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Fisheries and Wildlife Research

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1977



UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE



UNITED STATES DEPARTMENT OF THE
INTERIOR

CECIL D. ANDRUS, SECRETARY

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 historical 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.

Time-lapse photography studies have revealed that cottontails were a principal food of golden eagles nesting on a Northern Great Plains study area in 1977. Cottontails and prairie dogs represented 73% of the total recorded biomass fed to the young of four pairs of eagles. *Photo by Dean E. Biggins.*

Fisheries and Wildlife Research

1977

Activities in the Divisions of Research for
the Fiscal Year 1977

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

Brown pelicans have had less difficulty with eggshell collapse as DDE contaminations have diminished on the Pacific Coast. However, a trend toward increased productivity was reversed during 1975-77 due to nest abandonment and starvation of young caused by food scarcity and perhaps complicated by the DDE residues that pelicans still carry. *Photo by D. 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 1977 (October 1, 1976-September 30, 1977) 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

The research responsibilities of the Fish and Wildlife Service were carried out by four Divisions: Cooperative Research, Cultural Methods Research, Population Ecology Research, and Population Regulation Research. During fiscal year 1977, 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 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 25 major facilities, approximately 60 satellite field stations, and 45 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 1977, the Divisions of Research had 770 full-time permanent employees. The budget included approximately \$26,000,000 of appropriated funds and \$3,000,000 of other funds.

Animal Damage Control

DENVER WILDLIFE RESEARCH CENTER

Drought Causes Red-winged Blackbird Population Decline in the Dakotas. A census of male red-winged blackbirds, conducted in the 30,000 square miles of North and South Dakota censused in 1965-68 and in 1972, was made in June 1977 to monitor the population in relation to corn depredations in Brown County, South Dakota. Territorial males were counted while driving six 50-mile, east-west transects centered on the James and Souris rivers. The transects were 50 miles apart; the southern one was 50 miles south of the border between the Dakotas, and the northern one was 11 miles south of the Canadian border. In addition, 520 acres of fields on each transect were censused by walking 11.3 miles diagonally through square-mile sections.

In 1977 there was an average of 45.6 males per section, or an estimated 1,367,000 territorial males in the 30,000 sections of the habitat sampled. Breeding male redwings have declined about 20% since the five earlier censuses, which showed a territorial male population averaging 1,693,000 birds (range 1.56 to 2.08 million).

This year's decline in numbers of male redwings was greater in fields (25%) than along roads (about 5%). The decline is attributed to the effects of the droughts of 1975 and 1976 in the Dakotas. In 1977 redwing nesting vegetation was scant around many lakes, and many potholes were planted to crops. Because prime wetland habitat for nesting was in poor condition, a greater proportion of nonroadside redwings had established territories in crop fields, particularly oats, where production of young is likely to be much lower.

A Continental Overview of Movement and Migration Patterns of Red-winged Blackbirds. Blackbird and starling populations in North America are receiving increased attention because of their reported crop depredations, health hazards, and nuisance aspects, especially when congregated in large roosts. These problems are difficult to solve because they are widespread, and the bird populations are highly mobile. Management measures necessary in one area may affect



Estimating bird damage to sweet corn. *Photo by A. R. Stickley, Jr.*

distant areas. Thus, effective management requires a thorough knowledge of the overall movement and migration patterns of each species. To obtain this type of information on red-winged blackbirds, band recovery data were analyzed to determine (1) the general continental pattern of movements and migration and (2) the banding and recovery effort for 27 regions of North America.

In most regions except the Northwest, redwings did not migrate long distances (>200 km) until after the fall molt in October; thus, most crop damage in late summer is caused by local (<200 km) birds. Apparently, intermingling of populations from widely divergent breeding areas (e.g., north-central Ohio and Chesapeake Bay) occurs during the winter-roost period. Thus, a high mortality rate at a single roost or cluster of roosts in winter would probably affect redwing populations indigenous to a wide area. Intermingling of wintering populations does not occur, however, when the birds return to their breeding areas;

nearly all birds return to within 50 km of where they were hatched.

A preliminary information system was developed to keep track of the locations of populations indigenous to the various regions of North America as they move from their breeding areas to winter-roost areas and back again. This system is incomplete at present because of the sparsity of banding data in several important regions, particularly in the southern United States where large winter-roosting populations are found.

Starling Movements Examined in Relation to Problem Areas. Because large flocks of feeding and roosting starlings cause problems, Service biologists banded 26,079 starlings in north-central Colorado from December 1960 through July 1974 to learn more about their movements. They also analyzed over 1,100 starling band recovery records related to Kentucky-Tennessee problems.

In Colorado, most birds were caught at cattle feedlots and at roosts near Longmont, Brighton, and Platteville. Of 550 band recoveries (2.1% recovery rate), 450 were within 80 km of the banding locality; 100 were more distant, at points ranging north to Canada and south to southern New Mexico. The population that breeds in north-central Colorado appears to be largely nonmigratory, whereas some birds from more northern breeding populations are highly migratory. Some of the northern birds winter in north-central Colorado and others are transients. The main axis of migration, slightly NE-SW, appears to be inherent. Abnormally heavy snowfall and low temperatures during the autumnal migratory period apparently caused starlings to migrate farther south than usual.

Most birds that are bred in Tennessee-Kentucky remain there through the winter. Most migrants from farther north arrive in Tennessee-Kentucky in November and early December. Some of these continue south beyond Tennessee. Some southward migration can occur even in late December, but December 15 to January 31 is a relatively stable period. About 60% of the midwinter population is composed of migrants, but many of them can be expected to winter in a different area, mainly farther north. The breeding range of migrants wintering in Tennessee-Kentucky extends from Kentucky north to eastern Wisconsin and northeast through Ohio to southern Quebec. Spring migration occurs at least as early as February 12.

Because of long-term land-use changes and im-

balances in banding efforts among States, habitats, years, and seasons, a well-designed, coordinated, and consistent banding program is still needed to produce the type of data most necessary for better understanding and management of starling populations with respect to the problems in Colorado, Tennessee, and Kentucky.

New Chemosterilant Test Method Developed. Communal starling breeding pens appear to offer a practical alternative to testing chemosterilants on wild populations of starlings. Four cages, 10 x 20 x 10 feet (L x W x H), were constructed in the fall of 1975 and 10 starling nest boxes were attached to the inside of each cage. In November 1975, 10 male and 10 female starlings were placed in each cage and their reproductive activities were observed through June 1976. In November 1976, 10 new starling pairs were placed in each cage and a similar test was run until June 1977; however, all males in each cage were treated with one of two promising chemosterilants in early February or mid-March 1977. During the control breeding season in 1976, the 40 pairs produced 247 eggs, and the fertility rate was 84%. During the 1977 breeding season, only 88 eggs were laid, and the average fertility rate was 64%. The tests indicate that breeding cages may provide an excellent environment to test chemosterilants or environmental pollutants for their effects on the reproductive success of wild starling populations. The basic test procedure was adapted from breeding experiments carried out by A. C. Risser, Sr., at the University of California, Davis.

Baiting Reduced Starling Numbers in Winter Roost and Feeding Areas in Kentucky. In the southeastern part of the United States, wintering blackbirds and starlings congregate in large numbers at feeding and roosting areas, sometimes causing serious economic losses to agriculture and creating health hazards and nuisance problems. In these mixed roosts, starlings appear to cause the most damage to agricultural crops, and therefore control efforts involving population reduction should be directed at this species.

A toxicant (Starlicide Complete pellets) placed in troughs in areas where starlings congregated, both adjacent to a roost and in five feedlots near Campbellsville, Taylor County, Kentucky, killed large numbers of starlings in January 1977 and reduced consumption of cattle feed by birds. Calculations based on bait consumption data indicated that 50,487 birds were killed after consuming 277.4 pounds of Starlicide Complete pellets



Starlicide pellet baits exposed in a battery of troughs adjacent to a winter roost of blackbirds and starlings in Kentucky proved effective for selectively killing large numbers of starlings. Photo by Jerome F. Besser.



Starlings are the primary species involved in the cattle and hog feedlot problem in the Southeast. In Kentucky, exposing Starlicide pellet baits in troughs within the lots selectively reduced starling populations substantially. Photo by Jerome F. Besser.

diluted 1:1 with untreated pellets. Starlings composed more than 92% of the dead birds found in sample areas in the roost and in index areas and more than 90% of those that fed from troughs containing pellets. Only four birds of four non-target species were found dead, three in the index areas, indicating the selectivity of the baiting method.

Similar baits exposed for 18 days at a hog and cattle feeding area in Laurel County, Kentucky, reduced a population of 12,000 starlings about 85%. At another cattle feeding site, three times as many starlings (9,800) were killed as were ever observed there at any one time. Apparently, congregations of starlings can be selectively reduced in problem areas safely and economically.

Starling Damage to Sprouting Wheat in Tennessee and Kentucky. During the winter of 1976-77, Service biologists surveyed bird damage to winter wheat in 218 fields in two major wheat-growing regions in Tennessee and one in Kentucky where large winter populations of blackbirds and

starlings occur. They estimated the amount of bird damage and examined the characteristics of damaged fields in order to assess the economic importance of the problem and to formulate research objectives and management recommendations to solve it.

Estimated loss of sprouts to birds, almost exclusively by starlings, averaged 3.8, 0.5, and 0.4% for northwest Tennessee, south-central Kentucky, and south-central Tennessee, respectively. Estimated loss of sprouts to freezing averaged 4.4, 2.6, and 34.9% for these respective regions. Projecting these sample losses, bird and freeze damage to sprouts reduced the yield of wheat by about 0.2 and 2.1 million bushels, respectively, in the two States.

Loss of sprouts to both birds and freezing was substantially greater for fields planted after November 1 than for fields planted earlier. The greatest loss to birds occurred in late-planted fields located within 16 km of a large starling roost. The most obvious management recommendation to reduce bird damage in these areas is to plant wheat early, preferably by November 1. If damage to sprouting wheat makes reduction of bird populations necessary, the starling should be the target species. Native blackbirds pose little threat to sprouting winter wheat.

Tennessee Blackbird and Starling Roosts Easily Dispersed. Methods are needed for alleviating the perennial problem caused by winter-roosting starlings and blackbirds. Studies conducted near Shelbyville, Tennessee, and within the city limits of Jackson, Tennessee, during January and February 1977 showed that birds at winter roosts could be easily dispersed with scare cartridges (shell crackers) and noise bombs (firecrackers projected by a pistol). Before dispersal efforts began, radio transmitters were attached to a number of birds at each roost to aid biologists in locating the new roosting sites chosen by the dispersed birds.

A population of slightly over 1 million blackbirds and starlings roosting in 70 acres of cedars at Shelbyville was reduced by 95% within 6 days by a maximum of five people. The largest known concentration of the dispersed birds formed a new roost, also in cedars, about 1 mile distant. Radio-instrumented birds were found there and in 19 other locations up to 32 miles from their original roost.

About 110,000 of 123,000 blackbirds and starlings roosting in 19 acres at Jackson were frightened away the first evening by five people



Blackbirds and starlings gathering at dusk over a roost at Milan, Tennessee. This roost has been the focus of an intensive ecological study. *Photo by A. R. Stickley, Jr.*

using scare cartridges and noise bombs. These dispersed birds formed a new roost in evergreens in a 40-acre cemetery nearby and were again dispersed in one evening by three people using only noise bombs. Radio-instrumented birds were subsequently found at 31 other roosting locations within Jackson and up to 31 miles from where they were instrumented. These trials demonstrated that problems with certain winter roosts could be resolved quickly and economically.

Additional Toxicants Sought for Blackbird/Starling Roosts. The problems of human health and safety often associated with large blackbird/starling roosts cannot always be solved by nonlethal means such as scare devices. The PA-14 wetting agent, the only currently registered lethal control agent for roosts, is effective only under certain weather conditions, which limits its usefulness in reducing populations. There is a need, therefore, for new materials that are usable under more varied conditions but retain a high degree of environmental safety.

Two compounds—DRC-1347 and DRC-2698—have shown potential for selective blackbird/starling contact toxication and are undergoing further laboratory tests of their suitability for roost treatment. DRC-1347 is 3-chloro-4-methyl benzamine; DRC-2698 is *N*-[3-chloro-4-methylphenyl] acetamide, a metabolite of DRC-1347.

Formulations have been developed that permit dilution with water (DRC-1347) and corn oil (DRC-2698) for aerial spray applications. Median lethal application rates of the formulations to blackbirds and starlings range from 3.2 to 7.1 pounds of the active ingredient per 20 gallons per

acre. The two materials produced similar pathologic signs, most commonly urate deposition on internal organs and changes in kidney, liver, gizzard, and gall bladder.

Phytotoxicity of the formulations to plants typical of roost vegetation is under study. Applications up to 80 pounds per 80 gallons per acre initially affected leaves but seem to have produced no lasting ill effects on bamboo, pine, oak, and juniper. Observations will continue through one growing season.

Both materials in the technical form exhibited low toxicity to rats and to rabbits in oral and dermal tests. DRC-1347 may present hazards via the inhalation and ocular routes. Additional tests of formulated materials are under way. Neither compound was judged hazardous to aquatic animals at application rates up to 20 pounds per acre. Opossums sprayed with formulations of both materials showed no apparent effects.

The Use of Diphenadione for Vampire Bat Control in Endemic Rabies Areas, Northeastern Brazil. Dr. Rogerio Piccinini of Brazil was assisted in the development of a vampire bat control program in the States of Pernambuco and Alagoas, Brazil. The study area was 500 km² and had 219 farms. The bat population was controlled, and deaths to cattle from rabies in the study area dropped from 140 cases for the 2-year period before control to 2 cases for the 2-year period following control.

The following is an abstract of Dr. Piccinini's thesis from the University of California, Davis:

Vampire bat control using Diphenadione (2-Diphenylacetyl-1,3-indandione, an anticoagulant)



Corn, preferred over rice by about one-fifth of the population and grown on about one-fourth of the cropped land of the Philippines, is often severely damaged by rats. *Photo by Russell F. Reidinger.*

was applied in endemic rabies areas (Pernambuco and Alagoas States) in northeastern Brazil. Analyses using the field collected data were carried out showing that the estimated number of vampire bats living in the area was reduced by 99.4% 2 years after the control had been applied. The best single method was the systemic treatment of cattle, but its combination with topical treatment of vampire bats was better than the first alone. A statistically significant decrease in the number of rabies cases in livestock was observed in the 2 years following control. A regression model to predict the number of vampire bats that will be caught on a given farm is presented as a tool for control methods. Also an optional method of treating fresh bites with the paste on suckling calves and cows in their late gestational period provided good results. Recommendations are made to establish a Federal Pest Control Research Center in Brazil to study and solve economic problems in the agriculture and animal sectors such as vampire bat predation and disease transmission.

Protection of Corn Crops from Rat Damage by Sustained Baiting with Anticoagulant Rodenticides. Sustained baiting with anticoagulant rodenticides, developed in cooperation with Philippine personnel, has been used successfully to reduce rat damage in Philippine ricefields. Corn is another important cereal crop grown in the Philippines and other Asian countries and, although actual losses have not been quantified, corn is frequently subjected to heavy rat damage. As with rice, traditional methods of control appear ineffectual in reducing rat damage.

In 1976, the sustained baiting method was

evaluated at the Don Carlos Corn Project in Bukidnon, Mindanao, Philippines. This project is a large, mechanized corn plantation, so that production inputs, other than rat control, were the same for each study area.

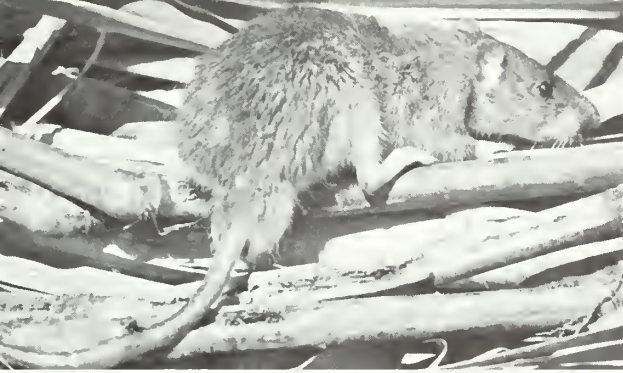
Six 2-ha plots were selected for the test. Three plots served as control and sustained bait stations were maintained on three plots. Four bait stations were uniformly baited for each test plot. Baiting began 6 weeks after planting and was maintained until harvest (week 12).

Eight hundred hills in each plot were sampled for rat damage before harvest. Damage to plants was 5.4% on the control plots and 0.86% on the treated plots. If these samples were typical of each of the plots, the sustained baiting reduced damage by 84%. Harvests in the treated plots averaged 7,521 lb/ha and in the controls 7,095 lb/ha. On the basis of current corn prices in the Philippines, the 6% increase in production on treated land means that the farmer earned \$27.20 more per hectare, or about \$7 for every dollar spent for control.

Rat Species—Composition Change in Sugarcane. A major shift from Polynesian to Norway rats has occurred during the last 9 years on sugarcane lands along the Hilo coast of Hawaii. The percentage of Norway rats increased from 5% in 1968 to 81% in 1976. Black rats declined steadily from 25% in 1969 to 5% in 1976. The shift resulted from reciprocal population changes—an increase in Norway rats and decreases in Polynesian and black rats—not from a change in abundance of a single species.

Species composition during a 24-month crop cycle has also changed. Formerly, Polynesian rats predominated throughout the cycle, with Norway rats making up less than 30% of the population at harvest. Polynesian rats now predominate only until the cane is 8-10 months old. In older cane, Norway rats have replaced Polynesians and constitute 90-100% of the population at harvest.

The shift cannot be attributed to a single cause, but the use of zinc phosphide bait to alleviate rat damage in cane is suspect. Zinc phosphide is more effective against Polynesian rats than Norway rats. The change in species composition coincides with the first bait application in cane 10-12 months old, and the major increase in Norway rats occurred 2 years after the use of zinc phosphide began. A new control technique is now needed to counter damage to sugarcane caused by Norway rats.



Control methods developed by the Wildlife Damage Research Station (Hilo, Hawaii) for Polynesian rats may have resulted in an increase in Norway rats (above), now the predominant rodent pest in Hawaiian sugarcane. *Wildlife Damage Research Station, Hawaii, Photo.*



Litter of black rats in Hawaiian sugarcane. The annual reproductive cycles of Polynesian, Norway, and black rats were studied to test the feasibility of population control with chemosterilants and lethal agents prior to reproductive peaks. *Wildlife Damage Research Station, Hawaii, Photo.*

Food Habits of Norway and Polynesian Rats in Hawaiian Sugarcane. How do Norway and Polynesian rats that cannot survive on a sugarcane diet flourish in mature cane, where alternate food supplies are superficially absent?

In a food habits study, rats were trapped along gulches adjacent to cane 0 to 6 months old and deep infield in 7- to 12- and 13- to 24-month cane during four sampling periods. Potential sources of noncrop foods were surveyed along each trapline. Microhistological techniques were used to determine composition of the diet in stomachs of 313 Polynesian and 363 Norway rats.

The diet of gulch resident Norway rats and infield rats of both species was 75-80% sugarcane and 5-15% each of animal matter and noncrop vegetation. Gulch resident Polynesian rats fed largely on fruit and insects. Animal matter occurred in over 90% of all stomachs and may be a required dietary supplement. Although a preference was found for fleshy fruits, no category of noncrop vegetation was consistently eaten by infield rats.

These results indicate that rat control by manipulation of food resources is impractical. However, since sugarcane seems to be a preferred and perhaps required carbohydrate source for Norway rats, it may be possible to delay their invasion into cane fields by eliminating volunteer sugarcane in gulches. The data also suggest that gulches may be the preferred habitat of Polynesian rats. If so, gulch baiting may reduce population pressure sufficiently to lessen or prevent field invasion by this species.

Reproductive Patterns of Hawaiian Rats. Reproductive patterns of over 1,600 Polynesian, 1,000 Norway, and 1,500 black rats were studied



Animal matter may supply protein required by Polynesian and Norway rats infesting Hawaiian sugarcane fields. A homemade "bug sucker" is used to sample invertebrates for a study of rat food habits. *Photo by Robert T. Sugihara.*

over a 5-year period to determine the feasibility of controlling rats with chemosterilants or increasing the effectiveness of baiting with acute toxicants before reproductive peaks.

On the average, 49, 33, and 13%, respectively, of adult female Polynesian, Norway, and black rats were pregnant each month. Peak reproduction for all species occurred in late summer to early fall. Secondary peaks were recorded in May-June (Norway), April (black), and December (Polynesian). The fewest pregnancies occurred in December (Norway), January (black), and March (Polynesian).

Combining the monthly reproductive rates of each species with the current species composition in sugarcane, at least one-quarter of the adult female population was pregnant during a 10-month period excluding December and March. This rate of breeding, together with (1) relatively rapid maturation, (2) potential compensatory reproduction, and (3) evidence of annual variation in the reproductive cycle, suggests that neither chemosterilants nor matching baiting schedules to rat reproduction cycles would be effective control measures.

In contrast, the primary rodent pest in macadamia nut orchards is the black rat. This species reproduces at a low rate except during two relatively short and well-defined breeding periods. Under these conditions, both chemosterilants and timed rodenticide applications may be useful in reducing nut losses to rats.

New Squirrel Guard Protects Cable. Damage to aerial communication cables by the gray squirrel is a serious and costly problem in the United States. Squirrel cable guards currently available were evaluated in a cooperative study with Bell Telephone Laboratories. Our observations, made with closed-circuit television, readily revealed the weaknesses of available guards. Based on these studies, a new guard was developed and evaluated in the laboratory. This new device not only overcomes the deficiencies of available guards but also provides a rapid and economical method of attachment to the cable. After 10 to 14 months of evaluations in New York, Texas, and California, none of the protected cable spans have been damaged by gray squirrels.

Delayed Sexual Development Among Yearling Buck White-tailed Deer. Lack of bone antlers and delayed puberty are two previously undescribed anomalies observed in free-ranging bucks at Mammoth Cave National Park, Kentucky. From 1969 to 1974 about 16% of the yearling bucks displayed these aberrancies. Antler development was restricted to bony protuberances covered with hair. The testes were subfunctional but contained germ

cells, type-A spermatogonia. The seminal vesicles were not producing seminal plasma. Abnormal deer had significantly smaller body and endocrine gland weights than normal yearling bucks. The abnormalities were transitory as they were not observed in older bucks. It is believed that these abnormalities were caused by a deficiency in hormone production by the testes, the anterior pituitary, or both, possibly related to malnutrition induced by herd size beyond the carrying capacity of the habitat.

The Seasonal Reproductive Cycle of the Black-tailed Prairie Dog. The seasonal changes occurring in the testes of prairie dogs over a 1-year period were studied in South Dakota to determine if reproductive inhibitors could be used to limit the size of prairie dog populations.

Prairie dogs breed only once a year during a 3-week period in late January or early February. At this time the testes reach their largest size (1.0 g), motile sperm are present, and the diameters of the seminiferous tubules are largest (January, 206 μm ; February, 214 μm).

The testes regress rapidly after the breeding season. By March motile sperm are no longer present, mitosis ceases in the type-A spermatogonia, and necrosis is evident in the round spermatids. By May diameters of seminiferous tubules decrease to 69 μm , and testes weigh one-tenth of their original weight (0.14 g). The testes remain inactive throughout the summer and fall, with the lumens of the tubules closed.

In December testes weights increase to 0.43 g, tubule diameters increase to 138 μm , and cellular activity is resumed. Young and old spermatocytes are present along with some round spermatids.

Young of the year achieve puberty at 8-9 months of age.

The limited period of spermatogenesis of approximately 2.5 months suggests that reproductive inhibitors may effectively suppress prairie dog populations.

Hazards of Ground Squirrel Control to Other Wildlife. A cooperative study with the Environmental Protection Agency was conducted to evaluate the primary and secondary hazards to nontarget wildlife associated with 1080 (sodium monofluoroacetate) aerial baiting to control California ground squirrels. The study was conducted in Tulare County, California, in the eastern foothills of the San Joaquin Valley. The vegetation is annual range grasses and associated forbs under open stands of oak, with cottonwood and buckeye



Aerial baiting with 1080 for the control of California ground squirrels may pose a hazard to wildlife in the area treated. *Photo by T. A. Gatz.*



Radio-tagged turkey vultures were one of several avian species, including eagles, hawks, owls, and ravens, used in studies to assess nontarget hazards. *Photo by T. A. Gatz.*

along streams. A large-scale operational baiting program was organized, supervised, and conducted by the Tulare County Agricultural Commissioner. About 200,000 acres were spot-treated with 0.075% 1080-treated oat groats at 6 pounds per swath acre by aircraft (actual surface area baited was less than 10% of the range). California ground squirrel populations were reduced about 70% following baiting.

Primary hazards to seed-eating birds appeared to be low. Of the 26 radio-equipped mourning doves and 9 radio-equipped California quail, only 1, a dove, was found dead after treatment, and none of either species was found dead during posttreatment carcass searches. Several dead cottontail rabbits were found after treatment, indicating some primary hazard to this species. Secondary hazards to predatory birds and mammals were determined by placing radio transmitters on 24 raptors (red-tailed hawks, turkey vultures, a golden eagle, great horned owls, barn owls, a screech owl, ravens, and crows) and 42 mammals (bobcats, coyotes, gray foxes, badgers, skunks, raccoons, and an opossum) and monitoring their movements before, during, and after treatment. The only treatment-related mortalities among this group of animals were 5 of the 6 radio-equipped coyotes and 3 of the 10 radio-equipped bobcats.

Even though 1080 residues in animal tissues have not yet been determined, aerial 1080 baiting for controlling ground squirrels apparently did little harm to seed-eating and raptorial birds. In contrast, 1080 baiting directly killed some cottontail rabbits and resulted in eventual death for several coyotes and bobcats.



A tranquilized bobcat after attaching a radio-equipped collar. Bobcats and other predators were radio-monitored to determine hazards to nontarget species. *Photo by G. Keith LaVoie.*

Rodenticide Baiting in Alfalfa Fields Presents Small Hazard to Feeding Geese. Data obtained in connection with efficacy evaluations of zinc phosphide-treated grain bait (for meadow mouse control) on Tule Lake National Wildlife Refuge, California, indicate little apparent hazard to migrating Canada, snow, and white-fronted geese.



The long-tailed weasel, an important predator of small rodents, is one of several nontarget species of concern in the development of rodenticide-based management programs for meadow mice in California. *Photo by James F. Glahn.*

Hazard studies were conducted with two species of geese, exposing them to zinc phosphide-treated bait applied in 8- x 32-foot enclosures erected in alfalfa fields. In the first test, two Canada geese were randomly assigned to each of four enclosures 3 days before testing. Green alfalfa was the only source of food. Water was provided in poultry waterers. During the 4-day test period, zinc phosphide bait (1.0% active ingredient), labeled with a fluorescent tracer, was broadcast into individual enclosures at 1, 3, 10, and 0 (control) times the normal rate of 6 pounds per acre. Enclosures were moved to new sites and fresh bait was applied daily to provide constant exposure and a new source of alfalfa. Body weights and general condition of geese were checked and droppings were collected to determine tracer levels at the end of each 24-hour test period. All geese survived 4 consecutive test days without significant weight loss. Tracer was found in droppings only once, indicating that most birds avoided bait entirely.

In a second test, two groups of eight white-fronted geese were exposed to zinc phosphide-treated grain bait (1.0% active ingredient), by the same infield test procedures. All geese survived without significant weight loss. An analysis of tracer in the droppings indicated that geese initially consumed sublethal quantities of bait but shunned it before the end of the test.

Rat Damage Has Impact on Florida Sugarcane Production. In cooperation with the Florida Sugar Cane League, rat depredations on sugarcane in south Florida were assessed during the 1974-75

harvest season. A total of 68,925 stalks from 41 fields were examined for rat damage. Incidence of damaged stalks ranged from 4.5 to 38.6% (average, 14.0%) in the sampled fields. Mean damage in three field strata, the center, edge, and middle ditch border, was significantly greater in the center, due to the small variation in damage between strata within fields. In future rodenticide field testing, only large differences in damage among fields will be detected, making stratified sampling within fields unnecessary. Damage was negatively correlated with weight of cane produced per acre, was weakly correlated with field age (ratoon), and was not correlated with percentage sugar yield, percentage solids, sucrose content, or date of harvest. Economic loss caused by rats was estimated at approximately \$95 per acre, or about \$6 million, in the plantations most intensively sampled.

Sheep Predation Rates with No Predator Control. A Great Basin band of sheep herded on open range was monitored intensively for losses between June 8 and September 29, 1976, in an area of California where organized predator control had not been conducted for the past 9 years. Livestock losses on "no control" areas were used as base lines for predicting the impact of predation on livestock where no predator control existed. Losses were tallied by field personnel who monitored sheep activities each day and necropsied all carcasses for cause of death. Verified losses from all causes totaled 69 (4.4% of the band), 59 (86%) of which resulted from predation. Forty-eight of the predator losses were lambs, a 6.3% loss of that age group. Ninety percent of the predator losses were attributed to coyotes, 2% to bobcats, and 8% to unknown predators. Physical condition was determined for 41 of the predator-killed sheep; only 7% were in poor condition. Predation intensity varied from about one loss every 5 days in June and July to about 1 per day in August and September. Eighty-five percent of the sheep attacked by coyotes had throat wounds. Coyotes fed on 95% of the fresh kills and returned to 94% of 33 carcasses checked for incidence of return. Most sheep carcasses were found at or near the bases of steep slopes in relatively open areas. Kills were commonly made during the early morning hours. Lamb losses among unherded, fenced, pasture-grazing sheep on no-control areas in New Mexico and Montana were reported to range from 12.1 to 29.3%, far exceeding the rate in our study.

Average lamb predation in areas with predator control usually ranges from 1 to 3%.



The coyote is a controversial animal and a number of studies are being conducted to define its population status, ecology, and its role as a predator, and to find ways of reducing its depredations on livestock. This group of coyote pups is inspecting the remains of a sheep. *Photo by Guy E. Connolly.*

Sheep Behavior and Vulnerability to Coyote Predation. A study contracted with Utah State University examined the activity patterns and social relationships between individuals in a large herd of domestic sheep in an effort to determine if behavioral characteristics predisposed certain sheep to coyote predation. Coyotes tended to select single lambs (as opposed to one of twins), lambs displaying aberrant movement, and lambs of ewes with restricted mobility. In the latter two situations, infirmities apparently caused those individuals to remain on the periphery of the herd, especially on the bedground, where they were more apt to encounter coyotes. Experiments with lambs unfamiliar with the herd (new introduction) showed that they were subordinate to other sheep, were forced into peripheral positions in the herd, and were more subject to attacks by coyotes.

Identifying individual sheep highly vulnerable to predation, or creating such individuals, will be essential to make the "toxic collar" a practical tool for reducing coyote predation. The collars, containing lethal chemicals, are placed on sheep so that attacking coyotes will receive a fatal dose, selectively removing the animals preying upon the herd.

Trends in Coyote Populations. Annual indices

of relative predator abundance were initiated by the Fish and Wildlife Service in 1972 primarily to determine trends of coyote populations. Results of those surveys, conducted at over 400 locations throughout the western States, suggest: (1) a general increasing gradient of coyote abundance from northern States to southern States; (2) lower densities in the mountain and intermountain States than to the east or west; and (3) fluctuations in coyote abundance since the use of toxicants to control coyotes was restricted in 1972. The average annual changes in relative abundance during the past 4 years (+10, +10, -5, and -7%, respectively) suggest that coyote populations may be fluctuating about long-term means. Results from individual States reinforce this interpretation, although patterns vary from one locale to another.

The Animal Damage Control Program coordinates and carries out most of the annual survey of predator abundance with assistance from other programs, State Fish and Game Departments, colleges and universities, and independent cooperators. In addition, the Fish and Wildlife Service is providing advice or materials for 48 other programs (universities, State Fish and Game Departments, foreign governments, etc.) attempting to determine relative numbers of predators.



Annual surveys of predator abundance are conducted throughout the western states each September. Lines of scent stations containing a predator attractant are set out and annual visitation rates are compared to determine relative predator densities. *Photos by Samuel B. Linhart.*

Coyote Mortality Studies. Forty-five percent of over 360 coyotes equipped with mortality-indicating radio transmitters since 1972 are known to be dead. Eighty-eight percent of the deaths were man-induced, primarily through shooting. Despite the extent of man-related mortality, there is little evidence suggesting reduced coyote populations as a result. Ancillary research suggests that intra-specific regulating mechanisms may be responsible for high early postnatal losses of pups in some years, since 50-72% of the placental scars (indicating fetal development) cannot be accounted for in fall age ratios.

The four radiotelemetry studies included sites in Texas, Utah, Idaho, and Wyoming. Despite the wide geographic spread, recovery rates only ranged from 38 to 56%, and man-induced mortalities ranged from 71 to 96%. Even in Jackson Hole, Wyoming, where coyotes are largely protected by a National Park and a Federal refuge, killing on private holdings was sufficient to permit recovery of 45% of the instrumented coyotes.

Responses of Coyotes and Other Wild Predators to Odor Attractants. With the completion of 1976-77 field tests in Texas and Arizona, 72 different predator lures have been tested since our odor attractant studies were initiated. These attractants included commercial lures, FWS Animal Damage Control Program lures, and Denver Wildlife Research Center synthesized compounds. Our objectives were to evaluate currently available attractants and to develop more effective and



Tracks indicate that a coyote visited this attractant station. Biologists at the Denver Wildlife Research Center are comparing and evaluating predator lures by exposing them in small, plastic capsules and reading "sign" left at the scent stations. *Photo by Frank J. Turkowski.*

more selective lures to control damage by coyotes and other predators. Also, basic information was obtained on how biological and physical factors affect animal responses to odorants.

A "scent-station" technique was used for our evaluation. Lures enclosed in perforated plastic tissue capsules were exposed in random sequence at a series of 3-foot-diameter circles of sifted or

raked soil placed at 0.3-mile intervals along unpaved roads. Each field phase compared predator response to several test lures, to a synthesized "base-line" or "standard" attractant, and to empty control capsules. Stations were checked daily, and tracks and other sign (chewing or pulling capsules, digging, rolling, urinating) indicated the relative attractiveness of each lure.

Thus far, over 40,000 test capsules have been exposed. About 7,000 coyote visits and as many behavioral responses have been recorded. Other predators attracted to the lures include gray and red foxes, bobcats, mountain lions, striped skunks, badgers, raccoons, coatis, and ringtail cats. Statistical analyses of coyote visitation rates and mean behavioral responses indicated that one of the most attractive lures was DRC-6500, a concentrated synthetic fermented egg formula synthesized by personnel of the Denver Wildlife Research Center. This formula and several other lures that were tested are presently being used experimentally, and initial reports indicate efficacy in controlling coyote depredations. An added advantage of synthetic lures is that they can be formulated with consistent properties. Geographic replicates of our Texas field tests are currently being conducted to determine if the ranking of test lures remains consistent under varying climatic and environmental conditions.

Information derived from our initial tests can be used to increase the efficacy and selectivity of methods of predator capture and control.

Oral Markers Tested on Mammals and Birds. To determine the probable effect of baiting on coyotes and nontarget species, the baits are treated with nonlethal chemicals that mark the animals ingesting them. Two compounds, DRC-727 and DRC-6061, evaluated as physiological markers for both mammals and birds, are being tested to determine their levels of retention and rates of disappearance in the blood of scavenging species.

Captive animals are held for at least 8 weeks after being fed a small tablet containing both compounds. A pretreatment blood sample, 24-hour posttreatment blood sample, and subsequent weekly samples for 8 weeks are used to chart retention of the chemical marker. Blood samples are analyzed by the Section of Supporting Sciences at the Denver Wildlife Research Center. DRC-727 has marked coyotes and golden eagles for more than 17 weeks after single doses. It has also marked all other test animals, including red foxes, striped skunks, badgers, raccoons, ground squir-

rels (except two species), turkey vultures, Mexican jays, magpies, great horned owls, ferruginous hawks, crows, *Peromyscus*, domestic cats, red-winged blackbirds, and starlings for at least 8 weeks. In an earlier study, DRC-6061 marked mammals, but it did not mark birds for more than a few days.

Since these markers can be detected in the blood, it is not necessary to kill the animals to determine whether the bait was eaten—a great advantage when working with protected species such as migratory birds, game animals, and furbearers.

Toxic Collar for Selective Control of Sheep-killing Coyotes. Toxicant-filled rubber or plastic collars are placed on the necks of sheep on ranges where coyote predation causes serious economic loss. When coyotes attack the sheep, they bite the collars and swallow lethal doses of toxicant. This device represents the most selective method known for the control of coyotes that kill sheep.

Laboratory and field experiments combined have developed the toxic collar to the point of biological and technical feasibility. In the latest series of field tests, toxic-collared sheep were placed on 15 ranches. One or more collared sheep was attacked in 11 of these tests, and on 10 ranches at least one toxic collar was broken by the attacking coyotes. Seventy percent of the attacks resulted in broken collars, and presumably in the delivery of lethal doses of toxicant to the attacking coyotes. Unfortunately, it is usually not possible to recover the dead coyotes because of the time lag between dosing and death.

Although problem coyotes can be taken with the toxic collar, the only toxicant known to be effective in the collar is sodium monofluoroacetate. When an experimental use permit is received for this compound, further tests will be made to determine the effectiveness and economic feasibility of the collar under different field conditions.

Sheep Losses During Tests of Predator Control Methods—Cook Ranch, Florence, Montana. Because earlier studies had shown high rates of coyote predation on sheep at the Cook Ranch, sheep losses were monitored for a 3rd year by the Montana Cooperative Wildlife Research Unit during tests of experimental control methods by the Denver Wildlife Research Center. At different times between March 15 and October 1, 1976, toxic collars and Komondor guard dogs were placed on the Cook Ranch, and aerial hunting and other conventional techniques were used between tests of the experimental methods. In apparent re-



Research is continuing on a toxic sheep collar that would eliminate only those coyotes attacking sheep. Approximately 70% of the coyotes that attacked collared lambs broke the collars and received lethal doses of the poison. *Photo by Guy E. Connolly.*

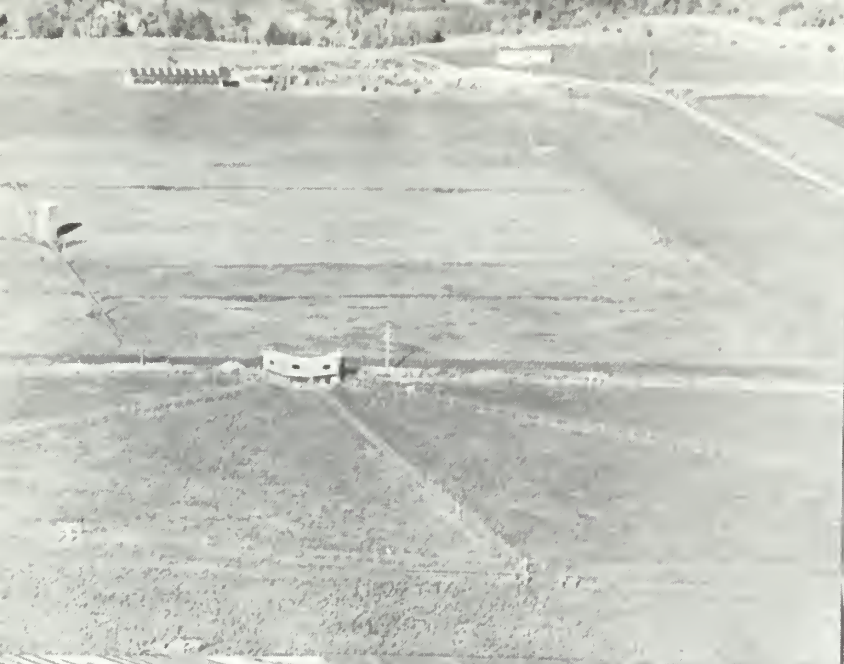
sponse to this variety of controls, the number of sheep killed by coyotes was lower in 1976 than in the previous 2 years. Coyotes killed 227 sheep (8.7% of the exposed herd) between March 15 and October 1, 1976, compared with 444 sheep (13.0% of the animals exposed) and 363 sheep (17.8% of animals exposed) during comparable periods in 1975 and 1974, respectively.

Although the guard dogs appeared to be the most effective deterrent to coyote attacks, they themselves harassed the sheep. The dogs were present on the ranch for only 20 days, and it is uncertain whether they would repel coyotes for longer periods of time.

The effectiveness of the toxic collar was hard to evaluate because of the slow action—6 to 16 days between dosing and death—of the toxicant, diphacinone. Coyotes ruptured 13 collars. One coyote was found soon after it died from diphacinone poisoning and as many as 10 coyotes may have been killed with the collars. Fewer sheep were killed by coyotes during the collar tests than in comparable time periods in previous years. Aerial hunting produced only slight reduction in sheep losses.

The Cook Ranch went out of the sheep business when it was sold on September 30, 1976.

Predator research facilities at Logan, Utah, are being used for detailed studies of coyote behavior, and as a testing site for new techniques to curtail coyote depredations among domestic animals. *Photos by R. E. Griffith, Jr. and W. M. Stephensen.*



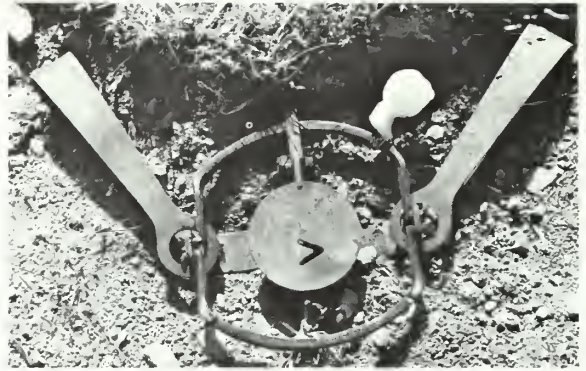
Conditioned Avoidance of Coyotes to Prey Evaluated. Several years ago researchers at the University of Utah reported that baits containing lithium chloride, an illness-inducing compound, could be used to reduce coyote attacks on sheep and rabbits. They postulated that if coyotes ate wool- or hair-covered lithium chloride baits, associations between the taste, sight, odor, and texture of these baits and subsequent gastrointestinal disorders would extend to the live prey and inhibit future attacks on those species. Thus, in July 1975, the Denver Wildlife Research Center funded a 2-year contract to Colorado State University to study conditioned prey aversion in coyotes.

To date, numerous attempts have been made to avert coyote attacks on rabbits baited with lithium chloride. This work was conducted as a series of probes involving three to five animals each in a 6,400-m² coyote enclosure. Captive coyotes trained to consistently kill rabbits were treated solely or with combinations of lithium chloride baits, laced rabbit carcasses, and intraperitoneal injections. They were subsequently tested for prey aversion by exposing them to live rabbits. The data indicated that prey aversion is not as easily established nor as long-lasting as suggested in recently published reports. Neither intraperitoneal injections, nor injections in combination with baits and laced carcasses, consistently induced long-term aversions such that use under field conditions would be feasible. However, lithium chloride-treated rabbit carcasses having prominent visual, auditory, and olfactory stimuli attached to them resulted in subsequent avoidance of live rabbits for at least seven successive 1-hour daily trials.

