those selected by the commercial fishermen. Between April and October 1977, only eight striped bass were included in the experimental samples. When the experimental catch per net was multiplied by the estimated total number of nets set by commercial fishermen, the estimated catch

rates of striped bass were only 0.005-0.040 fish per acre per year.

**Utah.** Studies on the warmwater fishery of Pelican Lake, a 680-ha (1,680-acre) desert lake in eastern Utah, have been completed. The lake, which routinely produces catches of bluegills with an average weight of more than 200 g (0.5 pound), has been under increasing fishing pressure in recent years. The Unit investigated the fishery to determine whether changes in management might be needed. Over the 3-year study period, an average of 7,600 angler days per year were recorded. Fishermen harvested about 41,000 bluegills and 4,000 largemouth bass per year. Most of the bluegills caught were 4 to 5 years old and weighed 194 to 211 g. Bluegills matured at 2 years of age and spawned from June to September, the peak being in June. Fecundity estimates for bluegills ranged from 11,000 mature ova (in fish 2 years old) to 46,000 (in fish 4 years old). Fecundity of largemouth bass of the same age groups was about

60% that of the bluegills. It was recommended that the present creel limit of 20 bluegills per day be increased but that the limit of 10 bass per day be maintained.

The Utah chub is a forage fish that frequently overpopulates western reservoirs to the detriment of more important recreational fish species. The Unit has investigated piscicides that might be useful for controlling the chub. Field and laboratory analyses of the toxicity of squoxin were conducted with several fish species under different water quality conditions. Selectivity and safety indices for the chub compared with two species of trout indicated a selective control potential for squoxin in hard water at 12° C and in very hard water at 5.6° and 18° C. Squoxin caused gill lesions that reduced the chub's respiratory efficiency and caused death. Chubs did not avoid the compound, and the chemical decomposed rapidly in the water. Work is continuing on the effects of squoxin and other piscicides on chub eggs and larvae. These data and information on the movement and behavior of chub populations in western reservoirs will help determine the feasibility of partly controlling the chub by spot treatments of its spawning areas.



The streamlined body shape of the bonytail chub is typical of several fish which live only in the swift and turbid rivers of the Colorado River system. The species may be classified as "endangered" because dams and other river modifications are reducing its habitat. This reduction has resulted in a large decline in the population. Photo by Steven H. Lanigan.

**Virginia.** The functioning of natural systems needs to be understood in assessing environmental impacts and understanding differences in perturbed systems. To understand and assess these systems and their differences, we studied two streams whose watersheds included inactive surface mines, and one that did not, in southwestern Virginia, for 2 years. At quarterly intervals we measured various physical and chemical characteristics; the composition, abundance, and biomass of fish and benthic invertebrates; and the

quantities of organic and inorganic materials present.

Alkalinity, conductivity, hardness, and sulfate were elevated in the streams with the mines, despite reclamation treatment of the watersheds 3 to 5 years earlier. The streams draining watersheds with mines carried a heavy benthic sediment burden, due primarily to the continued erosion from the mined areas and from abandoned haul roads. Inorganic sediment in the mining-impacted streams covered the natural rubble substrate, smoothing the bottom, filling in pools, and delaying the decomposition of allochthonous organic material, the principal energy source. Fine-particle organic material was trapped in the sediment, but the density of larger organic particles was reduced, possibly due to increased transport over the smoothed substrate.

The density, biomass, and diversity of benthic invertebrates and fish were consistently lower in the mining-impacted streams. This study demonstrates that sedimentation can be a severe and lasting after-effect of surface mining, even in the absence of acid drainage. Land reclamation did not result in stream reclamation and recovery. The inclusion of water quality criteria in the administration of mined-land reclamation would promote management practices conducive to recovery of the streams.

A small brook trout stream in southwestern Virginia was studied to determine the life history characteristics of native brook trout from high-gradient, sterile brook trout streams of the southeastern United States, and to determine the importance of primary tributaries in the population dynamics of brook trout. Backpack electrofishing, marking, and two-way weirs were used in sampling and population estimation.

No well-defined seasonal movements of brook trout were recorded in the study stream. Discrete populations in permanent primary tributaries remained discrete. Localized movements of brook trout in the main stream occurred, and there appeared to be limited seasonal use of intermittent tributaries by mainstream populations during the spawning season. The brook trout were short-lived and the population turnover rate was high. No fish were more than 4 years old and most were less than 2 years old. Growth was average during the first year and above average after the first year.

**Washington.** Artificial reefs have been used throughout the world to increase the fish produc-

tion potential of barren or relatively unproductive areas. In Puget Sound, Washington, the nearshore region is primarily a sand-bottom habitat, occupied by a few species of flatfish at a relatively low density; however, the addition of artificial structures has tended to increase the number of species and density of fish, simulating assemblages commonly observed on rocky bottoms. This study is part of an effort to develop an extensive public fishing pier and artificial reef program by the Washington State Department of Fisheries.

From April 1975 to May 1978, eight artificial reef habitats were surveyed, by SCUBA transects, for density, biomass, and species assemblages of potential sport species of fish. The open sand bottom at the depth range of 6 to 18 m was also surveyed. The interpretation of these data suggested several artificial reef designs and placements that would increase the concentrations of the most desirable sport species. Four reef configurations (flatsquare, triad, horseshoe, and pyramid) were designed, constructed, and evalu-

A tagged quillback rockfish on a triad tire reef design in the nearshore region of central Puget Sound, Washington. Photo by J. M. Walton.



ated during the study.

The artificial habitats changed the fish species composition in the nearshore area from one composed primarily of 5 species of flatfish to one composed of 29 potential sport species. The density and biomass of fish on the artificial habitats (0.7 fish/m<sup>2</sup> and 94 g/m<sup>2</sup>) was more than 12 times that estimated for the sand bottom. The optimum reef structure was the medium high relief triad design, for which the average density estimate was 2.4 fish/m<sup>2</sup> (308 g/m<sup>2</sup>). The artificial reefs supported twice the biomass and 11 times the density of fish found on natural reefs in Puget Sound.

Tagged fish were used to follow migration patterns and note the movement of individual fish, and as a means of population enumeration. Seasonal migrations resulted in a significant reduction in numbers of fish present in the area in the winter and spring. Fish of certain species, including the quillback rockfish, copper rockfish, brown rockfish, black rockfish, Pacific cod, Pacific staghorn sculpin, and rock sole, returned to the same location after the winter migration out of the area. Management of this fishing pier-artificial reef complex was based on the findings of our study.

**Wisconsin.** The stocking of legal-sized trout (152 mm long or longer) in lakes containing warmwater fish populations is a common management practice. To further assess the effectiveness of this practice, as applied in Wisconsin, we conducted creel surveys on three small lakes that had been stocked with rainbow trout or rainbow trout and brook trout.

The trout, which were stocked in spring, provided a popular sport fishery, but only for a short time; typically half or more of the stocked fish were caught during the 1st month of the 10-month trout fishing season. Estimates for different lakes or years of the percentage of the total numbers of fish returned in the 1st month of the fishing season (May) were 46, 73, 62, and 31 for rainbow trout and 64 for brook trout. Most anglers interviewed were fishing primarily for trout. In one lake, 95% of the anglers interviewed over a 9-month season were seeking trout, even though the trout fishery persisted for less than 2 months.

Fishing pressure, like the trout catch, was highest at the opening of the season, and declined sharply thereafter. In one lake 67% of the total annual fishing pressure occurred in the 1st month of the season and 79% in the 1st 2 months. Because the trout were harvested rapidly, relatively little of the production capacity of the lakes was

channelled into production of trout flesh. Therefore, the stocked trout provided a put-and-take fishery at little expense to the existent fishery for warmwater species (largemouth bass, bluegill, yellow perch, white sucker, black crappie, and smallmouth bass).

## COOPERATIVE WILDLIFE RESEARCH UNITS

**Alabama.** Forty-two wild turkey hens were captured and patagially marked immediately before the spring mating seasons of 1973 and 1974 on an area in east-central Alabama managed for cattle and timber. Thirty-eight additional hens were equipped with 164-MHz transmitters. Nine non-nesting hens preferred grazed pine habitat; the average maximum dispersal distance from capture site to the farthest point in their spring-summer ranges was 1.8 miles. Twelve nesting hens moved an average of 1.4 miles from capture site to nest site. Sixteen wild turkey nests were found during the study period. Ten nests were located in areas with similar understory and herbaceous vegetation and 14 in ungrazed areas. Eleven nests were concealed in moderately thick undergrowth; five were in the open. Seven nests were destroyed by predators. Summer ranges of hens with broods averaged 248.6 acres. The average spring-summer range for all hens was 785.2 acres. Nesting hens also showed a definite preference for grazed pine habitat, and their movements and habitat choices seemed to be influenced by grazed permanent pastures and grazed woodlands. No undue competition for food between cattle and wild turkeys was observed.

Seasonal waterfowl occurrence on aquatic habitats on surface-mined lands in Alabama 5, 15, and 25 years old were studied during 1976 and 1977. Trends in aquatic vegetation and plant succession were noted and production of known waterfowl foods was determined. The average number of birds counted per observation was 0.16, 0.19, and 0.85 for 5-, 15-, and 25-year-old ponds, respectively. Most frequently observed species were the wood duck, ring-necked duck, and pied-billed grebe. Cover analysis indicated an increase in percentage of vegetated shoreline and overhead cover as ponds increased in age. Aquatic vegetation was limited to one or two plant species. Factors limiting use of the ponds by waterfowl are believed to



Caribou seeking relief from insects on a gravel road near Prudhoe Bay, Alaska. Photo by D. R. Klein.

be the lack of shoal waters, the absence of cover on young ponds, and the scarcity of waterfowl foods. Recommendations for reclaiming strip mine ponds as waterfowl habitat were made.

**Alaska.** Observations of the behavior of caribou along the Trans-Alaska Oil Pipeline from the Brooks Range north to the Beaufort Sea indicated that caribou move in response to several features of the arctic environment. The northward migration of pregnant cows in early spring is apparently timed to reduce predation on calves by wolves and bears, perhaps also to take advantage of nutritious vegetation as it becomes green. Bulls move northward only after the cows have migrated, and arrive on the Beaufort Sea coast about the time of mosquito emergence. River deltas along the coast offer relief from mosquitos and oestrid flies. Relatively low densities of wolves and relief from insects attract caribou to coastal areas during summer.

During winter, caribou favor the northern foothills of the Brooks Range. Herds in this region break into small bands of about 10 caribou to make efficient use of limited winter forage in localized areas. Wolf predation tends to keep the caribou in small bands for protection; otherwise, it is possible that they would break into even smaller groups. Bands of about 10 caribou seem to be a compromise between the need to use limited browse efficiently and the need to seek protection from wolves.

Activity of caribou varied considerably between seasons because of parasitic insects and the availability of suitable forage. In general, grazing conditions are most favorable during summer on those days when insect harassment is minor and are least favorable during those winters when forage quality is unusually low.

The activity patterns of caribou near the pipeline haul road did not differ markedly from those of caribou more than 300 m away. However, during summer, cow and calf groups were highly sensitive to human activity and avoided the pipeline and the haul road. Observations of caribou near elevated sections of pipeline suggest that bulls may adapt to these sections.

Studies of the impact of resource development on movements and behavior of caribou are complicated by the seasonal and sexual differences in caribou behavior. Environmental factors significantly affect the sensitivity of caribou to human activity. Parasitic insects and severe winter weather decrease the sensitivity of caribou—the presence of potential predators increases it.

**Arizona.** A relict population of only 6 to 10 white-tailed deer was studied in a desert mountain range in southwestern Arizona. The deer were most commonly found at elevations between 3,000 and 4,000 feet, where temperatures are usually above 38° C and a 3- to 4-month rainless period is a yearly occurrence. The vegetation in this area is described as Sonoran desert scrub. The deer primarily inhabited three patches of suitable habitat within their range, each patch covering about 247 acres. Suitability of habitat was determined by forage, topography, and water availability. The presence of permanent water may be the key factor affecting the distribution of this small desert herd. Deer moved over 5 miles to obtain water during the hot, dry season of early summer. Some competition for food may be occurring with domestic cattle and bighorn sheep, but habitat and range separation appears to prevent competition with the mule deer and feral burros that also occupy this region.

A study of bird populations and of the use of dead tree snags by hole-nesting birds was initiated in the Santa Catalina Mountains near Tucson, Arizona. Three study areas were established: Upper Bear Canyon (6,000-6,200 feet), Rose Canyon (6,600-7,200 feet), and Mount Lemmon (8,000-8,600 feet). In June 1978, 53 species of birds were identified on these areas. Twenty nests of nine species of hole-nesting birds were located.



Large "gang" broods of as many as 40 Rocky Mountain Canada geese accompanied by only two or three pairs of adults are common in some breeding areas, indicating that even successful breeding adults may leave their broods and go elsewhere to molt. *Photo by William Krohn.*

Waterfowl production was studied on 13 natural basins of 3 to 300 acres in the Flagstaff area of Arizona during the spring and summer of 1978. Dominant vegetation associated with these ephemeral wetlands consists of pale spikerush and, on semipermanent water areas, tule bulrush. Basin areas are grazed at intervals corresponding to rest-rotation schedules determined by the U.S. Forest Service. The cattle congregate in the basins and feed heavily on spikerush, causing extensive mechanical damage to the shoreline vegetation.

Waterfowl production in 1978 was dominated by redheads, pintails, ruddy ducks, and cinnamon teals, in that order. Mallard, gadwall, and green-winged teal broods were also noted. Redhead broods were observed only on the basins where both bulrush and spikerush grew; cinnamon teal and ruddy duck broods were commonly found on these basins, too. Pintail broods were found on basins supporting mixed vegetation of various densities. Nests of cinnamon teals were found in dense spikerush. A pintail nest was located about 459 feet from the nearest water in a grass-shrub association, and a redhead nest was found over water in tule bulrush.

**Colorado.** A method for estimating the age of individual mountain lions has been devised that uses specific combinations of blood characteristics and body measurements to yield an age estimate to year class. No generally satisfactory method

existed previously.

Thirty-seven attributes from 76 samples taken from 54 captive mountain lions were evaluated. Globulins, blood urea nitrogen, total protein, alkaline phosphatase, zinc, percent monocytes, and percent neutrophils provided usable values from blood samples. The usable body measurements were distance from the cemento-enamel junction to the gum line of premolar and upper canine teeth, tarsal length, and total body length.

The method can be used to estimate the effect of hunting regulations on longevity and turnover rates of mountain lion populations.

Results of a survey of 468 randomly selected residents of the oil shale region in Colorado, Utah, and Wyoming showed public interest to be greatest, in descending order, in elk, deer, sport fish, pronghorn antelope, bighorn sheep, game waterfowl and shorebirds, raccoons and other furbearers, cottontails, upland game birds, and non-game birds. Threatened or endangered species ranked 12th in public interest and feral/wild horses ranked 18th. Poisonous reptiles ranked last among the 25 groups listed.

Of the respondents, 310 were male, 36 held environmental group memberships, 73 held sporting group memberships, and 324 were hunters. These results can be used as a guideline when priorities are set for species to receive some measure of protection during oil shale develop-





Cooperative (Canada, United States) banding of geese on breeding areas in southern Alberta has been a key factor in defining the range of the Rocky Mountain population of the western Canada goose. *Photo by William Krohn.*

ment.

A total of 42 square miles of wildlife habitat is estimated to be lost if production of oil from shale in Colorado, Utah, and Wyoming reaches 133,000 barrels per calendar day, a low level. The estimate increases to 100 square miles if production reaches 356,000 barrels, and 251 square miles if it reaches 828,000 barrels. The rate in the 20th century is likely to reach 356,000 barrels.

These estimates were the result of a study that identified 47 components of the shale oil extraction system, identified 27 types of outputs produced by those components, and delineated the boundaries of 38 sites where outputs might occur at levels that would preclude production of wildlife. Only 16 of the sites, all in Colorado and Utah, were judged to be viable, however. The extent of off-site areas affected was estimated indirectly and was not geographically specific.

The Shiras moose has expanded its distribution in the northern Rocky Mountains during the past century, an indication that moose are capable of colonizing vacant habitat. The colonizing mechanism must be understood to manage this species adequately. To this end, the following hypothesis is being tested: the solitary social organization of the Shiras moose will facilitate initial occupation of vacant habitat through a spacing of adults and the expulsion of juveniles from areas where adults have established home ranges. The test involves the introduction of 24

moose into unoccupied habitat in north-central Colorado. Twelve were released during March 1978 and 12 more were expected to be released in January 1979. All moose released were collared with radio transmitters. Relocations of animals after their release yielded data on home range selection, habitat preferences, and population dynamics. Four of six calves born to the moose introduced in 1978 were known to be alive at the end of September. Willow, lodgepole pine, and quaking aspen were preferred habitat types.

**Idaho.** Information collected over a 30-year period by waterfowl biologists of Canada and the United States concerning the geese of the intermountain region was analyzed by the Unit at the request of the Pacific Flyway Technical Committee and the Council with the hope that long-term management guidelines could be developed.

The analysis, begun in 1975, was completed in 1978. Banding data (19,000 recoveries) accumulated since the 1930's were analyzed; information on breeding biology and molt migration was assembled; and existing breeding and wintering survey routes were flown by the investigator to evaluate methods being used to gather data. With excellent cooperation from all States and Provinces involved, we compiled an extensive goose habitat inventory for the entire breeding and wintering ranges of the population. An examination of hunting mortality and survival rates, computed on the basis of band recoveries, showed that

sport hunting accounted for more than 86% of the mortality of fledged Canada geese of the intermountain region. The range of the Western Canada goose was delineated, and the population was divided into the Pacific and the Rocky Mountain populations, based on banding data and on migration and wintering behavior. The study produced a proposed management plan and a series of management and research recommendations for consideration by the Pacific Flyway Council and by Provincial, State, and Federal waterfowl management agencies.

**Iowa.** Local movements of nine female ring-necked pheasants in response to snowmobile activity were monitored by radiotelemetry in a large cattail marsh in northwestern Iowa during February 1978. Snowmobiling was confined to six 1,120-m trails, 160 m apart, in a section of marsh used by pheasants as winter cover. No radio-equipped birds left the trail area during snowmobile activity, and no changes in roost-site location or daily behavior were observed. Only once in 24 instances was an aberrant movement detected in direct response to snowmobiling; this pheasant moved toward, not away from, the trail area. In cattail marshes similar to the one studied, snowmobiling probably would have little or no effect on pheasant populations if traffic could be confined to a few widely spaced trails.

Effects of snowmobiling on wetland vegetation were examined from December 1976 to June 1978. Densities of cattail, sedge, and giant burreed were unaffected by trail grooming without subsequent snowmobiling, but cattail height decreased 12 cm. Trail grooming with snowmobiling was followed by a 23% decrease in cattail density, a 12% (12 cm) decrease in cattail height, and a 44% increase in sedge density. Snowmobiling had no effect on bluejoint reedgrass density or sedge height. No vegetative differences were detected between trails with 440 snowmobile trips and those with 180 trips per season. With snowmobiling confined to dispersed trails, no serious alteration of wildlife habitat would result from the degree of vegetative change observed in this study. Long-term effects are not yet determined.

Effects of channelization on riparian habitat were determined from interpretation of aerial photographs of 100 short-reach channel realignment projects (1945-70) primarily dealing with bridge building and bypassing of meanders. Overall, forest and woodland did not change, but herbaceous cover decreased and cropland increased

where stream alteration occurred. Birds and mammals were censused in a variety of habitat types, from hayfields to closed-canopy woodlands. Observations of 52 bird species in the following six habitat types were used to calculate indices of tolerance to potential habitat alterations: woody vegetation removed, leaving pasture or hayfields; woody vegetation reduced to narrow strips along streams; woody overstory partly removed; woody overstory partly removed and shrubs thinned; shrubs thinned; and snags removed. Effects on nine species of mammals were predicted with the following set of potential habitat alterations: timber removal; light grazing; heavy grazing; channelization; invasion of trees and shrubs; and cessation of grazing. Meadow voles used the narrowest range of habitats, white-footed mice the broadest. About 380 taxa of vegetation occurred in 47 community types within 250 m of stream banks. Effects of grazing, clearing overstory trees, and channelization on riparian vegetation were determined. These studies of birds, plants, and small mammals in riparian communities make it possible to predict the effects of habitat disturbances before they occur, and are thus of importance to resource managers.

**Louisiana.** The fall migration of waterfowl into Louisiana was monitored for 2 years to determine the relative usage of the Mississippi and Central flyways. Radar stations were operated in Slidell and Lake Charles, Louisiana, in 1975, and in Little Rock, Arkansas, and Lake Charles, Louisiana, in 1976. Waterfowl targets on the radar screen were recorded photographically, and the frequency of waterfowl tracks per axis of movement was recorded. The directional heading of waterfowl over Slidell was primarily south-southwesterly, which suggested that these birds traveled primarily within the Mississippi Flyway. The major waterfowl headings over Little Rock were southeasterly, indicating that these birds traveled in both the Central and Mississippi flyways. Migration over Lake Charles was predominantly southeast; these waterfowl apparently traveled primarily within the Central Flyway. On the basis of a previous estimate of waterfowl traffic along these routes, it seems that the greater number of migrants reach Louisiana by way of the Central Flyway. The peak frequencies for migration into Louisiana were from mid-October through mid-November.

**Maine.** Captive eastern coyote pups were studied to gain information on some aspects of



Spatial segregation of nesting Sandwich (smaller) and royal terns makes aerial estimates somewhat easier. Each bird of both species is incubating a single egg. *Photo by John W. Portnoy.*

coyote development not known for the eastern variety. Body length, body weight, height at shoulder, and other measures of physical development were taken at regular intervals. Dominance hierarchy formation, hierarchy changes, and formation and dissolution of tied ranks were observed. For the entire litter, few significant correlations were noted between hierarchy rank and aggression, defensive actions, play, self-play, or ability to act as initiator. However, a negative relationship was consistently seen between rank and defensive behavior.

**Massachusetts.** Breeding populations of 27 Atlantic species of colonial water birds from Portland, Maine, to North Carolina were inventoried in 1976 and 1977. Ground, aerial, and boat counts gave an estimate of 241,119 pairs of breeding birds in 512 colonies. Location, nesting habitat, and chronology were also documented. Herring gulls (76,693 pairs), laughing gulls (64,657), and common terns (26,904) were the most abundant of 16 seabird species. Least abundant, and also marginal in their range, were the southern Sandwich and Caspian terns and the Nearctic black guillemot; each was found at only one location. The most common of the 11 wading bird species were snowy egrets (10,303 pairs), black-crowned night herons (9,082), and cattle egrets (6,515); green herons and white ibises were the rarest. One pair of white ibises found in Virginia in 1977 represents

a northern expansion for the species. Virginia, New Jersey, and Massachusetts had the highest concentrations of nesting water birds, Connecticut and New Hampshire the lowest. Abundance of water birds is generally correlated with wetland area and most nesting colonies are on barrier, marsh, or coastal islands. In some highly developed coastal areas (New Jersey, Delaware, Long Island), a number of beach-nesting species have been forced to marsh or dredge islands in adjacent embayments.

Analysis of historical breeding data (1900-77) for the 27 species inventoried showed large gull populations to be stabilizing in northern New England but rapidly increasing from New Jersey to Virginia. The common tern seems to be stable everywhere except Rhode Island, and cormorants continue to increase. Herons and egrets extended their ranges to the Northeast in the last 10-20 years, but the only large coastal colonies of great blue herons are found in the Chesapeake Bay area.

**Missouri.** The mourning dove is the most important migratory game bird in terms of number harvested; however, important questions remain concerning migratory pathways, survival rates, and the impact of hunting on mortality rates. Analysis of band-recovery data from 1968 to 1976 indicated that doves banded in eastern Missouri generally migrated south-southeast to Kentucky, Tennessee, Mississippi, Alabama,

Georgia, Florida, and South Carolina. Those banded in central and western Missouri moved south-southwest through Kansas and Oklahoma to Louisiana, Texas, Mexico, and Central America. Although adults were shot closer to the site of banding, they had higher survival rates (42.4%) than did immatures (25.1%). Hunting did not increase annual mortality rates, accounting for only 19% of the mortality of immature birds and 18% of that of adults.



Student biologists testing a collar equipped with a radio transmitter, placed on a white-tailed deer fawn. This collar is designed to monitor fawn mortality, an important informational need in deer management. *Photo by James E. Rathert.*

Moist soil plants provide important food for waterfowl and other wildlife, yet their management by water level manipulation, disking, burning, or mowing is not adequately understood. Comparison of species diversity and seed yield of moist soil plants on the Mingo National Wildlife Refuge indicated that timing of water level manipulation was important. An early water drawdown decreased species diversity and stem density. Species diversity also decreased after disking but seed production increased 100%. Burning increased species diversity as well as stem densities of important species. Because costly fertilizers and herbicides are not used, moist soil management provides an economical yet effective method of producing food for wildlife.

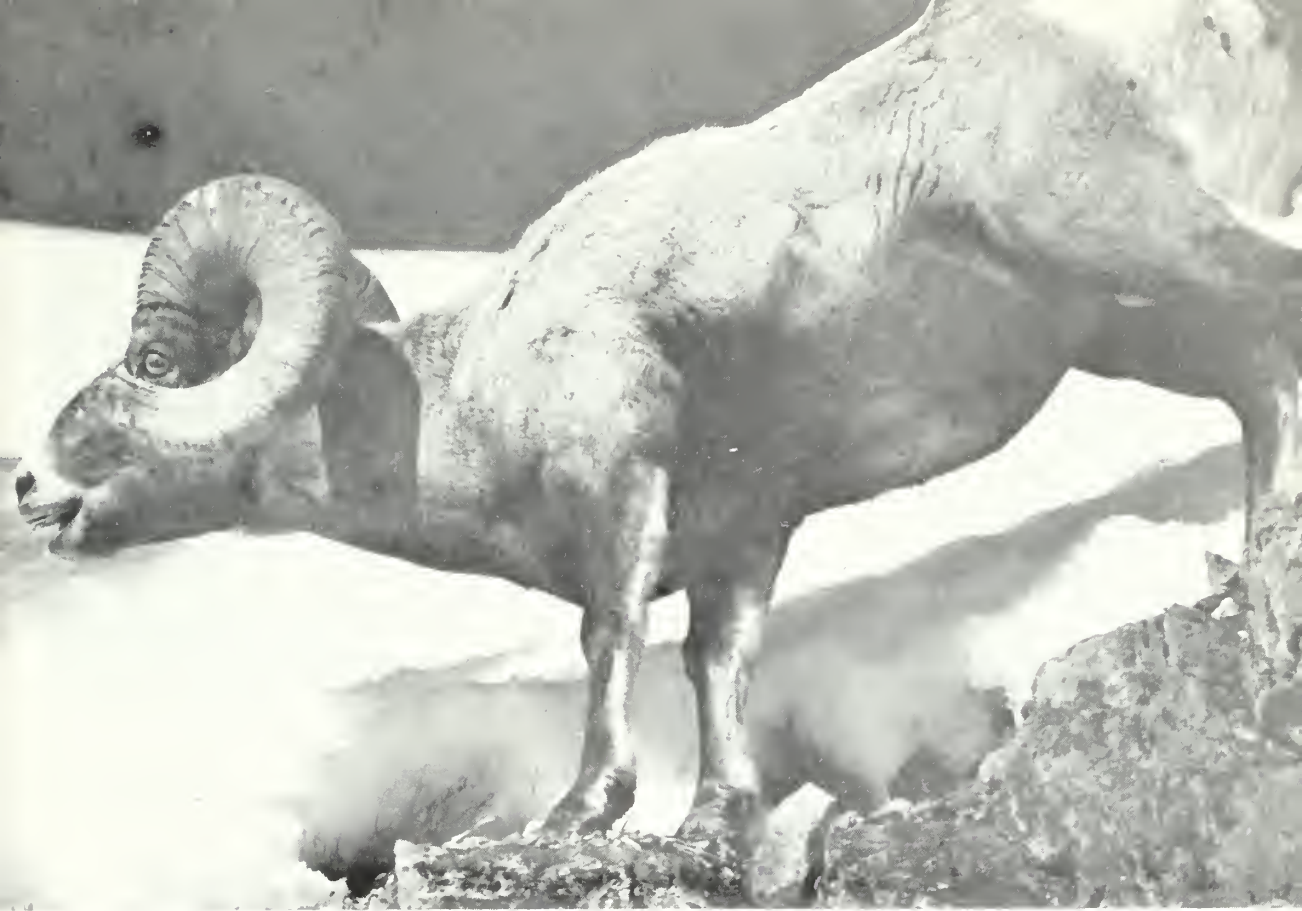
A knowledge of wood duck feeding ecology and nutrition improves our understanding of their energy requirements for reproduction and is

helpful in the management of their dwindling habitat. Females consumed more aquatic invertebrates and a greater diversity of animal foods than did males during the breeding season; in fall the proportions of animal foods were similar. Animal foods are important sources of protein during egg production; they are richer in protein than are plants and have a better balance of essential amino acids for egg composition. Females prepared for laying eggs by storing large quantities of fat; however, fat losses during incubation were small, suggesting that nearly all energy needs for incubation were met by foraging. Thus the ability to ingest and assimilate protein may be the major factor limiting clutch size in wood ducks.

A description of habitat used by ruffed grouse is crucial in determining future management plans and as a basis for evaluating response to management operations. Spring populations of grouse on the Daniel Boone Memorial Forest ranged from one pair per 23.6 ha to one pair per 28.8 ha. Grouse consistently used the middle and lower portions of north- to east-facing slopes and adjacent bottomlands. Grouse preferred drumming log sites with a high stem count and a low canopy coverage; unoccupied habitat was the most successional advanced. Land resource units, delineated by soil type subdivided by aspect, were used to measure the effect of management practices and would be applicable to similar plant communities elsewhere.

The planning and development of water resource projects require a full knowledge of aquatic and wildlife resources within the project basin. Selected references included in a literature survey of the Meramec River basin, Missouri, were listed under the following comprehensive categories: aquatics, mollusks, wildlife, bats, general, and related studies. In addition, over 75 persons were contacted during the survey, and their addresses and respective areas of expertise were listed, as were ongoing projects affecting or related to the basin. A computerized file of citations will allow rapid future revision of the bibliography.

Swan Lake National Wildlife Refuge hosts major wintering concentrations of bald eagles, an endangered species. Prey availability significantly influenced daily movement and distribution of eagles; the availability of Canada geese crippled during the hunting season was particularly important. Eagles consistently used four night roosts adjacent to open areas but protected from north-



The winter food habits of mountain sheep are under observation in Montana and Idaho. *Photo by Dean E. Biggins*

ern and westerly winds. Daily movements of color-marked or radio-equipped eagles were limited to the Refuge and the nearby Fountain Grove Wildlife Area and Grand River bottomlands. Management recommendations for the wintering bald eagles include maintaining a steady food source, preserving existing roost sites, delaying public fishing until March, and alerting hunters to the presence of bald eagles.

**Montana.** Sightings of known doe pronghorns on the National Bison Range, Moiese, Montana, during the summers of 1975 and 1976 disclosed that doe home ranges covered an average of four buck territories. In one area, the territorial buck with which the does had the longest association did most of the breeding. In another area, one buck did most of the breeding although the does had used all buck territories equally during summer. This study indicated convergent evolution in social systems of North American pronghorns and similar African bovids.

During three winters, from January 1975 through March 1977, coyote predation was the

major cause of white-tailed deer mortality in the Miller Creek Drainage of western Montana. Coyotes generally attacked in pairs, chased deer downhill, and caught hold in the rump or throat regions. Predation seemed concentrated on deer 3 to 7 years old in excellent nutritional condition, and the coyotes did not require deep, crusted snow to gain advantage over deer. Coyotes killed most deer when snow cover was greater than 80% and temperatures were less than  $-8^{\circ}\text{C}$ . Coyotes apparently expended more effort hunting deer when snow and low temperatures reduced the availability of meadow voles—meadow vole activity was directly related to temperature and snow cover.

A study of white-tailed deer in the Salmon Lake area of western Montana (October 1975-March 1976) indicated 54 to 75 deer per square mile of winter range. Steep slopes that were quick to develop snow-free areas were used extensively whether or not the shrub species were heavily browsed. Overstory density did not influence deer use on the slopes. A study of the feasibility of



A recent Montana study showed high levels of golden eagle predation on domestic lambs. Trapping and translocating the eagles may have been helpful but did not solve the problem. *Photo by Bart O'Gara.*

using broadcast burns to stimulate shrub growth on the slopes was recommended.

A study of radio-collared and unmarked mountain sheep in the Bitterroot Mountains, Montana and Idaho, provided data on seasonal home ranges, migration route, population size and health, winter food habits, and winter and spring habitat selection. These data led to recommendations for (1) reduced disturbance of sheep and their habitat, (2) prescribed and natural fire management, and (3) establishment of a systematic annual ground count of sheep.

The reactions of birds and microtine rodents near Franklin Bluff, Alaska, during the summer of 1976, indicated that these species can adapt behaviorally to the auditory and visual stimuli connected with postconstruction pipeline activities. Predation by arctic foxes, attracted to handouts and by improper garbage disposal, was the primary cause of nesting failures. The loss and modification of habitat also adversely affected bird and microtine populations along the pipeline. In subjective order of importance, disruptive factors were (1) graveled areas, (2) structural barriers to drainage patterns, (3) human disturbance, (4) low-



Survival of color-banded great black-backed gull chicks is being monitored by researchers of the New York Unit to determine the effects of oil contamination on seabirds. *Photo by Steve Lewis.*

flying aircraft, (5) dust from the haul road, (6) terrain disturbance by off-road vehicles, and (7) contamination of vegetation by oil.

**New York.** Oil pollution of aquatic environments continues to be a serious problem. Death of avian species from exposure and sublethal pathologies from ingesting oil are well documented. Although the direct effects of oil contamination are most obvious, even trace amounts of oil applied to the eggshell drastically reduce egg hatchability. Embryonic mortality is most severe when oiling occurs in early developmental stages; embryos become more resistant as they near hatching. In a recently completed research study, 60 nests of the great black-backed gull were studied on Appledore Island, Isles of Shoals, Maine. In 30 randomly selected nests all eggs were treated with 20  $\mu$ l of No. 2 fuel oil (API Reference oil III). Four 5- $\mu$ l droplets were applied to the top of each egg as it lay in the nest. Eggs in the remaining 30 nests served as controls. Because embryos are most sensitive to oiling before day 10 of incubation, efforts were made to conduct this study when most eggs in the colony were between 1 and 10 days old. Hatchability of the eggs treated with No. 2 fuel oil was significantly reduced; 78% of the 83 control eggs hatched, but only 24% of the 86 treated eggs hatched. Two chicks or more

hatched per control clutch but only 0.7 chick hatched per treated clutch. The critical minimum age at which black-backed gull embryos can survive oiling is about 9 days, although oil treatment apparently causes some mortality even after that age. Among eggs treated after 9 days, 8% fewer treated eggs than control eggs hatched. For great black-backed gulls, the indirect effects of oil contamination are a more serious threat to population stability than are the direct effects that lead to adult mortality. The dramatic results of this study clearly indicate the need for an expanded research effort aimed at the critical area of environmental contamination and inadvertent oiling of avian marine species.

**Ohio.** Ringed turtle doves were fed pigeon chow containing 25 ppm PCB (Aroclor 1254) to learn whether sublethal doses altered estrogen-influenced behaviors and thus delayed egg laying. Experimental and control birds were observed during a 2-week pretreatment period, after 15 weeks of treatment, and after 2 weeks on a 10% food reduction. Neither courtship behavior nor the number of courtship performances by either sex was affected by treatment. Adipose PCB levels greater than 470 ppm in females at pairing delayed egg laying. The increased time between nest solicitation by males and egg laying was attributed to estrogen degradation by PCB-induced hepatic enzymes. Food reduction and PCB treatment delayed egg laying and, in combination, decreased male nest cooing and nest size and quality.

The hunter harvest of cottontail rabbits on a central Ohio wildlife area increased dramatically in 1974 on management units having a newly initiated, shorter crop rotation system (3 years vs. 5 years). It was hypothesized that the summer diet produced on these units had a higher protein content and thus increased juvenile survival. Young rabbits were collected by shooting during May-August, and stomach contents were identified by histologic examination and analyzed for crude protein. Results indicated that juveniles from short rotation sites obtained a nutritionally superior diet in 1975 but not in 1976. Whether nutritive quality of food affected juvenile survival was not determined.

**Oklahoma.** Cow elk and their offspring were monitored by radiotelemetry to determine their use of available habitat on an area of the Wichita Mountains National Wildlife Refuge near Lawton, Oklahoma. Home range of the elk was 25% dense forest, 66% open forest, and 9% grass-



Ohio Unit student removing a cottontail rabbit from a trap during a food nutrition study. *Photo by Gerald A. Grau.*



A tranquilized coyote equipped with a radio transmitter and ear tags lies quietly until the drug begins to wear off. The animal was marked during a study of coyote-deer-elk interactions on the Wichita Mountains National Wildlife Refuge and adjoining Fort Sill Military Reservation by the Oklahoma Unit. *Photo by John Litvaitis.*



Western Canada geese readily use nest structures placed on islands in the Columbia River on the Umatilla National Wildlife Refuge. These nest structures are adversely affected by accelerated erosion to the islands from "power peaking" at dams on the Columbia River. Management designed to control this erosion must be undertaken. *Photo by T. McCabe.*

land. Dense forest was heavily used by cows during the daylight hours. Young calves spent the first 5 weeks in hiding, and cows apparently located hidden calves by scent and hearing. Calves selected locations for daytime beds that were cooler than ambient air. Deer appeared to avoid elk and were seldom observed in areas containing large numbers of elk.

White-tailed deer fawns and coyotes were captured and radio-collared in the Wichita Mountains area of Oklahoma to learn why such a large percentage of fawns inhabiting prairie and woodland edges were lost to coyotes. Deer fawns primarily inhabited grasslands, made intermediate use of savannah, and used forested areas least. Coyotes ranged over wide areas but preferred savannah and avoided prairie areas in general; however, coyotes were successful in locating and killing

fawns in the prairie areas. The mean age at death due to coyote predation for 36 fawns was 20 days (range, 3-76; SD = 12.8). The coyotes consumed rodents, birds, and plant foods in relation to abundance.

Channelization and land-use changes along two prairie streams in south-central Oklahoma resulted in loss of wetland habitat, loss of 86% of bottomland forests, and reduction of richness, diversity, and relative abundance of plant and animal species. Of the original bottomland forest, 81% (26,600 acres) was lost before 1940. Species diversity and richness and density of woodland canopy were greatest for bottomland forests along unchannelized streams.

Weather Bureau and Federal Aviation Administration radars were used to estimate the numbers of sandhill cranes along the Platte River in Nebraska in March: 25% of the cranes left the roosts by sunrise, 72% had left by 30 minutes after sunrise, and 90% had departed by 60 minutes after sunrise. The aerial census failed to count the birds that left the roost before the passage of the plane. Presently available radar facilities and technology offer no practical means of eliminating the need for the coordinated survey.

A flock of parasite-free mallards was exposed to wild waterfowl during migration and wintering; wild waterfowl were later collected and examined for presence of hematozoan infections and numbers of parasites. Hematozoa were not transmitted from wild birds to parasite-free mallards, but the flock acquired seven species of helminth parasites. Blood films from 18% of 563 wild waterfowl were positive for at least one parasite—*Leucocytozoan*, *Haemoproteus*, or microfilariae.

An interdisciplinary team was formed to investigate losses of pecans in Oklahoma pecan orchards to crows and blue jays. The ripening of the nuts in October and November coincides with migratory and wintering activities of the birds. The usual methods of frightening birds from orchards are not effective against blue jays. Horticulturists and wildlife specialists are attempting to identify practices that might reduce depredations.

**Oregon.** The use of standing dead trees (snags) by birds was investigated in Douglas-fir forests of different ages on the Coast Range in Oregon. In general, hole-nesting birds of 10 species foraged on and nested in Douglas-fir snags averaging more than 60 cm wide and more than 15 m tall. These snags usually had broken tops, few or no branches, decayed sapwood and heartwood, and peel-





Preparing to measure, examine, and tag a bear trapped in a culvert. Pike County, Pennsylvania. *Photo by J. S. Lindzey.*

ing bark. Snags this large and old were found primarily in older forests; consequently, use of snags by hole-nesting birds was concentrated in the oldest forests examined—stands 100 and 200+ years old. A census of birds indicated that the density and species diversity of hole-nesting birds increased significantly as forests matured. Density of hole-nesting birds during the breeding season was closely correlated with snag diameter and snag volume per unit area. Because management of Douglas-fir forests for maximum timber production does not provide for production or retention of large snags, populations of many species of hole-nesting birds can be affected.

**Pennsylvania.** For management purposes, movement patterns of radio-instrumented black bears were monitored to collect needed additional information on use of time and space by bears in Pennsylvania.