Future studies will be aimed at the use of enhancing stimuli, the effects of lithium chloride on nonkiller coyotes, and problems associated with field application and evaluation.

Research on Tranquilizer Tabs for Steel Traps Shows Promise. Public concern over the use of steel leg-hold traps to reduce predator damage has noticeably increased in recent years. In response to this concern, we have continued efforts to develop more effective tranquilizer tabs. These tabs, affixed to the jaw of a trap, are chewed by captured animals and result in reduced foot damage and trauma.

After laboratory evaluation of a number of candidate tranquilizers, a tab containing 200 mg of Tranvet, 1.5 mg of reserpine, and 398.5 mg of starch was field-tested in south Texas in January-



The Denver Wildlife Research Center is continuing efforts to develop a tranquilizer trap tab that, when ingested by trapped coyotes, reduces foot injury and trauma. *Photo by Guy E. Connolly.*

March 1977. Different methods of delivery, duration of effect, and extent of the reduction in foot damage were documented. Because some States require inspection of traps at 24-hour intervals and others at 48 hours, effectiveness of the tabs was primarily based on the latter time intervals. Coyote foot damage was determined from staked No. 3 long-spring (malleable jaw) traps without trap tabs. Injuries were grouped into six categories: no damage, swollen foot, slight cut, moderate cut, severe cut, and broken bone(s). Tabs were then fastened to traps of the same type, the traps were checked at approximately 24- and 48-hour intervals after capture, and coyote foot damage was again recorded.

Eighty-six percent (at 24 hours) and 90% (at 48 hours) of the coyotes taken in traps without tabs had moderate cuts, severe cuts, or broken bones. Of those taken in traps with tabs, only 41% (24 hours) and 45% (48 hours) sustained the same degrees of damage. In two other tests, with 600 mg of Tranvet alone, only 18 and 25% of the coyotes checked at 24 hours had moderate or severe cuts or broken bone(s).

It is hoped that results of the continuing laboratory and field tests will lead to Federal registration of an effective trap tab in the near future.

Viruses Fail as Physiological Markers in Birds. Metal leg bands, plastic streamers, colored dyes, and radio transmitters are among the various methods and materials used to mark birds for migration and other movement studies. Although widely used, they all share a common disadvantage—inefficiency. For example, only about 1% of the metal leg bands (the most commonly used markers) are recovered.

A long-lived marker that could be easily applied to entire flocks of birds (sometimes numbering in the thousands) would greatly advance the study of bird movements. The feasibility of viruses as marking agents for birds was investigated. Viruses can induce the formation of antibodies that can be easily detected in the blood of infected animals. Some antibodies persist for several months, and it was postulated that they could serve as long-term markers for the study of baiting effectiveness and migration patterns in red-winged blackbirds and African weaver finches.

Three strains of Newcastle Disease viruses, Turkey parainfluenza, and Yucaipa virus were administered either by aerosol or in food or water. The infection incidence was 50 to 93% by aerosol exposure but was negligible by the other two means of administration. The antibody response in infected birds lasted at least 3 weeks but rarely over 6 weeks. Because biologists need markers that persist for several months, it is not practical to consider these viruses as serological markers in birds.

Chemical Stability of Sodium Cyanide in M-44 Cyanide Capsules. Periodically the stability of sodium cyanide (NaCN) in M-44 cyanide capsules is questioned. It is known that NaCN is very stable when stored under moistureproof conditions, but until recently there were no analytical data to indicate its stability in the capsules.

A batch of 100 capsules, each containing a theoretical content of 88.78% NaCN, was formulated by the Pocatello Supply Depot and stored at room temperature for 1 year. Contents of 10 capsules were analyzed initially and thereafter at 3-month intervals for 1 year. The mean difference between theoretical and analyzed NaCN content ranged from -0.2 to -1.4%. There was no indication of a decrease in content of NaCN during the year. These data show that the shelf-life chemical stability of NaCN in the formulated product is excellent.

Physiological Marker for Coyotes. Research aimed at resolving the problem of coyote predation on sheep involves field studies in which identification or marking of individual animals is necessary. A good marking agent should be sensitive, long-lasting, and easy to detect. Iophenoxic acid appears to meet these criteria. It is an organic iodine chemical used in clinical medicine as a diagnostic radiopaque drug for x-ray contrast visualization. From a biochemical standpoint, iophenoxic acid is unique because it binds to blood

plasma proteins for long periods of time. Its presence in the blood can be indirectly determined by measuring the protein-bound iodine (PBI) content.

The normal PBI value in coyotes is about 10 $\mu\text{g}/100$ ml plasma. Twenty-four hours after a single oral dose (1 mg/kg) of iophenoxic acid, the PBI content is elevated about 90-fold. A rapid decline in the PBI value occurs initially, and after 12 days the value is about 45 times the norm. The remaining iophenoxic acid is tightly bound, hence is eliminated at a relatively slower rate. After 140 days the PBI level is about 2 times normal. A practical way of using iophenoxic acid would be to add it to baits, thus positively identifying individual animals that consumed them. The PBI determination is not tedious and 60 to 90 samples can be easily analyzed in a day.

Wildlife Transmitters: Research Tools. Wildlife-tracking transmitters are now established as important biological research tools. They are so popular that our Bioelectronics project is having difficulty in meeting the demand. Programs needing 100 transmitters are common, and one single study required 450 transmitters. Since 1970, the Denver electronics laboratory has supplied 2,600 transmitters for the field.

Transmitters are now available to monitor a variety of biological factors including such things as mortality in an animal population, activity patterns, seasonal movements, and temperature. Improvements are continually being made to increase the reliability and performance of both transmitters and receiving equipment. Many researchers discouraged by their first experience with "electronic gadgets" are now taking an enthusiastic second look. The state-of-the-art has made substantial gains, and biologists can expect to spend more time collecting data and less time troubleshooting the electronics.

Early users of telemetry were generally satisfied to report a travelogue for an instrumented animal, but sophisticated, purpose-oriented experiments are now being designed. One area of urgent concern is the collection of data for the EPA registration of pesticides. In several studies, telemetry provided the key for determining the relationship of a pesticide exposure to the postbiological and environmental effects. Data measured through telemetric techniques are also providing basic information for advanced computer models of animal populations. In summary, wildlife telemetry provides biological data obtainable by no other



The 4.4-kg transmitter collar attached to this female polar bear is received and tracked by the NIMBUS 6 satellite system as the bear travels through its habitat north of Barrow, Alaska. *Photo by A. Lawrence Kolz.*

means, and researchers are rapidly taking advantage of this methodology.

Efficacy of Ultrasonic Devices for Repelling Rodents. Ultrasonic devices have been marketed and used for several years to repel rats from food storage buildings. However, there are no definitive data showing that these devices are effective under all circumstances. A series of semifield pen tests were conducted to compare the relative efficacy of different devices and to define some of the limitations of their use under different conditions.

Only one of five different test conditions produced complete feeding repellency in ricefield rats.

After the rats had been adapted to a low-noise environment, the three devices under test (20 kHz, 20-30 kHz, and 40 kHz) were switched on. Feeding and activity of ricefield rats were almost eliminated in the sound chambers instrumented with the 20-kHz device, but no repellent effects were noted in wild Norway rats. This 118-dB, 20-kHz device could therefore be useful for temporarily eliminating a ricefield rat infestation in a closed structure.

When the intensity of this 20-kHz device was reduced to 88 dB, no repellency was observed. The decreased intensity would be equal in effect to a



A repellent-test chamber used to assess the effects of nonlethal chemical aerosols upon the behavior and physiology of little brown and big brown bats. (Insert) A close-up of a big brown bat. *Photo by Ray T. Sterner.*

30-foot increase in distance from the device. Thus, 20-kHz ultrasound effectively repels ricefield rats only over moderate distances in rooms that contain low amounts of sound-absorbent material.

Whether wild Norway rats are less sensitive than wild ricefield rats to the 20-kHz frequencies could not be established from the test data. Wild Norway rats tend to fight when confined in small enclosures, which may have interfered with the test. The laboratory data for ricefield rats support previous findings showing that they adapt to ultrasound in a few weeks and that only high intensities repel them. Although established ricefield rats are easily repelled by 20-kHz ultrasound after adaptation to a low-noise environment, the device does not act as a sound barrier to prevent further infes-

tation. As indicated in previous reports, ultrasonic devices can serve as an adjunct to other control methods but they do not usually afford long-term protection from rat damage.

A Search for Bat Repellents. The roosting of little brown and big brown bats in buildings poses potential public health and nuisance problems in many areas of the country, particularly New England. Transmission of diseases and ectoparasites, coupled with odor and noise problems, are the most frequently cited concerns of homeowners.

Recently, staff at the Denver Wildlife Research Center have begun to evaluate selected chemicals as potential repellents of house-dwelling, insectivorous bats. The effects of such agents as allyl isothiocyanate (oil of mustard), orthochlorobenzal-

malonitrile (CS gas), and paradichlorobenzene (moth crystals) are being assessed. Individual bats are placed in an airtight glove chamber, standard amounts of aerosols are then sprayed into the chamber, and the subsequent movements and stress responses of each bat are monitored. Initial results show that various concentrations of oil of mustard produce the greatest response. Mixtures of formalin and CS gas produce moderate responses when compared with moth crystals, which have almost no measurable effects.

An initial field trial based upon these data was conducted to assess further the effects of oil of mustard. Several vacant buildings in central Massachusetts, with resident colonies of bats, served as test sites. Each site was sprayed with 10% concentrations of oil of mustard. This aerosol flushed bats within the roost areas, but never were large numbers driven from the buildings. More research is needed to investigate alternative chemicals or other nonlethal methods (e.g., ultrasound, light) to prevent bat infestations.

Environmental Contaminant Evaluation

COLUMBIA NATIONAL FISHERY RESEARCH LABORATORY

During 1976-77, the research program at the Columbia National Fishery Research Laboratory greatly expanded. A major thrust of our research staff involved planning and initiating the new "Pre-crisis Environmental Contamination Evaluation and Prediction Program." This new work will be integrated into the existing Environmental Contaminant Evaluation Program to better identify, evaluate, and predict the effects of environmental contaminants on fish and wildlife. This new program should provide the data base and knowledge needed to predict future contaminant problems before they become emergencies.

Considerable progress has been made in the Laboratory's basic anticipatory research program. Research on the toxicity of several candidate forest insecticides has been completed with both fish and invertebrates. A cooperative agreement was undertaken with the Environmental Protection Agency (EPA) to provide toxicity data to be used in the fish and wildlife risk analysis in support of the Rebuttable Presumption Against Registration (RPAR) process. EPA funding for investigations of the toxicity of Kepone and mirex to aquatic organisms is progressing as scheduled. Cooperative studies with the Patuxent Wildlife Research Center on biochemical effects of toxaphene in black ducks were completed.

Acute Toxicity of Chemicals. Toxicity tests

were performed on 40 chemicals at the Columbia National Fishery Research Laboratory and its field stations. A wide variety of compounds were tested, including industrial chemicals, insecticides, herbicides, fungicides, prophylactics, a rodenticide, and an insect regulator.

Testing of the experimental forest insecticides Dylox, Matacil, Sumithion, Orthene, methomyl, and carbaryl has been completed with both technical and formulated material. All of these chemicals except Orthene were over 40 times more toxic to aquatic invertebrates than to fish. Orthene was relatively nontoxic to both fish and invertebrates; 96-hour LC_{50} 's exceeded 50 mg/l. Among other insecticides, methoxychlor and Abate (candidates for blackfly control) were nearly 7 times more toxic to Atlantic salmon in combination than singly. Maralite, a form of methoxychlor, was 10 times more toxic to salmon than its technical form. Kepone was much more toxic than mirex to invertebrates: 48-hour EC_{50} 's (effective concentrations) for Kepone were 60 μ g/l for daphnids and 300 μ g/l for scuds, whereas those for mirex were above 1 mg/l for both organisms.

Of the industrial chemicals tested, a planar fraction of Aroclor 1248 was the most toxic to daphnids. Several chlorinated phenol bactericides had LC_{50} 's between 0.01 and 0.1 mg/l for fish; an oil demulsifier (JW-8226) was toxic at 3 to 6 mg/l; two aryl phosphate components of hydraulic fluids were toxic at concentrations below 0.5 mg/l.

The fungicides Benlate (recommended mainly for ornamental plants and field crops) and Lignasan (used for control of Dutch elm disease) were far more toxic to channel catfish than to scaled fish. The 96-hour LC_{50} for catfish exposed to technical Benlate was $5.6 \mu\text{g/l}$ for sac fry, and $29 \mu\text{g/l}$ for fingerlings; Lignasan, a liquid form similar to Benlate, was equally toxic to catfish.

Impact of Forest Insecticides on Aquatic Invertebrates. The current spruce budworm epidemic involves 200 million acres of softwood forests in northeastern North America. Despite previous control efforts, the pest problem remains severe in 8.3 million acres of spruce-fir forest in Maine alone, and in many millions of acres of forest in neighboring Quebec and New Brunswick. In 1977 the Forest Service sprayed over 1 million acres for the control of the spruce budworm. Major insecticides used included Sumithion, Dylox, Orthene, and carbaryl. Many of the areas sprayed included productive fishery habitats containing diverse aquatic fish-food organisms that are generally more vulnerable to toxic perturbations than are fish.

Tests were conducted on the acute toxicity of Dylox, Matacil, Orthene, Sumithion, and carbaryl to scuds (*Gammarus*) and stone fly naiads (*Pteronarcella*). These two important aquatic invertebrates were as much as 500 to 1,000 times more sensitive to these insecticides than were brook trout and cutthroat trout. Stone fly naiads were generally more susceptible to the forest insecticides than were the scuds. Orthene was the least toxic insecticide to both invertebrates, and Sumithion the most toxic. Orthene was not toxic to scuds in 96 hours at concentrations of $25,000 \mu\text{g/l}$ in water of pH 6.5, 7.5, and 8.5. The 96-hour LC_{50} of Orthene for the stone flies was $6,400 \mu\text{g/l}$ at pH 6.5 and $21,200 \mu\text{g/l}$ at pH 8.5. Water concentrations of Sumithion between 4.3 and $8.8 \mu\text{g/l}$ killed 50% of the scuds and stone flies in 96 hours under all three pH conditions. Assuming that stream concentrations would not exceed $600 \mu\text{g/l}$, Orthene could be considered safe for scuds and stone fly naiads at all pH's tested; all of the other insecticides tested were toxic to invertebrates at lower concentrations under various pH conditions.

Evaluation of Chemicals Used for Controlling Blackflies. Blackflies are serious pests during the summer in the upper New England States. The insecticide methoxychlor has been applied directly into streams several times per season in New York to control these insects. Northern New England

States are considering other chemicals such as Abate. Methoxychlor has been applied to streams at concentrations ranging from 50 to $300 \mu\text{g/l}$.

To evaluate potential hazards to aquatic life, we studied the effects of methoxychlor and Abate on brook trout, Atlantic salmon, and scuds. Eyed eggs of brook trout were not affected by a 96-hour exposure to $50,000 \mu\text{g/l}$ of methoxychlor, and sac fry were not affected by methoxychlor concentrations of $400 \mu\text{g/l}$ tested under various combinations of temperature, water hardness, and pH. However, advanced brook trout fry were about 50 times more sensitive to methoxychlor than were sac fry. The toxicity of methoxychlor to Atlantic salmon was similar to that for brook trout; however, its toxicity was about 10 times greater to scuds than to the fish. Compared with Abate, methoxychlor was 300 times more toxic to Atlantic salmon. Results from our studies suggest that application of methoxychlor to streams at concentrations of 50-200 $\mu\text{g/l}$ could cause mortalities of fry of trout and Atlantic salmon and certain important food chain organisms. The use of Abate would be less hazardous to aquatic life.

Picloram May Be Hazardous to Fish. Herbicides are used extensively in the western United States to control noxious rangeland weeds along streams. Picloram is one of the more effective herbicides because it is persistent in the soil. Picloram tends to move with runoff water, however, and this presents a contamination problem for local surface waters. Application normally occurs in June and July when small cutthroat trout are in upstream nursery areas.

Early life stages of cutthroat trout were exposed to picloram at concentrations simulating field conditions. An initial weekly exposure of 48 hours to concentrations of picloram greater than 1.3 mg/l decreased fry survival; concentrations of 0.6 mg/l or more decreased fry growth by 25%. No adverse effects were observed when concentrations were below 0.3 mg/l . Picloram concentrations in runoff and stream water have been greater than 0.3 mg/l when rainfall occurred within 30 days of application, and in one field study the picloram concentration in runoff water was 2.7 mg/l . The weed control program along stream banks could thus pose a serious threat to the fishery. These findings were submitted directly to the State Game and Fish agencies involved.

Oil Exploration and Production Could Threaten Cold-water Fisheries. The current emphasis on the development of western energy



Picloram, a herbicide used to control weeds along streams, reduces growth in cutthroat trout: left, 63-day-old fry from control groups; right, 63-day-old fry exposed to picloram at 0.6 mg/l.

resources has resulted in exploration of mountain areas for oil and gas deposits. Many of these deposits are in regions that support a cold-water fishery resource. The fishery habitat may be affected by drilling fluid, oil-treatment chemicals, and the oil from a production operation. We are attempting to assess the toxicity of certain by-products used in well-drilling and production.

The chlorinated phenols, which are used to prevent bacterial action on the drilling head lubricant, were the most toxic of the drilling fluid components tested. The 96-hour LC_{50} of these chemicals to cutthroat fingerlings ranged from 0.01-0.1 mg/l. The total drilling fluid material was less toxic to cutthroat trout, but a 5% dilution resulted in 60% mortality in 96 hours.

Demulsifiers are used in the field treatment of crude oil to help separate oil-in-water emulsions. The discharge permits for oil production waters are based on 10 mg/l actual oil and grease. The demulsifiers are used at a continuous rate of 5 to 20 mg/l, however, and the acute toxicity of the water-soluble demulsifiers tested ranged from 3 to 6 mg/l. In tests with one demulsifier, continuous

exposure (60 days) of cutthroat trout fry to concentrations greater than 1.5 mg/l resulted in 100% mortality. Growth and survival of cutthroat trout were not affected at concentrations of 0.75 mg/l or less. Our results indicate that discharge permits for oil treatment facilities may not be based on the most toxic component. In future tests we will attempt to determine concentrations of total organics that can occur in the discharge water without having an adverse effect on the fishery.

Kepone-mirex Research. Kepone and mirex are two structurally similar organochlorine insecticides that are well documented as environmental contaminants. Kepone has been a major pollutant of the James River and Chesapeake Bay in Virginia, and mirex has been used throughout the southeastern United States for the control of fire ants. These chemicals have contaminated many important aquatic habitats. Tests of the chronic effects of Kepone and mirex on fish and aquatic invertebrates, and persistence of Kepone in freshwater hydrosols are being conducted under an interagency agreement between the Columbia National Fisheries Research Laboratory and the

EPA. In addition to generating toxicity data necessary for the development of water-quality criteria, studies are also being conducted to evaluate the use of certain biochemical factors as predictors of environmental contaminants.

Results of these studies show that Kepone concentrations of 12 $\mu\text{g/l}$ or higher lowered reproduction of *Daphnia magna*. The 3-week LC_{50} was 15 $\mu\text{g/l}$, indicating that reproductive impairment is more sensitive than survival as a measure of toxicity. Emergence of midges (*Chironomus plumosus*) was reduced after 30 days of exposure to Kepone concentrations of only 2 $\mu\text{g/l}$.

New methods were developed for the analysis of Kepone and mirex in fish tissue and hydrosol samples. The methods were effective in separating background polychlorinated biphenyls from Kepone and mirex residues for the quantitation of these materials by gas chromatography. A possible metabolite of Kepone was detected in a composite fathead minnow tissue sample (whole body) after a 9-day flow-through exposure to ^{14}C -Kepone at 0.4 $\mu\text{g/l}$. Gel permeation chromatography of the ^{14}C -extract resulted in three radioactive peaks. Two of these peaks were identified by gas chromatography as different hydrated forms of Kepone; however, the third peak coeluted with PCB's, indicating a molecular change. The unidentified peak represented 50% of the total radioactive residue.

Sublethal Effects of Endrin on Catfish. Endrin is an organochlorine insecticide that has been used extensively in the southern United States for the control of insects on cotton and other field crops. It has become an important aquatic contaminant with potential hazard to aquatic life because of its widespread use on croplands near commercial and sport fishing waters.

Preliminary flow-through toxicity tests with 2-year-old channel catfish indicated that endrin was acutely toxic at an exposure concentration of only 1 $\mu\text{g/l}$ (96-hour LC_{50} value).

During a chronic exposure for 100 days during the prespawning phase, the growth of adult channel catfish was not significantly altered by exposure to endrin concentrations of 6, 12, 23, 52, and 100 ng/l . During reproduction, viable eggs were produced in all concentrations and numbers of eggs, egg size, incubation time, and the hatchability of eggs produced were not affected. However, increases in the average length of time between pairing and spawning and the number of females that died after pairing, and decreases in

the percentage of females spawning successfully indicated that sexual maturation was adversely affected by endrin. Fish in the control and in 6-, 12-, and 23- ng/l concentrations spawned 3-4 days after pairing, but those in the 52- and 100- ng/l concentrations did not spawn until 5-14 days after pairing; no mortality occurred among paired females in the 6- and 12- ng concentrations, but one female died in each of the 23- and 52- ng/l concentrations and three in the 100- ng/l concentration; and percentages of females successfully spawning in the control, 6-, 12-, 23-, 52-, and 100- ng/l exposures were 71, 75, 62, 12, 50, and 38, respectively. Thus sublethal concentrations of endrin may lower reproduction in channel catfish.

Daphnids Produce PCB Metabolite. Freshwater daphnids represent a major component of pond and lake ecosystems. These organisms may play a dual role in the transport of chemical contaminants in freshwater communities, both as a passive conveyance in the form of tissue residues and as an active metabolic force in the movement of contaminants within food chains. Recently, we found that *Daphnia magna* metabolizes the highly persistent polychlorinated biphenyl (PCB), 2,4,5,2',4',5' hexachlorobiphenyl. During a 96-hour degradation study, nearly 20% of the ^{14}C -labeled PCB was degraded by the daphnid to a more polar unknown degradation product. In freshwater hydrosol, this hexachlorobiphenyl shows no evidence of degradation under either aerobic or anaerobic conditions after 28 days of incubation. Zooplankton may thus play a more important role in the degradation of some environmental contaminants than do bacteria and other microflora and fauna.

Burrowing Mayflies Prove Effective in Monitoring PCB's and Other Contaminants. The burrowing mayfly (*Hexagenia*) is one of the most abundant natural fish-food organisms in navigational pools of the Mississippi River. It is an excellent organism for monitoring aquatic contaminants, because it spends almost its entire life as a bottom-dwelling immature. Also, since the life cycle is normally completed within 1 year and the adults do not migrate, residue concentrations in the adults represent an annual accumulation that can be followed from year to year.

In 1976, adult mayflies were collected and analyzed to determine benthic distribution of PCB's in the Upper Mississippi River. In 1977 the study was expanded to include additional contaminants and the entire Mississippi River system; lock and

dam personnel, riverboat captains, and other interested river residents assisted in the collection of samples. Residues of PCB's were detected in all of about 150 samples collected at stations along the river from St. Paul, Minnesota, to New Orleans, Louisiana. Residues were highest in samples collected between St. Paul and Rock Island, Illinois. Total insecticide residues (dieldrin, cis-chlordane, trans-chlordane, heptachlor epoxide, DDD, DDE, and DDT) were significantly ($P < 0.05$) greater in mayflies collected in the lower half of the Upper Mississippi River (the section in Illinois from Gladstone to Cairo) than in those collected farther upstream—perhaps because agricultural land bordering the River in Illinois is the more extensive.

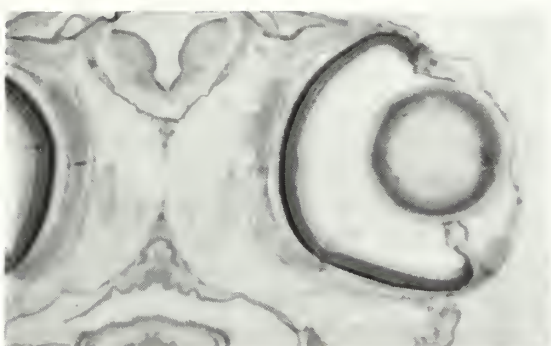
Potentially Toxic PCB Fractions Resolved for Study. Residues of PCB mixtures have been recognized as major aquatic contaminants for several years. However, little information exists on the composition of PCB residues in environmental samples or on how PCB component structure relates to observed toxicological effects of the residues. In addition, the biological significance of PCB impurities, such as extremely toxic chlorinated dibenzofurans, has not been resolved. Component characterization may become more important in the future, inasmuch as the composition of aged PCB's in closed-system applications has been shown to be significantly altered, sometimes resulting in increased dibenzofuran content.

Last year we demonstrated the feasibility of separating classes of PCB components on the basis of molecular planarity or increasing chlorine substitution in the biphenyl ortho, ortho' positions. Since then, we have improved the methodology by using an experimental carbon column with high PCB absorption capacity and high resolution Apiezon L gas chromatography; the improvement has resulted in increased PCB component separation and the identification of a large number of structurally related components in PCB mixtures. Several grams of Aroclor 1248 were fractionated and characterized. Rainbow trout fingerlings have been exposed to two of these PCB fractions in a flow-through system. Whole body residue analyses were completed for one of these fractions. After 29 days, fish exposed to $4\mu\text{g/l}$ of a 1248 fraction containing 1- and 2-ortho substituted tetra- and penta-chlorobiphenyls concentrated these compounds 20,500 times. At the end of the 28-day elimination cycle, all but one of the six PCB components (2,5,2',3'5') were detected in whole body samples. Whole body residues of

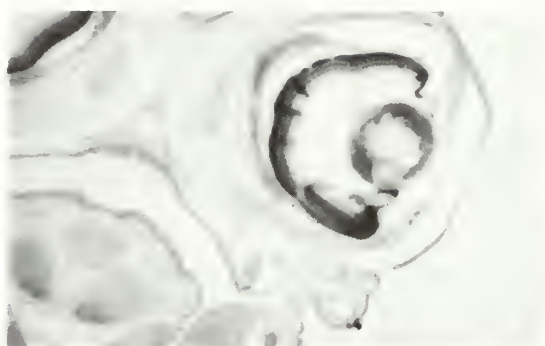
the six-component mixture declined from $82\mu\text{g/g}$ to $28\mu\text{g/g}$ during the same 28-day elimination period. Although no significant mortalities were observed during this study, delayed toxicological responses for other planar chlorinated aromatics, such as chlorinated dioxins, have been reported for fish.

PCB Substitute Not Hazard-free. Many new types of chemicals are commercially being used as substitutes for PCB-based products, since PCB's have been frequently found in environmental samples from many parts of the world at levels which may adversely affect aquatic organisms. Industrial phosphates, both triaryl and alkyl-aryl phosphate esters, are used mainly as fire-resistant hydraulic fluids and as fire-retardant plasticizers. Total annual production of the phosphate esters in 1973-75 averaged 90 million pounds. Nearly all (97 or 98%) of the production of these esters was used in the United States. Of the annual consumption of hydraulic fluids, about 80% occurs as a result of leakages in hydraulic systems. Therefore, phosphate esters would be expected to occur in industrial effluents and consequently in aquatic systems. Pydraul 50E, a product of Monsanto Chemical Company and similar to other commercially produced phosphate ester hydraulic fluids, is a blend of alkyl-aryl phosphate esters. It was selected as a representative phosphate ester hydraulic fluid for a study of the acute and chronic toxicity of these commercial compounds to fish.

Yolk-sac fry of rainbow trout were exposed to the phosphate ester in concentrations ranging from 2 to $192\mu\text{g/l}$. In the higher concentrations ($23\text{--}192\mu\text{g/l}$), mortalities were so extensive that the exposure was terminated after 30 days. Exposures to the lower concentrations ($2\text{--}15\mu\text{g/l}$), which caused considerably less mortality, were continued for 90 days. Growth was significantly ($P < 0.05$) reduced in concentrations of $8\mu\text{g/l}$ and above within 15 days, and the extent of growth reduction increased with time. Eye development was severely affected in fish exposed to concentrations as low as $8\mu\text{g/l}$. Lesions consisted of abnormal development of the lens and its suspensory apparatus, lens opacity, retinal degeneration, and connective tissue infiltration through much of the visual apparatus. Backbone collagen, which is used as a biochemical indicator of growth, was significantly ($P < 0.05$) reduced in all concentrations, resulting in an increase in the normal ratio of mineral content to organic matrix in bone compositions. Such a condition is believed



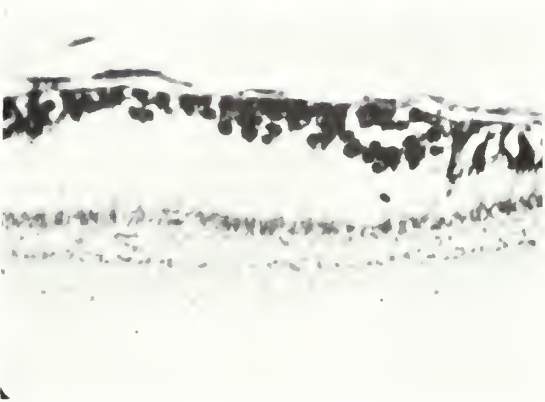
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Effects of Pydraul 50E exposure on eye structure in rainbow trout: (1) normal lens of controls, (2) cataract condition, (liquifaction of peri-nuclear lens fibers with luxation of lens) of treated fish, (3) normal retina, and (4) degeneration of retina of treated fish.

to cause an increase in bone fragility.

Benthic Hydrosol Communities, Biogeochemical Cycling, and Contaminant Impacts. The metabolic activity of microorganisms in freshwater hydrosol is important for the mineralization of organic matter and the recycling of inorganic nutrients. The activity of these microorganisms can directly influence the nutrient concentration in the overlying water and photosynthesis, and indirectly affect fishery productivity. The well-being of all organisms is linked with microbial activity in the sediments, yet it is not known whether chemical contaminants in hydrosol adversely affect such activity.

Recent experiments in which the rate of microbial decomposition of organic matter from heterotrophic uptake of $^{14}\text{CO}_2$ was measured show promise as a means of monitoring the effects of chemicals on aquatic nutrient cycles. Heterotrophic bacteria obtain a small amount of their carbon by incorporating CO_2 primarily through the nonphotosynthetic Woods-Werkman reaction.

Concentrations of only $10\text{ }\mu\text{g/l}$ Dylox caused a fivefold to sixfold increase in $^{14}\text{CO}_2$ uptake in bacteria after a 24-hour exposure.

Laboratory Procedure Developed for Determining Impact of Chemicals on Planktonic Communities. Procedures for testing the effects of environmental contaminants on freshwater communities involve either the culture of individual species in the laboratory for several days or weeks, or the use of natural communities for only several hours. A new procedure is being tested at the Columbia National Fisheries Research Laboratory in which laboratory techniques are used for predicting field assessment of chemical contaminants. Natural planktonic communities composed of numerous species of algae, heterotrophic microorganisms, and zooplankton are collected from uncontaminated pond water and placed in replicated chemostats. Several ecological characteristics are measured during a 10-day period: total chlorophyll *a*, relative rates of photosynthesis, and changes in the number and kinds of algae and zoo-

plankton.

We have tested copper sulfate, several water-soluble fractions of crude oil, benzene, and toluene, and both pentachlorophenol and sodium pentachlorophenate. Chemicals were added at concentrations of 1, 5, and 10 mg/l. Copper depressed both chlorophyll *a* and ^{14}C uptake at 1 mg/l, and completely destroyed the planktonic community at 5 mg/l. Benzene, pentachlorophenol, and sodium pentachlorophenate had no apparent effect on either chlorophyll *a* or ^{14}C uptake. Concentrations of 10 mg/l toluene reduced ^{14}C uptake after 4 days of exposure, but uptake returned to normal thereafter.

Response of Aquatic Communities to Chemical and Biological Control Methods. Current methods for control of aquatic vegetation were compared with biological control by the grass carp, an exotic species that has been released in several river systems in the eastern United States, even though its potential impact is unknown. One-year pond studies were conducted to determine the effects of removal of rooted submerged plants on a variety of ecological characteristics. Analyses of the data showed that plant removal lowered the concentration of chlorophyll *a* and of some dissolved inorganic nutrients. The grass carp produced conditions similar to those produced in ponds treated with herbicides.

Tests of pond sediments with a specially built probe showed that vegetation removal also raised the oxidation-reduction potential of the soil surface. This increase could reduce the resuspension of nutrients precipitated on the bottom, which are necessary for phytoplankton production.

Analytical Survey Methods for Determining Presence of Phenols in Fish Tissues. The production of industrial and agricultural chemicals involves the use of large quantities of phenols or phenolic intermediates. The manufacture of chlorinated fungicides and carbamate and phosphate insecticides, and their direct use as pesticides, consume a major portion of these phenolic compounds. Degradation of these pesticides results in the formation of phenols, which may appear as environmental contaminants. Because fish tissue contains co-extractable lipids and large amounts of emulsion-forming fatty acids, many analytical methods established for phenols cannot be employed in surveys for these environmental contaminants.

We have found that gel permeation chromatog-

raphy removes the bulk of these interfering materials and greatly improves sample cleanup. Additionally, the technique appears promising for further separation of phenols from neutral contaminants such as polychlorinated hydrocarbon pesticides. Preliminary results indicate that a combination of gel permeation chromatography and classical cleanup techniques for phenolic compounds affords a general approach to the determination of phenolic residues in fish tissue at the part-per-billion level.

Organochlorines in Striped Bass Eggs, Young, and Adults. An attempt was made to associate residues of selected organochlorine compounds with the survival of striped bass for 8 days after hatching. Samples collected included sperm and eggs, young (newly hatched, and 3 and 6 days old), and fillets of adults. These samples were analyzed for DDT residues and other related compounds such as PCB's, dieldrin, endrin, toxaphene, chlordane, and lindane. The only residues of possible biological significance were the DDT's (*p,p'*-DDT, -DDD, -DDE), PCB's (Aroclor 1248, 1254, 1260), and toxaphene. The sample was not large enough, nor was sufficient biological information available to support correlations between reproductive success and residues of environmental contaminants.

Analyses did indicate that residue concentrations generally decreased between the egg stage and the fry stage (6 days after hatching). This trend is apparently related to the combined effects of growth and metabolism of the residues on the tissues of the young (i.e., a combination of dilution and degradation). Toxaphene exceeded 1 $\mu\text{g/g}$ through 3 days of development of the young, and average total PCB's exceeded 5 $\mu\text{g/g}$ at hatching and 3 days after hatching. Similar residue levels in tissues of other fish species exposed chronically to PCB's or toxaphene have resulted in skeletal abnormalities and decreased growth.

One striking result of the analyses indicated that Aroclor 1248 contamination occurred within the hatchery during the progress of the test. No Aroclor 1248 was found in egg tissues, but 1.63 $\mu\text{g/g}$ was noted at hatching and 3 days post-hatch. The mean residue dropped to 0.47 $\mu\text{g/g}$ by 6 days post-hatch, indicating that the young may be able to metabolize Aroclor 1248.

Toxaphene-like Material Found in Great Lakes Fish. The Columbia National Fisheries Research Laboratory reported, for the second consecutive

year, the presence of a material strongly resembling toxaphene in tissues of lake trout collected from the Great Lakes. Residues based on a toxaphene standard averaged 7.7 $\mu\text{g/g}$ (range, 4.3-11.4) in carcasses of 9 lake trout taken from Lake Michigan (near Saugatuck, Michigan) and 2.0 $\mu\text{g/g}$ (range, 1.4-2.7) in 10 lake trout from Lake Superior (near Bayfield, Wisconsin). Toxaphene had not been previously reported in Great Lakes fish; however, the insecticide has been reported in eggs of migratory waterfowl that nest in the area.

Toxaphene is a chlorinated camphene insecticide, and has been shown to be highly toxic in low concentrations to early life stages of fish. Due to the complexity of chemical structures composing toxaphene, it is difficult to quantify them accurately, and tissue residues must be confirmed by methods other than routine electron-capture gas chromatography. Though toxaphene appeared to be present in lake trout when the fish were analyzed by routine methods, chemical ionization-mass spectrometry raised uncertainties about the presence of "true toxaphene." Results of mass spectrometry indicated that some, but not all, of the components which appear in toxaphene were present in extracts of the lake trout tissues. The toxaphene-like residues found may be the most environmentally persistent constituents of toxaphene, or they may be related to toxaphene or a similar material derived from the chlorination of camphenes originating from wood pulping or plywood manufacture. Another alternative is that the residues are some other heretofore unrecognized group of environmental contaminants.

Residues of Environmental Contaminants in Tissues of Freshwater Fish in the United States. Fifty-five stations in lakes and drainage systems throughout the United States were sampled during the fall of 1976 to monitor trends in concentrations of environmental contaminants occurring in tissues of freshwater fish. Three composite samples of about five fish each were collected at each station; one sample consisted of a carnivorous species and the remaining two of representative bottom-feeding species. A total of 21 chemicals were screened.

The chemicals that appeared with the highest frequency were DDT and related metabolites, dieldrin, PCB's, chlordane, and benzene hexachloride. All of these compounds or chemical groups were observed in more than 86% of the samples analyzed, and DDT (total *p,p'*-DDT,

-DDD, and -DDE) occurred in 98.6%. All other compounds were observed in less than 35% of the samples. Residues of PCB's (total of Aroclors 1242, 1248, 1254, and 1260) were the highest reported; in 9.1% of the samples, concentrations exceeded 5 $\mu\text{g/g}$. The chemicals and percent occurrence among samples analyzed that exceeded 1 $\mu\text{g/g}$ were toxaphene (5.6), PCB (34.3), and DDT (5.6). All other detected chemicals were at concentrations below 1 $\mu\text{g/g}$. Neither aldrin nor methoxychlor were detected.

Interagency Agreement Initiated to Monitor Toxic Substances. The Fish and Wildlife Service initiated an agreement with EPA in November 1976 to obtain geographic information on the presence of toxic substances in fish tissues. This information will be used by EPA in assessing risks caused by these substances to man and the environment and to help identify areas of greatest concern for each substance to be investigated.

The Columbia National Fisheries Research Laboratory will provide residues of selected chemicals in tissues of frozen samples stored since 1967. Over 120 chemicals will ultimately be analyzed at the Columbia Laboratory or at some other laboratory approved by EPA. Only about one-third of the organic chemicals on the list can be readily measured in fish by current methods. Initial surveys for heavy metals and commonly measured pesticides and PCB's have begun on fish tissue contained in our archive fish samples collected as a part of the National Pesticide Monitoring Program. A general procedure suitable for mechanization is being developed for the analysis of phenols in fish. We are also examining techniques for isolating highly toxic chlorinated dibenzofurans and dibenzo-*p*-dioxins, using gel permeation chromatography combined with sequential absorption chromatography (charcoal-polyurethane foam).

These survey techniques are expected to be suitable for electron capture gas chromatography but the chlorinated dioxins will require specialized gas chromatography-mass spectrometry for detection. The data on the occurrence of the toxic chemicals will be useful in planning future surveys of their occurrence in aquatic ecosystems.

Biochemical Methods Under Development for Determining Reproductive Effects in Fish. For the past several years we have investigated the sublethal, biochemical effects of organic contaminants on growth and bone development in fish. We began similar research this year on bio-

chemical responses associated with reproduction. Although sexual maturity and reproduction are accompanied by dramatic metabolic changes, no definite correlation exists between reproductive success and biochemical responses in fish. In controlled laboratory studies with brook trout and channel catfish, various factors—gonad maturation, spermatocyte and oocyte viability, egg production, and offspring success—will be correlated with changes in gonadal, pituitary, and thyroidal hormones to determine if there are meaningful relationships between biochemical responses and reproductive success. The use of biochemical profiles indicative of reproductive success will be a useful tool for evaluating adverse effects of contaminants on reproduction in fish.

PATUXENT WILDLIFE RESEARCH CENTER

DDT Twice as Toxic to Little Brown Bats as to Laboratory Rodents. Heavy mortality occurred when a nursery colony of little brown bats in Hillsborough County, New Hampshire, was sprayed with DDT and chlordane in August and September 1973.

In May and June 1974, we collected live, dead, and convulsing bats and analyzed their brains and carcasses. Concentrations of chemical residues in brains of surviving bats were compared with those of dead and convulsing bats. These comparisons indicated that DDT was the cause of death. Lethal brain concentrations of DDT in adults averaged 24.5 ppm (wet weight) and suggested that adult little brown bats are approximately twice as sensitive to DDT as are adult laboratory rats and mice. Juvenile bats were about 1.5 times more sensitive than adult bats.

Because we obtained these data opportunistically rather than from a deliberate controlled experiment, they are subject to certain potential biases. With this factor in mind, we note that this study is the first to use measured brain levels to compare the toxicity of an insecticide to bats versus mammals. The results substantiate the widely held belief that bats are more sensitive to DDT than are other mammals.

Organochlorine Contamination of Marine Mammals. Seals, sea lions, porpoises, and whales are upper-level consumers that feed in the oceans where many chemical pollutants ultimately con-

centrate. Mercury contamination is believed to be the cause of endangerment of the Finland seal, and questions have been raised regarding the possible involvement of organochlorine compounds in problems of California sea lions.

A survey of residues in several species from several countries, conducted jointly with the National Fish and Wildlife Laboratory, showed highest residues in tissues of mammals from southern California. Maximum levels of DDT and its metabolites were reached in the blubber of a bottlenose dolphin where concentrations reached 2,695 ppm. Maximum levels of PCB's were 450 ppm. Tissues of mammals from Uruguay generally contained the lowest levels of contaminants.

Endrin and Toxaphene Impair Learning in Bobwhites. Operant conditioning is well adapted to studying effects of pollutants on learning of birds. Birds are trained to peck one of two similar symbols to obtain food. The correct and incorrect symbols are frequently switched back and forth from right to left. Once a bird has learned to peck the correct symbol, that symbol is changed to become the incorrect symbol. This exchange is called a reversal. The bird must then learn to select the other symbol. After a series of these reversals, new symbols are introduced to make selection more difficult. An electronic apparatus controlled by a punched tape automatically varies symbols, provides the reward, and records responses.

Endrin was given continuously at 0.1 ppm and 1.0 ppm in the diet. Treated birds made up to 139% more errors than controls. Birds continued to make errors as long as they received endrin; they returned to normal performance only after 50 days on clean feed. The results of endrin treatment were remarkable in three ways: (1) Birds on 0.1 ppm did significantly worse than those on 1 ppm. This is not believed to be an artifact. (2) The ability of birds to learn new symbols became progressively poorer through the series of tests although endrin must have reached equilibrium in the body long before testing began. (3) With any given pair of symbols, errors tended to drop sharply after the third or fourth reversal. The conclusion is that the chief effect of endrin was to impair the ability of the birds to react appropriately to new problems. In the field, this effect could be especially severe on the young, to whom many problems are new.