Home range and activity patterns were determined for 15 black bears, based on 1,662 radiolocations and direct observations made from August 1974 through December 1975. The average home range for five males (196 km<sup>2</sup>) was significantly larger ( $P < 0.05$ ) than that of eight females (37 km<sup>2</sup>). Seven female bears traveling with offspring maintained significantly larger ( $P < 0.05$ ) home ranges than seven solitary females.

Adult solitary females denned between October 27 and December 7, which was generally earlier than the dates for males and most females with cubs; many denned before the late November hunting season. Females with cubs tended to move long distances during September and October and



Large male bear in foot snare before being examined and tagged for a movement and population study. Healed wound on nose gives evidence of past injury. *Photo by G. L. Alt.*



A wild bear that had become so accustomed to being fed by humans that she freely approached them for handouts. This animal and her cubs provided many useful data because, although unusually tame, she was free ranging and could be observed readily. *Photo by G. L. Alt.*

remain more active during the winter than any other group.

Data were collected on 25 translocations of 21 nuisance bears from July 1974 through June 1976. Recovery data for 21 of the 25 translocations showed that 17 homed, 3 did not home, and 1 yearling male that had been translocated to his natal home range returned to a point near the nuisance area. Four radio-collared adults were translocated, on five occasions, an average of 26.8 km. The average time it took them to return home was 6 days. Two adult females separated from their cubs began the homeward journey on the first night after release and soon rejoined their progeny on their home ranges. Translocation of adults farther than 64 km appeared to reduce substantially the chance of their return to the nuisance area.

**South Dakota.** Crude density of ferruginous hawks in a 7,000-km<sup>2</sup> study area in northwestern South Dakota was 292 km<sup>2</sup> per pair in 1978 and 412 km<sup>2</sup> per pair in 1977. Thirteen of 18 nesting attempts were successful in 1976; 14 of 17 attempts were successful in 1977. Mean clutch size for the 2 years was 3.3 eggs per nest. Fifty-nine eggs were laid in 1976; 52 hatched and 34 young were fledged. Fifty-six eggs were laid in 1977; 52 hatched and 39 young were fledged. Successful nests were in unbroken, ungrazed, or lightly grazed prairie. All nest sites were on the ground on riverbed mounds, river cutbanks, hills, or mud buttes. Disturbance during incubation causes adult hawks to abandon their nests. Prey consisted primarily of thirteen-lined ground squirrels, western meadowlarks, and white-tailed jack rabbits. For 2 weeks after fledging, young birds returned to the nests to roost and to obtain food from the parents; they left the study area during the 5th week after fledging. Increased farming activity in the study area may cause hawk populations to decline as a result of nest disturbance and a limited food supply.

**Utah.** The U.S. Air Force is required by the Sikes Act to operate its large land holdings under a Land and Wildlife Management Plan consistent with military objectives. Personnel of the Utah Unit conducted a biological inventory to provide basic information necessary for preparation of an appropriate management plan for the Hill and Wendover Bombing and Gunnery ranges. A species list of plants and vertebrate animals was made as well as cover-type maps of the area. Specific recommendations made included the construction of nesting platforms for raptors, the transfer of marshland to the Utah Division of Wildlife Resources, the construction of check dams and gallinaceous guzzlers to increase the supply of water, and the improvement of range through replanting and sheep management.

**Virginia.** Twelve study areas on abandoned mines in southwest Virginia were surveyed for relationships between characteristics of breeding bird populations and structure of the vegetation. Territorial mapping was used to census the birds. Species diversity and the number of breeding species, breeding pairs, and observed species were determined for each disturbed area. Vegetation was sampled within units of similar vegetation on each mine site; 17 variables recorded for each unit were weighted by the size of each vegetational unit and averaged for each disturbed area. Linear and

multiple regressions of each population variable were performed on 51 vegetation and site-factor variables.

Bird population variables of the disturbed areas and the total study areas showed positive relationships with several aspects of revegetation on disturbed sites. Decreases in bird populations were observed on forested orphan mines when canopy closure apparently suppressed understory vegetation. Bird populations on forested orphan mines decreased when those in marginal areas declined with reforestation of the disturbed areas, apparently reflecting a decrease in edge effect.

The relationships indicated by this study suggest that reclamation of the disturbed areas and total study areas should strive to establish dense vegetative cover, increase the amount of ground layer vegetation, and provide for development of higher vegetational strata.

Because of declines in eastern cottontail populations over much of Virginia, studies were conducted to determine whether tularemia and *Baylisascaris procyonis*, a nematode parasite, were affecting the cottontails.

The cottontail harvest at Fort Pickett has declined, and a serological survey for antibodies against tularemia in mammals and quail was conducted from blood samples. Antibodies were detected in 13 of 90 animals tested. Evidence of tularemia was found in a raccoon, opossum, striped skunk, Norway rat, white-tailed deer, chipmunk, and bobwhite quail. This widespread infestation indicated that the disease is prevalent at Fort Pickett. The fact that tularemia can be transmitted to rabbits by many species of ectoparasites common to animals found infected may explain the continued decline in cottontail numbers.

The larval stage of *B. procyonis* has caused mortality in cottontails in Virginia. A survey for the adult stage of this ascarid, which lives in the small intestine of raccoons, was conducted to determine where this parasite might be affecting cottontail populations. The small intestines of 72 raccoons from 11 counties were examined. The ascarid was found only in counties west of the Blue Ridge Mountains. This finding indicates that the parasite may be an important factor in cottontail mortality in the mountainous portion of Virginia.

**Wisconsin.** At least nine States reimburse agriculturists for crop depredation by deer. In Wisconsin, browsing by deer in apple orchards is an

important aspect of wildlife damage. Claims for deer damage in mature orchards are often controversial because the actual impact on apple production is poorly understood and standard methods of appraisal are lacking. One objective of this study was to develop methods for evaluating the damage caused by browsing of deer in mature apple orchards in winter. In an experiment where browsing on branches of apple trees was simulated and subsequent production was monitored, the simulated browsing had a significant negative effect on apple production.

The impact of natural browsing by deer was studied in three commercial orchards in southwestern Wisconsin. Estimates of the proportion of apple buds available to deer, the percentage of available buds browsed, and apple production

were obtained for more than 500 sample trees in 1975 and 1976. Accuracy and precision of estimation procedures were evaluated and the relationship between browsing and apple production was analyzed. Intensity of browsing was related to variety, size, and location of apple trees. In the orchards studied, 34 and 10% of the growing points were removed by deer in 1975 and 1976, respectively. Analyses indicated that browsing by deer lowered production on dwarf and semi-dwarf apple trees but not on standard-sized trees.

Two methods for evaluating deer damage in mature orchards were proposed. The first method uses estimates of production and browsing; the second method requires only an estimate of the number of buds browsed.

## Publications

Listed below are titles of articles published from October 1, 1977 to September 30, 1978 and a few publications that were not listed in previous annual reports. The articles were published in technical and scientific journals, magazines, proceedings, transactions, and other media.

- AGGUS, L. R., AND S. A. LEWIS. 1978. Environmental conditions and standing crops of fishes in predator-stocking-evaluation reservoirs. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30(1976):131-140.
- AHNE, W., AND K. WOLF. 1977. Spring viremia of carp. U.S. Fish and Wildlife Service, Fish Disease Leaflet 51. 11 pp.
- ALCORN, S. R., AND C. D. ZIEBELL. 1978. Limnological characteristics and fishery potential of man-made desert ponds. Journal of the Arizona-Nevada Academy of Science 13(1):29-32.
- ALDRICH, J. W., AND J. S. WESKE. 1978. Origin and evolution of the eastern house finch population. Auk 95(3):528-536.
- ALLEN, S. K., JR. 1978. Engineering sex in fish. Maine Fish and Wildlife 20(2):29.
- ALLEN, S. K., JR., AND J. G. STANLEY. 1978. Reproductive sterility in polyploid brook trout, *Salvelinus fontinalis*. Transactions of the American Fisheries Society 107(3):473-478.
- ANDERSON, D. R., K. P. BURNHAM, AND B. R. CRAIN. 1978. A log-linear model approach to estimation of population size using the line-transect sampling method. Ecology 59(1):190-193.
- ANDERSON, S. H., AND J. K. PARTELOW. 1978. Inland aquatic birds. Pages 113-120 in W. T. Mason, Jr., editor. Methods for the Assessment and Prediction of Mineral Mining Impacts on Aquatic Communities: A Review and Analysis, Workshop Proceedings. U.S. Fish and Wildlife Service, FWS/OBS-78/30. 157 pp.
- ANDERSON, W. L. 1978. Vocalizations of scaled quail. Condor 80(1):49-63.
- ANTHONY, R. G., G. R. BIEREI, AND R. KOZLOWSKI. 1978. Effects of municipal wastewater irrigation on select species of mammals. Pages 281-287 in H. L. McKim, coordinator. International Symposium. State of Knowledge on Land Treatment of Wastewater, Volume II. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. vi + 423 pp.
- ANTHONY, R. G., AND A. R. FISHER. 1977. Wildlife damage in orchards—a need for better management. Wildlife Society Bulletin 5(3):107-112.
- ANTHONY, R. G., AND N. S. SMITH. 1977. Ecological relationships between mule deer and white-tailed deer in southeastern Arizona. Ecological Monographs 47(3):255-277.
- ANTHONY, R. M., V. G. BARNES, JR., AND J. EVANS. 1978. "Vexar" plastic netting to reduce pocket gopher depredation of conifer seedlings. Proceedings of the Vertebrate Pest Conference (University of California, Davis) 8:138-144.
- APPLEGATE, R. L., AND W. L. KRUCKENBERG. 1978. First-year growth and food of largemouth bass in a South Dakota borrow pit stocked with fathead minnows. Progressive Fish-Culturist 40(1):7-8.
- ARNOLD, D. E., AND G. L. STORM, editors. 1977. Cooperative Research Units Fishery and Wildlife Annual Report 1975-76. U.S. Fish and Wildlife Service, Washington, D.C. 332 pp.
- ARTMANN, J. W. 1977. Woodcock status report, 1975. U.S. Fish and Wildlife Service, Special Scientific Report—Wildlife 201. 36 pp.
- ARTMANN, J. W. 1977. Woodcock status report, 1976. U.S. Fish and Wildlife Service, Special Scientific Report—Wildlife 209. 21 pp.
- AVERY, M. L., P. F. SPRINGER, AND N. S. DAILEY. 1978. Avian mortality at man-made structures: An annotated bibliography. U.S. Fish and Wildlife Service, FWS/OBS-78/58. 108 pp.
- AVERY, M. L., AND J. S. WESKE. 1978. Racial composition and differential migration of tower-killed

- Savannah sparrows in southeastern North Dakota. *Bird-banding* 49(2):182-184.
- AYALA, S. C., J. M. RAMAKKA, V. F. RAMAKKA, AND C. E. VARELA. 1977. Haemoproteus, plasmodium, and hippoboscoid ectoparasites of Colombian wild doves. *Revista do Instituto do Medicina Tropical de Sao Paulo* 19(6):411-416.
- BAER, C. H., R. E. SEVERSON, AND S. B. LINHART. 1978. Live capture of coyotes from a helicopter with ketamine hydrochloride. *Journal of Wildlife Management* 42(2):452-454.
- BANKS, R. C. 1978. Nomenclature of the black-bellied whistling-duck. *Auk* 95(2):348-352.
- BANKS, R. C. 1978. Prealternate molt in nuthatches. *Auk* 95(1):179-181.
- BANKS, R. C., AND J. BAIRD. 1978. A new hybrid warbler combination. *Wilson Bulletin* 90(1):143-144.
- BANKS, R. C., AND R. C. LAYBOURNE. 1977. Plumage sequence and taxonomy of Laysan and Nihoa finches. *Condor* 79(3):343-348.
- BARNES, V. G., JR. 1978. Survival and growth of ponderosa pine seedlings injured by pocket gophers. *Tree Planters' Notes* 29(2):20-23.
- BART, J. 1977. Impact of human visitations on avian nesting success. *Living Bird* 16:187-192.
- BART, J. 1977. Winter distribution of red-tailed hawks in central New York State. *Wilson Bulletin* 89(4):623-625.
- BARTOO, N. W. 1977. Proportions of a yellow perch population surfacing after a rotenone treatment. *Progressive Fish-Culturist* 39(1):27-28.
- BAYLEY, S., V. D. STOTTS, P. F. SPRINGER, AND J. STEENIS. 1978. Changes in submerged aquatic macrophyte populations at the head of Chesapeake Bay, 1958-1975. *Estuaries* 1(3):171-182.
- BEAN, J. R., AND R. E. WHITE. 1977. Unheated external column and inlet modification of a gas chromatograph for phosphine determinations. *Analytical Chemistry* 49(9):1468-1469.
- BEATTIE, K. H. 1977. Ghost of the heath hen. *Virginia Wildlife* 38(11):28-29.
- BEATTIE, K. H., R. H. GILES, JR., AND C. J. COWLES. 1977. Lack of research in wildlife law enforcement. *Wildlife Society Bulletin* 5(4):170-174.
- BEATTIE, K. H., AND T. A. PIERSON. 1978. Profile of the hunter! *Virginia Wildlife* 39(2):10-12, 21.
- BELLROSE, F. C., AND J. B. LOW. 1978. Advances in waterfowl management research. *Wildlife Society Bulletin* 6(2):63-72.
- BENGTSON, D. A., A. D. BECK, AND H. A. POSTON. 1978. Comparative effects of live and artificial diets on growth and survival of juvenile Atlantic silversides, *Menidia menidia*. *Proceedings of the Annual Meeting of the World Mariculture Society* 9(1978):159-173.
- BENNETT, D. E., AND R. S. WYDOSKI. 1977. Biology of the redbtail surfperch (*Amphistichus rhodoterus*) from the central Oregon coast. U.S. Fish and Wildlife Service, Technical Paper 90. 23 pp.
- BENNING, D. S., S. L. RHOADES, L. D. SCHROEDER, AND M. M. SMITH. 1978. Waterfowl status report, 1974. U.S. Fish and Wildlife Service, Special Scientific Report—Wildlife 211. 98 pp.
- BERRY, C. R., JR. 1978. The Co-ops at USU. *Edge* 1(1):19-21.
- BESSER, J. F. 1978. Improvements in the use of 4-aminopyridine for protecting agricultural crops from birds. *Proceedings of the Vertebrate Pest Conference (University of California, Davis)* 8:51-53.
- BESSER, J. F., AND W. K. PFEIFER. 1978. Improvement of baiting methods for protecting ripening sunflowers from blackbirds. *Proceedings of the Sunflower Forum* 2:11-12.
- BEST, L. B., K. L. VARLAND, AND R. B. DAHLGREN. 1978. Effects of stream channelization on land-use practices in Iowa. *Iowa State Journal of Research* 52(4):411-423.
- BJORNN, T. C. 1978. Survival, production, and yield of trout and chinook salmon in the Lemhi River, Idaho. Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow. *Bulletin* 27. 57 pp.
- BJORNN, T. C., R. R. RINGE, AND P. HIEBERT. 1978. Seaward migration of Dworshak Hatchery steelhead trout in 1976. College of Forestry, Wildlife and Range Sciences, University of Idaho Technical Report 6. iii + 45 pp.
- BOGAN, M. A. 1978. A new species of *Myotis* from the Islas Tres Marias, Nayarit, Mexico, with comments on variation in *Myotis nigricans*. *Journal of Mammalogy* 59(3):519-530.
- BOGAN, M. A., H. W. SETZER, J. S. FINDLEY, AND D. E. WILSON. 1978. Phenetics of *Myotis blythi* in Morocco. Pages 217-230 in R. J. Olembo, J. B. Castelino, and F. A. Mutere, editors. *Proceedings of the Fourth International Bat Research Conference*. Kenya National Academy for Advancement of Arts and Sciences. Nairobi. 328 pp.
- BOOKE, H. E., B. HOLLENDER, AND G. LUTTERBIE. 1978. Sodium bicarbonate, an inexpensive fish anesthetic for field use. *Progressive Fish-Culturist* 40(1):11-13.
- BRIDGES, B., AND H. L. KINCAID. 1978. Finding fish to fit a fishery. *Wyoming Wildlife* 42(5):24-27.
- BRITTON, P. L., AND G. B. RATHBUN. 1978. Two migratory thrushes and the African pitta in coastal Kenya. *Scopus* 2(1):11-17.
- BROOKS, R. P., AND W. E. DODGE. 1978. A night identification collar for beavers. *Journal of Wildlife Management* 42(2):448-452.
- BROWNIE, C., D. R. ANDERSON, K. P. BURNHAM, AND D. S. ROBSON. 1978. Statistical inference from band recovery data—a handbook. U.S. Fish and Wildlife Service, Resource Publication 131. 212 pp.
- BROWNING, M. R. 1977. Geographic variation in *Contopus sordidulus* and *C. virens* north of Mexico. *Great Basin Naturalist* 37(4):453-456.
- BROWNING, M. R. 1977. Geographic variation in dunlins, *Calidris alpina*, of North America. *Canadian Field-Naturalist* 91(4):391-393.

- BROWNING, M. R. 1977. The types and type-localities of *Oreortyx pictus* (Douglas) and *Ortyx plumiferus* Gould. Proceedings of the Biological Society of Washington 90(4):808-812.
- BROWNING, M. R. 1978. An evaluation of the new species and subspecies proposed in Oberholser's *Bird Life of Texas*. Proceedings of the Biological Society of Washington 91(1):85-122.
- BRYAN, C. F. 1977. A comparison of some water quality characteristics of Bayou Petite Prairie and City Park Lake. Pages 1-56-1-84 (Appendix I) in Lakes restoration project. City-Parish of Baton Rouge, Louisiana. Nuclear Science Department, Louisiana State University. 148 pp.
- BRYAN, C. F., AND D. J. DEMONT. 1977. Some limnological characteristics of Baton Rouge, Louisiana municipal lakes. Pages B-1-B-21 (Appendix B) in Lakes restoration project. City-Parish of Baton Rouge, Louisiana. Nuclear Science Department, Louisiana State University. 148 pp.
- BRYAN, C. F., AND D. S. SABINS. 1978. Management implications in water quality and fish standing stock information in the Atchafalaya River Basin, Louisiana. Proceedings of the Coastal Marsh and Estuary Management Symposium 3:293-316.
- BULKLEY, R. V. 1977. Variations in DDT concentration in muscle tissue of channel catfish, *Ictalurus punctatus*, from the Des Moines River, 1971. Pesticides Monitoring Journal 11(4):165-169.
- BULLARD, R. W., editor. 1978. Flavor chemistry of animal foods. American Chemical Society, Washington, D.C. viii + 175 pp.
- BULLARD, R. W., T. J. LEIKER, J. E. PETERSON, AND S. R. KILBURN. 1978. Volatile components of fermented egg, an animal attractant and repellent. Journal of Agricultural and Food Chemistry 26(1):155-159.
- BULLARD, R. W., S. A. SHUMAKE, D. L. CAMPBELL, AND F. J. TURKOWSKI. 1978. Preparation and evaluation of a synthetic fermented egg coyote attractant and deer repellent. Journal of Agricultural and Food Chemistry 26(1):160-163.
- BULLARD, R. W., R. D. THOMPSON, AND G. HOLGUIN. 1976. Diphenadione residues in tissues of cattle. Journal of Agricultural and Food Chemistry 24(2):261-263.
- BULLOCK, G. L. 1978. Pasteurellosis of fishes. U.S. Fish and Wildlife Service, Fish Disease Leaflet 54. 7 pp.
- BURGER, J., M. A. HOWE, D. C. HAHN, AND J. CHASE. 1977. Effects of tide cycles on habitat selection and habitat partitioning by migrating shorebirds. Auk 94(4):743-758.
- BURY, R. B., AND C. ERNST. 1977. *Clemmys* Ritgen. Marsh turtles. Catalogue of American Amphibians and Reptiles 203.1-203.2.
- BURY, R. B., AND R. A. LUCKENBACH. 1977. Censusing desert tortoise populations using a quadrat and grid location system. Pages 169-178 in M. Trotter, editor. The Desert Tortoise Council Proceedings of the 1977 Symposium. viii + 187 pp.
- BUTLER, R. L. 1978. Fish behavior observation techniques. Pages 104-107 in W. T. Mason, Jr., editor. Methods for the assessment and prediction of mineral mining impacts on aquatic communities: A review and analysis. Workshop proceedings. U.S. Fish and Wildlife Service, FWS/OBS-78/30. 157 pp.
- BYSTRAK, D. 1977. The Maryland Christmas counts of 1976. Maryland Birdlife 33(1):20-30.
- BYSTRAK, D., AND C. S. ROBBINS. 1977. Bird population trends detected by the North American breeding bird survey. Polish Ecological Studies 3(4):131-143.
- CAMPBELL, D., AND J. EVANS. 1978. Establishing selected native forbs to provide compatible deer use of Douglas-fir plantations. Annual Meeting of the Pacific Division, American Association for the Advancement of Science 59:21. (Abstract)
- CAMPBELL, D. L., AND J. EVANS. 1978. Establishing native forbs to reduce black-tailed deer browsing damage to Douglas-fir. Proceedings of the Vertebrate Pest Conference (University of California, Davis) 8:145-151.
- CAMPBELL, H. W., AND A. B. IRVINE. 1977. Feeding ecology of the West Indian manatee *Trichechus manatus* Linnaeus. Aquaculture 12:249-251.
- CAPEN, D. E. 1977. Evaluating the impact of pesticides on the white-faced ibis in Utah. Pages 196-201 in W. E. Southern, compiler. Proceedings of the 1977 Conference of the Colonial Waterbird Group. Northern Illinois University. 205 pp.
- CAPEN, D. E. 1978. Time-lapse photography and computer analysis of behavior of nesting white-faced ibises. Pages 41-43 in A. Sprunt IV, J. C. Ogden, and S. Winckler, editors. Wading birds. National Audubon Society, Research Report 7. ix + 381 pp.
- CARLINE, R. F. 1977. Production by three populations of wild brook trout with emphasis on influence of recruitment rates. U.S. National Marine Fisheries Service. Fishery Bulletin 75(4):751-765.
- CARLINE, R. F., AND O. M. BRYNILDSON. 1977. Effects of hydraulic dredging on the ecology of native trout populations in Wisconsin spring ponds. Wisconsin Department of Natural Resources, Technical Bulletin 98. 40 pp.
- CARNEY, S. M., M. F. SORENSEN, AND E. M. MARTIN. 1978. Duck stamps sold within states and counties during sales years 1966-67 through 1975-76. U.S. Fish and Wildlife Service, Special Scientific Report—Wildlife 210. 46 pp.
- CARPENTER, J. W. 1978. Propagation and management of endangered species at the Patuxent Wildlife Research Center. Proceedings of the Annual Meeting of the American Association of Zoo Veterinarians 1977:23-33.
- CARPENTER, J. W., AND M. N. NOVILLA. 1977. Diabetes mellitus in a black-footed ferret. Journal of the American Veterinary Medical Association 171(9):890-893.
- CLARK, D. R., JR., AND J. C. KROLL. 1977. Effects of DDE on experimentally poisoned free-tailed bats (*Tadarida brasiliensis*): lethal brain concentrations. Journal of Toxicology and Environmental Health 3(5-6):893-901.

- CLARK, D. R., JR., T. H. KUNZ, AND T. E. KAISER. 1978. Insecticides applied to a nursery colony of little brown bats (*Myotis lucifugus*): lethal concentrations in brain tissues. *Journal of Mammalogy* 59(1):84-91.
- CLARK, D. R., JR., R. K. LAVAL, AND D. M. SWINFORD. 1978. Dieldrin-induced mortality in an endangered species, the gray bat (*Myotis grisescens*). *Science* 199(4335):1357-1359.
- COLWELL, J. E., D. S. GILMER, E. A. WORK, D. L. REBEL, AND N. E. G. ROLLER. 1978. Use of Landsat data to assess waterfowl habitat quality. National Aeronautics and Space Administration and U.S. Fish and Wildlife Service. National Technical Information Service, E78-10120. 83 pp.
- COMBS, G. F., JR., AND H. A. POSTON. 1978. Species differences in sensitivity of digestive proteases to inhibitors. *Poultry Science* 57(4):1130. (Abstract)
- CONLEY, W., AND J. D. NICHOLS. 1978. The use of models in small mammal population studies. Pages 14-37 in D. P. Snyder, editor. *Populations of small mammals under natural conditions: Symposium Proceedings*. Pymatuning Laboratory of Ecology, University of Pittsburg, Special Publication Series, Volume 5. 237 pp.
- CONLEY, W., J. D. NICHOLS, AND A. R. TIPTON. 1977. Reproductive strategies in desert rodents. Pages 193-215 in R. H. Wauer and D. H. Riskind, editors. *Transactions of the Symposium on the Biological Resources of the Chihuahuan Desert Region, United States and Mexico*. 658 pp.
- CONNOLLY, G. E. 1977. The value of population dynamics models in coyote management. *Proceedings of the Annual Conference of the Western Association of State Game and Fish Commissioners* 57:93-103.
- CONNOLLY, G. E. 1978. Predator control and coyote populations: A review of simulation models. Pages 327-345 in M. Bekoff, editor. *Coyotes: Biology, Behavior, and Management*. Academic Press, New York. xx + 384 pp.
- CONNOLLY, G. E., R. E. GRIFFITHS, JR., AND P. J. SAVARIE. 1978. Toxic collar for control of sheep-killing coyotes: A progress report. *Proceedings of the Vertebrate Pest Conference (University of California, Davis)* 8:197-205.
- COON, R. A., J. S. LINDZEY, AND J. L. GEORGE. 1978. Nesting, fall migration, and harvest of American woodcock in Pennsylvania. *Pennsylvania State University Research Briefs* 11(1):3-6.
- COURET, C. L., JR., AND D. C. L. WONG. 1978. Larval development of *Halocaridina rubra* Holthuis (Decapoda, Atyidae). *Crustaceana* 34(3):301-309.
- COWLES, C. J. 1978. Nature's better mousetrap: The barn owl. *Virginia Wildlife* 39(3):4-5.
- CRASE, F. T., AND R. W. DEHAVEN. 1977. Food of nestling tricolored blackbirds. *Condor* 79(2):265-269.
- CURRIER, M. J. P., S. L. SHERIFF, AND K. R. RUSSELL. 1977. Mountain lion population and harvest near Canon City, Colorado, 1974-77. Colorado Division of Wildlife, Special Report 42. vi + 12 pp.
- CUSTER, T. W., AND R. G. OSBORN. 1978. Feeding site description of three heron species near Beaufort, North Carolina. Pages 355-360 in A. Sprunt IV, J. C. Ogden, and S. Winckler, editors. *Wading birds*. National Audubon Society, Research Report 7. ix + 381 pp.
- DAVIS, N., AND G. R. VANBLARICOM. 1978. Spatial and temporal heterogeneity in a sand bottom epifaunal community of invertebrates in shallow water. *Limnology and Oceanography* 23(3):417-427.
- DAWSON, V. K., P. D. HARMAN, D. P. SCHULTZ, AND J. L. ALLEN. 1978. Rapid method for determining concentrations of Bayer 73 in water during lampicide treatments. *Journal of the Fisheries Research Board of Canada* 35(9):1262-1265.
- DE GRAZIO, J. W. 1978. World bird damage problems. *Proceedings of the Vertebrate Pest Conference (University of California, Davis)* 8:9-24.
- DE GRAZIO, J. W., J. F. BESSER, J. L. GUARINO, AND C. P. STONE. 1977. [Blackbird damage to corn]. Page 131 in Supplement 2 of *Crop loss assessment methods*. Food and Agriculture Organization of the United Nations, Rome. xix + 136 pp.
- DELAHUNTY, G., C. B. SCHRECK, AND V. L. DEVLAMING. 1977. Effect of pinealectomy, reproductive state, feeding regime, and photoperiod on plasma cortisol in goldfish. *American Zoologist* 17(4):873. (Abstract)
- DIETER, M. P. 1977. Acute and chronic studies with waterfowl exposed to petroleum hydrocarbons. Pages 35-43 in C. Hall and W. Preston, compilers. *Program Review Proceedings of: Environmental Effects of Energy Related Activities on Marine/Estuarine Ecosystems*. U.S. Environmental Protection Agency. EPA-600/7-77-111. ii + 304 pp.
- DIETER, M. P., AND M. T. FINLEY. 1978. Erythrocyte  $\delta$ -aminolevulinic acid dehydratase activity in mallard ducks: Duration of inhibition after lead shot dosage. *Journal of Wildlife Management* 42(3):621-625.
- DIETER, M. P., AND J. L. LUDKE. 1978. Studies on combined effects of organophosphates or carbamates and molsodren in birds. II. Plasma and cholinesterase in quail fed molsodren and orally dosed with parathion or carbofuran. *Bulletin of Environmental Contamination and Toxicology* 19(4):389-395.
- DIETER, M. P., AND S. N. WIEMEYER. 1978. Six different plasma enzymes in bald eagles (*Haliaeetus leucocephalus*) and their usefulness in pathological diagnosis. *Comparative Biochemistry and Physiology* 61C(1):153-155.
- DOLBEER, R. A. 1978. Movement and migration patterns of red-winged blackbirds: A continental overview. *Bird-banding* 49(1):17-34.
- DOLBEER, R. A., P. P. WORONECKI, A. R. STICKLEY, JR., AND S. B. WHITE. 1978. Agricultural impact of a winter population of blackbirds and starlings. *Wilson Bulletin* 90(1):31-44.
- DOLTON, D. D., compiler. 1977. Mourning dove status report, 1976. U.S. Fish and Wildlife Service, Special Scientific Report—Wildlife 208. 27 pp.

- DOWNING, R. L., E. D. MICHAEL, AND R. J. POUX, JR. 1977. Accuracy of sex and age ratio counts of white-tailed deer. *Journal of Wildlife Management* 41(4):709-714.
- DREWIEN, R. C., AND E. G. BIZEAU. 1978. Cross-fostering whooping cranes to sandhill crane foster parents. Pages 201-222 in S. A. Temple, editor. *Endangered Birds: Management Techniques for Preserving Threatened Species*. University of Wisconsin Press, Madison. 466 pp.
- DROBNEY, R. D., AND R. D. SPARROWE. 1977. Land use relationships and movements of greater prairie chickens in Missouri. *Transactions of the Missouri Academy of Science* 10-11:146-160.
- DUEBBERT, H. F., AND J. T. LOKEMOEN. 1977. Upland nesting of American bitterns, marsh hawks, and short-eared owls. *Prairie Naturalist* 9(3/4):33-40.
- DUNCAN, T. O. 1978. Collection bucket for use with tow nets for larval fish. *Progressive Fish-Culturist* 40(3):118-119.
- DUNCAN, T. O. 1978. Nonmetallic electrofishing booms and accessory tackle. *Progressive Fish-Culturist* 40(3):98-100.
- DUPREE, H. K. 1977. Vitamin requirements. Pages 26-29 in R. R. Stickney and R. T. Lovell, editors. *Nutrition and feeding of channel catfish*. Alabama Agricultural Experiment Station, Auburn University. Southern Cooperative Series, Bulletin 218. 66 pp.
- DUPREE, H. K. 1978. You asked for it! Late winter planning increases the efficiency of labor scarce fish producer. *Commercial Fish Farmer and Aquaculture News* 4(3):42-43.
- DUSENBERRY, W. E., AND K. O. BOWMAN. 1977. The moment estimator for the shape parameter of the gamma distribution. *Communications in Statistics—Simulation and Computation* B6(1):1-19.
- DWYER, W. P., F. L. MAYER, J. L. ALLEN, AND D. R. BUCKLER. 1978. Chronic and simulated use-pattern exposures of brook trout (*Salvelinus fontinalis*) to 3-trifluoromethyl-4-nitrophenol (TFM). U.S. Fish and Wildlife Service, Investigations in Fish Control 84. 6 pp.
- EDWARDS, C. J. 1978. Algal infections of fish tissue: A recent record and review. *Journal of Fish Diseases* 1(2):175-179.
- ELDER, W. H., AND W. J. GUNIER. 1978. Sex ratios and seasonal movements of gray bats (*Myotis grisescens*) in southwestern Missouri and adjacent states. *American Midland Naturalist* 99(2):463-472.
- ELFVING, D. C., W. M. HASCHEK, R. A. STEHN, C. A. BACHE, AND D. J. LISK. 1978. Heavy metal residues in plants cultivated on and in small mammals indigenous to old orchard soils. *Archives of Environmental Health* 33(2):95-99.
- ELIAS, D. J., R. D. THOMPSON, AND P. J. SAVARIE. 1978. Effects of the anticoagulant diphenadione on suckling calves. *Bulletin of Environmental Contamination and Toxicology* 20(1):71-78.
- ELLIS, D. H., S. J. DOBROTT, AND J. G. GOODWIN, JR. 1978. Reintroduction techniques for masked bobwhites. Pages 345-354 in S. A. Temple, editor. *Endangered Birds: Management Techniques for Preserving Threatened Species*. University of Wisconsin Press, Madison. 466 pp.
- ELLIS, D. H., J. G. GOODWIN, JR., AND J. R. HUNT. 1978. Wildlife and electric power transmission. Pages 81-104 in J. L. Fletcher and R. G. Busnel, editors. *Effects of Noise on Wildlife*. Academic Press, New York. x + 305 pp.
- ELLIS, R. W. 1977. Checking in at Maggie Valley. *Virginia Wildlife* 38(11):4-5.
- EMMERICH, J. M., AND P. A. VOHS. 1978. Woodland habitat utilization by birds in eastern South Dakota. Proceedings of the Annual Meeting of the Forestry Committee, Great Plains Agricultural Council 30:90-91. (Abstract)
- ERNST, C. H., AND R. B. BURY. 1977. *Clemmys muhlenbergii* (Schoeppf). Bog turtle. Catalogue of American Amphibians and Reptiles 204.1-204.2.
- ERWIN, R. M. 1978. Coloniality in terns: The role of social feeding. *Condor* 80(2):211-215.
- ESTES, J. A. 1977. Population estimates and feeding behavior of sea otters. Pages 511-526 in M. L. Merritt and R. G. Fuller, editors. *The environment of Amchitka Island, Alaska*. U.S. Energy Research and Development Administration, Springfield, Virginia. TID-26712. xii + 682 pp.
- ESTES, J. A., AND J. R. GILBERT. 1978. Evaluation of an aerial survey of Pacific walrus (*Odobenus rosmarus divergens*). *Journal of the Fisheries Research Board of Canada* 35(8):1130-1140.
- EVANS, J. 1976. Wildlife damage and western hemlock management in the Pacific Northwest. Pages 148-154 in J. Murphy, editor. Proceedings of the Western Hemlock Management Conference, University of Washington, Seattle. 317 pp.
- FENDER, D. C., AND D. F. AMEND. 1978. Hyperosmotic infiltration: Factors influencing uptake of bovine serum albumin by rainbow trout (*Salmo gairdneri*). *Journal of the Fisheries Research Board of Canada* 35(6):871-874.
- FERGIN, T. J., AND E. C. SCHAFER. 1977. Toxicity of dieldrin to bobwhite quail in relation to sex and reproductive status. *Archives of Environmental Contamination and Toxicology* 6(2/3):213-219.
- FERRIS, C. R., D. S. PALMAN, AND V. B. RICHENS. 1977. Ecological impact of Interstate 95 on birds and mammals in northern Maine. Maine Department of Transportation, Materials and Research Division. Technical Paper 77-12. 122 pp.
- FINLEY, M. T., AND M. P. DIETER. 1978. Influence of laying on lead accumulation in bone of mallard ducks. *Journal of Toxicology and Environmental Health* 4(1):123-129.
- FINLEY, M. T., AND M. P. DIETER. 1978. Toxicity of experimental lead-iron shot versus commercial lead shot in mallards. *Journal of Wildlife Management* 42(1):32-39.
- FINLEY, M. T., AND R. C. STENDELL. 1978. Survival and reproductive success of black ducks fed methyl mercury. *Environmental Pollution* 16(1):51-64.



- FINLEY, R. B., JR. 1978. Review of *Wild Mammals of New England* by A. J. Godin. Johns Hopkins University Press, Baltimore, Maryland. 1977. 304 pp. *Journal of Range Management* 31(4):319.
- FISHER, R. D., AND M. A. BOGAN. 1977. Distributional notes on *Noctiosorex* and *Megasorex* in western Mexico. *Proceedings of the Biological Society of Washington* 90(4):826-828.
- FLEMING, D. M., A. W. PALMISANO, AND T. JOANEN. 1978. Food habits of coastal marsh raccoons with observations of alligator nest predation. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):348-357.
- FLEMING, W. J., AND D. W. SPEAKE. 1978. Losses of the eastern wild turkey from a stable Alabama population. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):377-385.
- FLOYD, T. J., L. D. MECH, AND P. A. JORDAN. 1978. Relating wolf scat content to prey consumed. *Journal of Wildlife Management* 42(3):528-532.
- FOGL, J. G., AND H. S. MOSBY. 1978. Aging gray squirrels by cementum annuli in razor-sectioned teeth. *Journal of Wildlife Management* 42(2):444-448.
- FOLMAR, L. C. 1978. Avoidance chamber responses of mayfly nymphs exposed to eight herbicides. *Bulletin of Environmental Contamination and Toxicology* 19(3):312-318.
- FOX, J. L. 1978. Summer mountain goat activity and habitat preference in coastal Alaska as a basis for the assessment of survey techniques. Pages 190-199 in W. M. Samuel and W. G. Macgregor, editors. *Proceedings of the First International Mountain Goat Symposium*. iii + 243 pp.
- FRAME, D. W., T. J. ANDREWS, AND C. F. COLE. 1978. Osteology of the American plaice, *Hippoglossoides platessoides*. Peabody Museum of Natural History, Yale University. Postilla 173. 32 pp.
- FRANZMANN, A. W., R. E. LERESCHE, R. A. RAUSCH, AND J. L. OLDEMEYER. 1978. Alaskan moose measurements and weights and measurement-weight relationships. *Canadian Journal of Zoology* 56(2):298-306.
- FRANZMANN, A. W., J. L. OLDEMEYER, AND A. FLYNN. 1975. Minerals and moose. *Proceedings of the North American Moose Conference and Workshop* 11:114-140.
- FREDERICKSON, R. C. A., I. H. SLATER, W. E. DUSENBERRY, C. R. HEWES, G. T. JONES, AND R. A. MOORE. 1977. A comparison of thalidomide and pentobarbital—new methods for identifying novel hypnotic drugs. *Journal of Pharmacology and Experimental Therapeutics* 203(1):240-251.
- FREDERICKSON, L. F., R. L. LINDER, R. B. DAHLGREN, AND C. G. TRAUTMANN. 1978. Pheasant reproduction and survival as related to agricultural fertilizer use. *Journal of Wildlife Management* 42(1):40-45.
- FREDRICKSON, L. H., T. S. BASKETT, G. K. BRAKHAGE, AND V. C. CRAVENS. 1977. Evaluating cultivation near duck blinds to reduce lead poisoning hazard. *Journal of Wildlife Management* 41(4):624-631.
- FRIEND, M. [1978]. Diseases of Wildlife: Problems in diagnosis and control. *Proceedings of the Annual Meeting of the American Association of Veterinary Laboratory Diagnosticians* 20(1977):83-92.
- FRIEND, M., chairman. 1978. Working group: Research priorities. Pages 120-126 in M. L. Avery, editor. *Impacts of transmission lines on birds in flight*. U.S. Fish and Wildlife Service, FWS/OBS-78/48. 151 pp.
- FRITZELL, E. K. 1978. Aspects of raccoon (*Procyon lotor*) social organization. *Canadian Journal of Zoology* 56(2):260-271.
- FRITZELL, E. K. 1978. Habitat use by prairie raccoons during the waterfowl breeding season. *Journal of Wildlife Management* 42(1):118-127.
- FROUNFELKER, C. R. 1978. Experimental recovery of small mammal ear tags in horned owl pellets. *Journal of Wildlife Management* 42(2):459-461.
- GARDNER, A. L. 1977. Review of *Mammals of the Yukon Territory* by P. M. Youngman. National Museum of Natural Sciences, National Museums of Canada, Publications in Zoology 10. 1975. 192 pp. *Journal of Mammalogy* 58(4):698-699.
- GARNER, G. W., J. A. MORRISON, AND J. C. LEWIS. 1978. Mortality of white-tailed deer fawns in the Wichita Mountains, Oklahoma. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):493-506.
- GARRISON, M. V., R. L. REID, P. FAWLEY, AND C. P. BREIDENSTEIN. 1978. Comparative digestibility of acid detergent fiber by laboratory albino and wild Polynesian rats. *Journal of Nutrition* 108(2):191-195.
- GILBERT, R. J. 1978. Status of the spotted bass (*Micropterus punctulatus*) (Centrarchidae) in the eastern United States. *Bulletin of the Association of Southeastern Biologists* 25(2):57. (Abstract.)
- GILMER, D. S., I. J. BALL, L. M. COWARDIN, J. E. MATHISEN, AND J. H. RIECHMANN. 1978. Natural cavities used by wood ducks in north-central Minnesota. *Journal of Wildlife Management* 42(2):288-298.
- GILMER, D. S., R. E. KIRBY, I. J. BALL, AND J. H. RIECHMANN. 1977. Post-breeding activities of mallards and wood ducks in north-central Minnesota. *Journal of Wildlife Management* 41(3):345-359.
- GIPSON, P. S. 1978. Coyotes and related *Canis* in the southeastern United States with a comment on Mexican and Central American *Canis*. Pages 191-208 in M. Bekoff, editor. *Coyotes: Biology, Behavior, and Management*. Academic Press, New York. xx + 384 pp.
- GIPSON, P. S., AND J. A. SEALANDER. 1977. Ecological relationships of white-tailed deer and dogs in Arkansas. Pages 3-16 in R. L. Phillips and C. Jonkel, editors. *Proceedings of the 1975 Predator Symposium*. Montana Forest and Conservation Experiment Station, University of Montana, Missoula. 268 pp.