Toxaphene fed continuously at 10 and 50 ppm reduced the ability of bobwhites to learn new sym-

bolts and to make reversals. Although the effects were relatively moderate, the treated birds made 50% more errors than controls. Eventually the birds adjusted to their toxaphene intake and gradually came to do as well as controls, although still on dosage. Wild birds, of course, could be in danger during any period of erroneous behavior responses.

Dieldrin and Endrin Are Not Additive in Avian Mortality. When animals are exposed to a mixture of chemicals, each chemical is likely to contribute to mortality, each in proportion to its toxicity and the amount present. Residues of organochlorine pesticides in the brain at death show that each chemical contributed proportionally to cause death. We find, however, that endrin and dieldrin are not additive in this respect, even though they are optical isomers of the same thing. We killed grackles with dietary dosages of endrin, dieldrin, and mixtures of the two that were roughly equal in toxicity. Endrin killed much more quickly. In the groups receiving mixtures, residues in the brain and the time to death showed that endrin was the chemical that killed. Even when dieldrin residues approached fatal levels they did not cause any reduction in the lethal amount of endrin present. This finding is supported by data for white pelicans that were killed by endrin in the Tule Lake area of California-Oregon. The endrin in brains was ample to account for death, but fair amounts of dieldrin were present as well. The importance of this work lies in proving that we cannot assume that chemicals are additive even though they are closely related.

Diagnostic Residues Established for Endrin. Birds of protected species, including white pelicans and at least one eagle, are still being killed by endrin in the field. The Service needs legal evidence of cause of death. We have produced data on the diagnostic residues of several chemicals, but endrin has been difficult because of analytical problems and paucity of data. We therefore worked with the chemists to refine and standardize methods and then ran a large-scale test with four species of blackbirds. The results show that a bird was almost certainly killed by endrin if its brain contains 0.8 ppm (wet weight) or more of endrin. If the brain has less than 0.6 ppm of endrin, the bird did not die from the neurotoxic effects of endrin. Between 0.6 and 0.8 ppm is a gray zone containing both dead birds and survivors. Other studies reveal that these limits apply equally well to bald eagles and mallards. Earlier

work on small brains suffered from analytical problems and is now considered invalid in showing lower residues at death.

12-Ketoendrin Not Found in Birds. British work, confirmed at Patuxent, proves that rats killed by endrin have little or no endrin in their brains but instead have the more toxic 12-ketoendrin. British workers pointed out that rabbits, unlike rats, did not form 12-ketoendrin. We can add that white mice, which are close relatives of rats, form a little 12-ketoendrin but have more endrin. We looked for 12-ketoendrin, but found none, in endrin-killed grackles, Japanese quail, a white pelican, and in mallards near to death from long endrin dosage. As no 12-ketoendrin appeared in birds of four distinct orders, the difficult analysis for this chemical need not ordinarily be undertaken when analyzing birds for endrin. An exception should be made, however, for raptors that may have been feeding on endrin-killed rodents.

Danger Level Determined for Dieldrin Residues in Birds. Birds killed by persistent organochlorine pesticides generally have diagnostic, lethal residues in brains. However, birds quit eating and lose weight for many hours, or even days, before death, and during this period their brain residues are constantly rising. The critical question is: What is the residue level in the brain when feeding stops? The residue at that time is the danger level, the point of no return. No residue of this level can be considered safe.

The problem was approached by feeding dieldrin to male cowbirds at 20 ppm. Each bird was in a separate cage and had a special feeder. Feeders were wired so that a signal was recorded every time a bird fed. Pilot tests revealed how frequently birds fed and how long a foodless interval had to be before it indicated that a bird had ceased to feed. Birds of one group were sacrificed as soon as it was established that they had stopped eating. Birds in the second group were allowed to die. Brains of both groups were analyzed and results were compared statistically.

Birds that were sacrificed at the time they ceased feeding had an average of 6.75 ppm dieldrin in their brains. Those that died of dieldrin averaged 16.21 ppm, or 2.4 times as much. The difference was highly significant and there was little overlap between groups.

The sacrificed birds had 1.5 to 12 ppm of dieldrin in their brains. Residues within this range must be considered highly dangerous and likely to lead to death. Dead wild birds sent in as possible

pesticide kills not infrequently have residues in this range. Factors such as disease or injury may cause illness and weight loss, but when they cause enough mobilization to make pesticide levels rise to the point at which a bird can no longer feed, recovery becomes impossible.

Chemicals of the Chlordane Group Are Lethally Additive. Technical chlordane is a mixture of related chemicals. These chemicals proved to be additive in causing death. In an experiment performed in cooperation with the Environmental Protection Agency, nine groups of birds were fed varying mixtures of the chlordane group. These mixtures varied from heptachlor at one extreme to pure alpha-gamma chlordane at the other. The mixtures killed with fewer ppm of chemical in brains than did the simple compounds. These results indicate that the several components of chlordane are additive in their effect.

Nonachlor Proves To Be of Low Toxicity to Birds. Residue chemists agree that trans-nonachlor is the most persistent chemical in chlordane, to judge from the frequency of its appearance in wildlife samples. This chemical also appears in brains of chlordane-killed birds and there were questions as to how much its residues contribute to death. A study was therefore conducted with cowbirds and starlings to learn how toxic nonachlor is and how large its lethal residues are in the brain. It was learned that nonachlor does not kill birds even in long, heavy dosage (100 ppm for 5 weeks). Residues of more than 100 ppm in the brain did not cause death. It is clear that residues of nonachlor found in the field, which are far lower than those produced in this study, do not contribute to avian mortality.

Explanations for Sublethal Residues in Dead Wild Birds. It is not uncommon to analyze birds that die in the field and find that residues in their brains are about half or a third as great as those required to cause death in experiments. Experiments in which pesticides are included in the diet of birds give some insight into this situation. In a fair number of these experiments, one or two birds die with exceptionally low residues in brains. Almost all of these individuals display some sign of illness at death, often hemorrhagic enteritis. In an endrin test, for example, the only two dead birds that had hemorrhagic enteritis had residues just under 0.5 ppm in their brains. These residues were below those of all other dead birds and were like those of many survivors. It is known that pesticides can interfere with an animal's system of im-

munity and can cause bleeding. The theory, then, is that a serious pesticide exposure triggers weakness and disease in especially vulnerable individuals, and that vulnerable individuals are well represented among wild animals whose deaths are suspected of being pesticide-related. Another consideration is that sick or injured animals lose fat and thereby mobilize whatever pesticides are in their fat. Some of these chemicals concentrate in the brain. The amounts that reach the brain depend upon the amounts in the body; therefore, they may be of any level, trivial to lethal. In some birds, the level is bound to fall into the puzzling sublethal range discussed in this report.

New Estimate of Persistence of DDE in Grackles. DDE is important in being primarily responsible for eggshell thinning. It is known to be long-lasting in ducks and pigeons, but is short-lived in a domestic bird, the coturnix. Estimates now available for the grackle indicate that the time required for the body to lose half of its burden of DDE is approximately 31 weeks, or 7.75 months. This estimate agrees well with the pigeon data. These findings mean that whenever and wherever a bird picks up DDE in its travels, much of it will be left, ready to cause trouble, at the time of the breeding season.

Kelthane Does Not Create a DDE Hazard for Birds. Kelthane, or dicofol, is a relative of DDT that is still used as a miticide, even on Federal refuges. Published reports state that it partially metabolizes in animals to DDE. As DDE is a notorious shell thinner, it was necessary to find out the amount of DDE that ingestion of kelthane creates in birds. Grackles were given 100 ppm in their food for a month, which is a long, hard dosage for a short-lived chemical. Birds were then sacrificed and their residues were compared with those of controls. The birds had accumulated only 4.5 to 6.3 ppm of DDE despite the severe exposure. In addition, it was found that the technical kelthane contained 0.4% of DDE, which is ample to account for the amounts in the birds. It was concluded that kelthane did not metabolize to DDE in any significant amount and that the use of kelthane on crops is unlikely to cause a DDE problem for birds.

Lethal Levels of Mercury in Four Species. Hazardous levels of mercury identified in four species of birds showed small but significant differences among the species. Red-winged blackbirds killed by mercury poisoning had the highest concentrations in all tissues and grackles had the



Royal terns and young at Cape Romain National Wildlife Refuge, South Carolina. The effects of chronic levels of oil pollution on terns, gulls, and other seabirds are being examined by the Patuxent Wildlife Research Center.

Photo by R. C. Szaro.

lowest. Redwings also survived dosage for a slightly longer period. Levels in starlings were second and cowbirds third, but the differences between these two were not statistically significant. Resembling lead, but differing from the fat-soluble organochlorine compounds, levels of mercury in birds that died of mercury poisoning broadly overlapped the slightly lower levels in birds that were dosed with equally high amounts but did not die. Mercury in brains of birds that died averaged 21 to 45 ppm; average levels in livers ranged from 54 to 126 ppm.



Great black-backed gull guarding its nest on Appledore Island, Maine. Gull embryo survival is dramatically decreased by application of 20 μ l droplets of No. 2 fuel oil.

Photo by R. C. Szaro.

Dicamba Herbicide Safe to Use in Bird Pens.

Scores of large outdoor pens at Patuxent become seriously overgrown with brush and vines. Herbicide control is the obvious answer, but investigators demand proof of safety before allowing chemicals to be used in their pens. A granular form of dicamba (= Banvel) was one herbicide under consideration. Groups of grackles were used to test this chemical. Two groups were forced 1 or 3 whole granules of 5% strength. One group was given a pan full of granules next to the food pan. Another group had granules mixed into the feed for a month. The final group had feed and legs soaked in a thick slurry made from the granules. None of the birds displayed any ill effects nor showed any tendency to eat the granules. The birds that had granules mixed into their feed for a month were dissected and proved to be in excellent condition.

Preservation of Blood Biopsy Samples in the Field. Field workers often wish to take a tissue sample for residue analysis without harming the animal. Whole blood is recommended as a representative tissue that may be sampled without causing harm. A sample of 3 ml is adequate and can be taken from many kinds of birds. But how is a field man, far from refrigeration for weeks on end, to preserve blood samples? A test was run to learn how formalin-preserved blood compared with frozen blood. A goose was dosed with DDE, DDT, and dieldrin at levels designed to create realistic body burdens and still yield measurable levels in blood. Chemicals were administered in dimethyl sulfoxide, a penetrating agent, to insure uptake into the system. The goose was sacrificed the next day, when distribution into tissues should have been complete. Some blood samples were frozen, some were treated with 1 part in 20 of chemically pure concentrated formalin. The latter were held for 1 week at 100°F. Analysis revealed that the formalinized samples were as well preserved as the frozen samples. Furthermore, they became solid gels that were easily processed in the laboratory. The technique is recommended to field men; a small vial of formalin is sufficient for a season.

Cause of Death of Bald Eagles, 1975-76. Progress has been made in reducing the shooting of eagles. A few years ago, half of the dead eagles sent to Patuxent for analysis had been shot. Only 20% of the 90 eagles studied in 1975-76 were shot. Injury was the leading cause of death, accounting for 27%; this category includes electrocution, impact, trapping, and other types of injuries.

Various diseases accounted for 12%. Lead poisoning from eating shot animals killed 8%. Pesticides, chiefly dieldrin, may have killed 4 to 8%. Cause of death could not be determined for the other eagles.

Residues in Bald Eagles, 1975-76. Ninety bald eagles found dead or dying during the 2-year period were necropsied at the National Fish and Wildlife Health Laboratory, Madison, Wisconsin, before being analyzed at Patuxent. These eagles came from 22 States scattered from Alaska to Florida.

Pesticides occurred at dangerous levels in brains of seven eagles; necropsy did not reveal other causes of death in these seven birds. Endrin at 0.71 ppm in one brain represented a level that is lethal in some individual birds but not in all. Dieldrin may have been lethal in brains that contained 11.0, 8.7, and 7.5 ppm. Dieldrin levels were at least dangerous in three brains for which readings were 5.0, 4.5, and 4.1 ppm. Two of these seven eagles came from Wisconsin.

Residues of PCB's occurred in the bodies of all eagles; amounts varied from 0.18 to 560 ppm. All bodies also contained DDE; amounts varied from 0.17 to 120 ppm. DDT, however, was found in only 27% of the bodies, and its highest level was only 0.6 ppm. Dieldrin, in contrast, appeared in 85% of the eagles, and at levels up to 12 ppm. The chlordane group was represented by six compounds; the two most dangerous of these, heptachlor epoxide and oxychlordane, were found in 58% of the eagles, although not at high levels (up to 2.8 ppm). Small amounts of toxaphene appeared in 28% of the birds. Hexachlorobenzene and mirex were detected at low levels in 20% and 45% of the birds.

As in years past, the eagles held many contaminants; DDE and PCB's were the most frequent and most abundant and dieldrin was the major single threat to life. Contaminants are often additive in action, so it is not surprising that eagles have serious problems.

High Organochlorine Residues in Eggs of Chesapeake Bay Bald Eagles. Reproductive success of bald eagles has been well below normal for many years, especially in Virginia, but has been improving. In 1976 and 1977, 14 eggs representing nine nesting attempts were collected after they failed to hatch. The DDE in these eggs averaged 18 ppm (wet weight) and ranged from 8.0 to 51 ppm. Dieldrin averaged 1.6 ppm and reached 1.0 ppm or more in eight of the nine clutches. PCB's

averaged 59 ppm and means for individual clutches were all higher than 20 ppm. One egg from a nest on the Potomac River contained 218 ppm PCB's, the highest known level of these compounds yet found in bald eagle eggs. Other organochlorines were also present in low to moderate amounts.

Eggs from Minnesota and Wisconsin contained much lower residues. Bald eagle reproductive success appears to be normal in these two States. Twenty eggs were collected from 24 clutches that failed to hatch. Eggs from only three of these contained 10 ppm or more of DDE, and eggs from only five clutches contained 1.0 ppm or more of dieldrin or 20 ppm or more of PCB's.

Lead Poisoning a Significant Factor in Mortality of Bald Eagles. Seven of the 90 bald eagles found dead or dying and submitted for analysis in 1975-76 apparently died from eating prey that contained lead shot, presumably prey that had been killed or crippled. Three of the eagles still had shot in the stomach; one had 75 shot. All seven had lead residues of 22.9 to 38.1 ppm in the liver. Necropsy findings were compatible with a diagnosis of lead poisoning.

Work is planned to elucidate the mystery of why eagles die from lead poisoning. Experiments with both red-tailed hawks and sparrow hawks have shown that feeding shot does not produce poisoning, largely because shot is soon regurgitated in castings.

Plasma Enzymes Altered in Eagles Exposed to Dieldrin. Six different plasma enzymes were measured in 20 bald eagles to begin a compilation of a biochemical profile as a basis for judging abnormal levels as indicators of chemical exposure. Dosage with dieldrin produced a dramatic increase in activities of four of the plasma enzymes, indicating altered membrane permeability in several organs resulting in an acute pathological release of the enzymes. Such enzyme changes precede overt changes and could be used to screen live bald eagles for possible occurrence of organochlorines before chemical analysis of the blood. Pathogenic diseases can cause similar biochemical changes but are usually of lesser magnitude and are accompanied by other diagnostic indices.

Kestrels Tested for Secondary Hazard of Lead Poisoning. Elevated lead residues have been detected in pine voles and other small mammals occurring in apple orchards where lead arsenate has been used for many years to control insect pests. Pine voles trapped in the orchards were fed to cap-

tive kestrels for 60 days to assess potential secondary exposure to lead. Control birds were fed laboratory mice.

Carcasses of pine voles contained an average of 38 ppm of lead compared with 0.1 ppm in laboratory mice. Kestrels fed this elevated amount of lead suffered no mortality and accumulated only low residues of lead in their tissues after 60 days of exposure. Livers of treated birds contained an average of 1 ppm of lead compared with 0.06 ppm in livers of controls. Leg bones of treated birds accumulated twice as much lead as leg bones of controls, although residues in both groups averaged below 1 ppm.

In a second experiment, exposure to lead either directly as lead shot or secondarily as lead in tissues of ducks dying from lead poisoning had no effect on survival of kestrels during a 60-day period, although tissues of birds receiving lead directly as shot accumulated higher residues. Kestrels regurgitated the shot when pellets were cast.

Sora Rails Exposed to Lead at the Patuxent River Marsh. Migrating sora rails use tidal marshes of the Patuxent River in Maryland during September and October, where they have been hunted for many years. Thirteen percent of the sora rails collected at the marsh during 1965-73 contained lead shot. During 1976, immature soras were collected to determine accumulation of lead by tissues and to estimate potential harmful effects resulting from lead shot ingestion.

Soras that had ingested shot contained up to 17 ppm in livers and up to 127 ppm in bones. Four of the 13 birds (31%) with ingested shot had more than 3 ppm of lead in their livers. The number of shot in gizzards of these birds varied from 6 to 15. Soras that had not ingested shot had low lead levels at all seasons.

Birds of Prey, DDT, and Tussock Moths in Pacific Northwest. Residues of DDT and its metabolites were compared in four species of birds of prey after the excepted use of this chemical in Washington and Oregon forests in 1974. The primarily insectivorous kestrel showed the least buildup of residues, which peaked 1 year (1975) after the spraying, possibly because of the relatively short insect food chain and faster population turnover. Despite the low residue buildup, kestrel eggshells in 1975 were 11.5% thinner than normal, residues in plasma averaged 0.78 ppm, and residues in eggs averaged 6.42 ppm. In 1976, eggshells were 6.7% thinner than normal, residues

in plasma dropped to 0.51 ppm, and residues in eggs dropped to 2.24 ppm.

Goshawks (primarily mammal-eating) in the spray area in 1975-76 showed a 2.6-fold increase in plasma residues over the 1975 peak for kestrels. The mammal- and bird-eating Cooper's hawk showed a 3.8-fold increase and the bird-eating sharp-shinned hawk showed a 6.1-fold increase. These increases in plasma residues cause concern for all three accipiters in the spray area. Sharp-shinned hawks may be contaminated over a much larger region than the spray area because of their more mobile prey (other birds).

Kepone in Fish-eating Birds. Because of the possibility of kepone accumulation in bald eagles of the Virginia and Maryland tidewater areas, tissues from 15 birds taken between 1966 and 1975 were removed from the freezer and reexamined by new methods developed for this purpose. An immature eagle taken in 1975 contained 130 ppm, and two adults taken in 1972 and 1974 contained 50 and 83 ppm; nine others contained 0.02-12 ppm.

Osprey eggs collected from 16 nests in 1976 all contained kepone at levels of 0.09-1.5 ppm.

Although kepone evidently shares the propensity to accumulation that is common to many other organochlorine compounds, the significance of these levels to the welfare of the birds has not been examined.

Systemic Insecticide Causes Secondary Effects in Owls. Organophosphate insecticides, generally short-lived, are not expected to produce secondary poisoning. However, famphur, a potent cholinesterase inhibitor used on the backs of cattle to control warbles, also appeared to have killed black-billed magpies, which forage on insects on and around the cattle. Could predators feeding on the poisoned magpies be affected? In a laboratory test designed to answer this question, barn owls were fed coturnix quail that had been killed by famphur. Each owl was given one poisoned quail per day for 10 consecutive days. Five were given whole, intact quail, and five were given quail with gastrointestinal tracts removed to insure that the only chemical they received had been absorbed by the quail. Five additional owls fed undosed quail served as controls.

No owls died, but all 15 that were fed famphur-dosed quail had depressed cholinesterase activity, a sign of organophosphate poisoning. Brain cholinesterase was inhibited 32 to 73% in the owls fed intact quail and 16 to 53% in those fed quail

with digestive tracts removed. Although inhibition of brain cholinesterase in excess of 50% has been associated with bird deaths under certain conditions, none of the owls showed any well-defined signs of intoxication. Clear signs of toxicity are difficult to observe in owls, however, because they are relatively inactive during the daytime. Despite the lack of overt response, the depressed cholinesterase activities clearly indicated that the owls were affected. The degree of inhibition was so near the lethal levels determined for other species that it is likely to be sufficient to increase their vulnerability to normal stresses of living in the wild.

Atlantic Coast Heron Colonies Provide Baseline Data for Contaminant Evaluation. In 1975 and 1976, 262 colonies of herons and their allies were located and censused along the Atlantic Coast from Maine to Florida. Sixteen of 186 colonies active in 1975 were inactive in 1976 (abandoned colonies). In addition, 7 of 177 colonies inactive in 1975 were active in 1976 (new colonies). New and abandoned colonies had fewer nesting adults and species than colonies that were active in both 1975 and 1976 (stable colonies). New and abandoned colonies were also nearer to stable colonies than stable colonies were to each other, which suggests that they are satellites of larger stable colonies. Stable colonies tended to remain constant in numbers of species and adults from 1975 to 1976, i.e., large colonies in 1975 were also large in 1976.

In correlated investigations, habitat utilization by nine species of herons, egrets, and ibises was examined by following birds from their nesting colony near Beaufort, North Carolina, to their feeding sites. Most individuals flew within 4 km of the colony and landed in salt marsh. The longest flight was 28 km by a great egret. Great egrets, the only species to feed in eelgrass beds, fed in fresh water only at high tide. Louisiana herons did not feed in fresh water at all. Great egrets, black-crowned night herons, and white ibises flew farther from their colonies at high than at low tide. In addition, great egrets flew farther away from their colonies when they used thermals.

Biological Control of Rangeland Grasshoppers Prevents Wildlife Damage. A nonchemical method for grasshopper control uses the spores of the protozoan *Nosema locustae*, which kill grasshoppers when they ingest them. The spores are spread in a bran bait by air in the same manner as a chemical treatment.

All laboratory tests indicated that *N. locustae*



Brown pelicans and young at Cape Romain National Wildlife Refuge. Pelican populations and breeding success continued to increase in 1977. Photo by R. C. Szaro.

spores affected only grasshoppers and related insects and were harmless to wild animals except possibly in massive quantities. To test effects in the field, a large-scale test was designed and conducted on 92,000 acres of rangeland in Montana. The spores were applied at two rates on several plots and their effectiveness against grasshoppers was evaluated. As a part of this study, we monitored resident wildlife populations. Data were obtained before and after treatment in 1975 and 1 and 2 years after treatment in 1976 and 1977. No evidence of harm to wildlife populations was found.

It will be a major step forward if *N. locustae* spores can replace much of the insecticide used on

rangelands. Another important advantage of *N. locustae* spores is that they do not cause the sudden sharp reduction of grasshoppers and other insects that is characteristic of the common broad-spectrum insecticides. Thus, the food supply for insect-eating birds and mammals remains adequate while range forage is protected. The *N. locustae* may also reinfect grasshoppers from year to year, providing a longer period of protection from grasshoppers than the chemicals in current use.

Brown Pelican Increase Continues in South Carolina and Texas. More than 3,000 pairs of brown pelicans nested in the two South Carolina colonies in 1977, up from 2,500 nests in 1976 and

1,100 in 1970. Reproductive success was excellent, an average of 1.4 young per nest at the Cape Romain colony; this level of production exceeds the estimated requirement for maintenance of a stable population.

Residues of most chemicals in the eggs also continued to decline, and eggshells were correspondingly thicker. Residues of PCB's, however, were essentially unchanged from the previous year.

Production of brown pelicans in Texas reached a 13-year high in the 1977 breeding season. Seventeen pairs of pelicans fledged 34 young, for an overall success rate of 2 per pair. This high rate of production suggests that the population may be rebounding from the severe decline in the late 1950's and early 1960's. Residues of both DDE and PCB's declined and shell thickness increased. Several factors contributed to the successful 1977 season, including an absence of severe storms, improved protection of colonies in bird sanctuaries, and an abundant fish supply near the nesting colonies.

Rate of Endrin Loss in Mallard Ducks. Endrin is not a persistent pesticide in living animals: its half-time in rats is only 2-4 days. Nevertheless, in recent years it has accumulated in white pelicans of the Northwest to levels that killed. It also appears in bodies and eggs of brown pelicans of the Gulf Coast. Do these accumulations occur because fatty, aquatic birds such as pelicans are slow to lose endrin? To answer this question, tests were made with another fatty, aquatic bird, the mallard. Groups of drakes were fed 20 ppm endrin for 13 days, when mortality began. All were then changed to clean food. Groups of five birds were sacrificed for analysis on days 0, 2, 4, 8, 16, 32, and 64 of cleanup. Both bodies and samples of blood were analyzed.

The rate of loss was rapid for about 2 weeks but then became very slow. Half of the endrin in bodies was lost by about 10 days. The loss from blood was more rapid.

Analysis of brains from endrin-killed ducks and survivors revealed differences in residue levels that were diagnostically useful. There was overlapping between 0.6 ppm and 0.8 ppm, but most of the survivors had levels below 0.6 ppm and most of the dead had levels above 0.8 ppm.

PCB's Reduce Egg Production in Mallards. Dietary dosage of 150 ppm of Aroclor 1242 reduced hatching success of eggs laid by 12 pairs of mallard ducks to 69%, compared with 83% for eggs from 12 pairs of control birds. The reduced

success resulted from increased embryo mortality; fertility was essentially the same in controls and dosed birds. There was no evidence of increased abnormalities among the dosed birds, but growth rates of hatchlings differed. Ducklings hatched from eggs produced by dosed birds were larger at 1 day of age than control ducklings but, at 3 weeks, weighed less than controls. Survival to 3 weeks was similar in both groups.

Effects of Toxaphene on Reproduction of Black Ducks. The effects of toxaphene on wildlife are still incompletely known despite its wide use in agriculture. Toxaphene is believed to be one of the less cumulative organochlorine pesticides. A 2-year reproductive study with black ducks, in which birds incubated and reared their own young, was completed in 1977.

Confirming results of the first year's research, toxaphene at dietary levels of 10 and 50 ppm caused no adult mortality, and there were no differences in numbers of hens that laid eggs, incubated, or abandoned their nests. Average clutch sizes were essentially the same in all groups.

Effects of 50 ppm toxaphene dosage included slow growth of ducklings during the first 2 weeks of life, decreased weights of males during summer months, and increased liver weights among females.

Although toxaphene-dosed birds appeared to be hyperactive, the empirical observations were not quantified.

In both years, however, the toxaphene-dosed birds began incubation a shorter time after initiation of laying than did the controls; although this relationship suggests the possibility of some hormonal effects, field implications are equivocal.

Cadmium Hazard to Waterfowl Explored. Experimental evaluations of the effects of cadmium on waterfowl were initiated in 1977 after chemical analyses showed that kidneys and livers of canvasback ducks from the Chesapeake Bay contained low to moderate amounts of this metal.

The first studies explored the uptake and retention of cadmium in the tissues of experimental mallards fed diets containing cadmium at levels similar to and exceeding those that might be obtained by wild ducks.

Seventy pairs (male and female) of mallard ducks were used in the experiment. Three groups of 20 pairs each were fed diets containing respective dosage levels of 200, 20, or 2 ppm cadmium, and 10 pairs were fed clean, untreated food.

Ducks fed 200 ppm for 60 or more days had en-

larged kidneys and the enlargement persisted even after 30 days of untreated food. Testes of males on all dosages were reduced in size and remained so even after 30 days of untreated food. No birds died and the blood picture remained normal.

Cadmium reached highest concentrations in livers and kidneys and did not decline during a month of untreated food. Cadmium levels increased in brain tissue during the month of clean food, evidently as a result of redistribution from other parts of the body. Little cadmium accumulated in eggs, but egg production was suppressed in birds fed 200 ppm.

To complete the evaluation we need to know the effects of lower doses of cadmium over longer periods of time.

Mercury on Eggshell Surface Toxic to Embryos. Industrial effluent streams and ponds containing both mercury and organics, including oil, have been reported to contain 10 ppm of mercury—and even higher levels in some areas. In experimental study, eggshell surface applications of methyl mercury chloride dissolved in a paraffin mixture proved to be almost as toxic as direct injections into the yolk sac of a 2-day-old embryo. Mercury in amounts of 9 μg or more increased embryo mortality above that of the controls or of the eggs treated with carrier alone. Mercury also increased teratogenic defects. Mallard embryos were more sensitive to mercury application than embryos of domestic chickens.

Egg Laying Increases Accumulation of Lead and Vanadium in Bone. Mallard hens that were laying eggs accumulated more than 4 times the concentration of lead in their bones as nonlaying hens when both were dosed with a single No. 4 lead shot. Drakes accumulated lead to less than one-fiftieth the level in laying hens. Lead accumulated to higher levels in bones with high medullary content (femur and sternum) than in bones with a lower medullary content (wing bone).

These results, which were based on the performance of 50 breeding pairs of ducks, suggest an interaction between lead and calcium.

A similar interaction was suggested for vanadium, which was fed at rates of 1, 10, or 100 ppm in the diet to a total of 20 pairs of mallards or 5 pairs for each rate and 5 pairs for control. Accumulation in drakes and hens on the lower dosages did not differ, but at 100 ppm, the hens accumulated vanadium in bones to 11 times the levels in drakes. Changes in lipid metabolism accompanied residue accumulation. High levels of

vanadium in petroleum indicate the need for further evaluation of its effects on the physiology of wild birds, particularly its reproductive effects.

Pollutants and Waterfowl Reproduction in Northwestern Lake Michigan. A broad survey of pollutants in merganser eggs, which will soon be published, revealed shell thinning and high DDE and PCB residues in mergansers nesting on islands of Door County, Wisconsin, in 1975. Residues of DDE averaged about 16 ppm and PCB's about 45 ppm, wet weight, in eggs of red-breasted mergansers. Shell thinning averaged 17.7%.

In 1977, a detailed study was made of nesting success of these mergansers and certain other ducks in the affected area. Data are not yet available on shell thinning and residues in 1977, but figures on hatching success reveal relatively good reproduction. In 83 active merganser nests that were observed to completion, 82% of the eggs hatched. In 24 mallard nests, 3 black duck nests, and 3 gadwall nests, the percentage of eggs that hatched was 89.6, 91.1, and 93.0. Clearly, the levels of pollution and shell thinning that prevailed in 1977 were not sufficient to depress reproductive success to any great extent. It must be remembered, however, that the reproduction of ducks has never been considered as sensitive to pollutants, particularly DDE, as has that of raptorial and fish-eating families of birds.

Environmental Contaminant Problems Revealed by Field Incidents. Birds long have served as indicators of environmental contaminant problems that ultimately concern man. First indications of present or future problems often have come from mortality incidents discovered by Fish and Wildlife Service Regional personnel. The year 1977 revealed problems with both old and new chemicals. Several examples follow.

Deaths of white pelicans at Tule Lake and in the Teton Dam area were determined to be due primarily to endrin poisoning. New experimental and chemical research was required to establish and validate lethal levels of this compound, which involves many complications. This incident was a reminder that endrin poisoning is still a serious threat to wildlife.

Wigeons died at the Sacramento National Wildlife Refuge as a result of carbofuran treatment of adjoining alfalfa fields. Positive diagnosis of cause of death was made by biological and chemical tests for use in the legal case that followed.

Large numbers of cardinals, mourning doves, black ducks, and other birds died at Cape May,

New Jersey, as a result of parathion poisoning. Cause of death was diagnosed biologically and chemically. Other chemicals than parathion had been suspected.

More than 300 cedar waxwings died in Texas because pyracantha berries were sprayed with Nema-cur (an organophosphate).

Heptachlor-treated grain is being used extensively in Oregon counties, resulting in several incidents of bird mortality. Analysis of brains of pheasants, magpies, and a golden eagle at Patuxent Wildlife Research Center clearly demonstrated the cause of death to be heptachlor poisoning and suggested the possibility of other secondary poisoning hazards.

Research/Research Management Program Initiated at Patuxent Wildlife Research Center. A new thrust in predictive pollution ecology was initiated late in fiscal year 1977 as a result of funding and ceilings received under a supplemental appropriation in the Bicentennial Land Heritage Program. Research in this program will integrate ecological and experimental studies, will increase and develop competence in this field in the Cooperative Wildlife Research Units, and will bring research staff and Regional staff together at the working level. Major research efforts will be directed toward the newer pesticides impacting wildlife and toward chemicals generated in industrial processes.

Cooperative agreements were established for work on the effects on wildlife of environmental contaminants that result from conversion of bottomland hardwoods to cropfields, pesticide and heavy metal contamination of selected Gulf Coast ecosystems, effect of oil on reproductive efficiency of nesting seabirds, and assessment of contaminant-related environmental disturbance caused by metal mining.

Two analytical contracts were awarded to provide chemical support for this research; quality control will be maintained through a system of sample exchange and analyses of standardized samples.

Research Evaluates Impact of Petroleum on Aquatic Birds. Research in 1977 on the impact of chronic low-level exposure of birds to petroleum suggested that petroleum presents a real hazard to embryos and young birds but can be tolerated at high dietary levels by adults during nonreproductive periods.

Fuel oil applied to eggs in the field kills developing embryos.—Very small quantities of oil applied

to waterfowl eggs in the laboratory significantly reduced hatchability in a series of studies conducted in 1976 and 1977. Field studies during the spring of 1977 in Texas and Maine with several species of aquatic birds confirmed the laboratory findings.

On the Texas Gulf Coast, oil applied to newly laid eggs resulted in 83% mortality for laughing gulls, 61% for Louisiana herons, and 56% for sandwich terns; mortality among control embryos was negligible. Twenty microliters of oil was applied to 60 eggs of each species and an equal number of untreated eggs served as controls. After the eggs were naturally incubated by the adults for 5 days, all eggs were collected and opened immediately to determine embryo mortality.

In Maine, similar applications of No. 2 fuel oil to 20 clutches of common eiders resulted in 20% embryo mortality 7 days after treatment. Mor-



Skeleton of 18-day-old mallard embryo from egg exposed to crude oil, showing missing and deformed neck vertebrae. Special methods were developed for clearing and staining duck embryos. Photo by D. Hoffman.



Application of a 5 μ l droplet of South Louisiana crude oil to the surface of a fertile mallard egg. This small quantity of oil decreased hatchability by 70%. Photo by J. Huff.

tality was 50% among 30 clutches of great black-backed gulls.

In 30 additional clutches of great black-backed gull eggs treated with 5 μ l of fuel oil and incubated to term by the parents, hatching success was again half that of controls and production of fledglings was one-third that of controls.

The minute quantities of oil that produce marked reductions in embryonic survival suggest that oil pollution could seriously affect marine and estuarine bird populations by transfer of oil from the plumage of incubating birds to their eggs.

Toxicity of four oils compared in tests with mallard embryos.—As little as 5 μ l of No. 2 fuel oil, South Louisiana crude, Kuwait crude or Prudhoe Bay crude oil applied to the shell surface significantly reduced hatching of mallard eggs by 70, 90, 68, and 26%. No embryos survived treatment with 50 μ l of any of the tested oils. Fifty microliters of oil represents approximately 1 ppm.

Crude oil decreases growth of duck embryos.—Eighteen-day-old mallard embryos from eggs treated on the 3rd day of development with 5 μ l of South Louisiana crude oil weighed less than controls and also were smaller and had shorter beaks.

Chick embryo skeletal clearing and staining techniques adapted for use with mallard embryos made rapid screening for skeletal defects possible. Skeletal abnormalities that resulted from the oil applications included deformed and missing neck vertebrae and incomplete ossification of digits and lower back vertebrae.

Growth of mallard ducklings depressed by oil in the diet.—Mallard ducklings survived from hatching to 8 weeks old on diets containing 0.025 to 5.00% (250-50,000 ppm) South Louisiana crude oil. Those fed 2.50 and 5.00% oil, however, were stunted and failed to develop flight feathers. Subtle biochemical and behavioral changes were detected in ducklings fed as little as 0.25% oil.

Egg production of mallard ducks impaired by diets containing 25,000 ppm oil.—Mallard ducks fed diets containing 25,000 ppm South Louisiana crude oil for 6 months produced 50% as many eggs as controls. Over a 90-day period, the oil-dosed birds laid an average of 35 eggs per hen compared with 69 for controls. However, eggs laid by the oil-dosed birds hatched as well as control eggs when artificially incubated and the hatchlings weighed as much as control hatchlings.

Mallards react to oil in the diet by increasing liver function.—Plasma clearance rates were en-

hanced in mallard drakes fed 4,000 ppm of a mixture of aromatic compounds typical of those found in South Louisiana crude oil. Although several plasma enzymes and electrolytes were monitored monthly, none were elevated above control levels. Adult waterfowl are apparently able to adapt to and tolerate high concentrations of petroleum hydrocarbons in their diet.

Radioactive naphthalene accumulates in ducks fed contaminated crayfish.—The gall bladder, fat, kidney, liver, and blood of mallards all contained radioactivity after the birds had fed on crayfish from water containing ^{14}C -labelled naphthalene. These food-chain studies are being used to estimate the uptake and tissue distribution of aromatic compounds in waterfowl.

Presence of petroleum hydrocarbons in avian tissues confirmed.—Development of methodology for the detection and quantitation of residues of petroleum in various avian tissues is nearing completion. This task has been particularly difficult because of the large number of compounds involved, the metabolic changes of these compounds that may occur in warm-blooded animals, and the

presence of natural hydrocarbons in animal tissues.

Chemical analysis requires separation of petroleum residues from both lipids and interfering pesticides. This separation has been accomplished by modifying the existing pesticide cleanup procedure. Use of pentane as a solvent reduces losses due to volatility. Detection and quantitation are achieved by glass capillary gas chromatography and gas chromatography/mass spectrometry.

New GC/MS offers additional sensitivity, convenience.—A Finnigan Model 3200 gas chromatograph/mass spectrometer is now in operation in the analysis of petroleum hydrocarbons in tissue. The additional sensitivity characteristic of this instrument also has made it possible to confirm the existence of low-level pesticide residues in tissues from the Arctic.

The versatility of the Finnigan GC/MS is greatly enhanced by the presence of a small computer. More data are thus acquired and saved for later examination. Other features include a computer-controlled plotter.

Coastal and Anadromous Fish

ATLANTIC SALMON INVESTIGATIONS

Atlantic Salmon in Rivers of Northwestern United States. The 1977 sport catch of sea-run Atlantic salmon in the Penobscot River was the largest in 40 years, and a small but encouraging number of returning adults in the Connecticut River will produce a second generation of salmon in that river. Yet, adults returning from the sea continue to face serious obstacles to upriver migration and reproduction. In a Service-sponsored study at the University of Maine, tiny radio transmitters were inserted into the stomachs of 80 adult salmon that returned to the Penobscot River. For several months thereafter, the tagged salmon were tracked in the River from aircraft and boats. Some of the fish wandered extensively within the River and tributaries; some remained

stationary below dams for several weeks and then moved 10 to 20 km upstream or downstream. One fish dropped back downstream 50 km into salt water. The tracking data disclosed that dams and inadequate fishways hinder upstream migration.

A 3-year ecological study of the Mattawamkeag River, a major tributary of the Penobscot, was concluded by the University of Maine under a Service contract. High water temperatures may be dangerous to parr and adult salmon in warm, dry summers. The introduced chain pickerel and smallmouth bass have become abundant in the Mattawamkeag and add to the stresses of predation and competition faced by young salmon.

The Atlantic Salmon Investigations Office at Orono, Maine, largely ceased functioning by the end of the fiscal year. Much biologically and ecologically oriented research remains to be done on

Atlantic salmon in New England, but the Service will emphasize hatchery production and stocking of salmon to achieve restoration of the species in selected rivers.

FISH CONTROL LABORATORY

Toxicity of Nitrite Nitrogen. The toxicity of nitrite nitrogen to rainbow trout, channel catfish, and bluegills at selected temperatures, hardnesses, and pH's was determined. Toxicity to rainbow trout was not affected by water temperature but was significantly increased in soft water and in acid water. Toxicity to channel catfish was not significantly affected by water temperature or pH, but was significantly higher in soft water (96-hour LC_{50} = 0.720 mg/l) than in hard water (LC_{50} = 2.37 mg/l). Toxicity of nitrite nitrogen to bluegills was significantly higher in warm water (LC_{50} = 131 mg/l) than in cold water (LC_{50} = 209 mg/l) and in soft, acid water (LC_{50} = 88.9 mg/l) than in neutral or alkaline water (LC_{50} = 174 mg/l).

Various invertebrates and frog eggs were exposed to sodium nitrite to determine the toxicity and possible deleterious effects of exposure to this compound. Juvenile freshwater prawns (glass shrimp, *Palaemonetes kadiakensis*) were the most sensitive invertebrate tested against the chemical. The 96-hour LC_{50} for this species in static tests ranged from 0.430 mg/l (as NO_2 -N) to 0.715 mg/l. The corresponding value for the shrimp in a flow-through test was 0.900 mg/l. When the flow-through test was continued for 10 additional days, the 14-day value was identified with the 7-day value of 0.500 mg/l. Hatching of frog eggs was unaffected at 15 mg/l of NO_2 -N, but larval survival was reduced at 0.8 mg/l.

Exposure of fish to nitrite ions induced methemoglobin formation, a lethal condition in fish previously reported by other workers.

Development of Parasiticides. Malachite green is widely used in fish culture to treat fish for external parasites. Although the compound is very effective, little is known of its effects on treated animals. Some workers have reported that malachite green may cause developmental defects if applied to developing eggs or larvae of fish.

Eggs of rainbow trout were treated with 2.2 mg/l concentrations of malachite green daily or at intervals of 2, 3, 4, 7, or 10 days. Eggs treated daily yielded a hatch of only 16% compared with

81% in control lots. All fry from eggs treated daily were grossly deformed. Eggs treated at 4-day intervals or less yielded 2½ times as many deformed fry as did untreated lots. Fry from frequently treated lots also showed reduced growth.

A basic objective of the Fish Control Laboratory concerns the development of chemicals for use in fisheries. One area of research involves the interaction of the chemicals in the aquatic environment.

Rainbow trout were first exposed to Aroclor 1254, a polychlorinated biphenyl (PCB), and later exposed to fishery chemicals, nitrogenous waste compounds, industrial contaminants, or metal ions to assess the effects of PCB residues on acute toxicity.

Fish exposed to the PCB were found to be more resistant than controls to antimycin and malachite green but more sensitive to rotenone and 2,4-D, as well as to chromium and cyanide.

Registration-oriented Studies. The Fish Control Laboratory has dual missions—one concerns the development of fish control tools and the other relates to the registration of fishery chemicals. The laboratory maintains files on all priority fishery chemicals, including reprints of research publications, technical data sheets, literature reviews, correspondence, and submissions to regulatory agencies.

Special reports, literature reviews, and annotated bibliographies are prepared on special subjects as required to meet needs of the research staff or other Service offices. Computer searches are run to check for reports of carcinogenicity, mutagenicity, or other adverse characteristics of candidate compounds.

Records are kept of the registration status of all fishery compounds, of the progress of submissions for registration, and of labeled uses. Requirements to be met when submissions are prepared and changes in regulations are also on file.