- GIUDICE, J. 1977. Overwintering feed program important: Warmwater fish need proper nutrition in cold months. *Commercial Fish Farmer and Aquaculture News* 4(1):13-14.
- GIUDICE, J. 1978. Proper construction of fish ponds is one key to profitable operations. *Commercial Fish Farmer and Aquaculture News* 4(2):25-27.
- GIUDICE, J. 1978. You asked for it! Many factors are the keys to success in fish farming. *Commercial Fish Farmer and Aquaculture News* 4(4):34.
- GODFREY, P. J. 1978. Diversity as a measure of benthic macroinvertebrate community response to water pollution. *Hydrobiologia* 57(2):111-122.
- GOULD, R. W., P. J. O'LEARY, R. L. GARRISON, J. S. ROHOVEC, AND J. L. FRYER. 1978. Spray vaccination: A method for the immunization of fish. *Fish Pathology* 13(1):63-68.
- GRANETT, J., S. MORANG, AND R. HATCH. 1978. Reduced movement of precocious male Atlantic salmon parr into sublethal Dimilin-G1 and carrier concentrations. *Bulletin of Environmental Contamination and Toxicology* 19(4):462-464.
- GREENWOOD, R. J. 1977. Evaluation of a nasal marker for ducks. *Journal of Wildlife Management* 41(3):582-585.
- GREGG, L. E., AND J. B. HALE. 1977. Woodcock nesting habitat in northern Wisconsin. *Auk* 94(3):489-493.
- GRIFFIN, B. R. 1978. Review of *Fluorescent Protein Tracing*, 4th (1976) edition. R. C. Nairn, editor. Churchill Livingstone, Edinburgh. 648 pp. *Journal of Fish Diseases* 1(3):279-280.
- GRIFFIN, B. R., AND E. M. DAVIS. 1978. *Myxosoma cerebralis*: detection of circulating antibodies in infected rainbow trout (*Salmo gairdneri*). *Journal of the Fisheries Research Board of Canada* 35(9):1186-1190.
- GRIFFIN, C. R., AND P. T. REDIG. 1978. Successful rehabilitation and reintroduction of bald eagles. *Wildlife Society Bulletin* 6(1):44-45.
- GRIFFITHS, R. E., JR., G. E. CONNOLLY, R. J. BURNS, AND R. T. STERNER. 1978. Coyotes, sheep and lithium chloride. *Proceedings of the Vertebrate Pest Conference* (University of California, Davis) 8:190-196.
- GRUE, C. E., R. R. REID, AND N. J. SILVY. 1978. A technique for evaluating the breeding habitat of mourning doves using call-count transects. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):667-673.
- GRUE, C. E., AND N. J. SILVY. 1977. Mourning dove breeding habitat in Texas—final report. Texas Agricultural Experiment Station and Department of Wildlife and Fisheries Sciences. Texas A. and M. University, College Station. 101 pp.
- HAAS, G. H. 1977. Unretrieved shooting loss of mourning doves in north-central South Carolina. *Wildlife Society Bulletin* 5(3):123-125.
- HALL, D. I., AND J. D. NEWSOM. 1978. The coyote in Louisiana. *Louisiana Agriculture* 21(4):4-5.
- HALL, H. T., AND J. D. NEWSOM. 1978. Summer home ranges and movements of bobcats in bottomland hardwoods of Southern Louisiana. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):427-436.
- HANSON, L. H., AND P. J. MANION. 1978. Chemosterilization of the sea lamprey (*Petromyzon marinus*). Great Lakes Fishery Commission, Technical Report 29. 15 pp.
- HARRINGTON, F. H., AND L. D. MECH. Wolf vocalization. 1978. Pages 109-132 in R. L. Hall and H. S. Sharp, editors. *Wolf and Man: Evolution in Parallel*. Academic Press, New York. xiv + 210 pp.
- HAYNE, D. W., AND P. H. GEISSLER. 1977. Hunted segments of the mourning dove population movement and importance. *Southeastern Association of Game and Fish Agencies, Technical Bulletin* 3. 152 pp.
- HEBERGER, R. F., AND J. B. REYNOLDS. 1977. Abundance, composition, and distribution of crustacean zooplankton in relation to hypolimnetic oxygen depletion in west-central Lake Erie. U.S. Fish and Wildlife Service, Technical Paper 93. 17 pp.
- HEINZ, G. H., AND M. T. FINLEY. 1978. Toxaphene does not affect avoidance behavior of young black ducks. *Journal of Wildlife Management* 42(2):408-409.
- HENNY, C. J., D. W. ANDERSON, AND C. E. KNOEDER. 1978. Bald eagles nesting in Baja California. *Auk* 95(2):424.
- HENNY, C. J., J. A. COLLINS, AND W. J. DEIBERT. 1978. Osprey distribution, abundance, and status in western North America: II. The Oregon population. *Murrelet* 59(1):14-25.
- HENNY, C. J., D. J. DUNAWAY, R. D. MALLETT, AND J. R. KOPLIN. 1978. Osprey distribution, abundance, and status in western North America: I. The northern California population. *Northwest Science* 52(3):261-271.
- HENNY, C. J., AND J. E. KURTZ. 1978. Great blue herons respond to nesting habitat loss. *Wildlife Society Bulletin* 6(1):35-37.
- HERKE, W. H. 1977. Dangers of mariculture in wetlands are further documented by Herke. *National Fisherman* 58(8):34-A.
- HERKE, W. H. 1977. More on mariculture. *Fisheries* 2(6):46-47.
- HERKE, W. H. 1978. Is coastal aquaculture in the public interest? *Marine Policy* 2(1):78-79.
- HERKE, W. H. 1978. A subsampler for estimating the number and length frequency of small, preserved nektonic organisms. U.S. National Marine Fisheries Services, *Fishery Bulletin* 76(2):490-494.
- HERMAN, C. M., S. S. DESSER, G. F. BENNETT, AND I. B. TARSHIS. 1977. Avian haematozoa. 3. Color atlas of *Leucocytozoon simondi* Mathis and Leger 1910. *Wildlife Disease* 70. 58 pp.
- HEUER, E. T., JR., AND H. R. PERRY, JR. 1978. Squirrel and rabbit abundances in the Atchafalaya Basin, Louisiana. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):552-559.

- HIAASEN, B., R. STEHN, J. BART, AND M. RICHMOND. 1978. A bibliography of the genus *Pitymys* (Rodentia, Mammalia) and homonyms *Microtus pinetorum* and *Microtus subterraneus*. Natural Resources Research and Extension Series 10, Cornell University. 43 pp.
- HIGGINS, K. F., AND M. A. JOHNSON. 1978. Avian mortality caused by a September wind and hail storm. *Prairie Naturalist* 10(2):43-48.
- HIGGINS, K. F., L. M. KIRSCH, H. F. DUEBBERT, A. T. KLETT, J. T. LOKEMOEN, H. W. MILLER, AND A. D. KRUSE. 1977. Construction and operation of cable-chain drag for nest searches. U.S. Fish and Wildlife Service, Wildlife Leaflet 512. 14 pp.
- HILL, E. F., J. W. SPANN, AND J. D. WILLIAMS. 1977. Responsiveness of 6 to 14 generations of birds to dietary dieldrin toxicity. *Toxicology and Applied Pharmacology* 42(2):425-431.
- HILL, E. P., D. N. LASHER, AND R. B. ROPER. 1977. A review of techniques for minimizing beaver and white-tailed deer damage in southern hardwoods. Symposium on Southeastern Hardwoods. U.S. Forest Service and Alabama Forestry Commission 2:79-93.
- HIRATA, D. N. 1977. Species composition of rats on Mauna Kea Sugar Company from 1967 through 1976. Hawaiian Sugar Technologists 1977 Report 36:91-94.
- HOFFMAN, D. J. 1978. Embryotoxic effects of petroleum hydrocarbons in avian embryos. *Teratology* 17(2):40A. (Abstract)
- HOFFMAN, G. L. 1978. Ciliates of freshwater fishes. Pages 583-632 in J. P. Kreier, editor. *Parasitic Protozoa*, Volume II. Academic Press, New York. 730 pp.
- HOFFMAN, G. L., AND A. J. MITCHELL. 1977. Diagnostic services available. *Commercial Fish Farmer and Aquaculture News* 4(1):33-37.
- HOFFMAN, G. L., AND A. J. MITCHELL. 1978. Fish disease diagnosis and control: When to ask for help . . . and how to go about it. *Commercial Fish Farmer and Aquaculture News* 4(4):20-23.
- HOFFMAN, R. D. 1978. The diets of herons and egrets in southwestern Lake Erie. Pages 365-369 in A. Sprunt IV, J. C. Ogden, and S. Winckler, editors. *Wading birds*. National Audubon Society, Research Report 7. ix + 381 pp.
- HOFFMAN, W., J. A. WIENS, AND J. M. SCOTT. 1978. Hybridization between gulls (*Larus glaucescens* and *L. occidentalis*) in the Pacific northwest. *Auk* 95(3):441-458.
- HOLDERMANN, D. A., AND J. S. LINDZEY. 1978. Rabbits in the brush. *Pennsylvania State University, Science in Agriculture* 25(2):12.
- HOOD, G. A. 1978. Vertebrate control chemicals: Current status of registrations, rebuttable presumptions against registrations, and effects on users. *Proceedings of the Vertebrate Pest Conference (University of California, Davis)* 8:170-176.
- HOPPER, R. M., H. D. FUNK, AND D. R. ANDERSON. 1978. Age specificity in mallards banded postseason in eastern Colorado. *Journal of Wildlife Management* 42(2):263-270.
- HOUF, L. J., AND R. S. CAMPBELL. 1977. Effects of antimycin A and rotenone on macrobenthos in ponds. U.S. Fish and Wildlife Service, Investigations in Fish Control 80. 29 pp.
- HOWE, M. A., R. B. CLAPP, AND J. S. WESKE. 1978. Marine and coastal birds. New York Sea Grant Institute, Albany. *Marine Ecosystems Analysis (MESA) New York Bight Atlas Monograph* 31. 87 pp.
- HOWE, M. A., R. C. LAYBOURNE, AND F. C. JAMES. 1977. Morphological variation in breeding red-winged blackbirds, *Agelaius phoeniceus*, in Florida. *Florida Scientist* 40(3):273-280.
- HSU, T. C., A. MARKVONG, AND J. T. MARSHALL. 1978. G-band patterns of six species of mice belonging to subgenus *Mus*. *Cytogenetics and Cell Genetics* 20(1-6):304-307.
- HUCKINS, J. N., D. L. STALLING, AND W. A. SMITH. 1978. Foam-charcoal chromatography for analysis of polychlorinated dibenzodioxins in Herbicide Orange. *Journal of the Association of Official Analytical Chemists* 61(1):32-38.
- HUGIE, R. D. 1977. How to bug a bear. *Maine Fish and Wildlife* 19(4):6-9.
- HUGIE, R. D. 1977. A new plan for managing Baxter's bears. *Maine Fish and Wildlife* 19(3):16-17.
- HUGIE, R. D. 1977. Use of chemical restraints in handling wildlife. *Parks* 2(3):19-22.
- HUISH, M. T., AND C. BENEDICT. 1977. Sonic tracking of dusky sharks in the Cape Fear River, North Carolina. *Journal of the Elisha Mitchell Scientific Society* 93(1):21-26.
- IRVINE, A. B., AND H. W. CAMPBELL. 1978. Aerial census of the West Indian manatee, *Trichechus manatus*, in the southeastern United States. *Journal of Mammalogy* 59(3):613-617.
- JACOBI, G. Z., AND D. J. DEGAN. 1977. Aquatic macro-invertebrates in a small Wisconsin trout stream before, during, and two years after treatment with the fish toxicant antimycin. U.S. Fish and Wildlife Service, Investigations in Fish Control 81. 24 pp.
- JACOBSON, E., J. W. CARPENTER, AND M. NOVILLA. 1977. Suspected lead toxicosis in a bald eagle. *Journal of the American Veterinary Medical Association* 171(9):952-954.
- JACOBSON, H. A., R. L. KIRKPATRICK, H. E. BURKHART, AND J. W. DAVIS. 1978. Hematologic comparisons of shot and live trapped cottontail rabbits. *Journal of Wildlife Diseases* 14(1):82-88.
- JACOBSON, H. A., R. L. KIRKPATRICK, AND B. S. MCGINNES. 1978. Disease and physiologic characteristics of two cottontail populations in Virginia. *Wildlife Monographs* 60. 53 pp.
- JACOBSON, H. A., B. S. MCGINNES, AND E. P. CATTS. 1978. Bot fly myiasis of the cottontail rabbit, *Sylvilagus floridanus mallurus* in Virginia with some biology of the parasite, *Cuterebra buccata*. *Journal of Wildlife Diseases* 14(1):56-66.

- JAMESON, R. J., AND K. W. KENYON. 1977. Prey of sea lions in the Rogue River, Oregon. *Journal of Mammalogy* 58(4):672.
- JENKINS, M. A. 1978. Gyrfalcon nesting behavior from hatching to fledging. *Auk* 95(1):122-127.
- JENKINS, R. M., AND D. I. MORAIS. 1978. Prey-predator relations in the predator-stocking-evaluation reservoirs. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30(1976):141-157.
- JENNI, D. A., AND J. E. HARTZLER. 1978. Attendance at a sage grouse lek: Implications for spring censuses. *Journal of Wildlife Management* 42(1):46-52.
- JENSEN, G. L., W. L. SHELTON, AND L. O. WILKEN. 1978. Use of methyltestosterone silastic implants to control sex in grass carp. Pages 200-219 in R. O. Smitherman, W. L. Shelton, and J. H. Grover, editors. *Culture of Exotic Fishes, Symposium Proceedings*. Fish Culture Section, American Fisheries Society. Department of Fisheries and Allied Aquacultures, Auburn University. vi + 257 pp.
- JOHNSON, D. H. 1977. Some Bayesian statistical techniques useful in estimating frequency and density. U.S. Fish and Wildlife Service, Special Scientific Report—Wildlife 203. 10 pp.
- JOHNSON, D. H., AND A. B. SARGEANT. 1977. Impact of red fox predation on the sex ratio of prairie mallards. U.S. Fish and Wildlife Service, Wildlife Research Report 6. 56 pp.
- JORDE, D. G., G. L. KRAPU, AND R. K. GREEN. 1977. Yellow-crowned night herons sighted in North Dakota. *Prairie Naturalist* 9(2):31-32.
- JUDD, S. L., AND R. R. KNIGHT. 1977. Determination and analysis of grizzly bear movement patterns using biotelemetry. Pages 93-100 in F. Long, editor. *Proceedings of the First International Conference on Wildlife Biotelemetry*, University of Wyoming. 159 pp.
- JULIN, A. M., AND H. O. SANDERS. 1978. Toxicity of the IGR, diflubenzuron, to freshwater invertebrates and fishes. *Mosquito News* 38(2):256-259.
- JUNE, F. C. 1977. Reproductive patterns in seventeen species of warmwater fishes in a Missouri River reservoir. *Environmental Biology of Fishes* 2(3):285-296.
- KALLEMEYN, L. W., AND J. F. NOVOTNY. 1977. Fish and fish food organisms in various habitats of the Missouri River in South Dakota, Nebraska, and Iowa. U.S. Fish and Wildlife Service, FWS/OBS-77/25. ix + 100 pp.
- KAO, Y. J., AND T. M. FARLEY. 1978. Thermal modulation of pyruvate substrate inhibition in the B<sub>1</sub>' and B<sub>2</sub>' liver lactate dehydrogenases of rainbow trout, *Salmo gairdneri*. *Comparative Biochemistry and Physiology* 60B(2):153-155.
- KASTER, J. L., AND G. Z. JACOBI. 1978. Benthic macroinvertebrates of a fluctuating reservoir. *Freshwater Biology* 8(3):283-290.
- KEMPINGER, J. J., AND R. F. CARLINE. 1977. Dynamics of the walleye (*Stizostedion vitreum vitreum*) population in Escanaba Lake, Wisconsin, 1955-72. *Journal of the Fisheries Research Board of Canada* 34(10):1800-1811.
- KEMPINGER, J. J., AND R. F. CARLINE. 1978. Changes in population density, growth, and harvest of northern pike in Escanaba Lake after implementation of a 22-inch size limit. Wisconsin Department of Natural Resources, Technical Bulletin 104. 15 pp.
- KENNELLY, J. J. 1978. Coyote reproduction. Pages 73-93 in M. Bekoff, editor. *Coyotes: Biology, Behavior, and Management*. Academic Press, New York. xx + 384 pp.
- KENNELLY, J. J., B. E. JOHNS, C. P. BREIDENSTEIN, AND J. D. ROBERTS. 1977. Predicting female coyote breeding dates from fetal measurements. *Journal of Wildlife Management* 41(4):746-750.
- KEPLER, C. B. 1978. The breeding ecology of sea birds on Monito Island, Puerto Rico. *Condor* 80(1):72-87.
- KEPLER, C. B. 1978. Captive propagation of whooping cranes: A behavioral approach. Pages 231-242 in S. A. Temple, editor. *Endangered Birds: Management Techniques for Threatened Species*. University of Wisconsin Press, Madison. 466 pp.
- KEPLER, C. B., AND A. K. KEPLER. 1977. The sea birds of Culebra and its adjacent islands, Puerto Rico. *Living Bird* 16:21-50.
- KEPLER, C. B., AND A. K. KEPLER. 1978. Status and nesting of the yellow-billed cuckoo in Puerto Rico. *Auk* 95(2):417-419.
- KERBY, J. H. 1978. Device for preparing improved chromosome squashes. *Progressive Fish-Culturist* 40(3):120.
- KETOLA, H. G. 1978. Dietary zinc prevents cataract in trout. *Federation Proceedings* 37(3):584. (Abstract)
- KINCAID, H. L. 1977. Rotational line crossing: An approach to the reduction of inbreeding accumulation in trout brood stocks. *Progressive Fish-Culturist* 39(4):179-181.
- KINCAID, H. L., W. R. BRIDGES, AND B. VON LIMBACH. 1977. Three generations of selection for growth rate in fall-spawning rainbow trout. *Transactions of the American Fisheries Society* 106(6):621-628.
- KING, K. A. 1978. Colonial wading bird survey and census techniques. Pages 155-159 in A. Sprunt IV, J. C. Ogden, and S. Winckler, editors. *Wading birds*. National Audubon Society, Research Report 7. ix + 381 pp.
- KING, K. A., E. L. FLICKINGER, AND H. H. HILDEBRAND. 1978. Shell thinning and pesticide residues in Texas aquatic bird eggs, 1970. *Pesticides Monitoring Journal* 12(1):16-21.
- KING, K. A., J. O. KEITH, C. A. MITCHELL, AND J. E. KEIRANS. 1977. Ticks as a factor in nest desertion of California brown pelicans. *Condor* 79(4):507-509.
- KING, W. B., J. A. JACKSON, H. W. KALE II, H. F. MAYFIELD, R. L. PLUNKETT, JR., J. M. SCOTT, P. F. SPRINGER, S. A. TEMPLE, AND S. R. WILBUR. 1977. The recovery team-recovery plan approach to conservation of endangered species: A status summary and appraisal. Report of the Committee on Conservation 1976-77. *Auk* 94(4, Supplement):3DD-19DD.

- KIRBY, R. E., AND M. R. FULLER. 1978. Observations and reinterpretation of kingfisher-raptor interactions. *Auk* 95(3):598-599.
- KLAAS, E. E., S. N. WIEMEYER, H. M. OHLENDORF, AND D. M. SWINEFORD. 1978. Organochlorine residues, eggshell thickness, and nest success in barn owls from the Chesapeake Bay. *Estuaries* 1(1):46-53.
- KLEIN, D. R. 1977. Winter food preferences of snowshoe hares (*Lepus americanus*) in interior Alaska. *Proceedings of the International Congress of Game Biologists* 13:266-275.
- KLEIN, D. R., J. HEMMING, L. MAYO, D. KEYES, AND F. THERRELL. 1976. Environmental sciences and surveillance on the Alaskan oil line: Good or bad precedents. *Proceedings of the Alaska Science Conference, Resource Development-Processes and Problems* 27:61-82.
- KLIMKIEWICZ, M. K., AND C. S. ROBBINS. 1978. Standard abbreviations for common names of birds. *North American Bird Bander* 3(1):16-25.
- KNOPE, F. L., AND V. C. BACHMAN. 1977. Birds of Gunnison and Cub islands, Great Salt Lake, Utah. *Great Basin Naturalist* 37(2):247-251.
- KNUDSEN, E. E., AND W. H. HERKE. 1978. Growth rate of marked juvenile Atlantic croakers, *Micropogon undulatus*, and length of stay in a coastal marsh nursery in southwest Louisiana. *Transactions of the American Fisheries Society* 107(1):12-20.
- KOLZ, A. L., J. W. LENTFER, AND H. G. FALLEK. 1978. Polar bear tracking via satellite. *Proceedings of the Rocky Mountain Bioengineering Symposium and International ISA Biomedical Sciences Instrumentation Symposium* 15(1978):137-144.
- KOLZ, A. L., L. J. ROOP, AND K. R. GREER. 1978. Death of a radio-marked grizzly. *Journal of Wildlife Management* 42(2):462.
- KOONCE, J. F., T. B. BAGENAL, R. F. CARLINE, K. E. F. HOKANSON, AND M. NAGIEC. 1977. Factors influencing year-class strength of percids: A summary and a model of temperature effects. *Journal of the Fisheries Research Board of Canada* 34(10):1900-1909.
- KORTE, P. A., AND L. H. FREDRICKSON. 1977. Loss of Missouri's lowland hardwood ecosystem. *Transactions of the North American Wildlife and Natural Resources Conference* 42:31-41.
- KORTE, P. A., AND L. H. FREDRICKSON. 1977. Swamp rabbit distribution in Missouri. *Transactions of the Missouri Academy of Science* 10-11:72-77.
- KRAMER, R. 1978. Lakeshore development. *South Dakota Conservation Digest* 45(3):24-25.
- KRAPU, G. L. 1978. Productivity of red-winged blackbirds in prairie pothole habitat. *Iowa Bird Life* 48(1):24-30.
- KRAPU, G. L., AND R. K. GREEN. 1978. Breeding bird populations of selected semipermanent wetlands in south-central North Dakota—1977. *American Birds* 32(1):110-112.
- KRAPU, G. L., AND G. A. SWANSON. 1977. Foods of juvenile, brood hen, and post-breeding pintails in North Dakota. *Condor* 79(4):504-507.
- KROHN, W. B., AND E. R. CLARK. 1977. Band-recovery distribution of eastern Maine woodcock. *Wildlife Society Bulletin* 5(3):118-122.
- LAPERRIERE, A. J., AND P. C. LENT. 1977. Caribou feeding sites in relation to snow characteristics in northeastern Alaska. *Arctic* 30(2):101-108.
- LAUNER, C. A., O. W. TIEMEIER, AND C. W. DEYOUE. 1978. Effects of dietary addition of vitamins C and D<sub>3</sub> on growth of pond-cultured channel catfish. *Progressive Fish-Culturist* 40(1):16-20.
- LAVAL, R. K., R. L. CLAWSON, M. L. LAVAL, AND W. CAIRE. 1977. Foraging behavior and nocturnal activity patterns of Missouri bats, with emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*. *Journal of Mammalogy* 58(4):592-599.
- LENTFER, J. W., H. G. FALLEK, AND A. L. KOLZ. 1977. Satellite radio-tracking of polar bears. IInd ARGOS Users Meeting. Paris, France, 2-3 November 1977. Service ARGOS, Centre Spatial de Toulouse, 18 Avenue Edouard Belin, 31055 Toulouse Cedex, France. 28 pp.
- LEWIS, D. H., AND L. R. UDEY. 1978. Meningitis in fish caused by an asporogenous anaerobic bacterium. U.S. Fish and Wildlife Service, Fish Disease Leaflet 56. 5 pp.
- LEWIS, J. C., AND J. A. MORRISON. 1978. Some demographic characteristics of mourning dove populations in western Oklahoma. *Proceedings of the Oklahoma Academy of Science* 58:27-31.
- LINDSAY, S. F., AND T. A. BOOKHOUT. 1978. Lead and mercury levels in vegetation from strip-mined areas in eastern Ohio. *Bulletin of Environmental Contamination and Toxicology* 19(3):360-364.
- LINDSAY, S. F., T. A. BOOKHOUT, AND G. C. WHITE. 1978. Nutritive levels in plants from stripmined areas in eastern Ohio. *Ohio Journal of Science* 78(2):70-79.
- LINDZEY, F. G. 1978. Movement patterns of badgers in northwestern Utah. *Journal of Wildlife Management* 42(2):418-422.
- LINDZEY, F. G., AND E. C. MESLOW. 1977. Home range and habitat use by black bears in southwestern Washington. *Journal of Wildlife Management* 41(3):413-425.
- LINDZEY, F. G., AND E. C. MESLOW. 1977. Population characteristics of black bears on an island in Washington. *Journal of Wildlife Management* 41(3):408-412.
- LOKEMOEN, J. T. 1978. Little brown birds are number one. *North Dakota Outdoors* 41(3):4-5.
- LOTTER, F., AND N. J. SCOTT, JR. 1977. Correlation between climate and distribution of the color morphs of the salamander *Plethodon cinereus*. *Copeia* 1977(4):681-690.
- LYNCH, T. E., AND D. W. SPEAKE. 1978. Eastern wild turkey behavioral responses induced by sonic boom. Pages 47-61 in J. L. Fletcher and R. G. Busnel, editors. *Effects of Noise on Wildlife*. Academic Press, New York. x + 305 pp.

- MACIOLEK, J. A. 1977. Taxonomic status, biology, and distribution of Hawaiian *Lentipes*, a diadromous goby. *Pacific Science* 31(4):355-362.
- MAGOUN, A. J., AND P. VALKENBURG. 1977. The river otter (*Lutra canadensis*) on the north slope of the Brooks Range, Alaska. *Canadian Field Naturalist* 91(3):303-305.
- MAHAN, B. R., AND P. S. GIPSON. 1978. Osteoarthritis in a coyote x dog hybrid from Nebraska. *Journal of Wildlife Diseases* 14(3):395-398.
- MAHAN, B. R., P. S. GIPSON, AND R. M. CASE. 1978. Coydogs play role in Nebraska's wilds. *Farm, Ranch and Home Quarterly*, University of Nebraska 24(4):17-18.
- MALVESTUTO, S. P., W. D. DAVIES, AND W. L. SHELTON. 1978. An evaluation of the roving creel survey with nonuniform probability sampling. *Transactions of the American Fisheries Society* 107(2):255-262.
- MANION, P. J., AND G. W. PIAVIS. 1977. Dentition throughout the life history of the landlocked sea lamprey, *Petromyzon marinus*. *Copeia* 1977(4):762-766.
- MANN, J. A. 1978. Diseases and parasites of fishes: An annotated bibliography of books and symposia, 1904-1977. U.S. Fish and Wildlife Service, Fish Disease Leaflet 53. 28 pp.
- MARKING, L. L. 1977. Method for assessing additive toxicity of chemical mixtures. Pages 99-108 in F. L. Mayer and J. L. Hamelink, editors. *Aquatic toxicology and hazard evaluation*. A Symposium of the American Society for Testing and Materials. Special Technical Publication 634. 307 pp.
- MARKING, L. L., AND J. H. CHANDLER, JR. 1978. Survival of two species of freshwater clams, *Corbicula leana* and *Magnoniais boykiniana* after exposure to antimycin. U.S. Fish and Wildlife Service, Investigations in Fish Control 83. 5 pp.
- MARKIW, M. E., AND K. WOLF. 1978. *Myxosoma cerebralis*: Fluorescent antibody techniques for antigen recognition. *Journal of the Fisheries Research Board of Canada* 35(6):828-832.
- MARSHALL, J. T. 1977. Family Muridae: Rats and mice. Pages 397-487 in B. Lekagul and J. A. McNeely, editors. *Mammals of Thailand*. Association for the Conservation of Wildlife, Sahakarnbhat, Bangkok. 758 pp.
- MARSHALL, J. T. 1978. Systematics of smaller Asian night birds based on voice. *American Ornithologists' Union, Ornithological Monographs* 25. viii + 58 pp.
- MARTIN, D. B., AND R. D. ARNESON. 1978. Comparative limnology of a deep-discharge reservoir and a surface-discharge lake on the Madison River, Montana. *Freshwater Biology* 8(1):33-42.
- MARTIN, D. B., AND J. F. NOVOTNY. 1977. Zooplankton standing crops in the discharge of Lake Francis Case, 1966-1972. *American Midland Naturalist* 98(2):296-307.
- MARTIN, M. 1977. You asked for it! Precautions on winter use of small fish ponds. *Commercial Fish Farmer and Aquaculture News* 4(1):25.
- MARTIN, M. 1978. Abundant supply of clean water is absolutely essential for commercial fish farming. *Commercial Fish Farmer and Aquaculture News* 4(4):15-18, 33.
- MARTIN, M. 1978. Fish farmer must know what to do when turbidity becomes a problem in his ponds. *Commercial Fish Farmer and Aquaculture News* 4(5):19-21.
- MARTIN, M. 1978. You asked for it! Despite major problems, the long-term future of fish farming appears bright. *Commercial Fish Farmer and Aquaculture News* 4(2):38-41.
- MARTIN, T. E., AND P. A. VOHS. 1978. Configuration of shelterbelts for optimum utilization by birds. *Proceedings of the Annual Meeting of the Forestry Committee, Great Plains Agricultural Council* 30:79-88. (Abstract)
- MATSCHKE, G. H. 1977. Fertility control in white-tailed deer by steroid implants. *Journal of Wildlife Management* 41(4):731-735.
- MATSCHKE, G. H. 1978. Diethylstilbestrol effects on antler and reproductive gland morphology in male deer. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):649-655.
- MATSCHKE, G. H., AND K. A. FAGERSTONE. 1977. Effects of a new rodenticide, benzenesulfonic acid hydrazide, on prenatal mice. *Journal of Toxicology and Environmental Health* 3(3):407-411.
- MATSCHKE, G. H., AND K. A. FAGERSTONE. 1977. Teratogenic effects of 6-aminonicotinamide in mice. *Journal of Toxicology and Environmental Health* 3(4):735-743.
- MATULA, G. J., JR., AND J. S. LINDZEY. 1978. Behavioral and physiological characteristics of black bears in northeastern Pennsylvania. *Pennsylvania State University Research Briefs* 11(1):15-18.
- MAUCK, W. L., P. M. MEHRLE, AND F. L. MAYER. 1978. Effects of the polychlorinated biphenyl Aroclor 1254 on growth, survival, and bone development in brook trout (*Salvelinus fontinalis*). *Journal of the Fisheries Research Board of Canada* 35(8):1084-1088.
- MAUCK, W. L., L. E. OLSON, AND J. W. HOGAN. 1977. Effects of water quality on deactivation and toxicity of mexacarbate (Zectran<sup>®</sup>) to fish. *Archives of Environmental Contamination and Toxicology* 6(4):385-393.
- MAUNEY, M. 1978. Bargain baits: Do it yourself and save. *Virginia Wildlife* 39(2):18-19.
- MAYER, F. L., AND P. M. MEHRLE. 1977. Toxicological aspects of toxaphene in fish: A summary. *Transactions of the North American Wildlife and Natural Resources Conference* 42:365-373.
- MAYER, F. L., AND P. M. MEHRLE. 1978. Collagen and hydroxyproline in toxicological studies with fishes. Pages 92-101 in W. R. Swain and N. K. Ivanikiw, editors. *The Proceedings of the 2nd USA-USSR Symposium on the Effects of Pollutants Upon Aquatic Ecosystems, Volume 11. USSR Symposium, June 22-26, 1976, Borok, Jaroslavl, Oblost. U.S. Environ-*

- mental Protection Agency, EPA-600/3-78-076. 158 pp.
- MAYER, F. L., P. M. MEHRLE, AND P. L. CRUTCHER. 1978. Interactions of toxaphene and vitamin C in channel catfish. *Transactions of the American Fisheries Society* 107(2):326-333.
- MCCLUSKEY, D. C., J. W. THOMAS, AND E. C. MESLOW. 1977. Effects of aerial application of DDT on reproduction in house wrens and mountain and western bluebirds. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Forest Service Research Paper PNW-228. 22 pp.
- MCCRIMMON, D. A., JR., AND J. BART. 1978. Using the North American Nest Record Card Program to monitor reproductive patterns in raptors. Pages 403-412 in S. A. Temple, editor. *Endangered Birds: Management Techniques for Preserving Threatened Species*. University of Wisconsin Press, Madison. 466 pp.
- MCGINNES, B. S., AND R. L. DOWNING. 1977. Factors affecting the peak of white-tailed deer fawning in Virginia. *Journal of Wildlife Management* 41(4):715-719.
- MCINTYRE, J. D., AND D. F. AMEND. 1978. Heritability of tolerance for infectious hematopoietic necrosis in sockeye salmon (*Oncorhynchus nerka*). *Transactions of the American Fisheries Society* 107(2):305-308.
- MCINTYRE, J. D., AND A. K. JOHNSON. 1977. Relative yield of two transferrin phenotypes in coho salmon. *Progressive Fish-Culturist* 39(4):175-177.
- MCLANE, M. A. R., E. H. DUSTMAN, E. R. CLARK, AND D. L. HUGHES. 1978. Organochlorine insecticide and polychlorinated biphenyl residues in woodcock wings, 1971-72. *Pesticides Monitoring Journal* 12(1):22-25.
- MCNEISH, J. D., AND R. W. HATCH. 1978. Stamina tunnel tests on hatchery-reared Atlantic salmon. *Progressive Fish-Culturist* 40(3):116-117.
- MEAD, E. R., AND T. A. BOOKHOUT. 1978. Recreational use of state wildlife areas in Ohio. *Transactions of the North American Wildlife and Natural Resources Conference* 43:122-130.
- MECH, L. D. 1977. Productivity, mortality, and population trends in wolves from northeastern Minnesota. *Journal of Mammalogy* 58(4):559-574.
- MECH, L. D. 1977. Record movement of a Canadian lynx. *Journal of Mammalogy* 58(4):676-677.
- MECH, L. D. 1977. Where can the wolf survive? *National Geographic* 152(4):518-537.
- MECH, L. D. 1977. Wolf-pack buffer zones as prey reservoirs. *Science* 198(4314):320-321.
- MECH, L. D. 1978. Foreword. Pages xiii-xiv in M. Bekoff, editor. *Coyotes: Biology, Behavior, and Management*. Academic Press, New York. xx + 384 pp.
- MECH, L. D., AND P. D. KARNS. 1977. Role of the wolf in a deer decline in the Superior National Forest. U.S. Department of Agriculture, Forest Service Research Paper NC-148. 23 pp.
- MENZIE, C. M. 1978. Metabolism of pesticides: Update II. U.S. Fish and Wildlife Service, Special Scientific Report—Wildlife 212. 318 pp.
- MERSON, M. H., C. J. COWLES, AND R. L. KIRKPATRICK. 1978. Characteristics of captive gray squirrels exposed to cold and food deprivation. *Journal of Wildlife Management* 42(1):202-205.
- MEYER, F. P. 1978. Incidence of disease in warmwater fish farms in the south-central United States. U.S. National Marine Fisheries Service, *Marine Fisheries Review* 40(3):38-41.
- MEYER, F. P., AND R. A. SCHNICK. 1978. The approaching crisis in the registration of fishery chemicals. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):5-14.
- MILLER, H. W. 1977. Strategies for preserving wetlands. *Proceedings of the Annual Meeting of the Soil Conservation Society of America* 32:58-61.
- MILLER, H. W., AND D. H. JOHNSON. 1978. Interpreting the results of nesting studies. *Journal of Wildlife Management* 42(3):471-476.
- MILLS, E. L., J. L. FORNEY, M. D. CLADY, AND W. R. SCHAFFNER. 1978. Oneida Lake. Pages 367-451 in J. A. Bloomfield, editor. *Lakes of New York State. Volume II. Ecology of Western New York*. Academic Press, New York. xiv + 473 pp.
- MITCHELL, G. C., AND R. J. BURNS. 1978. Combate químico aos morcegos hematófagos. Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). Centro Nacional de Pesquisa—Gado de Leite. 31 pp.
- MITCHELL, J., J. M. GRIZZLE, AND J. A. PLUMB. 1978. Nifurpirinol (Furanace; P-7138) related lesions on channel catfish *Ictalurus punctatus* (Rafinesque). *Journal of Fish Diseases* 1(1):115-121.
- MORTON, J. W. 1977. Ecological effect of dredging and dredge spoil disposal: A literature review. U.S. Fish and Wildlife Service, Technical Paper 94. 33 pp.
- MOTT, D. F. 1978. Control of wading bird predation at fish-rearing facilities. Pages 131-132 in A. Sprunt IV, J. C. Ogden, and S. Winckler, editors. *Wading birds*. National Audubon Society, Research Report 7. ix + 381 pp.
- MULLINS, W. H., AND E. G. BIZEAU. 1978. Summer foods of sandhill cranes in Idaho. *Auk* 95(1):175-178.
- MURAWSKI, S. A., AND C. F. COLE. 1978. Population dynamics of anadromous rainbow smelt *Osmerus mordax*, in a Massachusetts river system. *Transactions of the American Fisheries Society* 107(4):535-542.
- NAGEL, M. L., AND R. C. SUMMERFELT. 1977. Apparent immunity of goldfish to *Pleistophora ovariae*. *Proceedings of the Oklahoma Academy of Science* 57:61-63.
- NAGY, J. G., AND W. L. REGELIN. 1977. Influence of plant volatile oils on food selection by animals. *Proceedings of the International Congress of Game Biologists* 13:225-230.
- NELSON, W. R., D. B. MARTIN, L. G. BECKMAN, D. W. ZIMMER, AND D. J. HIGHLAND. 1977. Reservoir eco-