Technical reference services were provided to the Fish Control Laboratory staff, to the Fish and Wildlife Service Central Office, to other research laboratories or universities, and to State and private agencies on subjects related to the use of chemicals in the environment.

Information was requested and provided on the following topics: registration status of fishery chemicals; registered aquatic herbicides; effects of zinc on channel catfish; effects of formaldehyde on crops and orchard trees; toxicity of Phosvel; trout and warmwater fish farming; effects of

Kepone and mirex on the aquatic environment; microbial degradation; nutritional requirements of channel catfish; toxicity of diquat, endothall, and copper sulfate to invertebrates; electric barriers for fish and lampreys; homing; gastric emetics for fish; effects of sedimentation and dredging on freshwater mussels; jellyfish control; sulfamerazine suppliers; toxicity of cadmium and copper to fish; effects of rotenone on predaceous insects; aerial applications of rotenone; environmental effects of rotenone; aqualin as a fish toxicant; toxicity of insecticides to fathead minnows and goldfish; culture of oscar (*Astronotus ocellatus*); anatomy of sheepshead; pentachlorophenol toxicity to fish; carbon dioxide (CO₂) as an anesthetic for fish; analytical methods for copper; toxicity of copper to aquatic life; use of formalin, malachite green, and potassium permanganate in shrimp farming; and protocols for registrations.

SEATTLE NATIONAL FISHERIES RESEARCH CENTER

The Seattle National Fisheries Research Center emphasizes the study of fish health and disease from the aspect of the whole animal. Studies are designed to examine the interaction between the animal and factors in its environment. Research on problems of artificial propagation of the early life stages of Pacific salmonids, infectious diseases, and genetic variation in Alaskan fishes was emphasized during the year.

Propagation of Pacific Salmonids. The increasingly limited availability of high-quality water supplies has necessitated the development of hatchery systems which reuse the available water. These systems require the use of elaborate biofilters that depend on the action of a microbiological community. The maintenance of these life-support systems has presented highly complex problems for hatchery managers. Much of the work described here was undertaken to alleviate some of these problems.

Methylene blue, a common treatment chemical for fish parasites, has been shown to be useful at 0.1 to 1.0 ppm in treating nitrite poisoning. Since nitrite poisoning is a chronic problem in reuse hatcheries, it was important to determine the effect of methylene blue on biofilters. Oystershell reuse systems were built, nitrification was established, and methylene blue added at 0.01, 0.1, and

1.0 ppm. The results showed no adverse effects, as revealed by stable pH, ammonia, nitrite, and nitrate levels. Thus methylene blue treatments at up to 1 ppm appear to be safe in reuse hatcheries at water temperatures of 10-15°C.

The efficacy of mineral salts, pH, and methylene blue treatments in reducing the acute toxicity of nitrite to fingerling steelhead trout was determined in a static bioassay system at 10°C. It was concluded that mineral salt additions and pH control can be used to reduce the acute toxicity of nitrite to juvenile steelhead trout in soft water. Calcium chloride alone, at 50 mg/l, effectively increased total hardness to 300 mg/l. The control of nitrite toxicity problems requires that criteria for selecting reuse hatchery sites or establishing operating conditions specify a total water hardness of at least 100 mg/l, a pH of 7 or above, or chloride and calcium levels equivalent to at least 25 ppm calcium chloride.

Artificial propagation programs would benefit from the availability of a nonpersistent, wide-spectrum disinfectant for disease control. Ozone holds considerable promise. Studies showed that 0.03 ppm ozone effectively controlled *Saprolegnia* fungus on incubating eggs. Although ozone may prove to be a useful disease control agent, it is highly toxic to fish. Tests showed that concentrations of only 9 parts per billion resulted in extensive gill damage and disturbances in hydromineral balance, and in the death of 50% of the test fish within 96 hours. It was concluded that 2 parts per billion be recommended as a provisional guideline for the maximum safe exposure level.

Results of bioassays show that nitrate is mildly toxic to developing salmonid eggs and fry, and somewhat more toxic to rainbow trout than to chinook salmon. Caution should be used in hatchery site selection because early fry stages are susceptible to nitrate levels occasionally found in groundwater.

A direct seawater challenge followed by blood sodium analysis was evaluated as a procedure to identify optimum time, age, and size for smolt release. It was concluded that the blood sodium test for steelhead smolt functionality can detect the onset of osmoregulatory competence just as well as the more widely used ATPase test does. The sodium assay is the simpler and less expensive, and may be a more direct index of osmoregulatory competence.

Salmon and steelhead smolts can be injured by pollutants to an extent that the fish neither

migrate seaward nor tolerate ocean salinity upon reaching it. Other chemicals, used as medicine for fish, may have similar effects. Such an event could insidiously waste part or all of a hatchery's much needed contribution to the fishery. We completed tests on the 10 medicinal treatments and two anesthetics, using recommended therapeutic protocols. Coho salmon were treated and either placed directly in 28 o/oo seawater or given 4 days of posttreatment recovery in fresh water before contact with seawater. Adverse effects were noted in at least five treatments: Heavy mortality occurred in seawater following treatments with copper sulfate (100% mortality), potassium permanganate (80%), Hyamine 1632 (68%), and malachite green (44%); and when fish were overdosed with a commonly used anesthetic (MS-222), they recovered if placed in fresh water but died when placed in salt water. Treatments with 2,4-D, nifurpirinol, quinaldine, simazine, and trichlorofon were not associated with mortality in the 10-day test period. When adverse effects occurred from a given treatment, they were diminished, but not removed by 4 days of posttreatment recovery. These results suggest that great caution should be exercised in treating smolts immediately before release.

Hatchery practices require handling for grading, marking, transportation, and other purposes. These activities cause varying degrees of scale loss from the fish. We have suspected that this loss of protection results in lethal blood electrolyte imbalances during fish hauling, due to Mg^{++} and K^{+} uptake from the salt mixtures. From the studies conducted it was concluded that if 10 o/oo synthetic seasalt mixtures are to be used for stress mitiga-

tion and fungus control during smolt hauling, handling procedures should be modified to keep maximum scale loss at 12% or less. Scale loss also was found to result in death of some fish when they were put into natural seawater. Scale losses of 0, 8, 16, and 25% produced cumulative 10-day mortalities in seawater (28 o/oo) of 0, 30, 60, and 90%, respectively.

Infectious Diseases. The ability to recover infectious hepatic necrosis (IHN) virus from adult carrier sockeye salmon from Alaska was found to be critically related to the time samples are taken in relation to spawning. In one experiment, a group of salmon that were 100% negative before spawning became 100% positive within 48 hours after spawning. Similar results were obtained in a second experiment, although some of the fish were positive before spawning. The carrier rate was always higher in females than in males. For the best chance of detecting carrier fish, or for an accurate carrier rate determination, postspawning females should be sampled. All negative samples should be "blind passed" at least once because studies have shown that 2% of the fish tested and declared negative were actually carrying the virus.

Eggs and milt taken from spring chinook salmon infected with bacterial kidney disease were combined and the fertilized eggs were divided into two groups. One group treated with 100 ppm iodophor for 10 minutes had a low loss rate as eggs and fry, whereas the untreated control group showed much higher losses due to bacterial kidney disease. It is not known if the treatment eliminated the pathogen from the egg or temporarily suppressed the infection.

Endangered Species

NATIONAL FISH AND WILDLIFE LABORATORY

Studies of Peregrine Falcons. The National Fish and Wildlife Laboratory is supporting two major efforts related to the endangered peregrine falcon in the United States. One of these is an annual survey of peregrine eyries and nesting success in the

Rocky Mountains. In 1977, 31 historical and 4 newly found eyries were surveyed between southern Montana and southeastern Arizona. Of these, 15 had adult pairs and 1 had a lone adult. Despite the discovery of more pairs, the population appeared to have changed little over the last 2 years. Seven of nine long-studied eyries were used in 1977, compared with six and five in 1975 and

1976, respectively. Egg production averaged 3.2 eggs per clutch for eight pairs for which counts were made, but only half were considered healthy enough to be hatchable. All suspect eggs were removed and replaced first with dummy eggs and later with chicks hatched in captivity. These eyries ultimately fledged 1.7 young per pair compared with 0.9 young per pair at the seven sites where eggs were not manipulated. Eggshell condition remains poor in this population, averaging 21% thinner than pre-1947 shells from the region. DDE and PCB levels are yet to be measured in these eggs, but five eggs from two 1976 eyries averaged 31 ppm (wet weight) DDE and 4.7 ppm PCB, the former correlating with eggshell thinning in falcons.

In a related study the Laboratory is funding a program to propagate peregrine falcons in captivity at facilities in Ithaca, New York, and Fort Collins, Colorado. The young produced in captivity are being introduced into nests of wild peregrine falcons in the Rocky Mountains as a means of enhancing the wild population. In the East, where peregrines no longer nest, attempts have been made to release young captive-raised birds at old, natural eyries or on man-made eyries. These birds are established through a gradual acclimatization process known to falconers as "hacking," during which the young birds learn to hunt for themselves and become independent of their human providers. By these two methods, 62 young peregrines were released into the wild by the end of 1976. The success of these release projects is not fully known but numerous sightings of different individual peregrines have been made, some at distances of hundreds of miles from the point of release. Five of 12 birds successfully "hacked" in 1975 were present at or near their respective release sites in summer 1976. The first natural pairings and nesting attempts by released peregrines are expected to occur next year.

DENVER WILDLIFE RESEARCH CENTER

Status of the Peregrine Falcon in Baja California, Mexico. The first major effort to survey the entire Baja California peninsula and adjoining islands for peregrines was initiated in 1976. The range of the peregrine falcon in Baja California is significantly reduced from its historic extent. Increased human disturbance in the forms of

tourism, development, scientific collecting, and pesticide contamination, and the decline of prey species are thought to have played roles in the decline of the species. The eyries reported for the northwestern coast and islands have been unoccupied in recent years. The population in the Gulf of California still occurs within much of the historic range, but the reproductive health of these birds awaits evaluation.

In 1977, 20 active pairs plus 3 possibly active pairs and 3 single birds were located; information was received regarding the location of 1 other pair. In 1976-77, 26 pairs were known to have been active in the Gulf of California.

In 1977, the contents of five eyries were noted. One had four young. Another contained only one egg, which probably did not hatch. At a third eyrie, at least one downy young was noted and at two others, adults were feeding young. Prey brought to the eyries consisted principally of eared grebes, black storm-petrels, least storm-petrels, northern phalaropes, Craveri's murrelets, Bonaparte's gulls, and fish bats. Other shorebirds, passerines, doves, woodpeckers, and kingfishers were also present.

PATUXENT WILDLIFE RESEARCH CENTER

Endangered Gray Bats Dead of Dieldrin Poisoning in Missouri. In August 1973 the U.S. Army Corps of Engineers completed its Environmental Impact Statement for the proposed Meramec Park Lake, Missouri. Because this statement predicted adverse effects of the Lake on habitat of the endangered Indiana bat, a survey of all *Myotis* species in the park area was sponsored jointly by the Corps, the U.S. Fish and Wildlife Service, and the Missouri Department of Conservation. This 18-month study began in July 1975. The gray bat, which also occurs in the area, was added to the list of endangered species in 1976. Dead gray bats found in three caves during the survey were examined to determine whether organochlorine pollutants were a cause of death. These three caves contain the known maternity roosts of the gray bat in the area. All dead bats were juveniles.

Twelve dead bats from one cave contained only low levels of dieldrin and may have died after some unknown disturbance of the roost caused

their parents to drop them. At least 10 (probably 12) of 16 dead bats from the other two caves contained between 5 and 10 ppm (wet weight) of dieldrin in their brains. Such levels are known to be lethal in a variety of bird and mammal species. Milk from the stomachs of two dead bats with lethal brain levels contained 36 ppm dieldrin.

In July 1977 a follow-up visit to the cave where the larger number of poisoned gray bats had been found a year earlier revealed even greater mortality (74 dead bats were counted). The route that the dieldrin followed through the food chain to the pregnant or lactating adult bats is unknown. However, the source was aldrin (the parent compound of dieldrin) applied to the soil to control cutworms in corn. We suspect that one or more of the principal insect prey species of the bats accumulated the chemical from the soil where they spent their larval stages.

Even though aldrin and dieldrin were banned by the U.S. Environmental Protection Agency effective October 1, 1974, the sale and use of existing stocks remain legal. Therefore, we do not know when the use of aldrin will cease nor how long dieldrin will persist in prey insects once the use of aldrin has stopped. Another investigator demonstrated that soil residues of dieldrin had not declined significantly 6 years after application of aldrin on Missouri cornfields. We hope that the potential threat to these bats from the chemicals now being substituted for aldrin (heptachlor and toxaphene in Missouri) will be considered before their use becomes widespread.

Insecticides have long been blamed for declines of bat populations, but compelling data were lacking. Recently, strong, although indirect, data showed that food chain DDE probably has been an important cause of the decline of free-tailed bats at Carlsbad Caverns, New Mexico. Our data are the first to link observed field mortality directly to food chain insecticide residues that resulted from routine pest control practices.

New Approach to Pre-release Conditioning of Captive-reared Whooping Cranes. A new approach to the more effective use of whooping crane eggs produced at Patuxent for the cross-fostering experiment at Grays Lake National Wildlife Refuge in Idaho is being tested at the Patuxent Wildlife Research Center. Past experience indicates that sandhill crane chicks hatched and reared by captive parents are no less wild than those reared in the wild. Captive parents, hatched and reared in captivity, seemingly do not lose their

ability to train their chicks to hide and to remain as aloof from human caretakers as pen facilities will permit. These traits have continued through the first 2 years of life among juvenile birds reared by captive parents. However, incubator-hatched chicks reared in a community pen remain tolerant of human presence and even show gregarious behavior.

Facilities to implement the foster-parent rearing techniques developed with sandhill cranes at Patuxent are being prepared for next spring's whooping crane eggs laid before April 20. These facilities are needed because of the difference in nesting phenology between the Patuxent and Grays Lake Refuge areas resulting from differences in latitude and elevation. This difference was aggravated in 1977 by the cold, dry, and extremely late spring and late, heavy snowstorms in southeastern Idaho. These adversities doomed much of the earliest sandhill crane nesting effort and the eight whooping crane eggs transported from Patuxent and placed in Grays Lake sandhill crane nests on May 7.

In 1978, all whooping crane eggs laid at Patuxent before April 20 will be incubated by sandhill crane foster-parents in the new enclosure complex. The chicks will remain with their foster-parents until late fall and will then be moved to isolated holding pens. Human visitation will be restricted to the essentials of feeding, watering, and veterinary inspection. As full-winged yearlings, all surviving young will be transported the following June to Grays Lake Refuge for release according to procedures found successful with sandhill cranes. Yearlings should be stronger and better able to cope with other cranes and with predators and therefore should have a better survival rate than whooping crane eggs and chicks previously involved in the Idaho experiment. Less than a fourth of the eggs brought to Grays Lake Refuge from Wood Buffalo National Park during the past 3 years have hatched or the chicks survived throughout the 1st year of life. The success of this approach will depend upon the ability of the Patuxent yearling cranes to associate and migrate with other whooping cranes already present at Grays Lake Refuge. If this new method is successful, much of the mortality encountered by whooping crane eggs and chicks at Grays Lake Refuge and in Wood Buffalo National Park can be avoided.

Whooping Cranes Have Productive Season at Patuxent. From two pairs producing a total of five



Northern swift foxes were tagged and released as part of an ecological and life history study in western South Dakota. Photo by C. N. Hillman.

eggs last year, the number of productive whooping crane pairs has now doubled and the number of eggs laid has risen to 22. Fourteen of the eggs were sent to Idaho to be placed in greater sandhill crane nests, but the first eight, including two that hatched, were lost during blizzards in early May. The second shipment of eight eggs fared better, three of them hatching, but none survived because of predation and undetermined factors. Of the remaining eight eggs incubated at Patuxent, three of four fertile eggs hatched and two chicks have been reared.

Removing whooping crane eggs as they are laid and using artificial illumination to extend daylight hours have increased production by the captive birds. Beginning on the morning of Valentine's Day, light hours are extended by adding incandescent light to achieve a total of 14 hours of daylight and then increasing it 3% each week until June, when it reaches nearly 24 hours. The photoperiod and temperature conditions of the Canadian Northwest Territories where the wild whoopers breed are thereby simulated at the Patuxent Center.

Wolf Pack Buffer Zones Are Reservoirs for Deer Herd. An overlap or buffer zone about 2 km wide around each wolf pack territory becomes a reservoir for deer when the herd declines. Adjacent wolf packs may use the buffer zone but they

apparently feel less secure there. They spend little time in the zone and do not kill deer there unless desperate. Because buffer zones constitute 25 to 40% of a region, the relative safety of deer in these zones from attacks by wolves helps maintain a base population from which a deer herd can repopulate and even penetrate into core areas of wolf-pack territories.

Deer Blood Analysis Confirms That Wolves Kill Inferior Deer. Examination of teeth, bones, and tissues from wolf-killed deer have indicated that wolves tend to kill deer that are in some way inferior to the herd. An additional parameter has now been found that tends to confirm these earlier conclusions. Levels of nonesterified fatty acids (NEFA) were significantly lower in the blood of wolf-killed deer than in the blood of deer not taken by wolves. This finding suggests that deer killed by wolves have only marginal fat reserves or a limited ability to increase NEFA's in response to stress.

Scent-marking in Wolves Is Important in Courtship and Reproduction. Earlier studies have shown that scent-marking in wolves is important to territory maintenance. New studies indicate that scent-marking is also of critical importance to courtship and successful reproduction. All male and female captive wolves that produced pups had scent-marked before or during the breeding season, and those that did not produce pups, did not scent-mark. In the wild, no lone wolves of either sex scent-marked, but loners that joined a member of the opposite sex began marking soon after the encounter. These newly formed pairs marked more frequently than established pairs. Scent-marking is apparently part of the process of pair bonding and reproductive synchrony in wolves.

Continued Decline of California Condors. Only one California condor nestling had been found by mid-September 1977, indicating another year of below-normal production. The population continues to decrease, primarily due to inadequate recruitment of young. Ongoing programs of minimizing disturbance to nesting birds and supplementing local food supplies have failed to reverse the downward trend.

Antibiotics in Starting Diets of Young Masked Bobwhites Increase Hatchability. Young masked bobwhites are raised each year from eggs hatched at the Patuxent Wildlife Research Center. Approximately 25% mortality occurs in rearing chicks to about 6 weeks of age. Experience with other species suggested that mortality could be re-

duced by adding antibiotics to the starting diets of the young quail.

A 5-week study was conducted to examine the influence of two antibiotics, chlortetracycline and oxytetracycline HCl, upon the growth and survival of young masked bobwhite quail. Mortality was reduced from 25% to less than 5% when the starting ration was supplemented with either chlortetracycline or oxytetracycline HCl at the rate of 100 mg/lb. The antibiotics appeared to have no influence upon growth rates. This study indicates that antibiotic supplementation of starting diets can reduce mortality and increase production of young from the breeding population of masked bobwhites maintained at Patuxent.

Masked Bobwhite Reintroduction Effort Achieves Breakthrough. Beginning in 1937, biologists from various conservation organizations have unsuccessfully attempted to reintroduce the masked bobwhite into Arizona. Although an occasional bird survived for a year in the wild, no populations were established.

In 1976 over 500 chicks were given sterilized Texas bobwhite foster-parents and were released in the best available habitat. Many of the young birds survived into the winter and, with the onset of the summer rains, a population estimated at around 30 was located near the release sites. This population was the first demonstration of significant overwinter survival. On October 4, 1977, we made our first observation of chicks reared by fully wild parents of propagated stock.

This event is doubly significant because of the impending extinction of the last known population of masked bobwhites in Sonora. No birds were detected along one traditional call route in Sonora where 30-45 calling males could be heard daily in the late 1960's, and only three calling males were heard along the remaining call route.

Yellow-shouldered Blackbird Studies. The yellow-shouldered blackbird, a species endemic to Puerto Rico, has had its range drastically reduced by habitat destruction. It is now restricted to three main areas: coastal southwestern Puerto Rico, the coastal eastern tip of Puerto Rico (Roosevelt Roads Naval Station), and Mona Island. The yellow-shoulder is now the major host of the parasitic shiny cowbird, a species that has recently reached Puerto Rico from South America by way of the Lesser Antilles.

In 1977 all nests at Roosevelt Roads were parasitized by shiny cowbirds. Only one blackbird pair at Roosevelt Roads hatched eggs and none of



A sterilized Texas bobwhite cock leads a brood of adopted masked bobwhite chicks from the release box. Over 1,000 masked bobwhite chicks were released by this method in 1977. Photo by David H. Ellis.

these young fledged. In southwestern Puerto Rico 28 of the 32 (88%) blackbird nests with completed clutches were parasitized, but 44% of the nests were successful in fledging blackbirds, with an average of 0.9 young fledged per active nest. Blackbird productivity was enhanced at some nests by removal of cowbird eggs or chicks.

Cowbirds sometimes puncture blackbird eggs when they deposit their own eggs in the host nest. Perhaps this habit increases the cowbird's breeding success. All nests at Roosevelt Roads contained punctured eggs. Before 1977 no egg puncturing had occurred in the southwest population



Male yellow-shouldered blackbird (left) passing food to adult female at nest. The nest contains two shiny cowbird chicks. *Photo by James W. Wiley.*

but this year 7 of the 85 blackbird eggs were punctured.

Investigations have indicated that cavity-nesting, yellow-shouldered blackbirds fledge more young than pairs using open nests. To determine whether artificial nesting structures could further enhance productivity, 40 nest boxes were placed in the blackbird nesting areas in southwestern Puerto Rico. Blackbirds built nests in four boxes, laid eggs in three, and fledged blackbird young from one box. Although all boxes were parasitized by cowbirds, blackbird productivity was greater than that of open-nesting pairs.

Endangered Species in Rain Forests of Hawaii Inventoried. Survey teams completed a 3-month inventory of the rain forests on the windward coast of the island of Hawaii in 1977. This was the 2nd year in which teams of biologists and botanists surveyed rain forests on the island of Hawaii to determine the distribution and abun-

dance of rare birds and plants.

During this year's survey 329 km of trail were flagged and 2,452 sampling stations were established in the 105,938-ha study area. There were 4,896 count periods and 39,168 minutes of observations. Thirty-six species of birds were observed, as were numerous plants, among which were two species previously believed to be extinct. The seven species of endangered birds observed included the Manx shearwater (2), Hawaiian goose (135), Hawaiian hawks (187), Hawaiian creeper (552), akepa (285), akiapola'au (226), and O'u (61). The 61 observed O'u represent the largest number of this species seen in a single year since the turn of the century. The hoary bat (24) was the one endangered mammal observed.

Puerto Rican Parrot Studies. Between June 1976 and March 1977 the total wild Puerto Rican parrot population declined from 22 to 18 birds. As of July 1977 the wild population had increased by



Male Everglade kite about to transfer the extracted apple snail in his bill to his mate, who will feed the small young. The female performs most of the feeding chores when the young are small. *Photo by Paul W. Sykes, Jr.*



Everglade kite chicks waiting to be fed. The size difference among the three siblings is the result of asynchronous hatching. Nesting success in the last 3 years has been good in Florida. *Photo by Paul W. Sykes, Jr.*

only one bird despite the fledging of three young in May and June. Predation by red-tailed hawks is suspected as the source of this loss of free-flying parrots.

Three wild parrot pairs nested this year. All accepted artificial or improved natural nest sites that were deepened with plastic midsection "spacers," darkened with constricted entrances and baffles, and provided with well-drained floors. Pearly-eyed thrashers, the main nest predator and competitor of the parrots before this year, were not a problem to the nesting parrots in 1977. Thrashers occupied and defended alternative artificial nests placed near parrot cavities, thus effectively protecting the parrot nests from nonresident pearly-eyed thrashers. The parrots continued to show high fertility and all eggs laid by wild parrots hatched. Two parrot nests had all chicks infested with warble fly larvae. Two chicks were taken into the field aviary for treatment, which certainly saved their lives. At two nests one adult member of each pair suffered a wing injury and was unable to take normal care of the young. Biologists provided supplemental food to the nestlings and transported them from the nest to the aviary brooder each night and from the brooder to the nest the next morning until the parents had recovered.

The captive flock at the Puerto Rican Field Station now numbers 14 birds. In 1977 three young taken from wild nests and two adults formerly housed at Patuxent Wildlife Research Center were transferred to the Puerto Rico aviary for use in the captive breeding program. These birds represent

two family lines in addition to those previously at the aviary. Progress in producing captive-bred Puerto Rican parrots has been hampered by a lack of accurate sexing techniques for this species. Six eggs were laid in captivity this year but the pair proved to consist of two females, so the eggs were infertile.

Everglade Kite Population in Florida Increasing. Since 1969, when annual censusing of Everglade kites in Florida was initiated, the population level has oscillated, with an 8-year average of 98 birds. The most significant decrease was noted after the severe drought of 1971. Since 1974 the number of kites has increased steadily. This increase correlates well with the higher water levels in the main use areas. The latest census (December 1976) revealed a high of 142 birds, perhaps the largest number of kites observed in the United States since the 1920's and 1930's. It is probable that the population was never as low as was originally thought, but it may have declined to 20-25 birds in the late 1950's and early 1960's.

Most of the birds are now on the west side of Lake Okeechobee in Glades County and in eastern Conservation Area 3A in Dade County. Nesting success for the past 2 years has been good in both of these wetlands. Nesting success from 1968 through 1976 was 48% and the mean number of young fledged per successful nest was 2.1. No young were produced in the drought year of 1971. Nesting failure can be traced to at least 11 different causes, predation being the major problem. Many of the nesting losses can be eliminated through proper management.

NORTHERN PRAIRIE WILDLIFE RESEARCH CENTER

Population, Distribution, and Ecology of Aleutian Canada Geese on Migration and Wintering Areas. Arcata Field Station personnel of the Northern Prairie Wildlife Research Center continued a study on the population, distribution, and ecology of Aleutian Canada geese on their migration and wintering grounds. The major thrust of this work is to determine the status of this endangered "species" and the success of efforts to restore it to a secure population level.

Field observations indicate that most of the geese leave the breeding grounds on Buldir Island in the western Aleutians in September, fly to the eastern Aleutians, and then migrate to the Crescent City area in northern coastal California in late October, probably via a transoceanic route. Thereafter, they appear in the Sacramento Valley, the Delta area, and the San Joaquin Valley of central California. By mid-January, birds are return-

ing north to Crescent City, where the entire population is believed to stage during the first half of April. Most geese have resumed their northward flight by late April and the first birds reach Buldir by the end of the 1st week in May.

A total of 158 additional birds were cannon-netted and banded during the spring, at which time an estimated 25% of the total population was so marked. From fall to spring, 3,078 observations were made on 324 marked individuals.

Peak goose counts were 1,280 in the fall and 1,150 in the spring for a net loss of about 130 birds, or 10% of the population. Minimum known mortality included 19 to hunter kill, 3 to avian cholera, and at least 10 to other causes. The spring population peak was 28% higher than the corresponding peak of 900 in the previous spring. This increase is believed to be due largely to closure of key goose areas to all Canada goose hunting by order of the California Department of Fish and Game. On the basis of observations and recoveries of banded birds, closure boundaries were modified further during the 1976-77 hunting season.

Great Lakes Fisheries

FISH CONTROL LABORATORY

Removal of Chemicals from Water. The removal of chemicals from effluent waters is a prime objective of our present "clean water society." Various means of purifying contaminated water have been investigated, such as neutralization by chemical detoxifiers, chlorination, coagulation, filtration, and the use of certain adsorbants. The application of these techniques to fisheries is extremely limited.

Removal of fishery chemicals from water is feasible during some culture and management practices, and removal could eliminate registration requirements for information on such characteristics as residues, tolerances, detoxification, and hazards to the environment.

Several resins have been evaluated for their effectiveness in removing fishery chemicals and various oxidation states of nitrogen from water.

Activated carbon effectively removes certain chemicals, and a prototype filter for hatchery use has been evaluated. Clinoptilolite is more effective than the synthetic resins XAD-7, Biosorb, and pH filter resin for removing ammonia from water.

Funds from this program were also provided for the maintenance and operation of completed portions of the new National Fisheries Research Laboratory, La Crosse, Wisconsin.

Registration-oriented Studies on Lampricides. In 1976 the U.S. Fish and Wildlife Service submitted petitions for an exemption tolerance and an amendment of registration for use of the sodium salt of 3-trifluoromethyl-4-nitrophenol (TFM) as a lampricide. The EPA provided preliminary comments on October 22, 1976, to which the Fish and Wildlife Service responded. Additional comments from the regulatory agency were received in March and April 1977 and further data were developed in response to these comments.



Tissue residues of lampricides are determined by gas chromatography in order to determine rates of uptake and release by fish. *Photo by L. L. Marking.*

Data provided were adequate to support negotiations which eliminated the need for further studies involving acute oral toxicity tests; hamster feeding; characterization of residues in milk, cattle kidney, and other edible products of cultured mammals; and determinations of the distribution, retention, or elimination of TFM and its metabolites.

Points still being negotiated include an exemption for the application of DMF in streams as a part of TFM formulations, residue information in potable waters, possible restrictions in irrigation waters, and possible soil-binding effects. An Ames test to evaluate potential mutagenicity of TFM proved negative. Progress continues toward registration.

The chemicals Bayer 73 and TFM are used in combination to control sea lamprey larvae in large

tributaries to the Great Lakes. Both chemicals are under investigation to provide the necessary data for continued registration and use. Water, bottom soil, plants, fish, and invertebrates were collected from three rivers in Michigan. Samples were taken before, during, and up to 7 days after treatment of the rivers for control of sea lampreys. The materials are currently being analyzed for residues of Bayer 73.

A study was undertaken to monitor the concentration of Bayer 73 in two streams during and after lampricide treatment.

Water samples were analyzed by using a method developed by the Fish Control Laboratory during treatment of the Peshtigo River, Wisconsin, and by gas chromatography during treatment of the Menominee River, Michigan. In both streams the bolt of chemical peaked and declined as pro-

grammed, but the peak concentration detected was slightly less than that calculated for the streamflow. Water taken into the supply systems of Menominee, Michigan, and Marinette, Wisconsin, was monitored to check for possible contamination with lampricides. No lampricide residues were found in either water supply.

Studies were continued on the effects of lampricides on nontarget organisms. Glass shrimp were exposed to Bayer 73 to ascertain their susceptibility to this compound. Toxicity decreased as water hardness and pH increased. The 96-hour LC_{50} 's increased from 11.9 mg/l in very soft water to 25 mg/l in very hard water. The lampricide was more toxic to glass shrimp in flow-through tests than in static tests. These results suggest that the shrimp should not be adversely affected by use-pattern levels of Bayer 73.

A study was undertaken at the Fish Control Laboratory to determine the renal and biliary excretion of Bayer 73 in rainbow trout exposed to a sublethal concentration (0.05 mg/l) of Bayer 73 for 12 hours and in rainbow trout given an intraperitoneal (IP) injection of a known dose (200 μ g) of the lampricide. Renal excretion of Bayer 73 residues was rapid, the largest amounts being excreted during the 12 hours of exposure. Residues in urine decreased rapidly but were still present after 72 hours of withdrawal. Injected fish showed an excretion pattern similar to that of the exposed fish. Urine from the exposed fish was cleaned up by column chromatography on XAD-4 resin and analyzed by thin layer chromatography before and after incubation with β -glucuronidase. The results indicated that most of the Bayer 73 residue excreted in urine was in the form of the glucuronide conjugate.

Renal excretion of the lampricide in fish given an IP injection of the chemical compound accounted for about 25% of the injection dose and biliary excretion for another 25%.

Problems involving the separation of Bayer 73 from lipid fractions in animal tissues were resolved. A method for the analysis of Bayer 73 residues in fish and invertebrates has been developed. The new procedure makes it possible to monitor residues of the lampricide in the total ecosystem.

Studies were conducted to develop data on the persistence of Bayer 73 in water. Hydrolysis of the lampricide was investigated by using 14 C-Bayer 2353. No hydrolysis was observed in glass vessels filled with pond water or distilled water buffered at pH 5, 6.9, or 8.7 after 56 days.

The physiological basis for the selective action of TFM against lampreys appears to be the inability of the sea lamprey to conjugate and detoxify TFM. The formation of glucuronide conjugates in several other species of primitive fish was studied. Bowfins and shortnose gars exposed to TFM did not excrete as much conjugated TFM as did salmonids. These results suggest that fishes low on the phylogenetic scale are likely to be more susceptible than others to TFM.

GREAT LAKES FISHERY LABORATORY

The Great Lakes Fishery Laboratory, Ann Arbor, Michigan, which began as a limited two-person operation in 1927, now has four field stations (at Ashland, Wisconsin; Hammond Bay, Michigan; Sandusky, Ohio; and Oswego, New York) and five research vessels (the *Cisco*, *Kaho*, *Siscowet*, *Musky II*, and *Grayling*). Establishment of the Oswego Biological Station and completion of the 80-foot *Grayling* fulfilled a long-term commitment to provide Federal participation with State resource agencies in the assessment, protection, and enhancement of fishery resources on all five of the Great Lakes. Research during the year addressed a wide variety of Great Lakes problems that included evaluating the success of restoration of lake trout populations in Lakes Michigan and Superior, the distribution of larval fishes in Lake Huron, the effects of environmental factors on production of yellow perch in western Lake Erie, the effects of tissue burdens of PCB's on the reproductive success of lake trout, and the use of chemosterilants to reduce reproduction of sea lampreys.

A continuing feature of the 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 on Lake Superior. During the 1950's, a combination of intensive exploitation and predation by sea lampreys greatly reduced populations of lake trout in Lake Superior. Since then, partial control of the sea lamprey, protective fishery regulations, and intense stocking have resulted in generally encouraging signs of rehabilitation of lake trout populations.

The abundance of lake trout increased rapidly from 1962 through 1970 in both Michigan and Wisconsin waters. In all Michigan waters, except Whitefish Bay, abundance increased sharply in

1971 and remained at roughly the 1971 level through 1976. In Whitefish Bay, abundance fluctuated erratically upward from 1968 through 1974, but declined over 90% in 1975-76 to the lowest level since 1963. In Wisconsin, a gradual decline began in 1971, and by 1976 the abundance was only about half that in 1970. Abundance of large mature fish increased generally through the 1960's in both Michigan and Wisconsin, and increased through 1976 in Michigan waters except Whitefish Bay, where the stocks declined sharply in 1975-76. In Wisconsin, spawning stocks increased gradually in 1971-75, but declined by about one-third in 1976.

Observations during 1977 indicated further improvement in all lake trout populations except those near Grand Marais, Minnesota, and in Whitefish Bay, Michigan.

Data on lake trout populations in eastern Lake Superior, collected during cooperative spring surveys and summarized by the Michigan Department of Natural Resources, indicated that the abundance of lake trout 17 inches long or longer in the area from Keweenaw Point to Grand Marais rose 17% since the spring of 1976, 6% above the all-time high recorded in 1975. The increase was apparent in all length groups above 21 inches. The largest fish was 36 inches long. In Whitefish Bay, on the other hand, overall abundance continued to decline, and is now less than 7% of the all-time peak observed in 1974.

Around Isle Royale, the standardized catch of lake trout in experimental gill nets at four index stations was 70% higher than in 1974, the last time samples were taken at these stations. Further west at a station near Grand Marais, Minnesota, the index catch was only slightly lower than in 1974.

Survey trawling near Michigan Island (Wisconsin) in September yielded the largest catches of naturally produced young-of-the-year lake trout that we have taken since 1965. Three 15-minute tows with a 32-foot trawl, at each of seven depths between 14 and 51 m, produced 275 trout, whereas the same gear and amount of effort yielded 162 in 1974, 32 in 1975, and 29 in 1976.

Distribution of Larval Fish in Lake Huron. The Great Lakes Fishery Laboratory extensively sampled larval fish in the nearshore waters of western Lake Huron in 1973-75 to determine the species composition, distribution, and abundance, and to identify and delineate major spawning and nursery areas. This investigation was prompted by the need for information with which to determine

the possible impact that the operation of existing and proposed power plants may have on larval fish exposed to thermal effluents and to entrainment in cooling systems.

Larval fish were collected with a 0.5-m net with 351- μ m mesh, towed at 1-m intervals from the surface to a 4-m depth along the 5.5-m bottom contour and to a 6-m depth along the 9.2-m bottom contour.

Larvae of rainbow smelt, alewives, and yellow perch predominated in the collections, which also included larvae of burbot, ciscoes, fourhorn sculpins, lake whitefish, minnows, ninespine sticklebacks, and suckers. Most alewives were caught 1 to 3 m beneath the surface and most smelt from 2 to 6 m beneath the surface. The largest concentrations of larval alewives and yellow perch were found in Saginaw Bay, and the largest concentrations of larval smelt in northern Lake Huron.

The sequence of seasonal changes in the species composition of the nearshore ichthyoplankton was the same throughout western Lake Huron. Larval burbot, fourhorn sculpins, and coregonids (lake whitefish, bloater, and lake herring) were occasionally encountered in the nearshore water column but only immediately before and during the spring emergence of rainbow smelt fry. Rainbow smelt were dominant during spring and early summer and alewives during middle and late summer. Yellow perch, the only other species of larval fish regularly encountered, were captured during late spring and early summer; only once, however—in Saginaw Bay—were yellow perch fry more abundant than smelt fry.

Larval fish were most abundant in coves and bays, moderately abundant off sections of irregular shoreline, and least abundant off featureless shorelines. Important nursery areas are located in bays that have (1) large areas of shallow water (9 m deep or less), (2) rivers or streams flowing into them, and (3) few or no upwellings. These features affect the abundance of larval fish by attracting large numbers of spawning fish (shallow water and rivers and streams) or by slowing the dispersal of larval fish from spawning sites (because of the lack of, or infrequency of, upwellings). We delineated important rearing grounds for fish larvae in western Lake Huron as St. Martin, Thunder, and Saginaw Bays, and among Les Cheneaux Islands.

Dynamics and Interagency Management of Lake Michigan Bloaters. Our continuing effort in cooperation with the States to develop a technical

basis for projecting future allowable catches of chubs (mostly bloaters) was directed toward the problem of estimating mortality during the recent years of severe population decline and unstable population structure. Using trawl catch-per-effort data, we began computing total mortality for each year class between consecutive pairs of years, and averaged the results by age group for the year classes represented. Regression methods were used to smooth yearly irregularities in the indexes of abundance. All indexes showed significant declining trends in all geographic regions of Lake Michigan. Annual total mortality computed for 5-, 6-, 7-, and 8-year-old chubs in southeastern Lake Michigan during 1968-75 averaged 52, 65, 72, and 84%, respectively.

Total mortality estimated from trawl data includes a substantial amount imposed by the strongly size- and age-selective small-mesh gill-net fisheries, although even the trawl data themselves are not necessarily free of all size-selection bias. Previous observations that trawls take proportionately fewer large chubs than do graded-mesh gill nets were substantiated in a separate analysis of age-length data from the two gears fished at the same time off Grand Haven in 1974. Accordingly, annual mortality rates for fish of ages V to X, estimated by the Robeson-Chapman method (which assumes constant recruitment, survival, and vulnerability), were 78% based on trawl catches and 64% based on gill-net catches.

In a study of the fecundity of bloaters, regression relationships were determined between numbers of maturing eggs and fish length and weight. This information will be useful in quantifying the interacting effects of a severe population decline and an accelerated growth rate on reproductive potential and the capacity of the species to return to former levels of abundance.

Restoration and Management of Lake Trout Populations in Lake Michigan. Two decades of an intensive program to control the parasitic sea lamprey and reestablish self-sustaining stocks of lake trout have produced a large standing stock of lake trout estimated to contain several million individuals, representing all year classes planted since 1965. First signs of successful natural reproduction by the reconstructed lake trout populations were observed in 1977 in the form of lake trout fry impinged on power plant screens near Traverse City, Michigan. The capacity of the forage base to support the large population—now and as it becomes fully self-sustaining—together

with substantial stocks of Pacific salmon and other salmonids is a major question now facing fishery managers in the various States. Of equal concern is the need to establish a basis for gauging surplus production of lake trout and allocating it among user groups if the population becomes self-sustaining and present burdens of chemical contaminants are reduced to permissible levels.

To help managers address these important questions, we conducted three interrelated field and laboratory investigations in 1977, cooperating closely with the States through the Lake Trout Technical Committee of the Great Lakes Fishery Commission.

In the first of these activities, we helped to plan and conduct a lake-wide assessment survey of the lake trout populations that will be carried out annually by the States and the Service. As our field contribution to this program, we surveyed lake trout stocks at index stations near Milwaukee, Wisconsin, and Saugatuck, Michigan. Age-specific catch rates obtained from 1976 and 1977 sampling at Saugatuck suggested a mean annual mortality rate of 49% for lake trout of age VI and older.

The second of the 1977 lake trout investigations was a site-specific study of their seasonal depth distribution and their use of available forage stocks of alewives, smelt, and sculpins. This study was conducted off Milwaukee and Port Washington, to complement related work initiated in 1976 off Saugatuck on the east shore. Older and larger lake trout on both sides of Lake Michigan were more pelagic and less available to bottom gill nets during the spring than during the summer and fall.

Our third activity dealt with conceptualizing an approach for estimating the carrying capacity of the major stocks of forage fish in Lake Michigan (alewives, rainbow smelt, and sculpins) for introduced lake trout and Pacific salmon. This approach involves three parts: (1) estimating annual production of each major forage species over as many age groups as possible; (2) estimating annual consumption of the forage species by each major predator and mortality imposed by such other factors as fishing and entrainment or impingement in the cooling systems of power plants; and (3) comparing total production of forage with the fraction consumed by the salmonids—ultimately expressing forage consumed as mortality rates imposed on the prey populations.

The analytical and modeling methodology to implement this approach will be tested when

essential data on the vital statistics, dynamics, and bioenergetics of the major predator and prey populations become available.

Environmental Effects on Phenotypes of Great Lakes Coregonines. The ciscoes (Salmonidae, *Coregonus*) of the Great Lakes present one of the most complex taxonomic problems in North American ichthyology. Some species or populations are scarce enough to be considered threatened. Delineation of such forms is essential so that they can be adequately protected, and exploitation of them properly regulated. In one phase of this study, we attempted to clarify a critical point: Do observed morphological differences between similar species of ciscoes reflect true genetic differences or only environmental effects on development?

Samples of *Coregonus alpenae*, *C. zenithicus*, *C. hoyi*, and *C. kiyi* from the Great Lakes and their progeny hatched and reared in the laboratory were compared to test the hypothesis that these taxonomic entities are not valid species because the morphometric differences among them are the result of environmental modification during early development. Differences between parents and offspring were generally greater than differences among species, indicating strong environmental effects on the fish. These effects on most characters can probably be attributed to different developmental temperatures and perhaps pressures in the hatchery as compared with those in the Great Lakes. However, offspring of different species raised under identical conditions also differed significantly, indicating genetic differences among the stocks. Considering all aspects of the problem, *Coregonus hoyi* and *C. kiyi* appear to be morphologically near the species level of differentiation, but our samples of *C. alpenae* and *C. zenithicus* do not appear to represent different species. We view the four forms as locally adapted but genetically different stocks.

If this view is correct, it follows that the stocks remaining in the Great Lakes should be managed accordingly—as local populations, not as wide-spread species. This view also suggests that under conditions more favorable to increased abundance of cisco populations and recolonization of ciscoes into former habitats, relatively rapid rediversification of stocks could occur within several decades, leading to the return of ciscoes to fisheries from which they have been removed.

Effects of Environmental Factors on Production of Yellow Perch in Western Lake Erie. The

yellow perch, historically an important sport and food fish in Lake Erie, has declined drastically in abundance since the late 1960's. Landings from western Lake Erie by the commercial fishery decreased from 3.5 million kg in 1969 to 1.4 million kg by 1975. Annual recruitment was fair to poor in 1965-74, compared with 1959-65.

In this study, year-class strength, as measured by the indices of abundance for young-of-the-year and yearling perch, was shown to be highly variable during the 1959-74 period; later recruitment of individual year-classes to the fishery fluctuated accordingly.

The reproductive success of each year's brood stock from 1959 to 1970 was determined by calculating a coefficient of hatching and early survival, which is the ratio of the index of abundance of young of the year in August to the potential egg deposition of the parental brood stock. Estimates of brood stock were derived from cohort analyses, and the potential egg deposition each year was determined from known fecundity and sexual maturation characteristics of yellow perch of the western basin. The relative index of progeny survival between the April-May egg deposition and mid-August, the time by which perch year-class strength has become established, was strongly influenced by environmental conditions. High values for the coefficient of hatching and early survival were correlated with high mean air temperatures in May, faster rates of water warming in April and May, and lower frequencies of strong winds. Water levels during the 1959-70 period did not vary greatly and the small fluctuations apparently did not influence the success of perch reproduction.

These results are nearly identical with those of a previous study on year-class success of walleyes in western Lake Erie, where the rate and regularity of water warming during spring spawning and egg incubation periods were also strongly correlated with resulting year-class strength. For both periods, calm weather and faster-than-average rates of water warming reduced the length of the incubation period, which decreased egg exposure to such negative influences as siltation, low dissolved oxygen, disease, and dislodgment from spawning areas by strong currents.

The Fish Stocks of Lake Ontario, 1972. An interagency lake-wide survey of fish stocks of Lake Ontario was conducted during 1972-73 in conjunction with the International Field Year for the Great Lakes (IFYGL). Cooperating agencies were

the Ontario Ministry of Natural Resources, the New York Department of Environmental Conservation, Alfred University (Alfred, New York), and the Service. The chief objective of the survey was to determine the distribution and relative abundance of the fish stocks in offshore waters (deeper than 30 feet) and in shallower inshore waters, and thus provide a comprehensive new description of the radically altered fish fauna of Lake Ontario.

Technical reports on the survey results were completed during fiscal year 1977. The chief findings of all agencies, which have been synthesized into a comprehensive lake-wide overview of the fish stocks, are as follows:

(1) Fish biomass was dominated by alewives and rainbow smelt. Pelagic concentrations of both species were significant over the whole lake, with alewives occupying generally shallow depths. Smelt were relatively more abundant nearshore in the colder western end of the lake, and in bottom waters out to 150 feet. These species provide an excellent available forage base for the now abundant introduced salmonids: lake trout, brown trout, and Pacific salmon.

(2) Slimy sculpins were abundant where present, but were mainly confined to offshore benthic zones less than 245 feet deep.

(3) The main trench of the lake below 180 feet was almost devoid of fish, except for slimy sculpins during the summer. This is significant because 63% of the lake's surface area overlies water deeper than 180 feet.

(4) Although the sampling grid was coarse, no pelagic or shallow benthic areas of the main lake, now shoreline, were grossly depauperate of fish.

(5) No major reserves of historically important commercial species such as lake herring, lake whitefish, lake trout, deepwater ciscoes, blue pike, walleyes, or lake sturgeon remain in the lake. The burbot, a formerly important noncommercial predator, and the fourhorn sculpin, a once important forage species, are now nearly extinct.

(6) Besides the abundant alewives and rainbow smelt, the inshore fishes included several important species with various distributions: Yellow perch were abundant in the outlet basin but seldom captured in the central and western regions of the lake. White perch were more widely distributed, but their center of abundance was also in the eastern region. Brown bullheads, rock bass, pumpkinseeds, and smallmouth bass were fairly common in the outlet basin but uncommon else-

where. In contrast, white suckers were generally abundant in the main lake, but less so in the outlet basin. Spottail shiners were fairly common and widely distributed, whereas sizable concentrations of emerald shiners were detected at only three locations.

(7) A total of 69 species of fish were collected during IFYGL. However, species diversity was greater in the nearshore waters (59 species taken) than in offshore waters (27 species), and in the eastern outlet basin (54) than in the main lake (44). The greater diversity in the outlet basin region is due primarily to the greater diversity of habitat there.

Development of Methods of Sea Lamprey Control to Supplement the Use of Selective Larvicides.

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 will also include the use of repellants, attractants, sterilants, physical barriers, and such other methods as may prove useful and economical. The Great Lakes Fishery Laboratory, under contract with the Commission, performs research on alternative methods for controlling the sea lamprey. This research is conducted at two facilities—the Laboratory's Hammond Bay Biological Station, on Lake Huron near Rogers City, Michigan; and the Monell Chemical Senses Center, the University of Pennsylvania, Philadelphia.

One promising control method now being developed at Hammond Bay involves releasing artificially sterilized, sexually mature lampreys into streams containing spawning populations of lampreys. In principle, these sterile individuals will compete with fertile ones for mates and thereby reduce the reproductive success of the spawning population.

The search for an immunological means of sterilizing spawning run lampreys was begun at the Hammond Bay Station in 1976. Sea lamprey ova, sperm, and gonadal tissue were used to prepare antigens which, when mixed with Freund's adjuvant and injected into rabbits, cause the rabbits to produce antisera. These antisera were injected intraperitoneally into spawning run sea lampreys so that the antisera would come into direct contact with the lamprey's gonadal tissue. Antiserum against female sex products was injected only into

females and antiserum against male sex products only into males. The spawning lampreys were injected with various amounts of antisera, held for 25 hours, and spawned. If the injected lamprey was a female, a few of her eggs were collected and fertilized with sperm from an uninjected male. As a control, the same male was used to fertilize eggs from an uninjected female. If the injected lamprey was a male, it was used to fertilize eggs from an uninjected female. As a control, eggs from this female were also fertilized with sperm from an uninjected male. Results of this study show that one of the two male antisera tested resulted in steadily diminishing survival (from 93.9 to 1.9%) of advanced (stage-15) embryos, as the antiserum dose rate increased from 1 to 4 ml. Results with two female antisera were less marked, but both appeared to have some sterilizing action, and therefore deserve further testing.

Studies under way at the Monell Center are designed to identify and characterize nontoxic chemical substances, including sea lamprey pheromones, that will attract or repel sexually mature sea lampreys and facilitate capture of sea lampreys during their spawning migration. A total of 73 tests were conducted to determine if water in which spawning run sea lampreys lived would serve as an attractant for other spawning run sea lampreys. In one set of tests, 18 of 32 females showed a preference for "rinse" water from lampreys over fresh well water; 5 appeared to prefer fresh well water; and 9 showed no preference. In a second set of tests, 21 of 26 males showed a preference for the female rinse water; 3 showed a preference for well water; and 7 showed no preference. A third set of tests, in which six males were exposed to male rinse water and nine females were exposed to female rinse water, failed to yield evidence that lampreys were either attracted or repelled by rinse water from lampreys of the same sex. Thus, spawning run lampreys may release a substance that is attractive to the opposite sex (a sex attractant) but not to both sexes (a general aggregation substance). If further testing confirms these results, we will attempt to isolate and chemically characterize the active substance and test it under field conditions.

Distribution and Abundance of Macroenthos in the St. Clair-Detroit River System. The St. Clair-Detroit River System supports a valuable recreational fishery that serves large numbers of people in the metropolitan Detroit area. In 1973, about 1.4 million angler days were recorded for

the U.S. portion of these waters alone. Although not all factors responsible for the apparent high fish production of this System are known, the area is characterized by extensive stands of submergent aquatic plants that provide habitat for fish and also serve as substrate for a rich population of invertebrate organisms. The area also supports a rich invertebrate bottom fauna suitable as food for fish.

Proposed ice-management strategies designed to permit winter navigation in the System may create ice jams and dams in the navigation channels that could cause increased ice scouring or dewatering of portions of the bottom. To evaluate the potential impact of ice management techniques proposed for the lower St. Clair River, we sampled the benthic invertebrate populations between the village of St. Clair (Michigan) and the outlet of the North Channel in October 1976 and again in March and May 1977. Analysis of these samples revealed the presence of a highly diverse invertebrate community characteristic of a clean-water environment. Several species of mayfly nymphs and caddis fly larvae are common—though not abundant—throughout the study area. These immature insects are significant components in the diet of some Great Lakes fishes and their loss as a result of ice-management operations in the waterway might be reflected in a lowered carrying capacity of the System for fish.

Systematic surveys of the System to describe the submergent vegetation revealed that dormant stands of aquatic plants overwintered beneath the ice in some areas. In most areas, however, no stands were present until May, when the water temperature rose above about 9°C and growth began from the roots. In July, when plant growth approached full development, thin-leaf pondweed was dominant in the St. Clair River and stonewort (*Chara* spp.) in Lake St. Clair; wild celery (*Vallisneria americana*) and thin-leaf pondweed were co-dominant in the Detroit River.

Earlier studies of the distribution and abundance of aquatic plants in the lower Detroit River showed that the population had changed little from the late 1800's to the mid-1950's. Preliminary findings of our 1977 survey suggest, however, that substantial changes have occurred in the lower Detroit River since the mid-1950's. We found that *Chara* was absent from areas where it was once a dominant form, and that all vegetation was lacking in other areas where water celery was once dominant. Further studies are planned to de-

lineate more fully the magnitude of these changes.

Effects of Water-use Practices on Larval Fish Populations in the St. Clair-Detroit River System.

We studied the distribution and abundance of larval fish in the St. Clair-Detroit River System in a continuing effort to determine the impact of man's activities on these young fish. This System was selected for study because it provides an important sport fishery for a large metropolitan area, appears to be a major spawning and nursery ground for species that support valuable commercial fisheries in Lakes Erie and Huron, and is threatened by the increased use of its waters for waste disposal and navigation.

Larval fish sampling was conducted weekly from April to August (1977) with cylinder-on-cone plankton nets (0.5 m in diameter, 351 μm mesh) along four cross-river transects in the St. Clair River between Port Huron and the St. Clair cutoff, and along two cross-river transects in the Detroit River between Belle Isle and Grosse Ile. Three stations were located along each transect—one adjacent to each bank and the third near mid-channel. A total of three surface tows and six "stepped tows" (to depths of 9 m) were made during each visit to each station. During the study, three diel series were completed along each of four transects (Port Huron, St. Clair cutoff, Belle Isle, and Grosse Ile).

Inspection of the samples in the field at the time of collection revealed that large numbers of fish larvae were moving through the System during May-July. High numbers of larvae first appeared in early May in the Detroit River where the water was warmest, and in early June at all other locations. By the end of August few larvae were found in any samples. Laboratory examination of 280 of the approximately 2,500 samples collected revealed that smelt, alewives, and yellow perch were the most abundant species present.

The vulnerability of these larval populations to entrainment at water intakes and to exposure to other waste disposal operations in the system is being assessed.

Nutrient Additions by Streams to the Nearshore Waters of Lake Huron. Intensive limnological studies were conducted from 1973 to 1976 in the nearshore waters of tributary streams of northwestern Lake Huron near the Hammond Bay Biological Station to describe the influence of land runoff on the nutrient dynamics of the nearshore waters. Knowledge of nutrient dynamics in this relatively undisturbed portion of Lake Huron will

provide a basis for interpreting changes observed in other parts of the Great Lakes that have been heavily affected by man.

We collected water samples and streamflow data weekly, July 1975-July 1976, at the mouths of six tributaries to Lake Huron in the vicinity of Hammond Bay. In each of the six streams magnesium and calcium levels fluctuated fourfold to ninefold seasonally (range, 3-13 mg/l^{-1} and 6-55 mg/l^{-1} , respectively). Concentrations of calcium and magnesium were consistently lowest in Mulligan Creek, a small soft-water stream, and consistently highest in Trout River, a hard-water system. Concentrations of calcium and magnesium varied inversely with flow in all streams; concentrations were lowest in late March, owing to dilution by spring runoff, and highest in July, the time of base flow and lowest rainfall. Compared with calcium and magnesium, levels of potassium and sodium were much lower and fluctuated seasonally to a lesser extent in all streams (range, 0.3-1.7 mg/l^{-1} and 0.7-3.2 mg/l^{-1} , respectively).

Silica concentrations in the stream waters ranged from 1.0 to 12.1 mg/l , and were inversely related in each stream to the seasonal volume of stream discharge. Silica values were highest (7.6-12.1 mg/l) in all streams in July during the period of base flow, and lowest (1.0-3.86 mg/l) from March 15 to April 10, when high volumes of spring runoff diluted silica concentrations. Because highest concentrations of silica in the nearshore waters at the Hammond Bay Station intake (2.94 mg/l) occurred at the time of maximum spring runoff, we conclude that silica contributed by the tributaries in the spring added measurably to the seasonal silica maximum found in the nearshore waters at that time of year.

Preliminary analysis of nitrogen values in the same six streams revealed 57% of the nitrogen from this forested portion of Great Lakes coastline entered the lake in dissolved organic form. Dissolved organic nitrogen is frequently overlooked in nutrient budget studies owing to the specialized analytical procedures required for its analysis (UV-photolysis). Of the 80,812 kg of nitrogen added per year to Lake Huron by the six tributaries, 59% was carried by the Ocqueoc River.

Streamflow in all six tributaries varied seasonally from daily minima in October (range, 0.01-10 $\text{liters/day}^{-1} \times 10^7$) to maxima in March (range, 19-125 $\text{liters/day}^{-1} \times 10^7$). Of the six streams, the Ocqueoc River contributed over 60%

of the combined annual total discharge of $1.9 \times 10^8 \text{ m}^3$. Further analysis revealed a high correlation ($r = 0.998$) between areas of the drainage basin and our values for stream discharge. This high correlation was unexpected because some of these streams drain extensive wetlands and others do not, and the rate of runoff is partly a function of the type and degree of vegetative cover.

Few data other than those presented above are available to describe nutrient additions to the Great Lakes by small streams, draining undeveloped (forested) portions of the coastline.

The Role of DDE and PCB's in the Reproductive Failure of Lake Michigan Lake Trout. The standing stock of several million adult lake trout in Lake Michigan today appears to consist wholly of planted fish of hatchery origin. No naturally produced fingerling or adult lake trout have ever been found in 10 years of intensive sampling by State and Federal investigators. One possible explanation of this failure of natural reproduction is that organochlorine contaminants known to be present in the Lake, such as PCB's and DDE, so greatly reduced the viability and competitive fitness of naturally produced fry that they could not survive in the lake environment.

Our earlier studies showed that adult lake trout from the Saugatuck area in southeastern Lake Michigan contained average whole body concentrations of about $22 \text{ } \mu\text{g/g}$ PCB's, $7.5 \text{ } \mu\text{g/g}$ DDT, and $0.3 \text{ } \mu\text{g/g}$ dieldrin. Samples of 1-day-old sac fry hatched from eggs of Saugatuck lake trout analyzed by the Service's Fish-Pesticide Research Laboratory contained $5.7 \text{ } \mu\text{g/g}$ of toxaphene-like compounds, $3.8 \text{ } \mu\text{g/g}$ PCB's (Aroclor 1254), $2.3 \text{ } \mu\text{g/g}$ total DDT, $0.06 \text{ } \mu\text{g/g}$ dieldrin, and $0.12 \text{ } \mu\text{g/g}$ cis-chlordane. Despite the initial contaminant body burden in the fry, their later survival, even when they were deprived of food for more than 2 months, was generally equal or superior to that of fry hatched at the Great Lakes Fishery Laboratory from eggs of uncontaminated brood fish from the State hatchery at Marquette, Michigan. Although we found that eggs stripped from contaminated Lake Michigan lake trout hatched and the fry appeared to feed and grow normally under hatchery conditions, we did not know the effects of additional long-term exposure to PCB's and DDE on the survival of fry in the more rigorous Lake Michigan environment. Whereas fry raised in a hatchery live in a relatively contaminant-free environment, fry hatched in Lake Michigan not only contain the contaminants passed on to them by

their parents but also accumulate additional contaminants from the water and food. Thus, we thought that the "one-two punch" of initial contaminant body burdens and later chronic exposure to ambient levels of PCB's and DDE in the lake environment might reduce the stamina, speed, and wariness of the naturally hatched fry to such an extent that the fry could not survive.

To test this hypothesis, we conducted an extensive laboratory study in which nearly 20,000 fry of Lake Michigan lake trout were exposed for 6 months to PCB's (Aroclor 1254) and DDE in water and food. Concentrations tested were similar to those in offshore waters and plankton of Lake Michigan, as well as concentrations 5 and 25 times higher. We found no significant effects on growth rates, swimming performance, predator avoidance, or metabolism that were clearly attributable to exposure to PCB's or DDE. However, the cumulative mortality of fry exposed to simulated Lake Michigan levels of PCB's and DDE for 6 months was 40.7%—nearly twice that of control fry. At the highest combined level of PCB's and DDE tested (250 and 25 ng/l in water and 25 and $2.5 \text{ } \mu\text{g/g}$ in food, respectively), mortality was 46.5% and the preferred temperature of surviving fry was lowered from 11.2° to 8.7°C . These results show that current levels of PCB's and DDE may significantly reduce survival of lake trout fry in Lake Michigan. The added exposure to other organochlorines known to be present, such as toxaphene-like compounds, dieldrin, and chlordane, may reduce fry survival even more.

Trends in Contamination of Great Lakes Fishes. Man's water-use practices and the production and use of many new chemicals each year pose a serious threat to the fish and fisheries of the Great Lakes. For example, as mentioned in the preceding section, lake trout fry exposed to DDE and PCB levels comparable to ambient concentrations of these contaminants in water and food organisms in Lake Michigan experienced a mortality nearly twice that of unexposed lake trout fry in studies conducted at the Great Lakes Fishery Laboratory. Although no direct effects on human health from consumption of water or fish have been substantiated, many contaminant concentrations in fish exceed U.S. Food and Drug Administration (FDA) guidelines for food and have jeopardized commercial and sport fisheries by making fish unfit for human consumption.

Through 1975 the concentrations of PCB's in lake trout, bloaters, and coho salmon in our col-

lections from Lake Michigan remained temporarily stable. However, concentrations of PCB's in coho salmon collected from northeastern Lake Michigan were significantly lower in the 1976 samples. In addition, PCB concentrations in bloaters decreased significantly from 1974 to 1976, whereas no change in PCB concentrations in lake trout was detected. This was the first time that two of the three species sampled exhibited significant decreases in PCB concentrations, suggesting the beginning of a downward trend. Concentrations of DDT continued a gradual decline, as expected, in these same fish, whereas dieldrin concentrations have not changed between 1969 and 1976, even though a ban on production of aldrin and dieldrin has been in effect since 1974. Mercury concentrations in walleyes from Lake St. Clair, which have been monitored since 1970, decreased rapidly through 1973 and continued a gradual decline through 1976. However, the walleyes sampled during that period, 380 to 640 mm long, averaged 0.78 $\mu\text{g/g}$ in 1976—still above the 0.5 $\mu\text{g/g}$ FDA guideline for mercury.

Subcellular Distribution of Chemical Contaminants. Although the distribution of several pesticides and heavy metals in tissues and organs is known for some fish species, little information has been published on the distribution of chemical contaminants at the subcellular level. Such information serves as a basis for further studies on the mechanisms of toxicological action of contaminants on fish.

Since Lake Michigan lake trout are known to be high in several contaminants, notably PCB's, we prepared several sets of subcellular fractions of the liver, the major site of detoxification, of a large (643 mm long) lake trout collected in south-

eastern Lake Michigan.

Contaminant analyses of liver fractions showed that 97% of the PCB's and 96% of the total DDT were contained in the soluble fraction. One might expect that PCB's and DDT could interfere with the synthesis of fatty acids, which are precursors of prostaglandins, hormone-like substances that have been identified in fish sperm.

Total mercury was distributed as follows: 58% soluble fraction, 19% nuclear fraction, 14% microsomal fraction, 6.8% heavy mitochondria, and 1.8% light mitochondria. Examination (morphometric analysis) of these fractions by electron microscopy revealed that the fractions included the following components: heavy mitochondrial fraction—ribosomes, rough endoplasmic reticulum, nuclei, and lipid droplets; light mitochondrial and microsomal fractions—ribosomes and rough endoplasmic reticulum plus a small amount of smooth endoplasmic reticulum; and soluble fraction—primarily submicroscopic material (7700x magnification) plus a small amount of lipid droplets and cytoplasmic debris. The distribution of mercury on a volume basis, assuming equal affinity for all organelles, was 49% in submicroscopic material, 12% in cytoplasmic debris, 11% in ribosomes and other small particulate debris, 9% in lipid droplets, and lesser amounts in other organelles and materials. On the basis of results with other vertebrates, one might speculate that the mercury in the submicroscopic material is bound to metallothionein and hence is unavailable to interfere with metabolic processes. However, enzyme systems of protein synthesis and oxidative metabolism in the ribosomes and cytoplasmic debris might be sensitive to the small proportions of mercury present.

Inland Fisheries and Reservoir Management

FISH CONTROL LABORATORY

Registration Activities. Registration-oriented

activities of the Fish Control Laboratory continued throughout the year. Data were developed on numerous fishery chemicals for the use of the

Service Liaison Officer in negotiating with the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA). The Fish Control Laboratory interacted with companies that produce fishery chemicals, with university and Federal researchers, with fishery managers, and with personnel of the regulatory agencies.

Requirements for registration were compiled and a flow chart of the various kinds of research involved was prepared, and the current status of priority fishery chemicals was determined and summarized for reference.

Submissions were prepared on quinaldine sulfate, a quinaldine sulfate:MS-222 mixture, formalin, malachite green, and potassium permanganate. These are awaiting action by the regulatory agencies or are under review by the Division of Fishery Research.

Chemicals now registered for use on food fish include copper sulfate, 2,4-D, diquat dibromide, endothall, lime, MS-222, sodium chloride, calcium hypochlorite, simazine, sulfamerazine, and Terramycin. Compounds registered for use on nonfood fishes are antimycin, rotenone, Bayer 73, 3-trifluoromethyl-4-nitrophenol (TFM), the combination of TFM and Bayer 73, Masoten, Casoron, and Furanace.

Calcium hypochlorite received approval for a "Generally Regarded as Safe" classification and is now approved for use as a sanitizing agent in fish cultural facilities.

Collaboration with the industrial sponsor of Betadine resulted in progress to the point where a "New Animal Drug Application" will be filed with the Food and Drug Administration.

Development of Piscicides. The search for selective toxicants for the removal of nuisance organisms continued during the year. The chemical Glidden-Durkee GD-174, showed selectivity against the common carp in standardized laboratory tests and was considered a potential candidate for carp control. Preliminary tests were conducted in tanks and small ponds.

This chemical was tested in outdoor plastic pools to determine the toxicity to a variety of cold-water and warmwater fish. Fish were exposed to concentrations of 0.1, 0.15, 0.2, and 0.3 mg/l for 96 hours. The 0.2 mg/l concentration killed 100% of the carp, white suckers, and rainbow trout, but had no adverse effect on eight species: goldfish, black bullhead, channel catfish, green sunfish, bluegill, largemouth bass, yellow perch, and walleye.

Special on-site bioassays are run in ponds to be treated, to help determine the concentration needed for each ecotype. Such tests usually give highly accurate and reliable readings; however, on-site bioassays of GD-174 have been erratic and often unreliable. Concentrations that killed all carp in bioassays frequently were ineffective in open ponds. The causes of this difference are not yet understood. Several factors are under investigation. Biological, chemical, and physical elements may degrade the chemical faster in the pond than in plastic bioassay bags, and light intensity may also be higher in the open pond.

Early laboratory tests indicated that the toxicity of GD-174 to fish increases as the pH of the water increases. Further laboratory and field tests confirmed this observation, but expanded tests indicated that the chemical is much less selective in water of high pH.

It was also learned that the presence of rooted plants or algae reduces the effectiveness of GD-174, perhaps because they absorb or metabolize the compound. Suspensions of clay particles also interfere with the activity; adsorptions of the chemical on the clay is suspected.

Although field results have not yielded consistent results in selectivity tests, GD-174 continues to be a candidate fish toxicant. Problem species such as carp, bullheads, and suckers can be eradicated from fertile waters of high pH, in which other toxicants are much less effective.

The inability of carp to inactivate or metabolize GD-174 provides a strong clue to physiological systems that might be interrupted. Elucidation of the reasons for the susceptibility of carp to GD-174, whereas other species are more resistant, should provide information that can be exploited in the development of an effective carp control technique.

Chemists at the Fish Control Laboratory successfully developed methods for the separation, cleanup, and gas chromatographic determination of GD-174 residues in fish tissue. Recovery rates from spiked tissue ranged from 70 to 80%.

Grass carp are presently recognized as a potential problem species because they have been distributed widely and have extended their range in U.S. rivers. Many States ban the fish but others continue to propagate this exotic species. Control methods may be needed to eliminate the fish from selected waters if present concerns prove valid.

Although the chemical GD-174 has shown promise for selectively killing the common carp

from sport fish populations, results of standardized tests show that grass carp are more resistant than common carp to GD-174, antimycin, Noxfish, and Salicylanilide I by factors ranging from 1.5 to 4.0. Fishery managers should be extremely cautious in the propagation of grass carp because this species could be more difficult to control than the common carp.

Rotenone has been used for fish control in the United States for nearly 40 years. The labels for some registered formulations of rotenone that called for a treatment rate of 1 ppm were recently changed to allow a maximum of 5 ppm or more under certain conditions. Tests were conducted to assess the effects of the increased concentrations of rotenone on invertebrate organisms in static waters.

Two ponds were treated with the synergized formulation of rotenone, one at 2 ppm and one at 5 ppm. Benthic invertebrate and plankton samples were collected before treatment and up to 69 days after treatment.

The 2-ppm treatment reduced total numbers of benthic organisms by 66% and eliminated 3 of 11 taxonomic families. The 5-ppm treatment reduced total numbers of benthic organisms by 96% and eliminated 5 of 10 families. Both concentrations caused complete mortality of Asiatic clams (*Corbicula* sp.) in 24 hours. However, total numbers of organisms and total numbers of many families of organisms had recovered to pretreatment numbers or above by 37 days after treatment.

The efficacy of Pro-Noxfish, a synergized formulation of rotenone, is known to be influenced by environmental conditions. Tests were conducted to determine the factors that necessitate use of concentrations greater than the highest concentration (5 μ l/l) specified on the existing label. High fertility and the presence of organic matter are often cited as factors that reduce the activity of rotenone.

Tests were conducted in a pond that contained a dense plankton bloom and large quantities of soft organic muck, and had a pH of about 9.0 at time of treatment. Although these environmental conditions were considered adverse, a 1 μ l/l treatment completely eradicated goldfish and bullheads.

In preliminary tests with rotenone, increasing the ratio of sulfoxide to rotenone from the 1:1 ratio now used in Pro-Noxfish to 2:1 increased the activity against certain undesirable fishes.

The Asiatic clam, *Corbicula leana*, and a clam native to the southern United States, *Magnonaias*

boykiniana, were exposed to the fish toxicant antimycin at several concentrations for various periods and then placed in an untreated earthen pond for posttreatment observation. Both species survived the concentrations and exposure usually used in field application. However, latent mortalities were observed in the pond 3 months after a 30-day flow-through exposure of *Corbicula* to 3.6 to 30 μ g/l of antimycin. A single treatment (2 μ g/l in an earthen pond did not result in significant mortalities of *Corbicula* during 22 weeks. *Magnonaias* was more sensitive than *Corbicula* to antimycin, but both survived the maximum permissible use-pattern concentrations in flow-through tests.

Several geraniol-related compounds were screened for selective activity against carp. The structures represent different portions of the GD-174 molecules, and various substituted functional groups. Preliminary results suggest that some molecular configurations may contribute to the selective action of GD-174, but none of the structures were as toxic as GD-174.

Nitrite nitrogen has a known toxic effect on fish and has been considered a hazardous contaminant in fish culture. Since the compound is so common in nature and easily converted to less toxic forms, it may have potential as a general or selective fish toxicant. The toxicity of nitrate nitrogen (from sodium nitrite) was determined on several species of fish and invertebrates. Nitrite toxicity to rainbow trout was not affected by different water temperatures, but was significantly higher in soft than in hard water, and water of acidic pH. Toxicity to channel catfish was not significantly affected by water temperature or pH, but was significantly greater in warm than in cold water and in soft, acid water than in neutral or alkaline water. Also, under the same test conditions, nitrite was 145 times more toxic to rainbow trout and 233 times more toxic to channel catfish than to bluegills.

Aquatic invertebrates were not as sensitive as fish (other than bluegills) to nitrite nitrogen. The order of sensitivity (from least to most resistant) was: glass shrimp, two species of snails, and Asiatic clams.

Bactericides and Viricides. Betadine, a viricidal formulation of providonè iodine, is used to treat eggs to remove viruses from the surface. Eggs are treated in hatchery supply waters with a wide range in pH. Since the formulation is considered unstable at pH's above 6.0, a question arose about the effectiveness of the compound in water with a pH above 6.0.

Studies were conducted at pH's of 6.0, 7.0, 7.9, and 8.6. No drop in available iodine levels was noted after 24 hours at pH 6.0 and 7.0. At pH 7.9, the level did not change for 8 hours, but declined by 15% after 24 hours; at pH 8.6 about a 55% loss in activity occurred after 24 hours.

These results indicate that use-pattern levels and times currently used should be highly effective and that high pH causes no significant loss of activity during treatment of eggs.

Development of Parasiticides. Formalin is a widely used treatment for external parasites of fish. Despite its long history of safe and effective use, no data have been developed on residues that might be present in treated fish or treated waters.

Largemouth bass, channel catfish, coho salmon, and rainbow trout were exposed to 300 and 400 mg/l concentrations of formalin for up to 4 hours, or until severe distress occurred. Samples of muscle, blood, and liver were taken immediately after treatment and as long as 24 hours after transfer to fresh water. No residue of formaldehyde was detected in any tissue.

Channel catfish and largemouth bass were exposed to 35 mg/l of formalin, which is about the level used in ponds, in a plastic pool containing water, soil, and plankton. The pool simulated a pond with a so-called normal plankton bloom. Samples of water and fish were taken at 24 and 72 hours for analysis. No residue was detected in the fish, and the water content dropped from 13 mg/l formaldehyde on day 0 to 9 mg/l on day 1 and to "not detectable" on day 3.

Formaldehyde reacts with acetylacetone in the presence of excess ammonium salt to form diacetyldihydrolutidine, which can be read on a colorimeter. This technique was used to measure formaldehyde residues in spiked muscle, blood, and liver from channel catfish and largemouth bass. By slightly altering parts of the method, we were able to detect a spiked concentration of about 5 $\mu\text{g/g}$ of formaldehyde. The recoveries ranged from about 30 to 45% from spiked concentrations of 5 to 40 $\mu\text{g/g}$. The results were fairly consistent and can surely be used to estimate formaldehyde concentration down to about 5 $\mu\text{g/g}$ in fish tissue.

Concentrations of formaldehyde were determined in water samples with almost 100% recovery, and detectability of about 1 $\mu\text{g/ml}$.

Formaldehyde is a naturally occurring compound in the environment, and is also a decomposition product of animal tissues; consequently,

accurate determinations of residues resulting from treatment with formalin are difficult. Possible formaldehyde generation in frozen fish samples was checked to verify the validity of preserved samples in storage.

Coho salmon were exposed to 300 mg/l of formalin for 1 hour. No residue of formaldehyde could be detected in the muscle. Samples were then stored in a freezer and analyzed for formaldehyde residue. No formaldehyde residue was detected in the muscle after frozen storage for 4 months, and it was concluded that no formaldehyde residue was released or generated during storage.

Malachite green is widely used in fish culture to treat fish for external parasites. Although the compound is very effective, little is known of its effects on treated animals. Some workers have reported that malachite green may cause developmental problems in fish and invertebrates if applied to eggs, embryos, or larval stages.

A study on teratogenic effects of malachite green was conducted in timed-pregnant New Zealand white rabbits. A water solution of malachite green was administered into the stomach during days 6 through 18 of pregnancy, at rates of 5, 10, and 20 mg per kilogram of body weight. Thalidomide, a known teratogen, was administered at 150 mg/kg to other rabbits to provide a basis for comparison. Control animals received only water.

Animals dosed with malachite green had less gain in body weight, a higher incidence of fetal resorptions, and poorer reproductive performance. Malachite green induced a significant increase in gross, visceral, and skeletal anomalies at all treatment levels. Progeny body weights, sex distributions, and 24-hour survival times were not affected.

Standardized Test Procedures. Standardized test procedures are needed to develop toxicological information that is reproducible, dependable, and consistent with data developed at other laboratories.

Procedures for the registration of fishery chemicals have required the development and use of standardized methodology. Many of the data developed at the Fish Control Laboratory are used in the support of chemical registration.

Fish Control Laboratory contributions to the standardization of test procedures constitute a major portion of the guidelines established in Methods for Acute Toxicity Tests with Fish, Macroinvertebrates, and Amphibians and in the

standard methods established by the American Society for Testing and Materials (ASTM).

Formulations Research. Chemicals with potential use as fishery tools can be proven effective in small-scale laboratory tests but may not be usable in the field in the form used for laboratory tests. Formulations must be developed that are suitable for field use on the basis of solubility, safety, ease of application, dispersion in water, and other factors.

Work centered on formulations of GD-174, a potential carp control. The chemical can be made soluble in water in the laboratory by dissolving it in acetone. However, under field conditions the very large volume of acetone needed would present problems in transport and mixing, and would constitute a serious fire hazard.

Dilution of GD-174 with small volumes of 20% acetic acid appeared to render the chemical soluble in water. This formulation was tested in several ponds and laboratory pools. Results to date have been inconsistent and raise questions about the true solubility of the formulation in water containing different combinations of dissolved nutrients and aquatic organisms.

Analytical Methodology. Chemicals used in fishery management and culture encompass a large variety of structures, and analyses for residues of these compounds require application of both classical and non-classical approaches to analytical chemistry. During the year the possible use of polarographic techniques for analyses of Bayer 73 and GD-174 was evaluated. Although the technique did not prove to be practical for these compounds, it does show promise for the analyses of residues and may be applicable to other candidate compounds.

Ammonia Removal from Hatchery Effluents. Ammonia and related nitrogen compounds represent some of the most common organic substances found in effluents from fish hatcheries. In fish culture, ammonia is toxic if it is allowed to accumulate in water used to rear fish. Filtration through clinoptilolite is one of several techniques used to remove ammonia from water.

The efficiency of clinoptilolite for removing ammonia from water was determined at selected temperatures, hardnesses, and pH's. Solutions of ammonia ($\text{NH}_4\text{-N}$), 10 mg/l, were filtered through a 15-cm, 60-g (dry weight) bed of 20 X 30 mesh clinoptilolite. In all tests the flow rate was maintained at 25 ml per minute. Temperature had no effect on sorption capacity; however, water hard-

ness and pH did affect capacity. In very soft water the capacity for removing ammonia was 9.12 mg $\text{NH}_4\text{-N}$ per gram of clinoptilolite. This capacity was reduced as water hardness increased: it was 8.55 mg/g in soft water, 5.32 mg/g in hard water, and 4.30 mg/g in very hard water. The capacity was also reduced in soft acid water, pH 6.5 (3.42 mg/g), versus alkaline water, pH 9.5 (6.17 mg/g). Evaluation of mesh size showed little difference between 20 X 30 mesh and 30 X 50 mesh; capacities were 7.85 and 8.02 mg/g. The capacity was reduced to 5.37 mg/g at larger meshes (8 X 8).

FISH FARMING EXPERIMENTAL STATION

Bacteriology. Every year, particularly in the summer, thousands of fish are killed by bacterial infections. Some of the dangerous bacteria have been identified as *Aeromonas salmonicida*, which causes ulcers in goldfish, and *A. hydrophila*, which produces lesions in catfish. The causative agents of some other diseases have not been determined. A bacteriology section has been established to identify the organisms and to assist fish farmers in preventing fish losses.

Parasites and Diseases of Freshwater Fishes. Parasitic infections cause the loss of many cultured fishes. To properly initiate control measures, the culturist must be provided with accurate identifications and descriptions of parasites, and with improved control measures. To study the dangerous *Henneguya* sp., a parasite of the gills of channel catfish, biologists have established a controlled infection in the laboratory. Electronmicrography studies are in progress. Intimate knowledge of the host-parasite relationship should yield information that will eventually help control this dangerous parasite.

Diseases of baitfishes cause losses in the minnow industry. Emerald shiners with visible pustules on the head ("snow-nose") from Michigan and New York have been brought to our attention; from them, biologists have described a new genus and species of myxosporidan as *Dicauda atherinoidi*. This description should help other workers identify and control the parasite.

Because heavy infestations of *Ambiphraya ictaluri* (Protozoa:Peritrichia) have been causing losses of channel catfish in early spring, biologists

have initiated an electronmicroscopic study of the host-parasite relationships. A better understanding of these relationships should lead to better control measures.

The anchor parasite, *Lernaea elegans*, causes great losses of bait minnows and goldfish, and Masoten is not always effective. Therefore, biologists have established a "culture" of it on laboratory fish to test other control methods.

Malachite green has been used in research for controlling fish fungi but the effect of short-term exposure of channel catfish to malachite green does not appear in the literature; biologists determined that yearling catfish can tolerate 66 ppm for at least 45 seconds, and 0.4 ppm for 1 hour. One-month-old catfish fry exposed for ½ hour did not survive concentrations of 1 ppm, but did survive 0.4 ppm. Thus, a short dip in malachite green can be used for controlling fungus infections in catfish yearlings, and perhaps fry.

The control of diseases and parasites affecting warmwater fishes is possible. However, it requires a close working relationship between the research and diagnostic biologist, and the fish producer.

Amino Acids Requirements of Channel Catfish.

Inasmuch as the animal body is composed primarily of protein, foods containing protein must be eaten continually throughout life. The fish producer strives to efficiently convert plant and animal proteins in feeds to fish tissue.

The amount of protein required in the diet of fish is related to the indispensable amino acid pattern of the proteins contained in the diet, and to the protein digestibility. Should the dietary availability of a particular indispensable amino acid be only 50% of the nutritional requirement, growth would be only 50% of that expected, even though the vitamins, energy, carbohydrate and other nutrients were adequate to meet the animal's needs.

Ten amino acids have been determined to be indispensable for channel catfish: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Studies have been conducted to determine the quantitative requirements for the amino acids in the diet of channel catfish. Purified diets were prepared that contained 10% whole protein (8% casein and 2% gelatin) and 20% crystalline amino acids (devoid of the test acid), formulated to give a total amino acid pattern identical with 30% whole-egg protein. Other purified ingredients were added to meet the total nutrient requirement of

catfish. Graded levels of the amino acid to be tested were added to induce a growth response proportional to the requirement of the animal. Growth plots were made and correlated to the test amino acid content of the diet, thus establishing the minimum quantity for maximum growth.

Requirements for 4 of the 10 amino acids for channel catfish are: isoleucine 4.3% (1.3/30) of the total protein present in a 30% protein diet; leucine 5.7% (1.7/30); tryptophan 0.8% (0.23/30); and lysine 5.0% (1.5/30).

Quantitative requirement data for the amino acids, as well as for the other dietary ingredients, will allow the feed formulator more options in feed manufacture. The formulator can substitute the lower cost ingredients for expensive or non-available ingredients without reducing fish performance, and thus make the modified ration available at a lower cost.

Settleable Solids in Ponds. The discharge of silt-laden effluent from intensive production ponds into receiving streams can be detrimental to the native fish habitat. These effluents contain settleable and suspendible solids and include such materials as plant and plankton debris, uneaten feed, feces, and even colloidal clays. The discharges may damage the aquatic environment by imposing such effects as "siltling" in the receiving stream, causing excessive growth of biomass as a result of the fertility increase, or altering water and soil chemistry.

One method of controlling the amounts of solids in pond water discharges is to culture a second fish species in combination with the fish species normally grown. This secondary species eliminates or reduces the materials that normally make up the solids in ponds. When we compared a polyculture system of channel catfish, fathead minnows, and hybrid bigmouth buffalo X black buffalo with a monoculture system of only channel catfish in ponds of equal size, total fish production was 98 kg in the polyculture pond, and 77 kg in the monoculture pond. Channel catfish gained an average of 3.5 g per day in polyculture, compared with 3.1 g per day in monoculture. Polyculture had no detrimental effect on catfish production—production was actually increased—and settleable solids were significantly lower (9 ml/l) in the polyculture pond than in the monoculture pond (23 ml/l).

Surface drainage was found to be another effective way of reducing the amount of settleable solids in pond effluent; it very markedly reduced

the amounts of solids in the discharge water.

The use of combinations of fish species and surface water discharge appears to be a practical method of reducing solids in pond discharge water. The method has a further value to the fish husbandryman in that it increases production efficiency and diversifies his output.

Recycling Fish Culture Systems. The recycling or reuse of water in fish production has great potential. High-quality water for single use is decreasing in some geographical areas, and lacking in others. Recent cost increases in energy have made the cost of pumping groundwater prohibitive in many areas. Reuse of water, provided that it can be done with little energy input and without detriment to fish production, can reduce or eliminate many problems.

Research personnel and managers have suggested numerous ways of cleaning water for reuse. Some of these are being studied by other groups. Our studies involve the oxidation of waste metabolites and would be applicable in closed culture systems.

An additive agent that has shown promise in reuse systems is hydrogen peroxide (H_2O_2). In tests, the addition of either 1 or 7 ml/l of it per day to tanks containing channel catfish did not significantly increase their growth over control groups of fish. In a follow-up study the dosage level was increased to 14 or 28 mg/l per day. Fish cultured in tanks receiving these dosages had highly significant increases in mean weight of 102 g, compared with a mean increase of 76 g for fish in the control groups.

The use of hydrogen peroxide or possibly another untested oxidizing material to maintain fish growth in closed systems appears to be feasible.

Feeding Problems Related to Temperature. Water temperature has been shown to be a major factor in controlling fish growth and feed use. There is a narrow temperature range at which optimum fish growth occurs, which has been determined experimentally for several fish species. However, these determinations were made at constant water temperatures. Direct application of this information for designing feeding programs is difficult because in practical production facilities, such as ponds, stable temperatures do not occur.