- systems and western coal development in the upper Missouri River. Environmental Protection Agency, Region VIII, EPA-908/4-78-006. vii + 89 pp.
- NEMOTO, T., R. L. BROWNELL, JR., AND T. ISHIMARU. 1977. Cocconeis diatom on the skin of Franciscana. Scientific Reports of the Whales Research Institute 29:101-105.
- NEVES, R. 1978. Caddisflies. Massachusetts Wildlife 29(4):16-18.
- NEVINS, M. J., AND W. W. JOHNSON. 1978. Acute toxicity of phosphate ester mixtures to invertebrates and fish. Bulletin of Environmental Contamination and Toxicology 19(2):250-256.
- NEWCHURCH, E. J., C. F. BRYAN, D. P. HARRISON, R. A. MULLER, R. E. WILCOX, A. L. BACHMAN, J. P. NEWMAN, K. J. CUNNINGHAM, R. K. HILDING, AND J. A. REHAGE. 1978. A plan for the long term environmental assessment of geopressed resource development in the Louisiana Gulf Coast region. Institute for Environmental Studies, Louisiana State University. Prepared for Lawrence Livermore Laboratory and the U.S. Department of Energy. xii + 331 pp.
- NEWMAN, J. P., JR. 1977. Chironomidae (Diptera) of an intermittent stream in central Louisiana. American Zoologist 17(4):868. (Abstract)
- NEWSOM, J. D., H. R. PERRY, JR., AND P. E. SCHILLING. 1978. Fire ant-muskrat relationships in Louisiana coastal marshes. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30(1976):414-418.
- NORTON, S. E., A. S. TIMBOL, AND J. D. PARRISH. 1978. Stream channel modification in Hawaii. Part B: Effect of channelization on the distribution and abundance of fauna in selected streams. U.S. Fish and Wildlife Service, FWS/OBS-78/17. ix + 47 pp.
- O'GARA, B. W. 1977. Pronghorn. Pages 968-969 in H. R. Lamar, editor. *Reader's Encyclopedia of the American West*. Harper and Row Publishers, Inc., New York. xii + 1306 pp.
- O'GARA, B. W. 1978. *Antilocapra americana*. Mammalian Species 90:1-7.
- O'GARA, B. W. 1978. Sheep depredation by golden eagles in Montana. Proceedings of the Vertebrate Pest Conference 8:206-213.
- OHLENDORF, H. M., E. E. KLAAS, AND T. E. KAISER. 1977. Organochlorine residues and eggshell thinning in anhingas and waders. Pages 185-195 in W. E. Southern, compiler. Proceedings of the 1977 Conference of the Colonial Waterbird Group, Northern Illinois University. 205 pp.
- OHLENDORF, H. M., E. E. KLAAS, AND T. E. KAISER. 1978. Environmental pollutants and eggshell thinning in the black-crowned night heron. Pages 63-82 in A. Sprunt IV, J. C. Ogden, and S. Winckler, editors. Wading birds. National Audubon Society, Research Report 7. ix + 381 pp.
- OHLENDORF, H. M., R. W. RISEBROUGH, AND K. VERMEER. 1978. Exposure of marine birds to environmental pollutants. U.S. Fish and Wildlife Service, Wildlife Research Report 9. 40 pp.
- OKUNO, I., J. A. WHITEHEAD, AND R. E. WHITE. 1978. Flameless atomic absorption spectroscopic determination of heavy metals in whole-fish samples. Journal of the Association of Official Analytical Chemists 61(3):664-667.
- OLDEMEYER, J. L. 1975. Characteristics of paper birch saplings browsed by moose and snowshoe hares. Proceedings of the North American Moose Conference and Workshop 11:53-62.
- OLDEMEYER, J. L. 1977. "Home, home on the range . . ."—habitat improvement studies on the Kenai National Moose Range. Alaska Fish Tales and Game Trails 10(4):15-16.
- OLDEMEYER, J. L., A. W. FRANZMANN, A. L. BRUNDAGE, P. D. ARNESON, AND A. FLYNN. 1977. Browse quality and the Kenai moose population. Journal of Wildlife Management 41(3):533-542.
- PALMISANO, J. F., AND J. A. ESTES. 1977. Ecological interactions involving the sea otter. Pages 527-567 in M. L. Merritt and R. G. Fuller, editors. The environment of Amchitka Island, Alaska. U.S. Energy Research and Development Administration, Springfield, Virginia, TID-26712. xii + 682 pp.
- PAN, H. P., AND J. R. FOUTS. 1978. Drug metabolism in birds. Drug Metabolism Reviews 7(1):1-253.
- PAN, H. P., J. R. FOUTS, AND T. R. DEVEREUX. 1978. A comparative study of hepatic microsomal *N*-hydroxylation of *p*-chloroaniline and *p*-chloro-*N*-methylaniline in red-winged blackbird and rat. Proceedings of the International Congress of Pharmacology, Abstracts 7:459. (Abstract)
- PARRIS, R. W. 1977. A method for capturing adult great blue herons. Pages 163-165 in W. E. Southern, compiler. Proceedings of the 1977 Conference of the Colonial Waterbird Group, Northern Illinois University. 205 pp.
- PATTON, J. F. 1978. Indocyanine green: A test of hepatic function and a measure of plasma volume in the duck. Comparative Biochemistry and Physiology 60A(1):21-24.
- PAULEY, G. B. 1977. Bottomfish. Washington Fishing Holes 4(1):24-25.
- PAULEY, G. B. 1978. Pierce County's Silver Lake. Washington Fishing Holes 4(5):168-170.
- PAULEY, G. B., editor. 1978. Northwest bass and panfish guide. Western Bass Club, Seattle, Washington. 191 pp.
- PEARSON, E. W. 1978. A 1974 coyote harvest estimate for 17 western states. Wildlife Society Bulletin 6(1):25-32.
- PERRY, H. R., JR. 1977. Mourning dove population studies. Louisiana Agriculture 21(1):4-8.
- PETERS, R. P., AND L. D. MECH. 1978. Scent-marking in wolves. Pages 133-147 in R. L. Hall and H. S. Sharp, editors. *Wolf and Man: Evolution in Parallel*. Academic Press, New York. xiv + 210 pp. (Reprinted from American Scientist, 1975, 63(6):628-637.)
- PETTIS, J. P., AND C. J. COWLES. 1978. Gray squirrel, endangered species model. Virginia Wildlife 39(2):4-5.



- POSSARDT, E. E., AND W. E. DODGE. 1978. Stream channelization impacts on songbirds and small mammals in Vermont. *Wildlife Society Bulletin* 6(1):18-24.
- POSTON, H. A. 1977. The role of nutrition in preventing ocular lesions in salmonid fishes. *Proceedings of the Cornell Nutrition Conference for Feed Manufacturers* 1977:83-86.
- POSTON, H. A., J. L. WALLACE, R. C. RIIS, AND G. F. COMBS, JR. 1978. Cataractous and digestive protease responses of rainbow trout fed autoclaved isolated soybean protein and added methionine. *Federation Proceedings* 37(3):839. (Abstract)
- POWELL, J. A., JR. 1978. Evidence of carnivory in manatees (*Trichechus manatus*). *Journal of Mammalogy* 59(2):442.
- PRINCE, E. D., AND O. E. MAUGHAN. 1978. Freshwater artificial reefs: Biology and economics. *Fisheries* 3(1):5-9.
- PRINCE, E. D., AND O. E. MAUGHAN. 1978. Ultrasonic telemetry technique for monitoring bluegill movement. *Progressive Fish-Culturist* 40(3):90-93.
- PRINGLE, J. C., L. W. J. ANDERSON, N. E. OTTO, R. W. RAINES, AND U. T. JACKSON. 1978. Simazine residues in canal water and crops resulting from experimental application for ditchbank weed control. U.S. Bureau of Reclamation, Engineering and Research Center, REC-ERC-78-1. ii + 31 pp.
- PROUTY, R. M., W. L. REICHEL, L. N. LOCKE, A. A. BELISLE, E. K. CROMARTIE, T. E. KAISER, T. G. LAMONT, B. M. MULHERN, AND D. M. SWINEFORD. 1977. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for bald eagles, 1973-74. *Pesticides Monitoring Journal* 11(3):134-137.
- RALEIGH, R. F., D. H. BENNETT, L. O. MOHN, AND O. E. MAUGHAN. 1978. Changes in fish stocks after major fish kills in the Clinch River near St. Paul, Virginia. *American Midland Naturalist* 99(1):1-9.
- RATHBUN, G. B. 1978. The African pitta at Gedi Ruins, Kenya. *Scopus* 2(1):7-10.
- REDMAN, K. 1978. Team proofreading—alone. *Technical Communication* 25(2):31, cover 3.
- REGELIN, W. L., J. G. NAGY, AND O. C. WALLMO. 1977. Effects of snowdrifts on mountain shrub communities. *Proceedings of the International Congress of Game Biologists* 13:414-419.
- REGELIN, W. L., AND O. C. WALLMO. 1978. Duration of deer forage benefits after clearcut logging of sub-alpine forest in Colorado. U.S. Department of Agriculture, Forest Service Research Note RM-356. 4 pp.
- REYNOLDS, J. W., W. B. KROHN, AND G. A. JORDAN. 1977. Earthworm populations as related to woodcock habitat usage in central Maine. *Proceedings of the Woodcock Symposium* 6:135-146.
- REYNOLDS, R. E. 1977. Distribution of beaver in Oklahoma. *Proceedings of the Oklahoma Academy of Science* 57:83-85.
- REYNOLDS, R. E., AND J. C. LEWIS. 1978. Evaluating beaver guards on restricted flow risers of flood control impoundments. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):455-462.
- REYNOLDS, R. T., AND H. M. WIGHT. 1978. Distribution, density, and productivity of accipiter hawks breeding in Oregon. *Wilson Bulletin* 90(2):182-196.
- RIEGER, P. W., AND R. C. SUMMERFELT. 1978. An evaluation of the introduction of Florida largemouth bass into an Oklahoma reservoir receiving a heated effluent. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 30(1976):48-57.
- ROBBINS, C. S. 1977. Acadian flycatcher eats pokeberry fruit. *Maryland Birdlife* 33(3):126-127.
- ROBBINS, C. S. 1977. Bird atlas in the United States. *Polish Ecological Studies* 3(4):325-328.
- ROBBINS, C. S. 1977. Data bank of North American breeding bird censuses. *Polish Ecological Studies* 3(4):95-98.
- ROBBINS, C. S. 1977. Impact of the severe winter of 1977 on woodland birds in the Maryland piedmont. *Maryland Birdlife* 33(1):8-11.
- ROBBINS, C. S. 1977. Maryland and District of Columbia. Pages 135-151 in O. S. Pettingill, Jr. *A Guide to Bird Finding: East of the Mississippi* (second edition). Oxford University Press, New York. 689 pp.
- ROBBINS, C. S. 1978. Atlantic Flyway review: Region V. *North American Bird Bander* 3(2):66-70.
- ROBBINS, C. S. 1978. Census techniques for forest birds. Pages 142-163 in R. M. DeGraaf, technical coordinator. *Proceedings of the Workshop Management of Southern Forests for Nongame Birds*. U.S. Department of Agriculture, Forest Service General Technical Report SE-14. ii + 176 pp.
- ROBBINS, C. S. 1978. Forty-first breeding bird census: Hickory—oak—ash floodplain forest. *American Birds* 32(1):59-60.
- ROBBINS, C. S. 1978. Forty-first breeding bird census: Upland tulip-tree—maple-oak forest. *American Birds* 32(1):61-62.
- ROBBINS, C. S. 1978. Review of *The Sequence of Plumages and Moults of the Passerine Birds of New York* by J. Dwight, Jr. *New York Academy of Science Annals* 13(2):73-360, 1900, reprinted 1975. *Bird-Banding* 49(1):93.
- ROBBINS, C. S. 1978. Review of *Watching Birds—An Introduction to Ornithology* by R. F. Pasquier. Houghton Mifflin, Boston. 1977. 301 pp. *Journal of Wildlife Management* 42(2):466-467.
- ROBBINS, C. S. 1978. Thirtieth winter bird-population study: Hickory—oak—ash floodplain forest. *American Birds* 32(1):25.
- ROBBINS, C. S. 1978. Thirtieth winter bird-population study: Upland tulip-tree—maple-oak forest. *American Birds* 32(1):25-26.
- ROBERTS, J. D. 1978. Variation in coyote age determination from annuli in different teeth. *Journal of Wildlife Management* 42(2):454-456.
- ROBINETTE, W. L., AND M. K. CAUSEY. 1978. Tests of repellents to protect loblolly seedlings from browsing

- by white-tailed deer. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30(1976):481-486.
- ROBINETTE, W. L., N. V. HANCOCK, AND D. A. JONES. 1977. The Oak Creek mule deer herd in Utah. Utah State Division of Wildlife Resources, Publication 77-15. 148 pp.
- ROBINSON, F. W., J. C. TASH, AND S. H. HOLANOV. 1978. Cooling discontinuous waters with a single refrigeration unit. *Progressive Fish-Culturist* 40(1):15.
- ROGERS, J. G., JR. 1978. Repellents to protect crops from vertebrate pests: Some considerations for their use and development. *American Chemical Society Symposium Series* 67:150-165.
- ROGERS, J. G., JR. 1978. Some characteristics of conditioned aversion in red-winged blackbirds. *Auk* 95(2):362-369.
- ROGERS, J. G., JR., AND J. T. LINEHAN. 1977. Some aspects of grackle feeding behavior in newly planted corn. *Journal of Wildlife Management* 41(3):444-447.
- ROSS, M. R., AND R. J. REED. 1978. The reproductive behavior of the fallfish *Semotilus corporalis*. *Copeia* 1978(2):215-221.
- RUELLE, R., AND P. L. HUDSON. 1977. Paddlefish (*Polyodon spathula*): Growth and food of young of the year and a suggested technique for measuring length. *Transactions of the American Fisheries Society* 106(6):609-613.
- RUGGIERO, L. F., AND J. B. WHELAN. 1977. Chromic oxide as an indicator of total fecal output in white-tailed deer. *Journal of Range Management* 30(1):61-63.
- RULIFSON, R. A. 1977. Temperature and water velocity effects on the swimming performances of young-of-the-year striped mullet (*Mugil cephalus*), spot (*Leiostomus xanthurus*), and pinfish (*Lagodon rhomboides*). *Journal of the Fisheries Research Board of Canada* 34(12):2316-2322.
- RUOS, J. L., compiler. 1977. Mourning dove status report, 1974. U.S. Fish and Wildlife Service, Special Scientific Report—Wildlife 202. 26 pp.
- RUOS, J. L., AND D. D. DOLTON, compilers. 1977. Mourning dove status report, 1975. U.S. Fish and Wildlife Service, Special Scientific Report—Wildlife 207. 27 pp.
- RUSCH, D. H., M. M. GILLESPIE, AND D. I. MCKAY. 1978. Decline of a ruffed grouse population in Manitoba. *Canadian Field-Naturalist* 92(2):123-127.
- SANGSTER, M. E. 1977. Spring waterfowl migration in the Uinta Basin of northeastern Utah. *Great Basin Naturalist* 37(2):274-278.
- SARGEANT, A. B. 1978. Red fox prey demands and implications to prairie duck production. *Journal of Wildlife Management* 42(3):520-527.
- SAVARIE, P. J. 1977. Toxicity of pesticides to wildlife. *Proceedings of the Annual Colorado Crop Protection Institute* 7:93. (Abstract)
- SCANION, P. F., AND D. F. URBSTON. 1978. Persistence of lactation in white-tailed deer. *Journal of Wildlife Management* 42(1):196-197.
- SCHAFFER, E. W., JR. 1978. Recent developments in bird damage control chemicals. *Proceedings of the Vertebrate Pest Conference* (University of California, Davis) 8:32-35.
- SCHAFFER, E. W., JR., R. B. BRUNTON, D. J. CUNNINGHAM, AND N. F. LOCKYER. 1977. The chronic toxicity of 3-chloro-4-methyl benzamine HCl to birds. *Archives of Environmental Contamination and Toxicology* 6(2/3):241-248.
- SCHITOSKEY, F., JR., AND S. R. WOODMANSEE. 1978. Energy requirements and diet of the California ground squirrel. *Journal of Wildlife Management* 42(2):373-382.
- SCHMALTZ, J. E., AND J. S. LINDZEY. 1978. Diverse forest essential to improve grouse habitat. *Pennsylvania State University. Science in Agriculture* 25(2):3.
- SCHNEIDER, J. C., P. H. ESCHMEYER, AND W. R. CROWE. 1977. Longevity, survival, and harvest of tagged walleyes in Lake Gogebic, Michigan. *Transactions of the American Fisheries Society* 106(6):566-568.
- SCHNICK, R. A., AND K. A. GRAVES. 1977. *Investigations in Fish Control: Index to numbers 1-72, 1964-76*. U.S. Fish and Wildlife Service, Investigations in Fish Control 82. 19 pp.
- SCHOETTGER, R. A. 1978. Registration of pesticides: Consideration in conducting aquatic toxicity tests. Pages 166-180 in D. I. Mount, editor. *The Proceedings of the 1st USA-USSR Symposium on the Effects of Pollutants Upon Aquatic Ecosystems, Volume I. USA Symposium, October 21-23, 1975, Duluth, Minnesota*. U.S. Environmental Protection Agency, EPA-600/3-78-076. 226 pp.
- SCHOETTGER, R. A., AND W. L. MAUCK. 1978. Toxicity of experimental forest insecticides to fish and aquatic invertebrates. Pages 11-27 in W. R. Swain and N. K. Ivanikiw, editors. *The Proceedings of the 2nd USA-USSR Symposium on the Effects of Pollutants Upon Aquatic Ecosystems, Volume II. USSR Symposium, June 22-26, 1976, Borok, Jaroslavl, Oblost*. U.S. Environmental Protection Agency, EPA-600/3-78-076. 158 pp.
- SCHRECK, C. B., AND H. W. LORZ. 1978. Stress response of coho salmon (*Oncorhynchus kisutch*) elicited by cadmium and copper and potential use of cortisol as an indicator of stress. *Journal of the Fisheries Research Board of Canada* 35(8):1124-1129.
- SCHULTZ, D. P., AND P. D. HARMAN. 1978. Hydrolysis and photolysis of the lampricide 2',5-dichloro-4'-nitrosalicylanilide (Bayer 73). U.S. Fish and Wildlife Service, Investigations in Fish Control 85. 5 pp.
- SCOTT, J. M., R. L. PYLE, AND C. F. ZEILLEMAKER. 1978. Similar species of migratory waterbirds in Hawaii. *Elepaio* 39(1):1-5.
- SCOTT, J. M., AND J. L. SINCOCK. 1977. Recent observations on the birds of Koolau Forest Reserve, Maui. *Western Birds* 8(3):113-116.
- SCOTT, N. J., JR., L. A. MALMGREN, AND K. E. GLANDER. 1978. Grouping behaviour and sex ratio in mantled howling monkeys. Pages 183-185 in D. J.

- Chivers and J. Herbert, editors. Volume 1, Behaviour. Proceedings of the Sixth International Congress of the International Primatological Society. 980 pp.
- SCOTT, T. G., H. C. SCHULTZ, AND P. H. ESCHMEYER, editors. 1978. Sport fishery and wildlife research 1975-76. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. iv + 140 pp.
- SCOTT, V. E. 1978. Characteristics of ponderosa pine snags used by cavity-nesting birds in Arizona. *Journal of Forestry* 76(1):26-28.
- SCOTT, V. E., K. E. EVANS, D. R. PATTON, AND C. P. STONE. 1977. Cavity-nesting birds of North American forests. U.S. Department of Agriculture, Agriculture Handbook 511. 112 pp.
- SEESOCK, W. E., J. S. RAMSEY, AND F. L. SEESOCK. 1978. Life and limitation of the coldwater darter (*Etheostoma ditrema*) in Glencoe Spring, Alabama. *Bulletin of the Association of Southeastern Biologists* 25(2):56. (Abstract)
- SELGEBY, J. H., W. R. MACCALLUM, AND D. V. SWEDBERG. 1978. Predation by rainbow smelt (*Osmerus mordax*) on lake herring (*Coregonus artedii*) in western Lake Superior. *Journal of the Fisheries Research Board of Canada* 35(11):1457-1463.
- SERIE, J. 1978. The canvasback—changing times and traditions. *North Dakota Outdoors* 41(3):6-8.
- SHAFFER, C. W., AND G. L. KRAPU. 1978. A remote controlled system for capturing nesting waterfowl. *Journal of Wildlife Management* 42(3):668-669.
- SHANE, S. 1978. Suckerfish attached to a bottlenose dolphin in Texas. *Journal of Mammalogy* 59(2):439-440.
- SHAW, J. H., AND P. A. JORDON. 1977. The wolf that lost its genes. *Natural History* 86(10):80-88.
- SHELTON, W. L. 1978. Fate of the follicular epithelium in *Dorosoma petenense* (Pisces: Clupeidae). *Copeia* 1978(2):237-244.
- SHELTON, W. L., AND W. D. DAVIES. 1977. Pre-impoundment survey of fishes in the West Point Reservoir area (Chattahoochee River, Alabama and Georgia). *Georgia Journal of Science* 35(4):221-230.
- SHELTON, W. L., K. D. HOPKINS, AND G. L. JENSEN. 1978. Use of hormones to produce monosex tilapia for aquaculture. Pages 10-33 in R.O. Smitherman, W. L. Shelton, and J. H. Grover, editors. *Culture of Exotic Fishes*, Symposium Proceedings. Fish Culture Section, American Fisheries Society. Department of Fisheries and Allied Aquacultures, Auburn University. vi + 257 pp.
- SHEPHERD, M. E., AND M. T. HUIISH. 1978. Age, growth, and diet of the pirate perch in a coastal plain stream of North Carolina. *Transactions of the American Fisheries Society* 107(3):457-459.
- SHIRLEY, K. E., AND A. K. ANDREWS. 1977. Growth, production, and mortality of largemouth bass during the first year of life in Lake Carl Blackwell, Oklahoma. *Transactions of the American Fisheries Society* 106(6):590-595.
- SHORT, H. L., W. EVANS, AND E. L. BOEKER. 1977. The use of natural and modified pinyon pine—juniper woodlands by deer and elk. *Journal of Wildlife Management* 41(3):543-559.
- SHUMAKE, S. A. 1978. Food preference behavior in birds and mammals. Pages 21-42 in R. W. Bullard, editor. *Flavor Chemistry of Animal Foods*. American Chemical Society, Washington, D.C. viii + 175 pp.
- SIMENSTAD, C. A., J. A. ESTES, AND K. W. KENYON. 1978. Aleuts, sea otters, and alternate stable-state communities. *Science* 200(4340):403-411.
- SMARTT, R. A. 1977. The ecology of late Pleistocene and recent *Microtus* from south-central and south-western New Mexico. *Southwestern Naturalist* 22(1):1-19.
- SMARTT, R. A. 1978. A comparison of ecological and morphological overlap in a *Peromyscus* community. *Ecology* 59(2):216-220.
- SMITH, B. L. 1977. Influence of snow conditions on winter distribution, habitat use, and group size of mountain goats. Pages 174-189 in W. M. Samuel and W. G. Macgregor, editors. *Proceedings of the First International Mountain Goat Symposium*. iii + 243 pp.
- SMITH, H. T., C. B. SCHRECK, AND O. E. MAUGHAN. 1978. Effect of population density and feeding rate on the fathead minnow (*Pimephales promelas*). *Journal of Fish Biology* 12(5):449-455.
- SMITH, R. R. 1977. Recent research involving full-fat soybean meal in salmonid diets. *Salmonid* 1(4):8-11, 18.
- SMITH, R. R., AND G. L. RUMSEY. 1977. Nutrient utilization by fish. Pages 320-326 in P. V. Fonnesbeck, L. E. Harris, and L. C. Kearl, coeditors. *First International Symposium, Feed Composition, Animal Nutrient Requirements, and Computerization of Diets*. Utah Agricultural Experiment Station, Utah State University. xxi + 798 pp.
- SMITH, R. R., G. L. RUMSEY, AND M. L. SCOTT. 1978. Heat increment associated with dietary protein, fat, carbohydrate and complete diets in salmonids: Comparative energetic efficiency. *Journal of Nutrition* 108(6):1025-1032.
- SMITH, R. R., G. L. RUMSEY, AND M. L. SCOTT. 1978. Net energy maintenance requirements of salmonids as measured by direct calorimetry: Effect of body size and environmental temperature. *Journal of Nutrition* 108(6):1017-1024.
- SMITHERMAN, R. O., W. L. SHELTON, AND J. H. GROVER, editors. 1978. *Culture of Exotic Fishes*, Symposium Proceedings. Fish Culture Section, American Fisheries Society. Department of Fisheries and Allied Aquacultures, Auburn University. vi + 257 pp.
- SNIESZKO, S. F. 1978. Control of fish diseases. U.S. National Marine Fisheries Service, *Marine Fisheries Review* 40(3):65-68.
- SNIESZKO, S. F. 1978. Mycobacteriosis (tuberculosis) of fishes. U.S. Fish and Wildlife Service, *Fish Disease Leaflet* 55. 9 pp.
- SNYDER, N. F. R. 1978. Increasing reproductive effort and success by reducing nest-site limitations: A