To apply information known about optimum feeding temperatures, one must study feeding behavior and feed use in relation to fluctuating temperatures. To accomplish this, we developed facilities capable of duplicating diurnal water tem-

perature fluctuations. These facilities allow manipulation of water temperatures and the programming of feed quantities and feeding times.

Channel catfish have been successfully reared in the experimental system. Initial trials consisted of comparing the growth of small channel catfish that were fed on a rising and a falling water temperature regime similar to that measured in a pond last year. Control groups were maintained at a stable temperature of 82°F. To eliminate time-of-day bias, we fed groups representing all test conditions during the day and at night.

Fish exposed to a falling water temperature had a new yield of 18.2 g, which was very similar to that of the control group (18.5 g), held at a stable temperature; fish exposed to a rising temperature gained 20.4 g, a yield about 11% greater than that obtained under the other test conditions.

FISH GENETICS LABORATORY

Genetic Evaluation of Wild and Hatchery Strains of Rainbow Trout. This program is designed to characterize different strains of rainbow trout and to evaluate their suitability for various environments and management uses. A two-phase evaluation is conducted on each strain. The first phase consists of testing the fish under standardized rearing conditions at the Fish Genetics Laboratory, where the strain is characterized for a wide variety of fish-cultural, morphological, and biochemical traits. In addition, each strain is tested in the Laboratory's 2-acre pond to evaluate survival, growth rate, and susceptibility to angling pressure. The second phase is designed to evaluate the performance of the strain in a variety of hatchery and field environments. Most of these studies, conducted in cooperation with State and Federal hatchery and fishery managers, are in early stages of development.

Laboratory testing of nine strains has shown large differences among strains in many traits—especially growth, feed conversion efficiency, and susceptibility to angling. These large differences indicate good potential for matching strains of rainbow trout to specific management needs.

Inbreeding Depression in Rainbow Trout. Studies designed to measure the effects of different levels of inbreeding have demonstrated significant depression in a number of traits. After one generation of brother-sister mating, the fre-



Two 2-year-old rainbow trout: Upper—typical fish from the groups selected for accelerated growth. Lower—typical fish from the unselected control group. *Photo by W. F. Kohler.*

quency of crippled fry increased nearly 38%; decreases were observed in feed conversion efficiency (5.6%), fry survival (14.6%), growth rate to 147 days (6.0%), and growth rate to 364 days (23.2%). After two generations of brother-sister mating, frequency of crippled fry increased by 191%; further decreases were found in feed conversion efficiency (14.9%), fry survival (29.7%), growth rate to 147 days (13.4%), and growth rate to 364 days (33.5%). In addition, x-ray examination for vertebral abnormalities showed that the frequency of fusions and the average number of vertebrae involved in each fusion increased with the level of inbreeding.

Although the level of inbreeding in each of the present hatchery rainbow trout brood stocks is unknown, past breeding practices suggest that many of them carry inbreeding levels at least as high as one generation of brother-sister mating. Random

mating techniques and a system of rotational line mating have been developed for the use of the brood stock managers in decreasing the occurrence of further inbreeding in hatchery stocks.

Studies involving both inbred-line crosses (four generations of brother-sister mating) and strain crosses demonstrate the potential of hybridization for producing improved rainbow trout brood stocks. Results from growth studies still in progress indicate that hybrids between pure strains tend to reflect an average of the parent strains' performances, but a small percentage of the hybrids show performance superior to that of both the parent strains. Hybrids between inbred lines were superior to both parents in most of the crosses, and in three instances, these hybrids were superior to the best performing strain hybrid. This work suggests that hybridization is effective in restoring strain growth performance lost as a result

of inbreeding depression, but that better results might be obtained through the crossing of selected inbred lines.

Selection for Accelerated Growth Rate in Rainbow Trout. Comparison of growth rate of families selected for greatest family mean fish weight at 147 days of age with an unselected control population showed that there was dramatic improvement in the selected line after three generations of selection. Genetic gain in growth rate over this period was 30%, or 10% per generation. In addition, it was demonstrated that selection for juvenile growth rate produced fish which continued to grow faster at older ages. The selected families were 70% heavier than control fish at 1 year of age and 48% heavier at 2 years. Evaluation of the two groups under hatchery conditions at the Bozeman Cultural Development Center showed that the selected group was 25.9% heavier at 301 days of age. Brood stock managers can use this method of selection to improve the growth of several existing strains of trout.

NATIONAL FISH HEALTH RESEARCH LABORATORY

Transmission of Bacterial Kidney Disease. Bacterial kidney disease (KD) has been and continues to be one of the most serious diseases of hatchery-reared salmon and trout. One of the most effective means of preventing the spread of KD is to restrict movement of the causative bacterium. Since fertilized salmon and trout eggs are shipped extensively, it is imperative to know if KD is transmitted vertically, that is, from parent to offspring by way of the eggs or sperm. To determine this we obtained fertilized eggs and sperm from adult chinook salmon which showed clinical KD. The eggs were divided into four lots; two lots were disinfected for 15 minutes with 100 ppm of the organic iodine solution Betadine, and two lots were left untreated. After hatching, the fry were observed for mortalities and these were examined for KD.

Clinical KD was found in young salmon from the nondisinfected eggs 4 months after hatching, and in salmon from disinfected eggs 8 months after hatching. There is no doubt that KD can be vertically transmitted and that disinfection with Betadine did not prevent such transmission. Similar work is being carried out with furuncu-

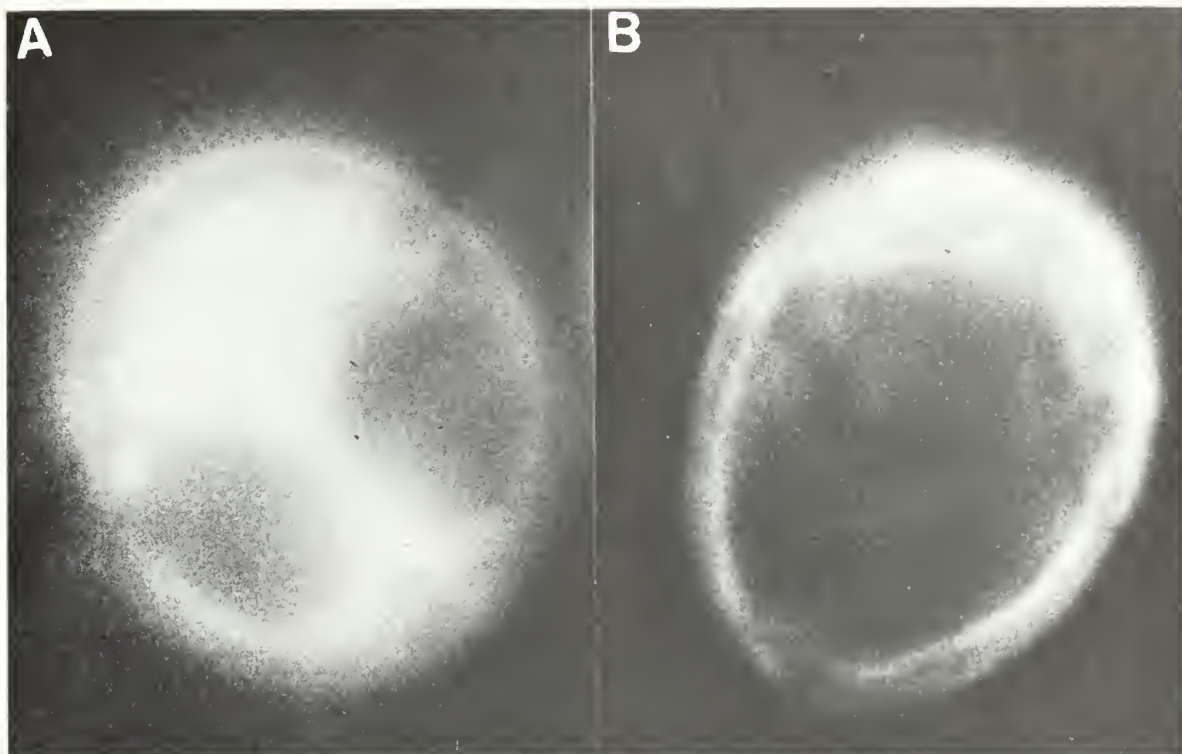
losis, another important disease of fishes, but results so far indicate that this disease is not vertically transmitted.

Diagnosis of Bacterial Kidney Disease. Until recently, diagnosis of KD has been based on observing KD bacteria in stained infected tissues. Because lightly infected fish could not be detected by this method, a fluorescent antibody test (FAT) was devised. A fluorescent dye is coupled to a specific KD antiserum and used to treat suspect KD tissue. Tissues so treated are examined with a microscope having an ultraviolet light source. If the bacteria are present, they are easily visible because of the apple-green fluorescence of the fluorescent dye. We have found that the FAT is at least a thousand times more sensitive in detection of KD bacteria than the old staining procedure. The test can be used to detect very low levels of infection in salmon and trout.

Biotyping of the Enteric Redmouth Bacterium. Enteric redmouth (ERM) is a serious disease of salmon and trout, which has now spread to all trout-growing areas of the United States and parts of Canada. The ERM bacterium has also been isolated from trout in Australia. To determine if ERM strains from various geographic areas are similar, we compared isolates from different areas of the United States and from Australia. Although cultures were similar in morphology and biochemical reactions, there were three different serological types. Fortunately, most of the current ERM outbreaks are caused by the originally described serological type, from which the commercial ERM "vaccines" (immunization preparations) are made.

Detection and Identification of *Myxosoma cerebralis*. *Myxosoma cerebralis* is the cause of whirling disease of salmon and trout. The spore-forming protozoan parasite was accidentally introduced into North America 20 years ago, and has been an important cause of crippling and death of fish ever since. Knowledge of the parasite's life cycle is fragmentary, and the only certain method of identification is based on the size and morphology of the spores. Accordingly, immunological methods were explored as a method of serological identification and to provide a new approach to solving the riddle of the life cycle.

Extracts made of spore and pre-spore concentrates were used to immunize rabbits. The resulting antisera were compared in direct and indirect fluorescent antibody tests. When antiserum or antibody was coupled to a fluorescent dye and



Mature spores of *Myxosoma cerebralis* showing a positive fluorescent antibody reaction with homologous anti-serum prepared in rabbits. (A) With the direct method the bulk of the spore interior is fluorescent—the exception being the polar capsules. (B) With the indirect method, fluorescence is at the spore surface and produces a halo-like appearance in which polar capsules are not readily evident. 8300 X. Photo by Maria Markiw.

added to slides holding the parasite, a specific bond was formed. The tagged antibody was attracted to and held by spores and pre-spore stages. In special microscopes that use ultraviolet light instead of visible light, the fluorescence is brilliantly evident as an apple-green color. When specificity of the reaction was tested with 12 other spore-forming fish protozoan parasites, the direct fluorescent antibody technique showed cross-reactivity with only 1, and it was a species of *Myxosoma*; the indirect method proved to be non-specific. The direct fluorescent antibody test provides diagnosticians with an accurate serological method of identification and researchers with a powerful tool for determining the parasite's life cycle.

Diagnosis of Virus Diseases. Viruses that cause diseases in salmonid fishes cannot be distinguished by their clinical or histopathologic manifestations. Consequently, they must be isolated and identified. This process usually requires 3 to 10 days by conventional cell culture isolation methods. Although these conventional techniques are effective, more rapid and sensitive, and less costly,

methods are needed. Fluorescent antibody (FA) assays are highly sensitive serological tests that permit simultaneous detection and identification of fish viral pathogens in a matter of hours. Specific antiserum, coupled to a fluorescent dye, combines with viral antigens in or on infected cells. When viewed with ultraviolet light microscopes, the affected cells are illuminated by the fluorescent dye, and the specific virus is identified. Since the FA test is so sensitive, highly purified virus must be prepared for antibody production. The National Fishery Center—Leetown has prepared highly purified virus stocks and corresponding antiserum and soon will be evaluating host tissues and cell culture preparations.

Inactivation of Salmonid Viruses by Ultraviolet Irradiation. The most effective method of controlling salmonid viral diseases is by preventing contact between the virus and the host. Such prevention requires that rearing facilities be disinfected, and fish or eggs that have been certified as specific-pathogen-free be introduced. A virus-free water supply is an integral part of disease control programs. The National Fishery Center—Leetown

is investigating the efficacy of ultraviolet irradiation as a means of inactivating fish viral pathogens in hatchery water supplies. Methods are being developed to detect very low levels of virus in very large volumes of water, since theoretically one virus particle can cause disease. Virus is recovered from water by a filtration process. In an acid environment, the virus adsorbs or sticks to the filter, whereas in an alkaline environment the virus is eluted or released. Thus, virus can be concentrated and recovered in smaller volumes. By present methods, about 70% of the introduced virus can be recovered. Preliminary studies indicate that the viruses of infectious pancreatic necrosis, infectious hematopoietic necrosis, and viral hemorrhagic septicemia can be effectively inactivated by ultraviolet irradiation.

Persistence of Lymphocystis Virus. A request from the American Type Culture Collection to replenish their stock of lymphocystis virus provided an inducement to quantify preparations of freeze-dried virus that had been stored for 13 years. Assays in yearling bluegills showed that as much as 4% of the original infectivity survived the long period of storage. The finding led to similar determinations of residual infectivity of lymphocystis virus that had been simply dried over phosphorus pentoxide 15 years earlier. Surprisingly for a virus from an aquatic vertebrate, simple drying also preserved infectivity at wholly satisfactory levels.

Growth and Function of the Biologics Section. The Biologics Section of the National Fisheries Center—Leetown distributes antisera, antigens, and other serodiagnostic reagents upon request to Federal, State, university, and private personnel involved in fish disease serodiagnosis or research. This 3-year-old section has seen a fourfold growth even within the last year as almost 500 requests have been filled from more than 29 States and 35 foreign countries. The biologics are used principally for rapid identification of microbial pathogens responsible for disease outbreaks in hatcheries, field stations, and research facilities. In addition, the antisera are used to help confirm pathogen strains and conduct various research studies. Standard immunological techniques such as agglutination, precipitin, fluorescent antibody, and serum neutralization tests are performed with the biologics.

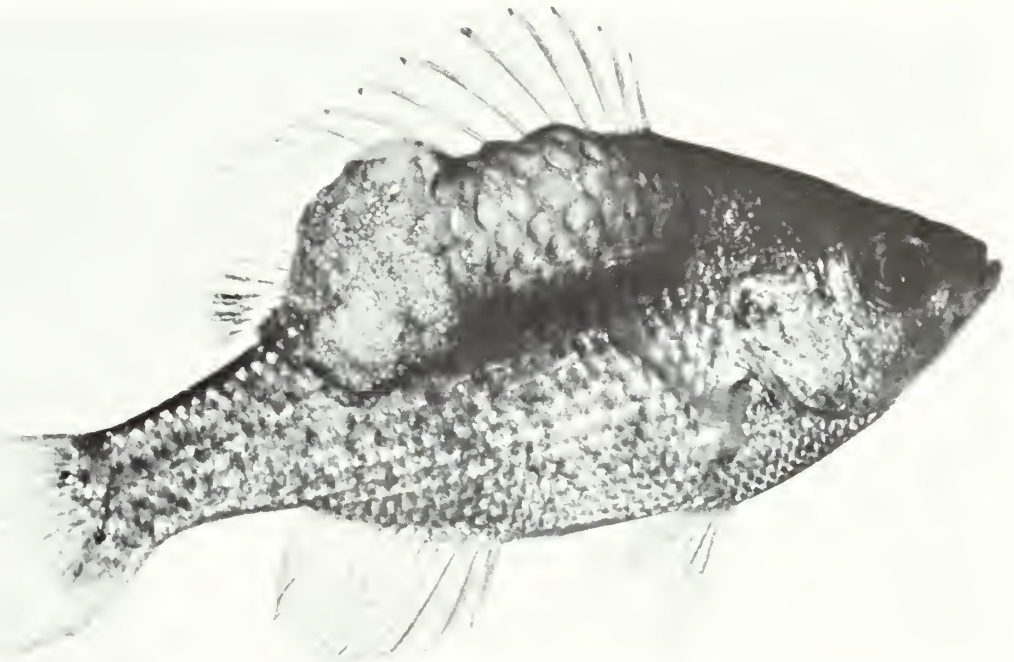
For the production of antisera, rabbits are kept in this laboratory under well-supervised sanitary conditions. After the rabbits are immunized with the appropriate disease antigens, the antisera are

drawn, standardized, and lyophilized to be later placed in the permanent Biologics file for distribution. In addition, control antigens for the serodiagnostic tests are made up in large batches in a 16-liter bacterial fermentation system. The production of large batches facilitates standardization of the antigen control systems.

In addition to serving a definite serodiagnostic function, the information feedback from the Biologics distribution enables our Laboratory to increase communication with other field and research personnel in this country and around the world. This communication helps us to better standardize our serodiagnostic tests, and also gives us more information concerning the importance of specific diseases in certain geographical areas.

Detection of Trout Antibodies to *Myxosoma cerebralis*. The diagnosis of parasitic diseases in humans and veterinary animals has long been facilitated by various serological tests for specific antibodies. Few such tests are available to assist the fish disease diagnostician faced with possible parasitic infections. Diagnosis of whirling disease, caused by *Myxosoma cerebralis*, depends on detection and identification of specific spore stages in cartilage taken from the animal. The procedure can be time-consuming if the animal carries few spores, and is unreliable if specific spore stages are not present. A technique has been developed which enables detection of small quantities of fish antibody on the surface of spores after the spores have been incubated with serum from the blood of an infected animal. This test is an "immunofluorescent" test, in which the presence of the antibody is demonstrated by means of a fluorescein-labeled reagent. Antibodies against *M. cerebralis* spores have been consistently found in rainbow trout known to have whirling disease, whereas they are consistently absent in disease-free trout. Tests are under way to adapt this technique for use in diagnostic laboratories.

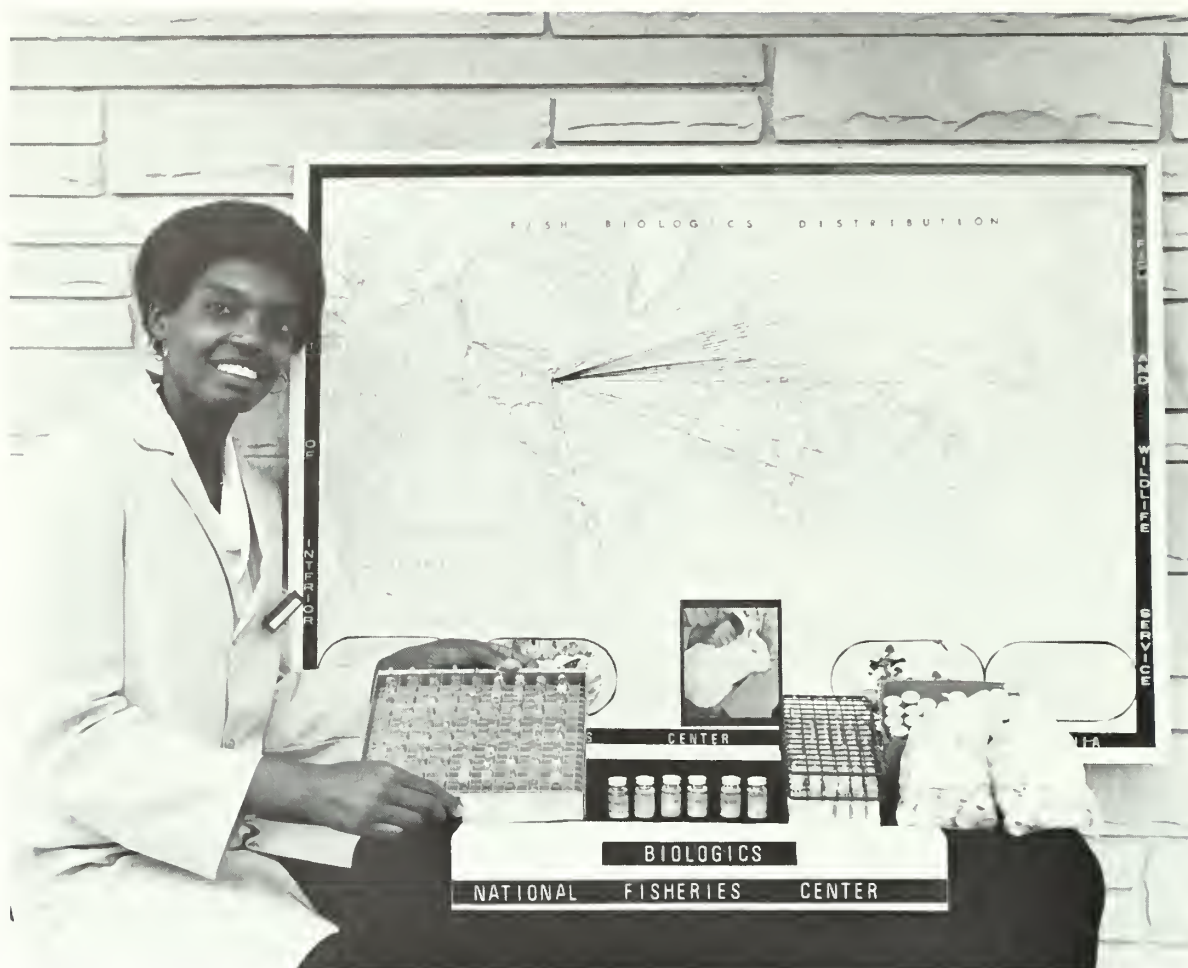
Antibody Production by Fish Lymphocytes. One of the ways a fish protects itself against disease is by the production of specific antibody by lymphocytes concentrated in the organs such as the spleen and kidney. Inasmuch as antibody can be detected in lymphocytes even before it can be detected in the blood serum, a hemolytic plaque test is being used to detect the antibody-producing lymphocytes. When fish are immunized with sheep red blood cells, the resultant antibody from "sensitized" lymphocytes lyses sheep red blood



Yearling bluegill experimentally infected with lymphocystis virus. With a procedure developed at the National Fisheries Center, virus is placed within a "pocket" that has been artificially formed beneath the skin. In this fashion unusually large amounts of virus can be produced by the fish and retained without loss. *Photo by Ken Wolf.*



This giant fish cell has a volume more than 10,000 times greater than adjacent cells of normal size (arrow). The enlargement is the result of the cell having been infected with lymphocystis virus, a rather common fish pathogen. The effect on the fish host is comparable to that of warts infecting man and livestock—unsightly but not serious. *Photo by Ken Wolf.*



Samples of lyophilized antisera and antigens, prepared at the National Fisheries Center, which are used in fish disease diagnosis. Requests for these biologics come not only from biologists of the National Fish Hatchery system, but also from field and research personnel throughout the world. Photo by H. M. Stuckey.

cells when they are placed in agar with the active lymphocytes. Most important, from a serodiagnostic point of view, is that the sheep red blood cells can be labeled with components of fish pathogens and then used to detect the presence of cellular antibody against those pathogens. Methods can now be perfected to show the lymphocytes producing antibody against specific diseases, before antibody in the blood serum can be detected by conventional methods.

Fish Health News. Distribution of *Fish Health News*, the quarterly release of the National Fish Health Laboratory, is now received by 450 research laboratories, diagnosticians, libraries, and interested administrators in both public and private agencies in the United States and abroad. There is no charge for *Fish Health News*. The publication—consisting of announcements, reviews,

and short contributed reports—has been well received, and requests far exceed our current production.

NATIONAL RESERVOIR RESEARCH PROGRAM

The Fish and Wildlife Coordination Act of 1958 emphasized the importance of developing methods for designing and managing reservoirs and tailwaters so that fishery potentials could be realized. There are about 1,500 reservoirs larger than 500 acres in the United States, totaling 10 million surface acres at average water levels, and supporting one-fourth of all freshwater angling. Basic research is fundamental to the development

of recommendations designed to protect, mitigate, and enhance fish and wildlife resources in water projects.

The National Reservoir Research Program was initiated in 1963 to describe and quantify factors influencing sport fish production in reservoirs, to synthesize these findings into techniques for improving reservoir sport fish production, and to communicate these findings to State and Federal agencies charged with the management of reservoir fishery resources. During fiscal year 1977, a staff of 40 professional and support personnel addressed a wide variety of reservoir problems, and the studies have yielded broad syntheses of reservoir production and ecology, as well as answers to current management problems on particular reservoirs and tailwaters.

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 of the White River in Arkansas-Missouri, which have been in progress since the early 1960's, have resulted in the development of extensive data bases that have proven invaluable in the formation of broad ecological concepts concerning reservoir fish populations. They have also provided useful information about the effects of variations in reservoir operational procedures on reservoir ecology. Upon completion, this effort will provide a long-term record of the ecology and productivity of reservoirs, and a broad understanding of these waters in terms of sport fishing potential.

Widespread concern over possible adverse effects of heated water in reservoirs has prompted an extensive, 10-year field investigation of Lakes Keowee and Jocassee in South Carolina. Studies of the fish assemblages and related trophic levels began in 1971, 2 years before start-up of Duke Power Company's Oconee nuclear generating and pump-storage facilities on the two lakes.

In 1974, the National Reservoir Research Program and the Environmental Effects Laboratory, Waterways Experiment Station, U.S. Army Corps of Engineers, began a cooperative 10-year study of the effects of varying the outlet depth of the dam on the ecology of DeGray Lake, Arkansas, and its tailwater. Coordinated field studies are under way to test elaborate physical and ecological simulation models currently being developed by the Environmental Effects Laboratory.

Studies conducted under the auspices of the National Reservoir Research Program have resulted in the publication of over 200 scientific papers and reports, addressing a wide range of topics concerning reservoir ecology and management. The studies have transcended the boundaries of river systems and drainages and in many instances have dealt with the effects of reservoir operational features or design characteristics on fishery resources.

Standing Crop and Harvest Predictions. In addition to the field studies, the National Reservoir Research Program has been actively engaged in the collection, collation, and analysis of biological information on all U.S. reservoirs larger than 500 surface acres. Emphasis has been on fish standing crop and harvest data from a wide variety of reservoirs for which selected physiochemical and other biological data are available. This information has been analyzed to derive simplified models for predicting fish standing crop and harvest on the basis of environmental variables. Many of these environmental variables are a function of reservoir design and operation. The regressions are periodically modified and updated as new information is obtained, and are routinely used by the Division of Ecological Services and other agencies for reservoir impact assessment and the solution of fishery management problems.

Formulas derived recently indicate that 63 to 81% of the variability in reservoir fish standing crops can be attributed to total dissolved solids content of the water. These formulas provide valuable indexes to average biotic conditions and help to identify stressed aquatic environments. Recent findings also show great promise in linking yearly variations in fish crops with variables such as the quantity of water flowing through individual impoundments.

Reservoir Ecosystem Modeling. The method of estimating available prey-predator relations in reservoir fish populations developed last year has been refined and used to define seasonal patterns in surplus production and prey availability, as determined by periodic "cove sampling" (treatment of blocked-off coves with rotenone and collection of the fish killed) throughout the growing season. For example, the analysis of 1977 samples from DeGray Lake indicated that surplus production more than doubled the biomass of prey and predators between May 18 and September 20. DeGray Lake is the prototype for the reservoir ecosystem model being developed by the Environ-

mental Effects Laboratory of the Waterways Experiment Station, U.S. Army Corps of Engineers. These studies provide understanding of causal mechanisms needed for dynamic model development, and will increase the accuracy and efficiency of future assessments of the environmental impacts of water resource development.

Analyses designed to develop the fishery portion of a reservoir ecosystem model indicated that five fish compartments and five corresponding fish-food compartments were most appropriate, considering the present state of the art. The fish-food compartments are prey fishes, zooplankton, benthos, organic detritus, and terrestrial organisms. To define relations among fishery compartments and other fish population parameters, we developed regional rate coefficients for fish production, reproduction, recruitment, growth, mortality, and sport and commercial harvest. Summaries of available data were also prepared on the ecological growth and assimilation efficiencies of fish, food consumption rates, respiration rates, temperature tolerances, half-saturation constants for growth, and chemical composition.

Tailwater Study Plans. Many State and Federal conservation agencies have become increasingly concerned over the loss of high-quality stream fishery resources as a result of reservoir construction and operation. Aside from the obvious problem of blocking migrations of anadromous fishes, the problems of tailwater resource management are extremely complex. Evaluating the impact of reservoir design and operation on tailwater fishery resources hinges on a sound working knowledge of the ecological requirements of tailwater biota. Negotiations were completed with the Waterways Experiment Station to begin a long-term, coordinated research effort designed to locate and describe conditions that optimize both coldwater and warmwater tailwater fisheries, the limits within which they can produce effectively, and the immediate and long-term effects of varied project operational procedures.

SOUTH CENTRAL RESERVOIR INVESTIGATIONS

White River Reservoir Studies. Studies on the White River reservoirs are directed toward identifying and quantifying factors that influence

sport fish production and harvest in large fluctuating storage impoundments. Field studies are centered on Beaver Lake (11,400 ha) and Bull Shoals Lake (18,400 ha) in Arkansas and Missouri.

Environmental Trends. The past year was one of environmental extremes in the Ozark Mountains. January 1977 was one of the coldest Januaries on record. This was followed by extremely dry weather in April and May, which resulted in low, stable water levels in the White River impoundments. These conditions provided biologists with valuable data on the effects of extreme temperature variations and low pool levels on fish stocks.

Regrowth of Peripheral Vegetation. The long-term fishery studies on White River impoundments have permitted biologists to begin quantifying relations between seasonal flooding of peripheral vegetation and year-class strength of certain fish species. However, to realize the value of this potential management relationship, managers need a better understanding of vegetation regrowth patterns after flooding. The low, stable water levels during 1977 permitted study of these regrowth patterns in the fluctuation zones of Beaver and Bull Shoals lakes. The study has provided information on the types and rates of vegetation regrowth on a seasonal basis. Results of this study will be of value in interpreting previously collected data, and in helping resource managers control water level for optimum fish production.

Underwater Observations of Black Bass Reproduction. Studies of the spawning of black basses, their nesting requirements, and reproductive potential continued in Bull Shoals Lake during 1977. Underwater observations were conducted each week from April 18 through June 1, in five study areas divided between shallow water in coves and somewhat deeper water off a steep bluff.

Bass spawning began on or about April 12, about 1 week earlier than the average date of first spawning observed since 1967. Water temperature at 3 m depth at time of first spawning was 14.4°C, and later lake warming proceeded at about the normal rate.

Water levels in Bull Shoals Lake remained relatively stable throughout the spring, about 3 m below conservation pool elevation. As a result, no flooded vegetation was available as cover for nesting bass or their young, as it was in the previous year when the bases of shoreline willows were sub-

merged in water 1 to 2 m deep. Nest cover used by largemouth, smallmouth, and spotted bass in cove habitats included large rocks, stumps, logs, and waterlogged branches. Nest depths in coves were less than those in the bluff habitat for largemouth and spotted bass. Average nest depths for largemouth bass were 1.6 m in coves and 2.5 m at the bluff, and for spotted bass, 2.1 m in coves and 2.8 m at the bluff. Average nest depth for smallmouth bass in coves was 1.9 m; smallmouth bass did not nest at the bluff habitat—the first spawning season since 1971 in which they avoided it.

Nest densities were much lower than in 1976 for largemouth bass, but were little changed for smallmouth and spotted bass. Nest densities per 100 m of shoreline in coves were 2.7 for largemouth bass, 0.8 for spotted bass, and 0.5 for smallmouth bass; at the bluff study area, the densities were 2.8 for largemouth bass and 3.3 for spotted bass.

Nest survival to the fry-school stage was about average, but later survival of fry schools to the time of dispersal was relatively low, except for smallmouth bass. The rates of survival to fry-school emergence from largemouth, spotted, and smallmouth bass nests were 54, 20, and 40%, respectively. The survival rates for fry schools in which some fry reached dispersal stages were 31% for largemouth, 22% for spotted, and 100% for smallmouth bass. It was apparent from the rapidly diminishing numbers of fry in the surviving schools that the scarcity of cover had a greater deleterious effect on fry survival than on nest success.

Production Estimates of Young-of-the-year Threadfin Shad. Midwater trawling is conducted on Beaver Lake throughout each summer. Regular sampling of young-of-the-year shad provides an estimate of production and a seasonal measure of the availability of food to sport fish. Extremely low temperatures during the winter of 1976-77 were lethal to threadfin shad, and apparently caused total mortality. (In Bull Shoals Lake the population was severely reduced.)

Gizzard shad reproduction was exceptionally poor and after a high mortality rate the trawl catch rate dropped to such a low level in July that it became impossible to develop meaningful estimates of abundance. Trawling was discontinued for the year in early July.

Abundance and Survival of Young Black Bass in Beaver Lake. Field studies to evaluate factors that influence abundance, growth, and survival of young black bass were concluded during the sum-

mer. The concept of effective fecundity was employed for largemouth bass, the average number of eggs per nest was determined by using SCUBA divers to collect samples, and population estimates of bass fry were conducted by using electrofishing gear and biological stains for mark and recapture. We estimated that in 1976 and 1977 only 1 in 6,000 largemouth bass eggs in the ovary, and only 1 in 13 fry in the nest, survived to age I.

Swimming Ability of Larval Fishes. Sustained swimming speed experiments have proved larval shad to be poor swimmers, but their ability improves greatly after the development of juvenile characteristics (e.g., full complement of fin rays and musculature). Larvae were sensitive to velocity changes. The sustained swimming abilities of larvae and juveniles improved when they were acclimated to increased velocities over a longer period. Recommendations were made concerning intake design where entrainment or impingement is probable.

Multi-Outlet Reservoir Studies. The team objectives of the Multi-Outlet Reservoir Studies are to assess changes in fish and zooplankton populations of DeGray Lake and its tailwater that result from different reservoir outlet levels. In addition, data are acquired for the development of ecosystem simulations. Since impoundment, all water has been released from the epilimnial outlet. Releases from the hypolimnion will begin in 1979. The studies are part of a cooperative effort between several State and Federal agencies and universities. The first 3 years of study have coincidentally provided data for a flood year, a dry year, and a normal year of rainfall.

Population Dynamics. Fluctuations in the abundance and production of black bass and shad are studied to provide indexes of the effects of the environment and dam operation on fish stocks in DeGray Lake. In 1977, the estimated spring largemouth bass population in DeGray Lake was 305 bass per kilometer of shoreline—28% less than in 1976, and 34% less than in 1975. The decline conforms to the predictions based on reservoir aging and production developed by the National Reservoir Research Program.

Catches of young threadfin and gizzard shad by midwater trawling in 1977 were so low that trawling was terminated in late July. Unusually low winter temperatures probably contributed to the low shad densities. These fluctuations in shad and black bass crops have occurred during a period when the outlet level was unchanged, and reflect

the importance of long-term data collection for evaluating reservoir operational changes.

Seasonal Changes in Fish Crops. In 1977, cove rotenone samples were collected in May, June, August, and September to define changes which occur in the biomass of fish during the growing season. From May to September, total standing crop of fish increased by more than 80%. The mean total standing crop estimate of 124 pounds per acre in August was 44 pounds per acre less than in 1976, primarily due to a reduction in adult gizzard shad.

Loss of Larval Fish and Zooplankton. Larval fish and zooplankton losses through DeGray Dam are measured each spring and summer to compare losses when releases are from the epilimnion with those planned for 1979 and later, when releases will be from the hypolimnion. Studies in 1977 indicated a 20% reduction in the volume of water released, but a 52% increase in the number of larval fish lost during the 5-month period April-August 1977, as compared with losses during the same period in 1976. Although fewer shad passed through the dam in 1977, the numbers of crappies and sunfishes were significantly greater. Crappie larvae lost during May were four times more numerous in 1977 than in 1976. Sunfish larvae were present in samples through the 3rd week in September, normally a month when few fish are discharged.

Fisherman Use and Harvest. Fishing pressure and sport fish harvest are used to verify other fish sampling techniques, and as an important measure of environmental and man-induced changes in the reservoir environment. A creel census conducted by the Arkansas Game and Fish Commission from July 1976 to May 1977 showed that over 75% of the weight of fish harvested from DeGray Lake was contributed by largemouth bass, and 15% by sunfish. Total fishing pressure was estimated at 303,500 angler hours, or about 21 hours per acre.

SOUTHEAST RESERVOIR INVESTIGATIONS

It is estimated that by the year 2000, demands for electrical power in the United States will require nearly 3 times the present generating capacity, resulting in increased discharges of heated water. Additional alterations will result from the construction of pumped storage hydroelectric plants where water is pumped to a higher

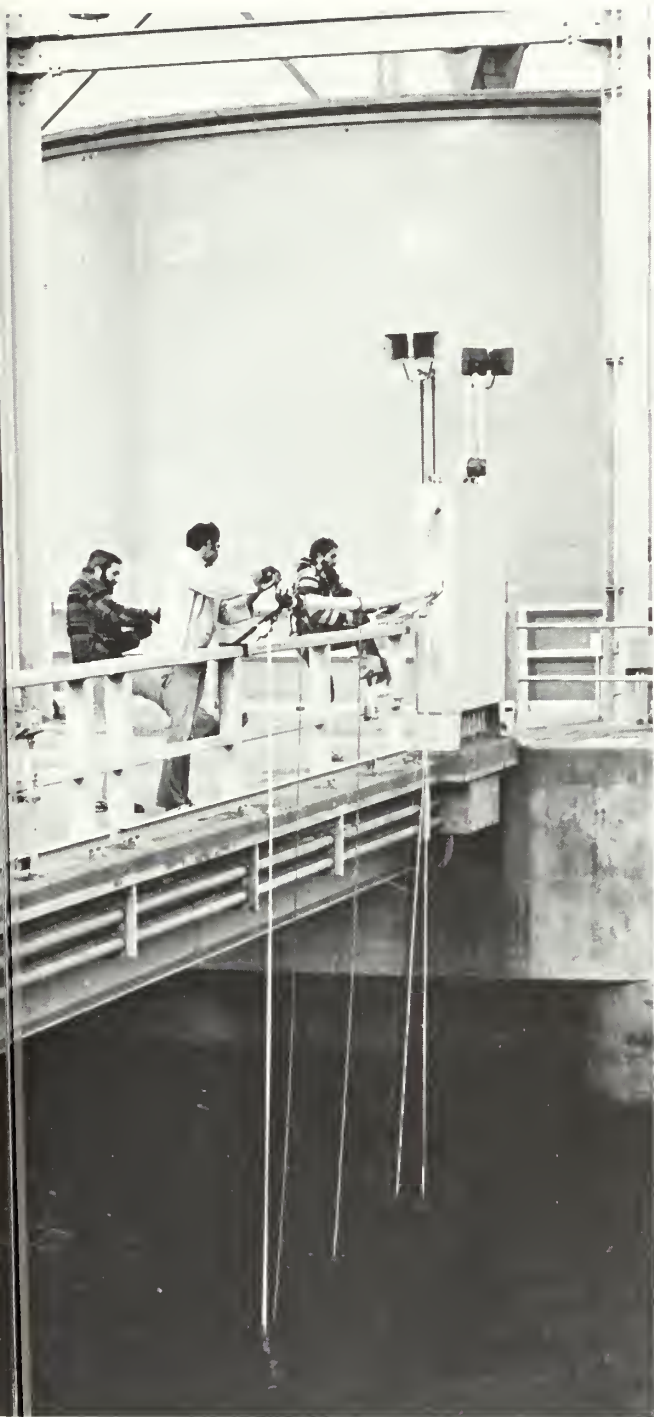
reservoir for storage during periods of low power demand and used for generating electricity during periods of peak power needs. Rapid changes in water level are the most dramatic habitat alterations caused by pumped storage power projects.

Southeast Reservoir Investigations was established to evaluate long-term effects of power plants on fish and other aquatic life in reservoirs. Research has centered on Keowee and Jocassee reservoirs in northwestern South Carolina. Keowee Reservoir (7,411 ha) serves as a cooling reservoir for the 2,658-MW Oconee Nuclear Station, supplies water for the 140-MW Keowee hydrostation, and also serves as the lower pool for pumped storage operations. A 610-MW pumped storage hydroelectric plant is located on Jocassee Reservoir (3,063 ha), the upper reservoir for the pumped storage plant. Research on these reservoirs should provide useful information for determining the location, design, and operation of future power plants to control detrimental environmental effects.

Zooplankton Abundance. Exposure to heated power plant effluents or entrainment in cooling water systems may affect zooplankton populations—an essential component of a reservoir food web. Zooplankton populations in Keowee Reservoir were sampled with a fine-mesh plankton net from 1973 to 1976 to determine if species composition and densities in various areas of the reservoir were being modified by the operation of Oconee Nuclear Station.

Species composition changed little during the 4 years of study, although surface concentrations of zooplankton decreased. This decrease resulted from a redistribution of zooplankton by the condenser cooling water. The cooling water is drawn from a depth of 19-27 m beneath a skimmer wall (a concrete dam with an opening at the bottom). This allows only water with concentrations of organisms lower than found in surface water to pass through the power station cooling system. As a result, there are fewer plankters in the discharge area than elsewhere. The discharge area covers 10-30% of the total lake surface during about 8 months of the year. Overall, the skimmer wall appears to reduce the effects of the operation on zooplankton populations.

Relative Abundance of Young Fish. Large volumes of cool water are withdrawn from depths of 19-27 m in Keowee Reservoir, circulated through the cooling system of the Oconee Nuclear Station, heated about 10 Celsius degrees, and dis-



Vertical gill nets (60 feet long) which reach to the reservoir bottom are used to assess the effects of pumping and generating on the distribution of fishes at the Jocassee pumped storage hydrostation intake towers.

Photo by W. E. Lorenzen.



During the generation of electricity at the Jocassee pumped storage hydroelectric plant in northwestern South Carolina, water flows down through 40-foot-diameter penstocks from Jocassee Reservoir to Keowee Reservoir. Plankton nets placed about 45 feet deep inside these conduits measure the loss of young fish.

Photo by E. D. Prince.

charged back into the reservoir. Since the effects of heated water on young fish were generally unknown, this study measured changes in the relative abundance of mid-reservoir populations of young fish in Keowee Reservoir before (1973-74) and after (1975-77) the operation of the Oconee Nuclear Station.

Young fish (6-40 mm long) were sampled by trawl from March through September 1973-77, in four areas of Keowee Reservoir. Yellow perch were first captured in March of each year; black crappies in May 1973, in April 1974 and 1975, and March 1976; and sunfishes in May of each year. Threadfin shad were stocked in the reservoir in January 1974 by the South Carolina Wildlife and Marine Resources Department. They reproduced the 1st year and the young were captured in May 1974 and 1975 and April 1976.

The average catch of all species except threadfin shad declined between 1973 and 1976. The average number of yellow perch captured per trawl haul declined from 19.2 in 1973 to 0.5 in 1976, and of black crappie from 4.3 in 1973 to 1.7 in 1976. Young sunfishes exhibited the greatest decline, from 21.5 in 1973 to 0.2 in 1976. Lowest annual catches of yellow perch, black crappies, and sunfishes were near the heated water discharge.

It is unclear whether the overall reduction of young fish results from stabilization of environmental conditions and fish population levels (as commonly occurs in new reservoirs) and other natural changes, or from the nuclear plant operations. The low catches near the heated effluent were attributed to possible avoidance of the area by adult spawners due to elevated temperatures or a flushing and diluting effect of water free of young fish being discharged by the nuclear plant. Discharge water temperatures during the spring were not in the range considered lethal for these species. Threadfin shad usually are killed when water temperatures decline to 10°C. However, the discharge of heated water apparently has contributed to successful overwintering of this species.

Life History Studies. Inasmuch as changes in feeding, growth, and reproduction of fishes usually follow temperature changes or other habitat modifications, we have studied the life histories of selected species in Keowee Reservoir. Young fish are less mobile than adults and often are unable to avoid heated water discharges. Young black crappies (5-17 mm long) were collected before and after the operation of the

Oconee Nuclear Station from areas adjacent to, and 11 km from, the plant discharge point. The crappies fed entirely on zooplankton. The kinds and numbers of organisms eaten in each area before and after the operation of the power plant did not differ significantly.

Environmental changes are known to affect the number of eggs produced by fish in 1 year. Adult black crappies were collected in the spring before spawning, before and after the operation of the nuclear plant, to determine if temperature changes affected egg numbers. Ovaries were removed and total number of eggs counted. Black crappies contained 17,900 to 226,600 eggs, and the numbers of eggs increased with increases in the length of the fish. However, numbers of eggs for fish of the same length were similar in all areas before and after the operation of the nuclear plant. Thus the heated effluent apparently had no effect on the number of eggs produced.

Entrainment of Young Fishes Due to Pumped Storage Operation. The regular interchange of water between the upper and lower reservoirs in a pumped storage system can have various effects on both impoundments, such as water quality alterations, displacement and mortality of adult fish, entrainment and mortality of fish eggs and young, and (because of the continuous and rapid water level fluctuations) reduced reproduction of species that spawn in shallow water. A study was begun in 1977 to evaluate the passage of young fishes during generating and pumping modes of the Jocassee hydrostation. About 1,100 m³ of water were filtered weekly with 1-m plankton nets. These nets were used at both ends of the penstocks (conduits for conducting water), to sample fish before and after passage through the turbines.

The primary species collected were yellow perch, black crappie, threadfin shad, and sunfishes. Nearly 6.3 times as many young fishes were passed upward during the pumping mode than downward during the generation mode.

The difference in density of young fishes passing through the Jocassee hydrostation during different operational modes appears to be related to the configuration of the basin surrounding the penstock openings, since the depth and design of the openings at both ends are similar. Abundance of young fishes in 1977 was similar in the upper and lower reservoirs, and concentrations were highest in the upper (0-7 m) water strata. Therefore, the pumping mode, which draws water from a relatively restricted shallow channel (less than

30 m deep), must entrain more surface water and consequently pass more young fishes than does the generating mode, which draws water from a relatively open area of deep water (more than 100 m deep). Controlling the depth from which water is withdrawn through the turbines at both ends of the penstocks appears to be an important consideration for controlling the effects of pumped storage operations on water quality and biotic communities.

NORTH CENTRAL RESERVOIR INVESTIGATIONS

Biologists of the North Central Reservoir Investigations, with laboratories in Yankton and Pierre, South Dakota, conduct studies on the main stem Missouri River reservoirs to determine causes for changes in the fish populations over time. Measures are advanced to increase sport fish abundance.

Effects of Energy Development on the Aquatic Resources of Two Upper Missouri River Reservoir Ecosystems. The national need for increased energy production has focused attention on the vast deposits of low-sulfur coal in the Northern Great Plains. Water availability and cost will to a large degree control the type, extent, and location of energy development in this semiarid region. The largest and most dependable water sources are the main stem Missouri River reservoirs. Lakes Fort Peck and Sakakawea are closest to the coal resources and are the principal candidate sources. A 1-year literature and field survey was conducted on Lakes Fort Peck and Sakakawea to obtain base-line data, identify the potential developments and their impacts, and suggest measures to mitigate environmental impacts.

The results indicated that water quality, phytoplankton and zooplankton stocks, and fish populations of Lakes Fort Peck and Sakakawea were generally similar to those previously observed in the lower four main stem reservoirs. Primary productivity in all Missouri River reservoirs is phosphorus-limited, and shallow areas of embayments and tributaries are the main spawning and nursery areas of reservoir fishes.

The historical average annual Missouri River flow at Sioux City, Iowa, was projected to be depleted about 50% by the year 2000, and in drought years the flow would be completely allocated. Irriga-

tion would be the largest water use (40%) and source of return flows (53%), and would affect 2.3 million ha of land. Development of coal resources was projected to deplete 15% of the water, return less than 2%, and affect about 0.1 million ha of land.

It was concluded that the cumulative effects of water depletions will have a greater impact on reservoir ecosystems than will site-specific effects from industrial development. Projected water depletions would lower the mean water levels of Lakes Fort Peck, Sakakawea, and Oahe by 10 m by the year 2000, and would profoundly affect these reservoir ecosystems. The construction and operation of coal strip mines and conversion plants will produce wastes that could be harmful to the reservoirs if not properly treated. However, these plants can be designed so their water-intake structures would not entrain significant numbers of fish eggs and larvae, and solid and liquid effluents would not be discharged. Proper design, coupled with the large dilution factor and high buffering capacity of Missouri River water, should limit the deleterious effects of energy development.

Limnology of Lake Sharpe. A 10-year study of the physical, chemical, and biological characteristics of Lake Sharpe, a 22,600-ha main stem Missouri River reservoir in central South Dakota, was completed in 1975. The purpose of the work was to determine the ecological effects of impoundment and later water management in this "flow-through" reservoir.

Lake Sharpe reregulates discharges from upstream Lake Oahe, and its principal function is power generation. The mean annual water-exchange rate has ranged from 27 to 46 days. Because of its high water-exchange rate and stable pool level, Lake Sharpe appears to have had a relatively short "aging" process after filling in 1964. Most of its physical and chemical properties showed considerable variability, but no significant trends over time were detected during 1966-75. Lake Sharpe is a relatively cool body of water. The annual mean temperature of the outflow ranged from 8.4° to 11.0°C, and the maximum summer temperature ranged from 21.1° to 25.2°C. Because of the large inflow volume from upstream Lake Oahe and rapid passage of the water through Lake Sharpe, the temperature structure in the upper one-half to two-thirds of Lake Sharpe is largely governed by the temperature of the inflow. Thermal stratification occa-

sionally occurred, but was weak, short-lived, and limited to the lower reservoir. The varying turbidity of the water is one of the most distinctive features of Lake Sharpe. Inflow from Lake Oahe is relatively clear, and this condition generally characterizes the upper river reach. However, highly turbid inflows from the Bad River, which is about 11 km downstream from Oahe Dam and which drains the South Dakota Badlands, combined with wave action on the shoreline, are responsible for the variable turbidity that prevails throughout the rest of the reservoir.

In contrast to the relatively stable physical and chemical properties of Lake Sharpe, its plankton changed somewhat during 1966-75. General abundance of phytoplankton—mostly diatoms, of which *Asterionella* was most common—increased, particularly during 1970-75. Phytoplankton was generally most abundant in the lower part of the reservoir and least abundant in mid-reservoir. Zooplankton abundance varied, but showed no particular general trend during 1966-75; however, cyclopoid copepods decreased in importance, and calanoid copepods increased. The decrease in cyclopoids appeared to be largely associated with increased summer discharge beginning in 1969.

Fish Population Changes in Lake Francis Case, 1954-75, and Suggestions for Management. Lake Francis Case, impounded in 1952, was the first Missouri River reservoir in South Dakota. It is one of six main stem Missouri River reservoirs constructed for flood control, irrigation, hydroelectric power, navigation, and other purposes. Lake Francis Case has a surface area of 37,600 ha and is characterized by large annual water-level fluctuations.

Fish were collected from the reservoir in 1954-61 by the State of South Dakota and in 1962-75 by the Service to document development and changes in the population in relation to water management and other environmental factors. Judging by an analysis of these collections, fish abundance in the early 1970's was only about half that in the late 1950's. Of a total of 39 species collected, 12 were abundant in the 1950's, and 8 in the 1970's.

Changes in fish abundance and species composition were a result of poor reproductive success caused by water-level fluctuations during the spring and early summer, and physical changes in the shoreline environment. Fish reproduction was most successful in years when the reservoir was filled in the spring and held at a nearly constant level through July. Fish survival and growth could

probably be improved if the pool drawdown in the fall were reduced. Fish abundance in Lake Francis Case could be increased if water-level management conformed more closely to requirements for fish reproduction. This is only possible in some years, however, because of the multipurpose function of the reservoir. Assuming that future water management is similar to that of the early 1970's, the fish population is expected to continue to be dominated by seven species: goldeye, emerald shiner, river carpsucker, channel catfish, yellow perch, white bass, and walleye.

A program of pool level management is recommended that should enhance both reproduction and growth of fish. Summer pool levels should be kept low for 2 consecutive years to encourage growth of shoreline vegetation, and then raised the 3rd year to flood the vegetation. This 3-year management cycle could then be repeated.

Fish and Fish-food Organisms in the Missouri River. Much of the natural free-flowing Missouri River has been eliminated by the construction of six main stem dams on the upper river and by channelization of the river from Sioux City, Iowa, to the mouth near St. Louis, Missouri. Although isolated segments of unimpounded and unchanneled river still exist, flow in these areas is controlled by the dams. The low sediment load of water released from the dams and the meandering of the river has resulted in extensive bank erosion in these areas. The U.S. Army Corps of Engineers has been authorized by Congress to develop bank stabilization methods that will prevent this bank erosion but not drastically alter the river environment.

The objective of this study was to determine the ecological value of various river habitats to the fish and fish-food organisms in the unchanneled Missouri River before a bank stabilization program was begun. Sampling stations were established on the segments of the unchanneled river that form the boundary between South Dakota and Nebraska, and on the channelized river south of Sioux City, Iowa. Sampling was done on the channelized river to assess the impact of conventional bank stabilization methods on aquatic organisms and to determine the ecological value of notches that had been cut in existing dikes and revetments.

Fish-food organisms sampled with drift nets consisted primarily of aquatic and terrestrial insects, and crustacean zooplankton. The outflow from the main stem reservoirs carried relatively

high populations of zooplankton into the study area. Drift samples collected near the rock revetments and dikes of the channelized river contained significantly more insects than did the samples from the unchannelized river.

Sampling of the fish populations with various types of fishing gear showed the most abundant species to be emerald shiner, river carpsucker, channel catfish, gizzard shad, red shiner, short-head redhorse, yellow perch, carp, and goldeye. Most of the species occurred in several habitats, but some species showed definite preferences for particular habitat. Thus, disruption of any of the habitats in this system would adversely affect some members of the fish community—particularly in backwaters and marshes, since more than half of the 46 species that were collected used them as spawning and nursery grounds.

The fish community in the channelized river was less diverse than that in the unchannelized river. Channel catfish, carp, and river carpsucker accounted for about 70% of the catch in the channelized river. Restoration of some habitat diversity to the channelized river appears to be feasible, since relatively large fish catches were taken from habitats that had been created by notching existing dikes and revetments.

SOUTHEASTERN FISH CULTURAL LABORATORY

Disease Prevention. Work was begun to develop a procedure for preparing vaccines of two principal bacterial diseases in black bass and catfish—hemorrhagic septicemia and columnaris. Progress after 3 months has been largely in our developing a limited disease-research capability. Cultures of *Aeromonas hydrophila* and *Flexobacter columnaris* are being grown and the bacteria processed to produce inocula. An isolation laboratory for fish is nearly ready for testing inocula prepared with various treatments for weakening cell walls, followed by high-pressure disruption, filtration, and concentration. The attenuation procedure, when perfected, is designed to permit processing in batch quantities for commercial production of vaccines.

Studies of endocrine mechanisms in fish promise a breakthrough in ways to control important physiologic functions such as growth and reproduction. When pituitary hormones are isolated

and characterized, extremely sensitive assays can be developed to estimate low circulating levels in the live organism. These estimates may be used to optimize conditions favoring growth or reproduction, and sets of varied environmental conditions then can be evaluated in short-term tests. Accordingly, we prepared pituitary fractions by Sephadex G-100 gel filtration and bioassayed them in channel catfish by alternate-day injections over 42 days under photoperiods of 8 or 12 hours of light. An extract gradient within the middle third of the column effluent was almost perfectly correlated with growth. The highest concentration increased immature channel catfish growth by 4.6 times that of controls in 8-hour light periods, and by 2.4 times in 12-hour light periods. Cross contamination effects from gonadotropin, thyrotropin, and growth hormone were expected because of the relatively low resolution of these similar-sized protein molecules in gel filtration. Gonad development could not be induced by any of the pituitary fractions, but the possibility of thyrotropic effects on growth has not yet been excluded. Further fractionation, to be done by preparative gel electrophoresis after gel filtration, should give sufficiently clean fractions to eliminate their complicating future bioassay results. Continued studies of endocrine mechanisms are intended to enlarge our understanding of how fish regulate their physiologic state in response to annual rhythms and to environmental variables that can be controlled to enhance fish propagation and growth.

Striped Bass Culture. Fish culturists generally acknowledge that if satisfactory artificial feeds were available for each life stage of the species being produced, major advances in fish production could be made. This is especially true for the critical postlarval stage, as well as for brood stock that could be held year-round for producing controlled quality and quantity of eggs and sperm. Present methods relying on live forage for striped bass fry limit production by requiring too much time and effort to grow sufficient quantities and acceptable kinds of forage organisms. To help hatchery programs give more reliable production, we have continued our studies to develop an artificial fry food that is nutritionally complete and has properly sized particles formulated with a binder that readily releases diet components in the fish gut without dissolving and fouling water before ingestion. Formulations from Samuel Meyers, Louisiana State University, and John Halver of the Service satisfied some of these cri-

teria and were tested at our Laboratory and at Auburn University. Prolarvae were shipped to us from Florida, Georgia, South Carolina, North Carolina, Virginia, and Tennessee to allow scheduling of trials over as long a term as practical. Numerous repeat trials were conducted at two laboratories to provide the broadest possible combination of approaches and to allow method adjustments during the brief time when fry were available. Several variations of four diets were compared with brine shrimp nauplii. In general, none was effective for feeding fry through their first 20 days. For example, the best results on one of the test diets (20-40 μm particle size, 50% protein from high gluten wheat and fish protein hydrolyzate; some krill homogenate to hold the desired protein, carbohydrate, and fat contents; a vitamin pack; and binding by plastein reaction for stability in water) yielded only 18% survival after 15 days, and almost no growth. In comparison, fry fed brine shrimp nauplii had 32% survival and a fivefold length increase.

To date, we have used as many as 16 sets of conditions, differing in such factors as lighting, salinity, and flow, to conduct feeding trials. Progressive adjustments served to improve methods for conducting feeding trials and provided the basis for updating guidelines for keeping the extremely sensitive postlarvae as healthy as is currently possible.

Work with the fingerling life stage of striped bass has proven far more productive in defining the basic requirements of the species. After earlier years of frequently poor conditions, we have completed the 5th year of holding some of the laboratory's original South Carolina stock.

Studies of this past year's fingerlings suggest that water having less than 50-ppm hardness is critically marginal for normal adaptation, as interpreted from soft water challenges.

On the basis of general growth comparisons, fingerlings may convert food to flesh at ratios within ranges of 3:1 to 4:1 on competitive commercial dry trout rations and of 1:1 to 1.2:1 on more expensive, high-protein salmon rations or equally high-quality casein-base research formulations. Also, after 84 days of controlled feeding, fingerlings from Virginia converted food no more or less efficiently than did those from North Carolina or from reciprocal hybrids (striped bass males, white bass females).

Other studies on 2-, 3-, and 4-year-olds showed that with improved facilities that permit control of

environmental conditions, one can maintain striped bass throughout a complete life cycle. An observation of more immediate practical use is that 4-year-old striped bass from the wild can be successfully trained to accept artificial rations by gradually replacing live forage with frozen chopped fish and then with the dry pellet. Transition is quicker in the presence of "domestic" striped bass.

TUNISON LABORATORY OF FISH NUTRITION

Water Reuse Research. Biological filters that use easily established bacteria and other simple organisms to digest and thus remove toxic waste products of fish from aquaculture systems are the most practical and economical means of permitting reuse and conservation of the culture water. Unfortunately, many nonbiodegradable waste products detrimentally accumulate in used, treated water unless the biofilters are regularly, periodically, and extensively backflushed, and 5 to 20% of the water in each cycle is replaced. These procedures cause at least three serious problems: (1) large volumes of make-up water must be tempered or treated, (2) large volumes of incompletely degraded solid and liquid waste must be treated or disposed of in the hatchery effluent, and (3) the biological filtration process is inefficient because some bacteria and bacterial nutrients are periodically removed from the aquaculture system. To circumvent these difficulties, the Tunison Laboratory designed and investigated systems in which nearly 100% of the water was reused.

Nearly 100% reuse of culture water required the application of advanced physicochemical waste water treatments. The most effective systems included the condensation and separation of an ozone-generated froth to remove surface-active complex organic wastes and associated mineral ions that were not biodegraded, followed by absorption with activated granular carbon to concentrate and remove the remaining organic wastes. A columnar activated-carbon filter also served as a filter base for bacteria that further degraded oxidized ammoniacal fish wastes to innocuous nitrogen gas.

These experiments established that the ozone-froth process maintains production loads of trout

and salmon from fry to adults healthy, at full growth potential, and capable of normal reproduction in an essentially closed-cycle aquaculture system. The amount and concentration of condensed waste froth can be regulated to permit nearly complete clarification of the effluent from efficient modular biofilters. Complete clarification and purification required use of the columnar activated carbon filter. A water replenishment rate of less than 4% per day, or less than 0.1% fresh water per cycle, was maintained under a wide variety of aquaculture conditions with salmonids. This system required only a modest replacement of lost nutrients to maintain the beneficial bacterial population, and significantly reduced the size of the biofilters required.

This information is being used to design a practical fish culture system for construction. Since any advanced waste water treatment is expensive, compared with simple, but incomplete, secondary biological treatment, research will be directed toward determining if reclamation of nutrient-rich concentrated effluents of this system, as well as the obvious conservation of water and energy, will justify its future application to aquaculture.

Nutrient Deficiencies Cause Specific Abnormalities in Trout Eyes. Trout apparently are highly susceptible to diet-related eye lesions. The recent increase in incidence of cataracts (cloudy and degenerated lenses) and other ocular lesions, apparently of dietary origin, in hatchery-reared salmonids throughout the world has had an adverse economic impact on the production of fish, as well as of fish feeds. Nutritional experiments were conducted to determine the effects of various nutrient deficiencies on the development of eye abnormalities in trout.

Feeding a supplement of the amino acid, methionine, either with or without supplemental lysine, prevented the development of a cataract that occurs in the lenses of trout fed a diet in which a commercial isolated soybean protein (ISP) is the only protein. However, supplemental lysine was not effective against cataract development in trout not fed supplemental methionine in their ISP diet.

In trout fed a semipurified diet containing casein and gelatin but deficient in the water-soluble vitamin, riboflavin, degenerative ocular changes included clouding and adhesion of the lens and cornea and thinning and perforation of the cornea.

Feeding trout a semipurified diet with sufficient

riboflavin, but deficient in the fat-soluble vitamin A, caused exophthalmos; the eyes had a markedly expanded, but thin, corneal surface and contained edematous chambers. Severe degeneration of the retina also occurred, but the lenses were transparent and had no structural abnormalities.

In other work, a mineral mix supplement prevented a lens cataract caused by feeding trout a commercial diet in which whitefish meal is the major source of protein.

These studies show that at least four nutrient-related lesions occur in the eyes of trout. A deficiency of an amino acid or mineral(s) caused lens cataracts; a water-soluble vitamin deficiency induced a lesion involving the cornea and lens; and a deficiency of fat-soluble vitamins caused lesions in the cornea and retina, but not in the lens.

Alternate Sources of Protein for Fish Feeds.

The high cost and limited availability of fish meal for inclusion in the diets of hatchery-reared fish continue to be the major factor controlling the expansion of fish production for sport fishing and direct human consumption. Fish meal, which is made from ocean fish that are not usually used for direct human consumption or from cuttings and waste from fish canning operations, has historically been the principal protein ingredient in dry diets for hatchery-reared fish. This material is becoming increasingly expensive, however, and good quality fish meal is not always available on the market. This trend is expected to continue as stocks of ocean fish become depleted, more efficient canning operations are used, and more fish products are channeled into the pet food industry or are used for human consumption.

Our search for alternate sources of protein has been directed mainly to soybean meal, not because it is the only product which could be used, but because it appeared most attractive from the standpoint of present and potential supplies, market availability, chemical composition, and cost.

Feeding trials have shown that the commercial solvent-extracted soybean meal now on the market is not suitable for inclusion at high levels in the diets of trout and salmon. However, when full-fat meal is made from soybeans that have been heated to temperatures much higher than are now commonly used, it is almost equal to good quality fish meal in trout diets and has been used successfully at levels as high as 80% of the diet. The rate of fish growth on these high soybean diets was slightly lower than on conventional diets but the

amount of feed required per unit gain was about the same. Trout reared on the high soybean diets were not different from those fed conventional diets in general health, survival in the hatchery, appearance, or taste.

At October 1977 market prices for soybeans, soybean meal, fish meal, and the other ingredients commonly used in fish feeds, a saving of \$140 to

\$150 per ton of feed could be realized if the high-fat soybean diets were used. This would amount to a saving of 10 to 15 cents per pound of fish produced, which could ultimately be passed on to the consumer, either in lower prices for the fish in the supermarket or in the form of more fish in the streams for the sport fisherman.

Migratory Birds

MIGRATORY BIRD AND HABITAT RESEARCH LABORATORY

Effects of Hunting on Mallards. The mallard is the most important North American duck from the standpoint of abundance and annual waterfowl harvest. Each year, waterfowl hunting regulations are set with the aim of providing the highest harvest consistent with maintaining a continuing abundance of birds. Unfortunately, measurement of the effect of hunting removal on populations has been subject to question.

A recent analysis of recoveries resulting from summer bandings of nearly 700,000 mallards since 1960 has provided new insight on this important question. Analytical techniques were developed to address hypotheses representing the following two extremes regarding effects of hunting mortality on population survival rates: (1) Hunting mortality is completely additive to total mortality. (2) Below a threshold point, hunting mortality is compensated for by a corresponding decrease in nonhunting or "natural" mortality.

The hypothesis that hunting is a completely additive cause of mortality was rejected. Instead, findings suggested that hunting mortality, when below some threshold point, is largely compensated for by decreased natural mortality. Unfortunately, it may be easy for the hunting mortality rate to exceed this threshold point on the breeding grounds or in other areas where the birds may be especially vulnerable.

These findings have major management implications. For example, there was no evidence that

survival increased in years of restrictive regulations. This finding suggests that mallards cannot be "stockpiled" during a hunting season as a means of returning more birds to the breeding ground the following spring.

The study raised a number of questions concerning mallard population dynamics and methods of managing the resource more effectively. There is a need to confirm the conclusion of compensatory mortality and identify the threshold point at which hunting mortality becomes additive. There is also a fundamental need to determine the time of year at which most natural mortality occurs, and the location and causes of such loss. Most waterfowl research has emphasized factors affecting reproductive success and has been concentrated on the breeding grounds. Results of the mallard banding analysis indicate a major need for research on the wintering grounds.

Duck Hunters' Activity and Success Reviewed.

A recent publication summarized a large body of information concerning the harvest of ducks and the activity and success of hunters from 1952 through 1974. Information on mallards was emphasized. The data in the report came from mail questionnaire and wing-collection surveys. The number of active adult waterfowl hunters per year has ranged from 0.9 to 2 million, with an average of 12.2 million man-days afield. The total harvest in the United States has fluctuated between 4.3 million and 15.8 million ducks. Before 1960, a mean of 5.4 million mallards was harvested. Since 1961, the mallard harvest has averaged 3.6 million. Fall flights were smaller and seasons more re-



Habitat requirements of canvasbacks are being studied on important wintering areas on the East Coast. Here, canvasbacks dive for their main food in Chesapeake Bay, the thin-shelled Baltic clam. Photo by G. Michael Haramis.

strictive during a portion of the later period. During 1961-70, composition of mallard harvests averaged 1.3 immature birds per adult, 1.3 immature males per immature female, and 2.0 adult males per adult female.

Largest harvests of mallards in the United States occurred in Washington, Oregon, Idaho, California, and Utah in the Pacific Flyway; the Dakotas in the Central Flyway; and Minnesota, Wisconsin, Illinois, Arkansas, and Louisiana in the Mississippi Flyway. Approximately 27% of the mallard harvest was taken in Canada.

Age ratios indicated that immature birds made up highest proportions of the mallard harvests in the northern portions of the Atlantic and Mississippi flyways and lowest proportions in the Central and southern Mississippi flyways. Immature birds made up steadily decreasing proportions of the harvests as the seasons advanced. Fifty-six percent of the young mallards bagged were males.

Hunter compliance with bag limits was poor when fewer than two mallards were permitted under a fixed bag limit. Hunter performance data indicated that the average hunter was relatively unselective in shooting at mallard drakes and hens but that varying degrees of selectivity can be induced with proper hunting regulations.

Effects of various regulations differed, sometimes drastically, from area to area. Therefore, to make a realistic evaluation, each regulation proposed must be considered on a State by State basis.

Research Continues on Shore and Upland Game Birds. The Migratory Bird and Habitat Re-

search 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. Twenty-nine projects in 18 States received these special funds in fiscal year 1977. Nine of the projects are being conducted by State Fish and Game Departments, 14 by universities, and 5 by Cooperative Wildlife Research Units (Louisiana, Missouri, Oklahoma, Pennsylvania, and Wisconsin).

The book, *Management of Migratory Shore and Upland Game Birds in North America*, was completed in fiscal year 1977. It represents more than 5 years of cooperative effort among the International Association of Fish and Wildlife Agencies, the U.S. Fish and Wildlife Service, and many affiliated organizations and individuals. The text contains information from more than 50 contributing State, Federal, and private wildlife administrators and biologists. It presents background information on the various species, outlines management accomplishments, defines research needs, and focuses on programs to maintain shore and upland game bird populations. The book should be a valuable guide for expanded research and management of these species. More than 5,000 copies were distributed.

Eight publications resulted from Accelerated



Many measurements, including bill coloration, are being used to develop methods of identifying black duck x mallard hybrids. *Photo by Walter J. Quist.*

Research Program funding during fiscal year 1977. The West Virginia Department of Natural Resources published a 46-page booklet based on 5 years of research centered in the Canaan Valley of northeastern West Virginia. The booklet included such topics as the life history of the woodcock in West Virginia, valuable management techniques for maintaining populations in desirable areas, woodcock hunting, and popular recipes for cooking woodcock. A publication of the Wisconsin Department of Natural Resources described the importance to woodcock of clearcut areas in northern Wisconsin aspen forests. Continued high demand for aspen pulpwood should be highly beneficial to woodcock.

Potential Harvest Units Outlined for Woodcock. In fiscal year 1977 Service biologists identified potential harvest units in the United States for the American woodcock. These units were based on the distribution of recoveries reported by hunters from almost 30,000 bandings made before the hunting season. Four sets of harvest units were defined; each showed low interchange of birds. However, one configuration that conforms to the existing boundary between the Atlantic and Mississippi waterfowl flyways was considered the most practical means of regulating harvest during the hunting season. There was less than a 5%

interchange in harvest of woodcock between the two units. Identification and use of harvest units for woodcock will allow better management of the resource as differences in the "Eastern" and "Central" populations become more apparent.

Effects of Large-scale Forest Clearing on Woodcock. A recent contract with the Michigan Department of Natural Resources provided new information on the effects of large-scale habitat manipulation on woodcock. Utilization of habitat by woodcock was studied on six quarter-townships in the northern portion of the Lower Peninsula. The clearcut on each unit amounted to 25, 50, or 75% of the area. Size of the clearings varied. The study indicated that an interspersed pattern of 50% field and 50% forest yields greatest woodcock utilization. Aspen communities are preferred diurnal habitat. The use of a particular singing ground is related more to proximity of suitable diurnal habitat than to vegetational features of the clearing. The structure of the understory vegetation appears to be a constant factor in habitat selection by woodcock. Understory density is predictable in utilized woodcock habitat.

Cooing Behavior of Mourning Doves. The Missouri Cooperative Wildlife Research Unit, under contract to the Migratory Bird and Habitat Research Laboratory, conducted research on the



Colored patagial tags were used in studies of the breeding behavior of mourning doves. Such studies are necessary to evaluate reliability of annual call-count surveys. *Photo by George H. Haas.*

cooing behavior of mourning doves. The research was conducted at the Carolina Sandhills National Wildlife Refuge in South Carolina.

The study added further evidence that the primary factor affecting the rate of perch cooing of wild male doves is the presence or absence of the pair bond.

Mean cooing rates were calculated by successive 15-minute intervals throughout a 2-hour morning observation period beginning the half-hour before sunrise. Differences were evident in the cooing pattern of mated and unmated males. Both mated and unmated males cooed at their highest rate during the half-hour before sunrise. Unmated males maintained a consistently high level of cooing throughout the 2-hour period. Conversely, cooing of mated males decreased markedly through the 1st hour and remained at a low level during the remainder of the 2-hour period.

Vocal interactions between cooing doves occurred under certain circumstances. However, the cooing rate of individual unmated mourning doves was not directly related to the number of cooing doves in an area. Nor were there significant differences in the mean cooing rates of both mated and unmated males on two areas of differing densities of cooing doves. Results indicate that area

differences in population levels of mourning doves will not lessen the reliability of the mourning dove call-count survey.

The cooing activity of both mated and unmated male mourning doves varied considerably. This variability was apparent between individuals of the same breeding status and in the same individual on different mornings.

Breeding Bird Survey Is Key Tool to Monitor Migratory Nongame Bird Populations. Since 1966, the Breeding Bird Survey has been used to measure bird population changes during the breeding season in the United States and Canada. There are 50 3-minute stops at 0.5-mile intervals along each random roadside route. More than 1,700 routes are covered once each year at the peak of the breeding season by highly trained amateur ornithologists. Results, analyzed by computer at the Service's Migratory Bird and Habitat Research Laboratory, indicate population trends and provide maps of relative distribution and abundance of key species.

The cattle egret, a native of Africa that reached the United States through South America, is still expanding its breeding range to the north and west, although its rate of population increase seems to be slowing. In contrast, the eastern popu-

lation of the house finch, stemming from a New York City release in about 1941, is still increasing exponentially as these birds expand southward into the Carolinas, westward across the Appalachians, and northward into New England.

Among several insectivorous species undergoing a steady decline, the loggerhead shrike is commanding special attention and concern. This species is decreasing at an annual rate of 4% over the North American continent.

In addition to showing trends for individual species, the Breeding Bird Survey is being used to detect population trends of groups of species representing specific habitats. Populations generally are stable in most of the habitats examined. In the northeastern spruce-fir forest, however, there has been a highly significant increase over the past decade in numbers of evening grosbeaks, warblers, and other passerine species that feed on spruce budworms. This increase suggests that either (1) the ample food resources are compensat-

ing for any loss of birds from pesticide application or (2) populations during this decade have been recovering from the extensive use of DDT in the 1960's.

NATIONAL FISH AND WILDLIFE HEALTH LABORATORY

Diagnostic Case Load Doubles at the National Fish and Wildlife Health Laboratory. A total of 2,675 birds, 28 mammals, 9 salamanders, and 4 fish were submitted for necropsy to the Service's National Fish and Wildlife Health Laboratory during the period of October 1, 1976 through September 30, 1977. These totals compare with 1,219 birds, 16 mammals, 1 salamander, and 2 fish submitted during the period of July 1, 1975 through September 15, 1976. In all, 3,620 specimens were accessioned by the Laboratory, including tissues



Avian botulism was widespread during the year. Outbreaks were reported from California to Delaware and from North Dakota to Mexico. Approximately 100,000 birds died from this disease at Lake Sayula in the State of Jalisco, Mexico, during the winter of 1976-77. This drake pintail is in the terminal stages of intoxication; wing droop, difficulty in holding the head erect, and paralysis of the nictitating membrane of the eye are all evident. *Photo by Milton Friend.*

and blood samples from 672 birds and 14 mammals, 57 bird eggs, 242 fecal samples, 10 feed samples, and 15 mud samples. Nearly half (1,204) of the 2,675 birds necropsied were Canada geese.

The most common findings were avian botulism type C, avian cholera, lead poisoning, aspergillosis, and traumatic lesions including crippling from gunshot.

Type C botulism was detected coast to coast and north to south. Outbreaks were diagnosed in California, New Mexico, Montana, Texas, the Dakotas, Wisconsin, Minnesota, Ohio, Illinois, Louisiana, Delaware, Pennsylvania, and North Carolina. However, the year's most severe loss from this disease occurred at Lake Sayula, approximately 80-100 km SSW of Guadalajara in the State of Jalisco, Mexico. An estimated 100,000 waterfowl and shorebirds were lost during that die-off. Type E botulism, an unusual occurrence in North American migratory birds, killed about 600 common loons on Lake Michigan during November 1976.

Avian cholera made its annual appearance in waterfowl wintering in California, appeared for the third consecutive spring in south-central Nebraska, and was also diagnosed in all three of the Pacific Coast States, the Dakotas, Nebraska, Montana, Wyoming, Idaho, Iowa, and Wisconsin. Reports from Canada indicated that spring migrants also carried this disease to Saskatchewan. Avian cholera losses in Nebraska have declined steadily from 25,000 in 1975 to 11,000 in 1976 to 7,500 in 1977. Strong cooperative control efforts maintained by the Nebraska Game and Parks Commission and the U.S. Fish and Wildlife Service have been instrumental in reducing these losses. This disease also appeared in pheasants being raised on a State game farm in the Midwest.

Coccidiosis reappeared for the 2nd consecutive year in lesser scaups on Nebraska's Bluestem Lake during the spring of 1977. *Eimeria aythya* caused the deaths of about 900 waterfowl (mostly lesser scaups) during April and May; a loss of approximately 300 lesser scaups occurred during the previous spring. Only two waterfowl die-offs from this protozoan parasite have been recorded in the literature; both involved lesser scaups during spring migration.

Lead poisoning was a major problem during the year, with significant die-offs occurring at Tule Lake National Wildlife Refuge in northern California, in the Horicon Marsh area of central Wisconsin, in southern Illinois, and in the coastal

marshes of Delaware. Estimated losses from lead poisoning ranged from approximately 1,000 to 5,000 waterfowl at these locations. Lesser losses from this disease occurred at numerous other locations throughout the United States.

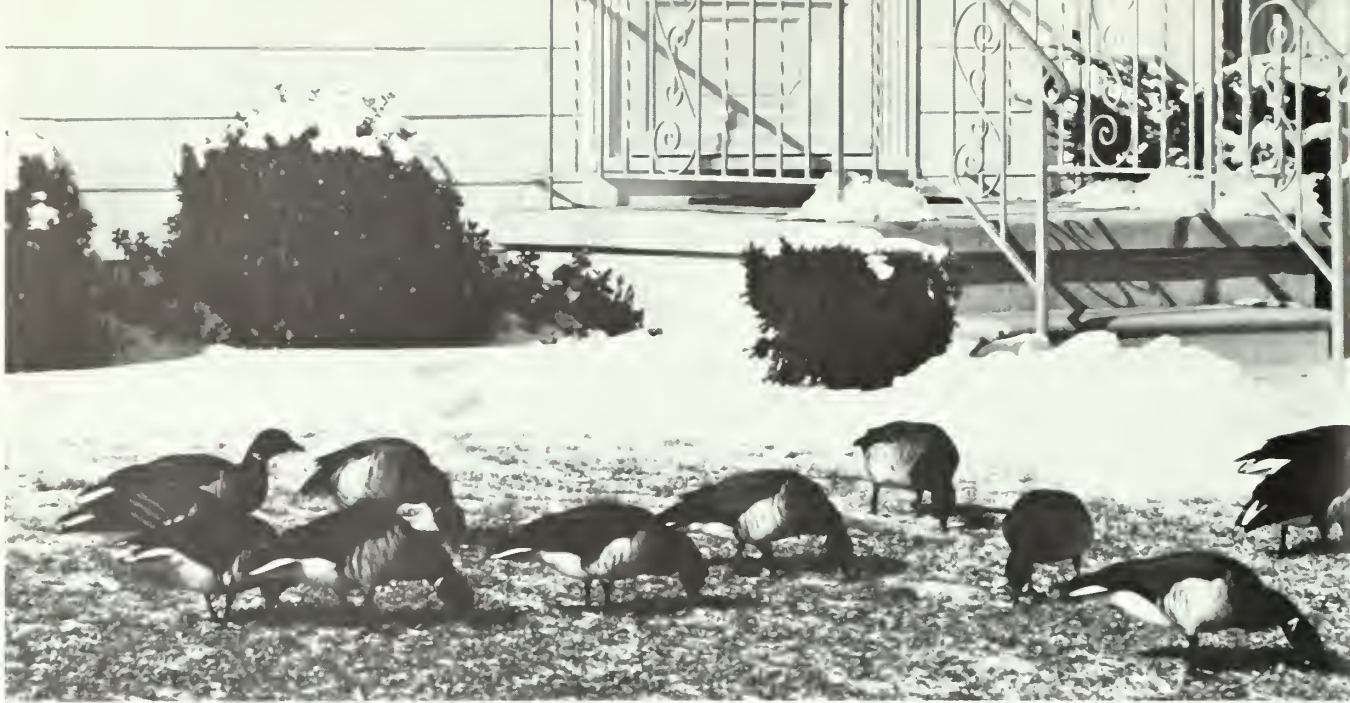
The die-off in southern Illinois claimed approximately 3,500 Canada geese. These birds had picked up small numbers of lead shot while feeding in grain fields after the end of the hunting season. A late winter storm that covered the surrounding wheat fields with snow and the onset of a prolonged period of severely cold weather were contributing factors in this die-off.

Weather also contributed to wildlife mortality in other parts of the country. A protracted period of extreme cold on the eastern seaboard caused food shortages that resulted in starvation and loss of body condition. Numerous cases of malnutrition were diagnosed, mostly in Atlantic brant and diving ducks. Drought conditions apparently resulted in the use of evaporation ponds from a ceramics plant in the area of Salt Lake City, Utah. The acidity of these ponds is equivalent to dilute hydrochloric acid. Ingestion of this water was believed responsible for the pathology observed in dead birds; their gastrointestinal tracts appeared to be "fixed" in formalin.

Salmonellosis was diagnosed in a variety of birds including sandhill cranes and a young brown pelican. The pelican died while being shipped from Florida to Louisiana to serve as brood stock for reestablishing breeding colonies in that State.

Duck plague was also evident during the year. The U.S. Department of Agriculture provided information on a die-off in muscovies near Groton, South Dakota; staff of the Health Laboratory and Region 1 assisted the California Department of Fish and Game in the control of a die-off in muscovies on a city lagoon in downtown Sacramento, California; and the Laboratory diagnosed an outbreak of this disease in captive waterfowl in Maryland (black ducks, Canada geese, and mallards). Another outbreak occurred in captive muscovies maintained for experimental purposes at the University of Wisconsin in Madison.

An undiagnosed enteritis killed several hundred snow geese in North and South Dakota during the year. The cause of this recurring problem has escaped detection despite studies by several laboratories during recent years. The disease was observed in South Dakota during fall migration and in North Dakota during spring migration. Approximately 200-300 geese died in each instance. A



Atlantic brant fed on lawns when the extremely cold winter of 1976 resulted in little open water. Many birds succumbed. *Photo by Ronald E. Kirby.*

similar ailment has also been observed periodically in small numbers of Canada geese.

Lead Poisoning Losses High at Horicon National Wildlife Refuge. Migratory bird losses at Horicon National Wildlife Refuge and nearby Eldorado Marsh and the Clark Farm were monitored in conjunction with implementation of changing management practices for the Mississippi Valley Canada goose flock. Investigations began in late summer, just before Canada geese moved into the area, and terminated with departure of most of the flock in early December. Causes of mortality and the magnitude of losses due to a particular cause varied with time.

Avian botulism (type C) and lead poisoning were evident on the Horicon Refuge at the start of the study. Small numbers of dead and dying ducks and shorebirds were observed in late August and early September. Botulism was diagnosed in 49% and lead poisoning in 29% of the 65 birds examined. Principal species affected by botulism were the lesser yellowleg, the western sandpiper, the American coot, and the mallard.

Lead poisoning losses were most prominent in the blue-winged teal, the redhead, and the mallard. Canada geese became victims of lead poisoning within a short time after their arrival. Approximately 20% of the 48 geese examined during October 1-9, 39% of the 127 geese examined during October 10-30, and 20% of the 111 geese

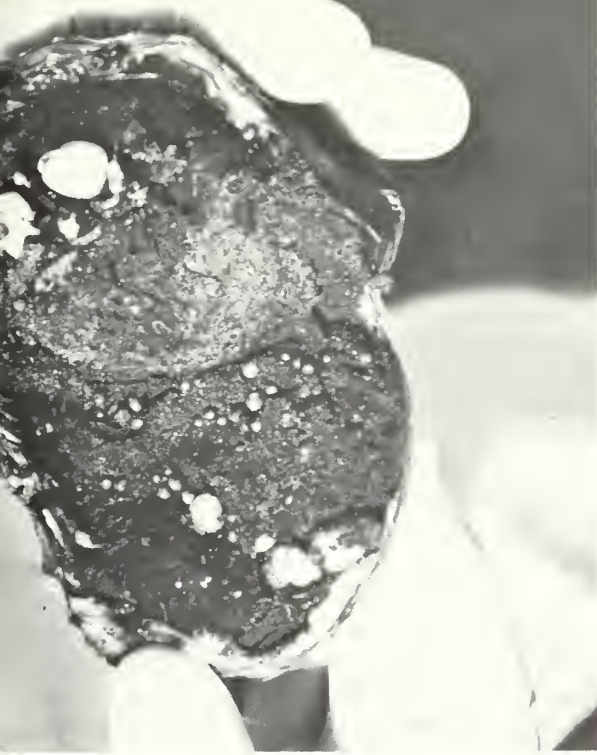
examined during November died from this disease.

During December 211 Canada geese from the other two marshes were examined. Seventy-five percent of the 134 necropsied geese from Eldorado Marsh died of lead poisoning, as did 53% of the 77 geese from the Clark Farm. These birds were representative of 480 geese picked up on these two areas.

Aspergillosis, a mycotic disease caused by fungi of the genus *Aspergillus*, killed 16% of the Horicon Refuge geese during October 10-30, 15% of those necropsied during November, 10% of the Eldorado Marsh geese, and 22% of the Clark Farm geese.

Gunshot mortalities were diagnosed in 20% of the geese and 30% of 22 ducks examined during the October 1-9 sample period, in 17% of the geese examined during the remainder of October, and in 57% of the geese examined during November. Approximately 10% of the geese from both Eldorado Marsh and the Clark Farm died of gunshot.