- review. Pages 27-33 in S. A. Temple, editor. *Endangered Birds: Management Techniques for Preserving Threatened Species*. University of Wisconsin Press, Madison. 466 pp.
- SNYDER, N. F. R. 1978. Puerto Rican parrots and nest-site scarcity. Pages 47-53 in S. A. Temple, editor. *Endangered Birds: Management Techniques for Preserving Threatened Species*. University of Wisconsin Press, Madison. 466 pp.
- SNYDER, N. F. R., AND J. D. TAAPKEN. 1978. Puerto Rican parrots and nest predation by pearly-eyed thrashers. Pages 113-120 in S. A. Temple, editor. *Endangered Birds: Management Techniques for Preserving Threatened Species*. University of Wisconsin Press, Madison. 466 pp.
- SPRINGER, P. F., G. V. BYRD, AND D. W. WOOLINGTON. 1978. Reestablishing Aleutian Canada Geese. Pages 331-338 in S. A. Temple, editor. *Endangered Birds: Management Techniques for Preserving Threatened Species*. University of Wisconsin Press, Madison. 466 pp.
- STAFFORD, C. J., W. L. REICHEL, D. M. SWINEFORD, R. M. PROUTY, AND M. L. GAY. 1978. Gas-liquid chromatographic determination of Kepone in field-collected avian tissues and eggs. *Journal of the Association of Official Analytical Chemists* 61(1):8-14.
- STALLING, D. L., AND J. W. HOGAN. 1978. Preparation, separation and identification of TMS derivatives of hydroxylated PCBs and chlorophenols. *Bulletin of Environmental Contamination and Toxicology* 20(1):35-43.
- STALLING, D. L., AND J. N. HUCKINS. 1978. Metabolism of 2,4-dichloro-phenoxyacetic acid (2,4-D) in bluegills and water. *Journal of Agricultural and Food Chemistry* 26(2):447-452.
- STANLEY, J. G. 1977. Review of *Fish of Rare Breeding: Salmon and Trout of the Donaldson Strains* by N. O. Hines. Smithsonian Institution Press, Washington, D.C. 1976. 167 pp. *Quarterly Review of Biology* 52(4):392.
- STANLEY, J. G. 1978. Introduction of special section: Grass carp in the United States. *Transactions of the American Fisheries Society* 107(1):104.
- STANLEY, J. G., W. W. MILEY II, AND D. L. SUTTON. 1978. Reproductive requirements and likelihood for naturalization of escaped grass carp in the United States. *Transactions of the American Fisheries Society* 107(1):119-128.
- STANLEY, J. G., AND A. E. THOMAS. 1978. Absence of sex reversal in unisex grass carp fed methyltestosterone. Pages 194-199 in R. O. Smitherman, W. L. Shelton, and J. H. Grover, editors. *Culture of Exotic Species, Symposium Proceedings*. Fish Culture Section, American Fisheries Society. Department of Fisheries and Allied Aquacultures, Auburn University. vi + 257 pp.
- STERNER, R. T., AND S. A. SHUMAKE. 1978. Bait-induced prey aversions in predators: Some methodological issues. *Behavioral Biology* 22(4):565-566.
- STERNER, R. T., AND S. A. SHUMAKE. 1978. Coyote damage-control research: A review and analysis. Pages 297-325 in M. Bekoff, editor. *Coyotes: Biology, Behavior, and Management*. Academic Press, New York. xx + 384 pp.
- STICKEL, L. F. 1978. Changes in a box turtle population during three decades. *Copeia* 1978(2):221-225.
- STRANGE, R. J., AND C. B. SCHRECK. 1978. Anesthetic and handling stress on survival and cortisol concentration in yearling chinook salmon (*Oncorhynchus tshawytscha*). *Journal of the Fisheries Research Board of Canada* 35(3):345-349.
- SUGIHARA, R. T., L. F. PANK, D. P. FELLOWS, D. N. HIRATA, R. S. STOTT, W. HILTON, AND H. KAYA. 1977. Noncrop habitat manipulation as a means of controlling rats and reducing damage to sugarcane. Hawaiian Sugar Technologists' 1977 Report 36: 84-90.
- SUMMERS, C. A., AND R. L. LINDER. 1978. Food habits of the black-tailed prairie dog in Western South Dakota. *Journal of Range Management* 31(2): 134-136.
- SUTTKUS, R. D., G. H. CLEMMER, AND C. JONES. 1978. Mammals of the riparian region of the Colorado River in the Grand Canyon area of Arizona. *Occasional Papers, Tulane University Museum of Natural History* 2. 23 pp.
- SWANSON, G. A. 1977. Self-cleaning screen for processing benthic samples. *Progressive Fish-Culturist* 39(4):177-178.
- SWANSON, G. A. 1978. Funnel trap for collecting littoral aquatic invertebrates. *Progressive Fish-Culturist* 40(2):73.
- SWANSON, G. A. 1978. A simple lightweight core sampler for quantitating waterfowl foods. *Journal of Wildlife Management* 42(2):426-428.
- SWANSON, G. A. 1978. A water column sampler for invertebrates in shallow wetlands. *Journal of Wildlife Management* 42(3):670-672.
- SWANSON, G. A., AND M. I. MEYER. 1977. Impact of fluctuating water levels on feeding ecology of breeding blue-winged teal. *Journal of Wildlife Management* 41(3):426-433.
- SZARO, R. C., P. H. ALBERS, AND N. C. COON. 1978. Petroleum: effects on mallard egg hatchability. *Journal of Wildlife Management* 42(2):404-406.
- TABOR, J. E., AND H. M. WIGHT. 1977. Population status of river otter in western Oregon. *Journal of Wildlife Management* 41(4):692-699.
- TACHA, T. C., AND R. L. LINDER. 1978. Analysis of aerial circling surveys for Canada goose breeding populations. *Wildlife Society Bulletin* 6(1):42-44.
- TACKETT, D. L. 1978. You asked for it! Water conservation, reuse and use. *Commercial Fish Farmer and Aquaculture News* 4(6):48-49.
- TARSHIS, B. 1978. Diets, equipment, and techniques for maintaining crayfish in the laboratory. *Bulletin of the Ecological Society of America* 59(2):59-60. (Abstract)
- TARSHIS, I. B. 1978. IV. Black flies (family Simuliidae). Pages 11-18 in R. A. Bram, compiler. *Surveillance and collection of arthropods of veterinary impor-*

- rance. U.S. Department of Agriculture, Agriculture Handbook 518. v + 125 pp.
- THOMPSON, R. D., D. J. ELIAS, AND G. C. MITCHELL. 1977. Effects of vampire bat control on bovine milk production. *Journal of Wildlife Management* 41(4):736-739.
- THUROW, R. F., AND T. C. BJORN. 1978. Response of cutthroat trout populations to the cessation of fishing in St. Joe tributaries. Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow, Bulletin 25. iv + 35 pp.
- TIMBOL, A. S., AND J. A. MACIOLEK. 1978. Stream channel modification in Hawaii. Part A: Statewide inventory of streams; habitat factors and associated biota. U.S. Fish and Wildlife Service, FWS/OBS-78/16.
- TIMMONS, T. J., W. L. SHELTON, AND W. D. DAVIES. 1978. Changes in the fish fauna of West Point Reservoir following impoundment. *Bulletin of the Association of Southeastern Biologists* 24(2):55. (Abstract)
- TOWEILL, D. E., AND E. C. MESLOW. 1977. Food habits of cougars in Oregon. *Journal of Wildlife Management* 41(3):576-578.
- TRAUGER, D. L., AND J. C. BARTONEK. 1977. Leech parasitism of waterfowl in North America. *Wildfowl* 28:143-152.
- TRAUGER, D. L., AND C. H. SCHROEDER. 1978. Canvasback workshop, a review. *Wildlife Society Bulletin* 6(2):93-94.
- TUTTLE, R. R., G. D. POLLOCK, G. TODD, B. MACDONALD, R. TUST, AND W. DUSENBERRY. 1977. The effect of dobutamine on cardiac oxygen balance, regional blood flow, and infarction severity after coronary artery narrowing in dogs. *Circulation Research* 41(3):357-364.
- VANBLARICOM, G. R. 1977. Preliminary observations on interactions between two bottom-feeding rays and a community of potential prey in a sublittoral sand habitat in southern California. Pages 153-162 in C. A. Simenstad and S. J. Lipovsky, editors. *Fish Food Habits Studies. Proceedings of the First Pacific Northwest Technical Workshop*. Sea Grant Program, University of Washington, Seattle. 193 pp.
- VANDENBERGE, R. J., AND P. A. VOHS, JR. 1977. Population status of beaver on the free-running Missouri River in southeastern South Dakota. *Proceedings of the South Dakota Academy of Science* 56:230-236.
- VAN RIPER, C., III, J. M. SCOTT, AND D. M. WOODSIDE. 1978. Distribution and abundance patterns of the palila on Mauna Kea, Hawaii. *Auk* 95(3):518-527.
- VARLAND, K. L., A. L. LOVAAS, AND R. B. DAHLGREN. 1978. Herd organization and movements of elk in Wind Cave National Park, South Dakota. U.S. National Park Service, Natural Resources Report 13. 28 pp.
- WADE-SMITH, J., AND M. E. RICHMOND. 1978. Induced ovulation, development of the corpus luteum, and tubal transport in the striped skunk (*Mephitis mephitis*). *American Journal of Anatomy* 153(1):123-142.
- WALBURG, C. H. 1977. Lake Francis Case, a Missouri River reservoir: changes in the fish population in 1954-75, and suggestions for management. U.S. Fish and Wildlife Service, Technical Paper 95. 12 pp.
- WALKER, W. 1977. Chlorinated hydrocarbon pollutants in Alaskan gyrfalcons and their prey. *Auk* 94(3):442-447.
- WARREN, R. J., AND R. L. KIRKPATRICK. 1978. Indices of nutritional status in cottontail rabbits fed controlled diets. *Journal of Wildlife Management* 42(1):154-158.
- WEBBER, P. J., AND D. R. KLEIN. 1977. Geobotanical and ecological observations at two locations in the west-central Siberian Arctic. *Arctic and Alpine Research* 9(3):305-315.
- WEDEMEYER, G. A., N. C. NELSON, AND C. A. SMITH. 1978. Survival of the salmonid viruses infectious hematopoietic necrosis (IHNV) and infectious pancreatic necrosis (IPNV) in ozonated, chlorinated, and untreated waters. *Journal of the Fisheries Research Board of Canada* 35(6):875-879.
- WEDEMEYER, G. A., AND W. T. YASUTAKE. 1978. Prevention and treatment of nitrite toxicity in juvenile steelhead trout (*Salmo gairdneri*). *Journal of the Fisheries Research Board of Canada* 35(6):822-827.
- WELLS, L. 1977. Changes in yellow perch (*Perca flavescens*) populations of Lake Michigan, 1954-75. *Journal of the Fisheries Research Board of Canada* 34(10):1821-1829.
- WESSON, J., C. COWLES, AND J. ESTEP. 1977. The opossum's unlikely tale of success. *Virginia Wildlife* 38(12):10-11.
- WHITCOMB, R. F., AND C. S. ROBBINS. 1977. Application of census techniques to habitat preservation strategy. *Polish Ecological Studies* 3(4):225-228.
- WHITE, D. H., AND E. CROMARTIE. 1977. Residues of environmental pollutants and shell thinning in merganser eggs. *Wilson Bulletin* 89(4):532-542.
- WHITE, D. H., AND M. P. DIETER. 1978. Effects of dietary vanadium in mallard ducks. *Journal of Toxicology and Environmental Health* 4(1):43-50.
- WHITE, D. H., AND M. T. FINLEY. 1978. Uptake and retention of dietary cadmium in mallard ducks. *Environmental Research* 17(1):53-59.
- WHITE, D. H., M. T. FINLEY, AND J. F. FERRELL. 1978. Histopathologic effects of dietary cadmium on kidneys and testes of mallard ducks. *Journal of Toxicology and Environmental Health* 4(4):551-558.
- WHITE, D. H., AND D. JAMES. 1978. Differential use of freshwater environments by wintering waterfowl of coastal Texas. *Wilson Bulletin* 90(1):99-111.
- WHITE, G. C., L. W. ADAMS, AND T. A. BOOKHOUT. 1978. Simulation model of tritium kinetics in a freshwater marsh. *Health Physics* 34(1):45-54.
- WHITE, J. A., AND C. E. BRAUN. 1978. Age and sex determination of juvenile band-tailed pigeons. *Journal of Wildlife Management* 42(3):564-569.

- WHITE, S. B., AND H. J. GRIESE. 1978. Notes of lengths, weights, and mortality of gray whale calves. *Journal of Mammalogy* 59(2):440-441.
- WIEMEYER, S. N., A. A. BELISLE, AND F. J. GRAMLICH. 1978. Organochlorine residues in potential food items of Maine bald eagles (*Haliaeetus leucocephalus*), 1966 and 1974. *Bulletin of Environmental Contamination and Toxicology* 19(1):64-72.
- WIEMEYER, S. N., D. M. SWINEFORD, P. R. SPITZER, AND P. D. McLAIN. 1978. Organochlorine residues in New Jersey osprey eggs. *Bulletin of Environmental Contamination and Toxicology* 19(1):56-63.
- WILBUR, S. R. 1978. The California condor, 1966-76: a look at its past and future. U.S. Fish and Wildlife Service, North American Fauna 72. 136 pp.
- WILBUR, S. R. 1978. Supplemental feeding of California condors. Pages 135-140 in S. A. Temple, editor. *Endangered Birds: Management Techniques for Preserving Threatened Species*. University of Wisconsin Press, Madison. 466 pp.
- WILBUR, S. R., R. D. MALLETT, AND J. C. BORNE-MAN. 1977. California condor survey, 1975. *California Fish and Game* 63(3):189-190.
- WILSON, D. E. 1978. *Thyroptera discifera*. *Mammalian Species* 104:1-3.
- WILSON, D. E., K. N. GELUSO, AND J. S. ALTENBACH. 1978. The ontogeny of fat deposition in *Tadarida brasiliensis*. Pages 15-19 in R. J. Olembo, J. B. Castellino, and F. A. Mutere, editors. *Proceedings of the Fourth International Bat Research Conference*. Kenya National Academy for Advancement of Arts and Sciences, Nairobi. 328 pp.
- WISEMAN, D. S. 1977. Food habits and weights of bobwhite from northeastern Oklahoma tall grass prairie. *Proceedings of the Oklahoma Academy of Science* 57:110-115.
- WOLF, K. 1977. Fish cell culture media. Pages 25-30 in M. Rechcigl, Jr., editor. *CRC Handbook Series in Nutrition and Food, Volume 4, Section G*. CRC Press, Inc., Cleveland, Ohio. 469 pp.
- WOLF, K. 1978. Ghoti cell culture—in perspective. TCA [Tissue Culture Association] Report 12(1):2-6.
- WOLF, K., R. W. DARLINGTON, W. G. TAYLOR, M. C. QUIMBY, AND T. NAGABAYASHI. 1978. *Herpesvirus salmonis*: Characterization of a new pathogen of rainbow trout. *Journal of Virology* 27(3):659-666.
- WOLF, K., AND M. C. QUIMBY. 1978. Systematic management of animal cell lines. TCA [Tissue Culture Association] Manual 4(1):741-744.
- WOLFERT, D. R. 1977. Age and growth of the walleye in Lake Erie, 1963-1968. *Transactions of the American Fisheries Society* 106(6):569-577.
- WOLFERT, D. R., AND H. D. VAN METER. 1978. Movements of walleyes tagged in eastern Lake Erie. *New York Fish and Game Journal* 25(1):16-22.
- WOLLARD, L. L., R. D. SPARROWE, AND G. D. CHAMBERS. 1977. Evaluation of a Korean pheasant introduction in Missouri. *Journal of Wildlife Management* 41(4):616-623.
- WYDOSKI, R. 1977. Realistic management of endangered species—an overview. *Proceedings of the Annual Conference of the Western Association of State Game and Fish Commissioners* 57:273-286.
- WYDOSKI, R. S., G. T. KLAR, T. M. FARLEY, J. C. BRAMAN, Y. J. KAO, AND C. B. STALNAKER. 1976. Genetic, biochemical, and physiological studies of trout enzymes. Utah Cooperative Fishery Research Unit. iii + 163 pp.
- YAKUPZACK, P. M., W. H. HERKE, AND W. G. PERRY. 1977. Emigration of juvenile Atlantic croakers, *Micropogon undulatus*, from a semi-impounded marsh in southwestern Louisiana. *Transactions of the American Fisheries Society* 106(6):538-544.
- ZILKER, A. P., AND J. S. LINDZEY. 1978. Productivity and summer and fall ecology of the mourning dove in southeastern Pennsylvania. *Pennsylvania State University Research Briefs* 11(1):26-27.
- ZIMMER, D. W., AND R. W. BACHMANN. 1978. Channelization and invertebrate drift in some Iowa streams. *Water Resources Bulletin* 14(4):868-883.
- ZINKL, J. G., J. RATHERT, AND R. R. HUDSON. 1978. Diazinon poisoning in wild Canada geese. *Journal of Wildlife Management* 42(2):406-408.

## Appendix

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Radio transmitters (above) were placed on Richardson's ground squirrels to determine their movements and mortality rates. Juvenile Richardson's ground squirrels (below) first appear above ground in late May in Colorado. At this time, they are not yet weaned. *Photo by Kathleen A. Fagerstone.*











A study of mountain goats in the Cabinet Mountains, Montana, showed that three of six wintering herds had been extirpated, apparently because roads and trails gave easy access to their wintering cliffs. Recommendations were made to control the goat harvest on a drainage-to-drainage basis, close logging roads leading to wintering cliffs, and reintroduce goats to certain drainages. Goat permits in the area have already been significantly reduced as a result of the study. *Photo by Bruce Smith.*

Data gathered by a University of Montana student led to recommendations for prescribed and natural fire management to keep winter ranges of mountain sheep in the Bitterroot Mountains, Montana and Idaho, in early seral stages. *Photo by Bart O'Gara.*