The sharp increase of gunshot mortalities at Horicon Refuge in November reflects the opening of the Horicon zone for goose hunting on November 1. The substantial percentage of gunshot mortalities during October reflects either illegal shooting of geese during the duck season, which began on October 1, or "cripples" that were shot legally



Several major die-offs from lead poisoning occurred during the year. The gizzard of this lead-poisoned Canada goose contains numerous lead pellets. Conversion to steel shot for waterfowl hunting will help to reduce losses from lead poisoning because most losses result from spent lead pellets deposited during that year's hunting season—approximately 3,000 tons of pellets annually. *Photo by Milton Friend.*

outside the Horicon zone and made it back to the Refuge to die. Because of the distance involved, illegal shooting is the more probable cause. Forty percent of 87 dead geese fluoroscoped before the opening of the goose season in the Horicon zone had body shot, as did 63% of 89 dead geese fluoroscoped during the goose season. Body shot was found in 41% of 46 dead geese from Eldorado Marsh and 31% of 75 dead geese from the Clark Farm.

Eagle Mortality. The National Fish and Wildlife Health Laboratory had 96 bald eagle and 114 golden eagle accessions during the period October 1, 1976 through September 30, 1977. Eighty-two bald eagles and 83 golden eagles were necropsied, the remaining specimens being less than whole carcasses. Nearly all of these specimens originated from the Mississippi and Missouri River drainages, the High Plains States, and Utah. Principal causes of mortality differed for these two species.

Gunshot killed 26% of the bald eagles examined and 7% of the golden eagles. The leading cause of death for golden eagles, traumatic injury resulting from impact, accounted for 25% of the deaths, compared with 8% for bald eagles. Electrocutation

was the second most common cause of death in both species—15% of the golden eagles and 12% of the bald eagles. Trap injuries killed 6% of the golden eagles and 5% of the bald eagles. Lead poisoning was suspected as the cause of death (based on tissue lead levels and pathology) in 11% of the golden eagles and 4% of the bald eagles. Two additional eagles that had died of traumatic injuries also had high levels of lead in their tissues.

Numerous other causes of mortality were detected. Approximately 7% of the bald eagles and 4% of the golden eagles died of pneumonia; two cases of strychnine poisoning, and single cases of avian cholera, erysipelas, hemorrhagic enteritis, cerebellar hemorrhage, gastric perforation with an accompanying peritonitis, cloacal impaction, and drowning were also diagnosed in bald eagles.

Approximately 4% of the golden eagles died from emaciation. Single cases of avian tuberculosis, avian pox, bumblefoot, lymphosarcoma, staphylococcal septicemia, nephrosis, and thallium poisoning were also diagnosed in this species.

The high incidence of gunshot deaths in bald eagles compared with that in golden eagles was not anticipated, nor were the findings of lead poisoning. Eagles readily feed on waterfowl that have died of lead poisoning and perhaps this is their primary source of lead exposure.

Waterfowl Parasite Burdens Influenced by Marsh Habitat. Studies of total parasite burdens in waterfowl are beginning to disclose ecological relationships between the type of marsh habitat and the amount of parasitism present in waterfowl on those marshes. About 600 waterfowl of 20 species have been examined, but only 15 birds have contained 20 or more species of helminth parasites. Only the mallard, redhead, canvasback, and trumpeter swan have shown such intensity of parasitic infection. It is significant that all of the 15 heavily parasitized birds were obtained from just three locations: 7 from Bear River Migratory Bird Refuge, Utah; 7 from Red Rock Lakes National Wildlife Refuge, Montana; and 1 from Ruby Lake National Wildlife Refuge, Nevada.

The 8 heavily parasitized birds from Red Rock Lakes and Ruby Lake refuges represent 20% of the 40 birds examined from those marshes. All 40 were sick, and all had much heavier parasite loads than birds of the same physical condition (age, sex, species, state of health) from other habitats. Parasitism was a direct cause of death in some of these birds and was considered a contributing factor in the death or illness of others. In

contrast, the seven heavily parasitized birds (at least five, and perhaps six, were reared locally) from Bear River Refuge comprised only 1.3% of the birds examined from that area and were a locally unique group.



Heavy parasite burdens, such as these tapeworms in the intestine of a redhead duck, can seriously affect the health of birds. This degree of infestation was found in a substantial number of redheads and lesser scaups that had died along the Missouri River during spring migration. Photo by Milton Friend.

The marshes at Red Rock Lakes, possibly Ruby Lake, and also Camas National Wildlife refuges appear to represent a habitat that often results in heavy waterfowl parasite burdens. This habitat consists of large spring-fed permanent marshes of high mountain valleys in the intermountain region. The vegetation of these marshes is lush and rich and supports a wide variety of animal life, providing intermediate hosts for many waterfowl parasites. Particularly abundant parasites in such marshes include the avian nasal leeches (75 were recovered from the nasal passages of one trumpeter swan cygnet, and 75% of the 40 birds examined were infested), and the thorny-headed

worms or acanthocephala (10,000 were found in one trumpeter cygnet, and 87% of the birds examined were infected). These worms use scuds (amphipod crustacea) as intermediate hosts. Scuds are also hosts for several other parasites (*Streptocara*, *Tetrameres*, *Lateriporus* and other cestodes) abundant in waterfowl in these marshes. *Streptocara* is a gizzard worm that often causes ulcers in the gizzard; 73% of infections at Red Rock Lakes showed these ulcers, whereas only 25% of infections found elsewhere were accompanied by ulcerated gizzards.

The high percentage of invertebrates in the diet of young waterfowl results in maximum exposure to waterfowl parasites through the consumption of appropriate intermediate hosts. A 1-week-old ruddy duckling found dead at Red Rock Lakes had an overwhelming infection of over 600 acanthocephala in the intestine. Another ruddy duckling (2 weeks old) had 16 leeches in the nasal passages. The leech infection was the probable cause of death.

Since heavy parasite burdens are detrimental to the health and vigor of waterfowl, a better understanding of the ecological considerations of host-parasite relationships is needed to provide guidance in the development and management of waterfowl production areas. For example, it appears that the maintenance of a year-round waterfowl population in permanent marshland at Red Rock Lakes intensifies rates of parasitic infection due to interaction between waterfowl and the invertebrate hosts of these parasites. The end result is a situation that may contribute to high cygnet mortality among trumpeter swans as well as high mortality among other young waterfowl. Completion of present studies on total parasite burdens is expected to provide initial guidance for refuge managers in the evaluation and development of waterfowl production systems.

Persistence of Avian Cholera Bacterium. Avian cholera has occurred in south-central Nebraska each spring since 1975. Attempts to control this disease there and in other locations have mainly consisted of field sanitation measures such as collection and disposal of carcasses. This costly activity was considered justifiable because of the persistence of the *Pasteurella multocida* bacterium in these carcasses. Questions regarding the applicability of studies conducted in California to springtime conditions in Nebraska resulted in selected waterfowl carcasses being covered with

“predator-proof” wire cages during the 1977 avian cholera outbreak.

These carcasses were “caged” during the week of March 20 and were “reclaimed” from the marsh at weekly intervals; liver, brain, and bone marrow were selected for isolation of the bacteria. An 8-week experimental period was planned, but by the 3rd week scavengers and maggots had consumed the livers from the remaining birds, by the 5th week only bone marrow was left for testing, and by the 6th week even the bone marrow had been invaded by maggots.

Pasteurella multocida was isolated from the livers of carcasses during both weeks that livers were available for testing, from brain tissue the 4 weeks that tissue was available, and from bone marrow during the first 4 weeks of the study. Failure to isolate *P. multocida* from bone marrow during the final 4 weeks of the study was probably due to carcass condition rather than limited bacterial persistence. During cooler weather, when carcass persistence is prolonged, *P. multocida* will probably remain so long as its nutrient requirements are met and its physical environment in the carcass (such as pH, oxygen, temperature, etc.) is not drastically disrupted. This study supports the value of carcass collection and proper disposal as a necessary measure of avian cholera control.

In a related investigation, methods for preserving this bacterium during transportation from the field were studied. Swabs of the intestinal tract from a goose naturally infected with avian cholera were placed in Amies transport media with charcoal and frozen at -70°C . Individual swabs were removed and cultured at 2, 3, 4, 5, 7, and 16 weeks. Growth of *P. multocida* at 16 weeks was as prolific as on initial isolation, with only a slight decrease in the size of individual colonies. In other studies, laboratory isolations of *P. multocida* from the livers of naturally infected geese could be easily made after freezing the tissue on dry ice in the field (with or without Amies transport media) and 6 days of storage at 5°C . However, laboratory isolates were less frequently made, and only with difficulty, from those livers that had been shipped from the field on wet ice. The combination of protective maintenance media and freezing at low temperatures is recommended for transportation of suspect materials from the field and for storage of these materials before laboratory testing.

Stability of Botulinum Toxin Exceeds 16 Years. The botulinum toxins are generally considered to

be rather fragile proteins that lose their potency quickly if not frozen or desiccated. However, past studies at Bear River Research Station demonstrated the retention of appreciable levels of toxin in blowfly carcasses stored for 5 years at both 8°C and 37°C and in other stored biological materials.

During the past year a liquid type C culture prepared in August 1961 and stored since then at 8°C was retitrated. After more than 16 years, the culture still retained 2.0×10^4 mouse mean lethal doses LD_{50} per liter. The original culture was prepared for the use of other investigators and therefore we do not have a record of the original toxicity, but judging from experience with similar cultures, it was probably about 4.0×10^5 mouse LD_{50} .

Inhibitory Effects of Three Household Detergents on Growth of *Clostridium botulinum*. In the late 1950's, it was observed at the Bear River Research Station that sodium lauryl sulfate (NaLSO_4) at a concentration of 10 ppm had a marked inhibitory effect on laboratory cultures of *Clostridium botulinum* type C. NaLSO_4 is a common constituent of household detergents and therefore is probably common in waters polluted by sewage.

Avian botulism has been observed on sewage observation ponds but, considering the large number of these ponds in the United States, such outbreaks are relatively uncommon. Whether the detergent content of the water influences the occurrence of outbreaks was the subject of a preliminary investigation in 1977.

Three popular detergents, one dishwasher type (A) and two laundry types (B and C), were tested by preparing serial dilutions (10-fold from 1:1,000 to 1:100,000 for type A and 2-fold from 1:200,000 to 1:800,000 for types B and C) of each in an appropriate laboratory culture medium. Each tube was inoculated with 0.5 ml of actively growing 24-hour culture *Clostridium botulinum* type C, as were two untreated control tubes.

After a 24-hour incubation period at 34°C , the volume of growth in each detergent-containing tube was compared with that in the control tubes. A was the least effective, B was intermediate, and C was the most active, causing complete inhibition of growth at 1:100,000 dilution (10 ppm) and partial inhibition at 1:200,000.

Many factors undoubtedly combine to precipitate botulism outbreaks. The results of this test suggest that sewage effluent discharge into the epi-

zootic area may be a factor worthy of greater attention.

C₂ Component of Botulism Toxin Over 1,000 Times More Toxic Than C₁ Component. Bear River Research Station has reported earlier on experiments in ducks with a previously unknown toxic component of *Clostridium botulinum* type C, which was described by American workers in 1972.

Designated C₂, the new component is produced at low levels of some strains of both C and D types of the bacterium. It appears to have low toxicity for mallard ducks by the oral route, and any effects it might have on aquatic birds would ordinarily be obscured by the predominant (paralytic) toxin, designated C₁.

Some strains of type C cured of their bacteriophages (with a consequent loss of toxigenicity) by exposure to ultraviolet light or acridine orange continue to produce C₂ toxin. It is possible, then, that *Clostridium botulinum* strains normally inhabiting waterfowl marshes may retain their capacity to produce C₂ toxin after they have lost their neurotoxicity.

Even though cultures of C₂-producing strains do not ordinarily cause signs of illness in mallards dosed orally (1 out of about 20 died after large volumes were force-fed), they are highly toxic when given by parenteral routes, particularly intravenously. In recent intravenous titrations, only 1.6 mouse intraperitoneal LD₅₀'s of C₂ toxin was needed to kill a test group of mallards, as compared with 2,000-4,000 mouse intraperitoneal LD₅₀'s of the neurotoxin. On the basis of mouse toxicity, then, the C₂ is 1,250 to 2,500 times as lethal as the C₁ toxin. This finding is significant when it is realized that C₁ toxin, along with the other botulinum toxin, is considered to be one of the most toxic substances of biological origin.

A substance as biologically active as the C₂ toxin merits further investigation. Studies now in progress aim to determine what part, if any, it plays in the pathogenesis of avian botulism. Its most obvious pathologic effect—the immediate cause of death in mallards—is massive pulmonary edema. If its primary action is to alter capillary permeability, perhaps it plays a role in the transport of the neurotoxin (a large protein molecule) through the intestinal mucosa and into the bloodstream. The current experiments will measure the influence of C₂ toxin on the susceptibility of ducks to neurotoxin (C₁). This investigation entails the preparation of C₁ and C₂ specific antisera, so that the effects of each may be observed individually.

NATIONAL FISH AND WILDLIFE LABORATORY

Investigation of Mid-Atlantic Coastal Populations of Terns. Breeding areas for terns, gulls, and skimmers were visited and investigated in Maryland, Virginia, and North Carolina. Where human recreational use of ocean beaches has deprived birds of their traditional nesting habitat, man-made islands formed from channel dredging operations often provide ideal alternatives. In North Carolina these spoil islands are the sites of all major royal and sandwich tern colonies. The previously noted breeding range extension of the sandwich tern has not continued farther northward, but the population is increasing within North Carolina, where over 1,300 pairs nested in 1977.

Band recoveries reveal that royal terns do not nest until they are 3 years old and that many delay nesting until they are 4. Yearlings and 2-year-olds pass the summer on the winter range. Breeding adults nest in the same general geographic area where they were hatched and raised, but only 12% nested in the same colony. About 50% bred at localities within 50 km of their natal colonies, and the remainder bred from 50 to 150 km away. Within colonies, older adults appear to nest earlier and occupy more desirable nest sites compared with young adults, which presumably are less experienced.

Royal tern juveniles and adults disperse from colonies in late summer and early fall, and some fly as far north as New Jersey. Florida and the Greater Antilles comprise the principal winter range of mid-Atlantic coastal royal terns. Individual terns are also commonly found along the Caribbean coast of Colombia and Central America. A few regularly remain along our eastern coast northward to Virginia, and others venture far south along the Pacific shore of South America in Peru and Ecuador. There is no evidence that royal terns from U.S. colonies move east of Venezuela and Guyana along the Atlantic coast of South America.

NORTHERN PRAIRIE WILDLIFE RESEARCH CENTER

Analysis of Food Remains in Raccoon Scats. Analysis of fecal material (scats) is of value in investigations of carnivore food habits. Early in-

investigators examined sources of error in this type of analysis, based on tests with captive red foxes. More recently, digestibility coefficients were derived for the red fox to estimate biomass consumed from quantity of residue produced. Because residues are influenced by type of food and by method of consumption, however, these digestibility coefficients would be invalid for a species with markedly different food habits. Therefore, a study was conducted at Northern Prairie Wildlife Research Center to determine digestibility coefficients for raccoons and to observe their food-handling mannerisms.

Twenty feeding tests were conducted with four captive yearling raccoons. An individual food was offered every 3rd day and left in the cages overnight. Raccoons were observed for the initial period of each test. Items offered included seeds, eggs, invertebrates, small and large vertebrates, and boned meat. Scats were collected and analyzed.

Raccoons "washed" or otherwise manipulated some items before ingesting them. Small items were consumed whole. Large items, including all vertebrates, were consumed by tearing off and ingesting bite-sized pieces one at a time. Most items were chewed well before they were swallowed. Undesirable parts were pushed aside and left unconsumed. Although food-handling mannerisms of the raccoons varied, they were fairly consistent among individual animals throughout the test series.

Most residue of ingested food was expelled within 2 days after consumption; occasionally a trace of residue was detected on the 3rd day. Residues recovered from scats, and hence digestibility coefficients, were influenced by the type of food consumed, the method of eating, and the effectiveness of recovery during analysis. Recoveries from vertebrates were good because feathers, hair, and bone were readily retained in analysis. Vertebrate remains reflected the amount of non-digestible material consumed. Residue from seeds, eggs, and invertebrates reflected not only the non-digestible material consumed, but also the thoroughness with which the foods were chewed. Average digestibility coefficients were low for seeds, moderately high for invertebrates, eggs, and shelled invertebrates, and high for soft invertebrates and boned meat. Individual digestibility coefficients varied greatly for some items among individual raccoons, reflecting diversity in the manner of consumption.

This study indicates that digestibility coeffi-

cients for a species as diverse in food habits and as dexterous as the raccoon are variable and should be used cautiously. When used with frequency of occurrence, corrected quantitative estimates will indicate the proportions of the more important foods consumed. Determination of biomass consumed by applying digestibility coefficients is of uncertain value.

Natural Cavities Used by Wood Ducks. Biologists of the Northern Prairie Wildlife Research Center used radiotelemetry to locate 31 wood duck nest cavities in 16 forest stands in north-central Minnesota. Stands were of two types: (1) mature northern hardwoods (10 nest sites) and (2) scattered mature quaking aspen with a northern hardwood understory (21 nest sites). Aspen was the most important cavity-producing tree and accounted for 57% of 28 cavities inspected. The average density of suitable cavities in stands used by wood ducks was about 4/ha. Trees containing nest cavities were in closer proximity to water areas and to forest canopy openings than were trees in a random sample from the same stands. A significant relationship existed between the orientation of the cavity entrance and the nearest canopy opening. Potential wood duck cavities were usually clustered within a stand rather than distributed randomly. Most cavities resulted from areas of heartwood decay excavated by woodpeckers for nest holes and further enlarged until they became suitable for wood ducks. Sites that contribute to rapid tree growth and decay and selection of trees by woodpeckers probably determine the availability of cavities used by wood ducks.

Implications of Red Fox Prey Demands for Prairie Duck Production. Experiments were conducted during spring and summer of 3 years with 33 wild-caught and pen-reared red foxes on a diet of natural foods to determine prey demands, feeding characteristics, and growth rates. Pups began eating prey during the 4th week after birth; weaning was possible by the 5th week. Prey consumption by pups for weeks 1-4, reflected mostly by increased feeding by the vixen, averaged 0.57 kg per pup per week. Consumption for the rest of the denning season averaged 1.38 and 1.90 kg per pup per week for weeks 5-8 and 9-12, respectively. Prey consumption for the postdenning period averaged 2.54 kg per pup per week. Feeding by adults averaged 2.25 kg per adult per week. Pairing had little effect on feeding rates of adults and fasting on alternate days was only partially compensated for by increased feeding when prey was



Studies of prey demands of red foxes revealed that a family of two adult and five pup foxes requires 144 kg of prey during the 12 weeks after whelping, a time when most prairie ducks are nesting. Nesting ducks average about 0.75 kg each and are a major source of food for foxes in the Prairie Pothole Region. *Photo by Alan Sargeant.*

available. Drinking water was not needed by either pups or adults. Growth rates of pups on simulated natural diets were slightly less than those of pups on ad libitum diets. Prey remains left by pups reflected prey availability. About 90% of the prey items offered to pups on simulated natural diets were consumed; remains, primarily nonconsumable parts, varied with prey availability and prey type. Prey biomass required by an average-sized fox family with a territory of typical size was estimated at 18.5 kg/km² for the entire 12-week denning season and at 2.4 kg/km² each week of the postdenning period. Because of the large prey demands, a small part of the foxes' diet could adversely affect a particular prey population, such as prairie-nesting ducks.

Breeding Birds Censused on Burned Grasslands. During the past 6 years, breeding bird populations were censused on seven grassland plots on the Woodworth study area, northwest of

Jamestown, North Dakota. The plots, ranging from 4.8 to 10 ha, have been subjected to various regimens of prescribed burning. Two plots were censused in years before and after burning, and one plot served as an unburned control. Bird populations were determined by plotting individual territories.

Results from work in 1972-76 demonstrate the difficulty of detecting effects of treatment; year-to-year variations in bird populations (independent of treatment) and variations caused by differences in precipitation (reflected in the number of wetlands) cloud the picture. Multiple regression analyses, incorporation effects due to year and plot as well as to treatment, suggested the following conclusions: Nearly all the common breeding species declined in number directly after a burn. The bobolink and grasshopper sparrow appeared to respond favorably in the years immediately after a burn, but the western meadowlark,

common yellowthroat, savannah sparrow, and clay-colored sparrow decreased in number. The red-winged blackbird and brown-headed cowbird seemed largely unaffected by grassland burning. The species diversity of recently burned plots was lower than that of older burns or of the control plot.

In 1977, the effects of an extremely dry year were readily apparent. Only 7% of the ponds on the study area contained water in late May, a situation reflected in a sizable decrease in numbers of ducks, red-winged blackbirds, and common yellowthroats on the plots. Despite the reduction in redwing numbers, nearly all the normally occupied wetlands were occupied in 1977—even though they were dry. However, in 1977 each male redwing appeared to occupy one to three wetlands, in contrast to the usual density of one to two males per pond. In effect, the average territory size increased as the population decreased.

This research clearly demonstrates that 1- or 2-year studies are inadequate for determining bird populations on grassland habitats or for predicting the impact of habitat changes on breeding birds. To place in perspective the variation caused by year-to-year changes in bird populations and climatological factors, it is necessary to conduct long-term base-line studies.

Foods Consumed by Dabbling Ducks on the Breeding Grounds. Prairie wetlands traditionally utilized by breeding waterfowl are being altered or eliminated throughout the glaciated prairie pothole region of North America. The loss of wetlands caused by partial or complete drainage is dramatic and can be readily documented. Impacts of the more subtle changes that alter the structure of plant and animal communities are less obvious and not well documented.

Adequate assessment of the impact of changes in the aquatic community on waterfowl ecology requires an understanding of the feeding niches occupied by the different species of waterfowl. Knowledge of feeding niches will provide wetland managers with guidelines to define critical and threatened habitat, to purchase wetlands of highest quality, and to manage existing wetland habitat efficiently.

Foods consumed by five species of dabbling ducks in the glaciated prairie pothole region of south-central North Dakota were investigated during 1967-77. Invertebrates accounted for 99% of the diets of laying blue-winged teals and shovelers, 70% of the diet of laying mallards, and 77% of

the diet of laying pintails. Animal foods accounted for 72% of the foods consumed by laying gadwalls that fed on fresh or saline lakes. Selected foods varied among species of dabbling ducks. Snails and aquatic insects dominated the diet of blue-winged teals, snails and crustacea the diet of shovelers, and insects and crustacea the diet of gadwalls. Earthworms were an important food of mallards and pintails. Filamentous algae formed a major part of the plant food consumed by gadwalls, and seeds were the dominant plant foods selected by mallards and pintails. Food selected by laying females was influenced by nesting chronology as well as food availability, which in turn was determined by invertebrate behavior and the current hydrological conditions within the wetland complex. During years of adequate precipitation, temporary, seasonal, and semipermanent wetlands provided successively abundant and highly available plant and animal foods throughout the breeding season.

During nesting or renesting periods, female anatids consume a high proportion of insects, snails, and crustaceans. Their ability to obtain these foods depends largely on the types of aquatic habitat available during the laying period. A habitat of high quality produces an abundant supply of small aquatic invertebrates during the nesting and brood-rearing periods. Quality aquatic habitat is particularly critical when nest predators destroy a large percentage of the nests, forcing hens to renest when their body reserves have been expended in previous attempts. A single hen has the potential for laying up to five clutches of eggs before a successful hatch is achieved or before she terminates her nesting efforts for the year. It is important, therefore, that the breeding grounds provide an abundance of high protein foods throughout the nesting period. The prairie wetland complex is an important element in the ecology of prairie dabbling ducks and its significance must be recognized and emphasized to achieve preservation of waterfowl habitat.

Populations and Behavior of Black Brant in Humboldt Bay, California. An 8,700-acre Federal refuge has been authorized in Humboldt Bay in northern coastal California to reestablish black brant as a fall and winter bird. Currently, most brant stop there only in the spring on their northward flight.

The fall population peaked at approximately 600 birds in early November. At the opening of the hunting season only one bird was observed.



Intensified use of agricultural land continues to degrade the quality of duck production habitat in the Prairie Pothole Region. This photograph in Stutsman County, North Dakota in July 1977 illustrates the degradation of wetlands through frequent tillage and lack of upland nesting cover. *Photo by H. F. Duebbert.*

Spring migrants started to arrive in early February and peaked at over 18,000 in mid-March. Most birds had resumed their northward flight by late April. During November and December, juveniles made up 43% of the brant aged, reflecting the high breeding success of 35% young noted on the fall staging area in Alaska. Foraging for eelgrass consumed most of the birds' daylight time.

During the 37-day hunting season in January and February, the observed kill was only 368 brant, an average of 0.1 bird per hunter-day. Young made up 22% of the kill. The observed crippling loss of nearly 14% provided a total estimated kill of 419—the poorest brant hunting year recorded on the Bay.

Aircraft operation, clamming, and boating caused only local, temporary movements of the brant in the Bay. Hunting had a more pronounced effect, however, and frequently forced the birds to leave the Bay and fly to the ocean beyond the breakers where the only available food was eelgrass that drifted out the inlet. Relatively few birds that were flushed from the Bay on overwater hunt days returned to the Bay to feed at night.

High Nesting Success of Ducks in an Area of Reduced Predation. Dabbling duck production was studied in 1969-74 on a 51-ha field of undisturbed grass-legume cover and a surrounding 8.13-km² area in north-central South Dakota. The study area was within a 259-km² block in a glaciated prairie wetland region where mammalian predators were reduced in number from May 1968 through August 1971. Dabbling duck breeding populations, nest densities, and hatching success attained high levels in the area where predators

were controlled. Pair densities of breeding mallards increased from 2.8/km² in 1969 to 16.8/km² in 1972 on the 8.13-km² area. Mallard nest density on the 51-ha field increased from 37 nests (0.7/ha) in 1969 to 181 nests (3.5/ha) in 1972. Seven dabbling duck species produced 1,062 nests, 864 (81%) of which hatched successfully; 146 (14%) were destroyed by predators and 52 (5%) had other fates. During years with effective predator control (1970-72), average hatching success for all dabbling duck nests was 94%. A minimum of 7,250 ducklings hatched on the 51-ha cover plot during the 6 years, including 2,342 ducklings in 1972. The study indicated that large numbers of ducks can be produced on small waterfowl management areas with good wetland and upland habitat in the glaciated prairie region if predation is controlled.

Use of Prairie Pothole Habitat by Breeding Mallards. Detailed information on the use of prairie pothole habitat by mallards during the nesting season is necessary to understand the needs of the species during the breeding period. Much information has been collected relating pair counts to habitat use and water conditions. However, pair-count data to assess wetland use emphasizes individual wetland units and does not sufficiently consider the total habitat required to sustain a breeding pair on a daily or seasonal basis. Therefore, researchers at the Northern Prairie Wildlife Research Center attempted to determine habitat use by individually radio-marked mallards during the breeding period.

Home range characteristics, habitat uses, and time budgets of breeding mallards were studied in

93.2 km² of prairie pothole habitat in North Dakota. Exclusive of time spent at nest locations, hens spent 77% of their time in wetland habitats and 23% in upland habitats. Individual hens occupied from 7 to 22 wetlands during the breeding season; seasonal and semipermanent ponds received the highest use. Hens restricted their movements to about a quarter of their total home range during the laying period. Time budget data

showed that activities of hens were strongly influenced by reproductive status; foraging was a dominant activity during the period of egg formation. Use by breeding pairs of a large home range containing numerous wetlands of several types increases the potential for meeting breeding requirements and underscores the value of preserving natural wetland complexes.

Mammals and Nonmigratory Birds

DENVER WILDLIFE RESEARCH CENTER

Apparent Response of White-tailed Jackrabbits to Sagebrush Removal with 2,4-D. In a study designed to determine wildlife diversity and abundance on a watershed covered with big sagebrush and on a similar watershed sprayed with the herbicide 2,4-D in diesel oil, greater numbers of white-tailed jackrabbits were counted on the unaltered area. Annual counts on both watersheds for 5 years before treatment produced an average of 2.5 rabbits per mile on the control and 2.7 rabbits on the area to be treated. After the smaller, 640-acre watershed was sprayed with the herbicide by helicopter, the count remained at 2.7 rabbits per mile, whereas the population on the untreated area increased to 8 per mile, almost triple the long-term average.

Both the open winter of 1976-77, when foraging was not impeded by heavy snows, and the open, warm spring of 1977 were favorable for jackrabbit survival, reproductive success, and rearing of young.

Treatment with 2,4-D significantly reduced cover and browse available to jackrabbits. Before herbicide application, the extensive stands of sagebrush on both control and to-be-treated drainages averaged 14.5 inches high at a density of 30-40 plants per linear foot. Living and partially living plants made up 76 and 15% of the overstory cover. One year after treatment, 13 and 20% were in these categories, and dead plants had increased from 8.6 to 67%.

This study is being conducted near Saratoga, Carbon County, Wyoming, in cooperation with the U.S. Bureau of Land Management and the Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service. The combined research effort is directed toward measurement of soil moisture, streamflow, aquatic and terrestrial vegetational production, and vertebrate and invertebrate populations.

Mule Deer on a Northern Plains Coal Mine—a Case Study. Are mule deer and western strip mining compatible? Answers to the question run to both extremes, with debate usually based on



The white-tailed jackrabbit is a common resident of the western sagebrush-covered rangelands. *Photo by Max H. Schroeder.*

rather scanty evidence. In 1976, we undertook a study designed to shed light on this and related questions. A study site near Decker, Montana, was chosen because it provided opportunities to observe the relationships of mule deer to their native environment as well as to an active coal strip mine and a newly developing mine. The small herd of deer on the active West Decker mine has already given some unexpected preliminary answers to our question.

The very existence of resident mule deer on the Decker mine tends to make the answer to the deer/mining compatibility question an obvious "yes." As usual, ecologically, things are not so simple. The process by which this deer herd became established on the mine is not well documented. Perhaps it could better be described as the process by which the mine evolved in the presence of the deer herd. Resident deer of the area would have had ample time to become conditioned to the increasing levels of disturbance associated with a developing mine (at least the more adaptable individuals). Habitat diversity itself was increased by the mining, resulting in a mosaic of interspersed disturbed "weedy" areas, steep mountains of spoils, settling ponds, and native communities of sagebrush, grassland, and a few junipers. Evidence gained from radio-tracking the deer shows that all vegetational types received some deer use, and seasonal shifts were prominent. Mine employees reported that the group of deer slowly increased in number during the first several years of mining. By July 1976, 17 deer were known to be present—4 does, 7 fawns, 5 1-year-olds (3 bucks, 2 does), and 1 large 4-point buck. These deer occupied about 1,000 acres of habitat, excluding large barren areas such as the coal pits. Substantially more deer per unit of land were present on the Decker mine than on surrounding, relatively unaltered habitat.

By the end of November 1976, two known deer remained, one mature radio-instrumented doe and one unmarked yearling doe. Accountable mortality came from several sources and included seven deer (six of them marked). One fawn died when hit by a coal hauler. Three neck-banded yearling bucks and a mature, radio-collared doe were killed in vehicle collisions on the Decker highway adjacent to the mine. Illegal hunting caused the remaining two known mortalities. A radio collar from a mature doe and a neckband from a yearling doe were dug from the hole where they were buried by poachers. Night-lighting

hunters were seen or heard in the Decker area several times during September and October, probably accounting for at least a portion of unidentified disappearances of mine deer.

The demise of this group of deer was facilitated by two important factors that increased their vulnerability to hunting and vehicular collisions: (1) In late summer and early fall, the deer began moving off the mine and across the highway to feed on succulent new forbs emerging on the mud flats of the receding Tongue River Reservoir; and (2) these deer had become conditioned to high levels of human and vehicular disturbances, making them less wary than their counterparts in the "natural" ecosystem.

A strong case for peaceful coexistence of western coal mining and deer can only be built by considering compatibility of deer with the physical environment of mining. The more direct human influences appear to conflict strongly with deer. Continued research on mule deer and mining should help provide broader-based solutions to the problems posed by this case history, as well as those relating to reclamation and rehabilitation of mined land.

Antelope Movements Prove Unpredictable. The increasing demand for energy in the form of strippable western coal raises questions concerning the effects of mining on wild animals resident in coal development areas. The habitat of pronghorn antelope is more extensively underlain by strippable coal than that of any other large North American mammal. To answer these questions, detailed information on pronghorn movements and patterns of habitat use is needed. In January 1976, the Sheridan field station (Denver Wildlife Research Center) initiated a study designed to produce the requisite data.

To assess movement patterns, over 100 antelope were fitted with individually identifiable neckbands; 31 of these were also radio-collared, allowing them to be located at any time or place. Research to date suggests that the concept of repeated use of traditional activity areas (e.g., winter range, summer range) may not apply to pronghorns.

Aerial surveys during the winter of 1975-76 indicated that two distinct herds of antelope wintered in the Youngs Creek area 15-20 miles north of Sheridan, Wyoming. A herd of 60 animals wintered south of Youngs Creek, and a group of 250-300 wintered along Squirrel Creek, 5-10 miles north of the other group. In January 1976, the en-

tire smaller group was captured and marked. About half of these marked animals moved great distances (up to 30 miles) to summer activity areas. The others moved little or not at all.

Although it was not clear whether the summer dispersal of marked antelope represented migration to a traditional summer range, we did expect them to return to the capture site during the following winter. By mid-December 1976, however, all of the instrumented animals and many neck-banded ones were using the Squirrel Creek area where the larger group spent the previous winter. A maximum of 274 pronghorns were using the area by January 1, 1977. If the two groups observed in winter 1975-76 had simply merged on Squirrel Creek, over 300 animals would have been present. The whereabouts of the rest of the animals was unknown.

Aerial surveys suggested that many antelope left the Squirrel Creek area during January 1977, and a maximum of 200 were observed there late in the month. The January movement of an instrumented female corroborated the results of the surveys. This animal and at least three neckbanded ones spent the remainder of the winter 6 miles farther north.

A similar inconsistency of activity areas is apparent near Decker, Montana, where we recently initiated antelope studies. Previously, no more than 30 antelope had ever been observed in the immediate area of the East Decker coal lease. There was a large influx of antelope to this lease area on about December 5, 1976, and at least 124 antelope used the area for the remainder of the winter. Where these animals came from is unknown, but because some were marked while in the winter group, we know that many of them moved very long distances to summer activity areas.

The extensive antelope movements noted so far emphasize the regional scope of potential impacts due to coal mining. For now, however, the unpredictability of those movements only confounds attempts at impact assessment.

NATIONAL FISH AND WILDLIFE LABORATORY

Polar Bear Research. The major field activity was radio-tracking polar bears from the Nimbus 6 earth-orbiting satellite. Three mature females presumed to be in estrus were fitted with transmitters

after being captured and transported to holding facilities at Barrow, Alaska. They were released when it was determined that they had accepted the collar and light attachment harness and that the satellite was providing accurate location data. All electronic components were encased in a polyurethane and lexan collar held in position by a light cable harness. The total weight was approximately 10 pounds. A backup transmitter allowed the bears to be tracked from an aircraft.

The first female was released on March 28, 1977, and was tracked by satellite and aircraft for 12 days. The radio was then removed because the battery had gone dead. Bears were released with the second and third transmitters on June 18, 1977. The second bear was about 200 miles to the east of the Point Barrow release site when the last satellite signal was received on July 18. Signals are still being received from the third animal, which in early September was about 250 miles northwest of Point Barrow.

Sea Otter Research. A surface survey of the Oregon-Washington coast where Alaskan sea otters were released in 1969-71 shows that the future of these populations is uncertain. Although some animals were undoubtedly missed in both areas, only 4 sea otters were sighted off Oregon where over 20 were counted in 1973. Off the Washington coast, where fewer than 10 had been sighted in previous years, 18 were counted including 4 pups.

Partial segregation of sea otters by age, sex, and reproductive condition has been recognized for many years. In Prince William Sound, where the sea otter population has been increasing and expanding into new habitats, two areas with nonreproducing aggregations of animals (predominantly male) have been observed for 3 years. At various times these aggregations contained 200-400 animals each. In 1976, one female with a pup was observed among these animals, and in 1977 nine female/pup pairs were counted. Behavioral and functional aspects of sea otter distribution are not known. Apparently, young nonreproductive otters are driven from areas containing reproductively active animals, but it is not clear how this comes about.

The 2nd year of intensive study of the recently established sea otter population at Attu Island was completed. Surveys indicated that pups constituted 34 and 26% of the population in 1976 and 1977, respectively. The population is expanding its range at a rate of about 5-10 miles of coastline per

year. During 1977 territorial behavior of males and partial segregation by sex or age were observed.

The population structure of green sea urchins—the sea otter's principal food and the habitat's principal herbivore—is changing dramatically within the sea otter's range. The kelp association, however, has shown no sign of recovery from the intense overgrazing by sea urchins that occurred before sea otters became reestablished on Attu. The abundance of nearshore fish is positively related to the presence of kelp. Up to 44 times the catch of fish per unit effort was obtained in kelp versus non-kelp areas. Sea otters feed almost exclusively on sea urchins at Attu. At nearby islands, where otters are at carrying capacity, 60% of their diet consists of fish. Otters at Attu spend less time feeding than otters at Amchitka Island, where the population is near carrying capacity.

Manatee Research. A Statewide communications network established by the Gainesville, Florida, field station, resulted in the salvage of 56 manatees during fiscal year 1977. Thirty-two animals recovered between January 15 and February 1977 apparently died of cold-related causes and represent the largest recorded manatee die-off. A majority of the winter dead were recovered north of historically reported winter range limits, and preliminary data suggest that the northward range expansion may be induced by warm effluents from power plants and industrial facilities.

Techniques for restraining and handling manatees weighing up to 600 kg have been perfected, making it possible to collect blood and urine and to insert stomach transmitters for metabolic studies. Metabolic measurements of manatees in water 15°-25°C are being recorded and, when completed during the winter of fiscal year 1978, should provide definitive data on manatee metabolism at different water temperatures.

Seney National Wildlife Refuge. The impact of the 1976 fire on the Seney National Wildlife Refuge was evaluated. Eight trapline transects established during October 12-23, 1976, produced 166 specimens representing 12 species of mammals. Trapping results clearly demonstrated the detrimental immediate effects of the Seney fire on local small mammal populations. Traplines on unburned areas yielded 125 (75%) of the 166 specimens. The unburned sites produced 11 species, whereas only 6 taxa were collected on the burn.

These 8 transects and 13 additional ones were trapped during the May 4-19, 1977, follow-up sur-

vey. Despite increased trapping effort, the total catch (83 specimens) was half that of October. The contrast between burned and unburned areas was still impressive. Transects on unburned areas yielded 87% of the mammals caught.

The principal immediate objectives of the field work at Seney have been achieved: (1) determination of the immediate impact of the fire on mammal populations; and (2) establishment of permanent transects on all major habitat types affected by the fire, including the Strangmoor Bog association in the wilderness area. Future monitoring will provide information on the long-term impact of the fire and on the recovery rates of the mammal populations, and will answer questions raised by the surveys already completed. One of the most obvious questions is: Were the comparatively low population numbers encountered during the May survey, both on and off the burn, the result of seasonally characteristic fluctuations in density (i.e., normal low overwinter survivorship) or were they due to a combination of effects wrought by the fire itself? Mortality due to exposure and reduced food availability, detrimental population disturbances caused by an influx of animals from burned areas, and intensified predation because of localized and concentrated prey populations are some possible fire-related explanations for the low densities encountered in the spring survey.

Cooperation with Mexican Fish and Wildlife Service. Several joint projects of the U.S. Fish and Wildlife Service and the Mexican Fish and Wildlife Service are under way. These projects are coordinated by the United States-Mexico Joint Committee on Wildlife Conservation under terms of an agreement signed by the Directors of the two agencies for joint research, conservation, and management of wildlife.

These projects are mainly concerned with the distribution, abundance, trends, and ecological relationships of the fauna of a certain region, or of species selected because of their importance as ecological indicators, status as endangered species, or impacts on agronomics and public health. In addition, there are primary concerns for management and protection of unique natural areas.

As part of a survey of the mammal fauna of the State of Nayarit and adjoining islands, a joint team from the National Fish and Wildlife Laboratory and the Fauna Silvestre surveyed the mammals, reptiles, and amphibians of the Tres Marias Islands and surrounding waters. These islands,

about 60 miles off the west coast of Mexico, support an interesting assemblage of animals that have differentiated from their mainland relatives in varying degrees. A good example of this phenomenon is the discovery of an undescribed species of bat of the genus *Myotis* during the survey.

The islands were visited in 1897 by a field party from the U.S. Biological Survey, and comparisons

of the flora and fauna today with those reported before the turn of the century are proving interesting. Changes induced by the establishment of a penal colony on one of the islands have resulted in the introduction and increase of species such as roof rats, deer, and feral goats. These species in turn have probably contributed to the extinction of a unique species of rice rat and to drastic changes in the distribution of deer mice.

Cooperative Research Unit Program

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. Twenty-five Fishery Units and 20 Wildlife Units are currently in operation. In 1973 the two Unit programs were merged into one, administered by the Division of Cooperative Research.

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 co-operators 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 1977, personnel of the Fishery Units conducted 322 research studies, 104 of which were completed. The Wildlife Units carried 315 studies and completed 86. These studies and other activities resulted in 115 publications from the Fishery Units and 104 from the Wildlife Units. The following table summarizes training activities at the 45 Units during 1976-77:

| | Fishery | | Wildlife | |
|------------------------------|---------|-------|----------|-------|
| | M.S. | Ph.D. | M.S. | Ph.D. |
| Students on program | 232 | 56 | 256 | 56 |
| Degrees granted | 60 | 11 | 68 | 6 |
| Employment ¹ | | | | |
| Fish and wildlife biology | 48 | 11 | 47 | 4 |
| Other biology | 0 | 0 | 1 | 0 |
| Education continued | 3 | 1 | 20 | 1 |
| Peace Corps | 3 | 0 | 0 | 0 |
| Miscellaneous and unemployed | 4 | 1 | 6 | 1 |

¹Includes students who accepted employment before completing all degree requirements.

COOPERATIVE FISHERY RESEARCH UNITS

Alabama. In many fishes, gonadal differentiation occurs after hatching and can therefore be influenced by exogenous hormones. The addition of a potent androgen to food, for example, can cause genetic females to develop testes and function as males; genetic males are usually not affected and thus also develop as functional males. Hormone-induced sex reversal can aid in genetic study of fishes or can be used to manage reproduction, as in the control of excessive spawning of tilapias in an aquacultural system. We studied the effects of androgen treatment on the commercially important Nile tilapia. One of two synthetic androgens, methyl testosterone or ethynyl testosterone, was added to food at 30 or 60 mg/kg of food and fed to sexually undifferentiated fry for 3, 5, or 8 weeks. Examination of the fish after they became mature revealed that all-male populations were produced with the 60-mg treatment for all three feeding periods and with the 30-mg treatment for the 5- and 8-week feeding periods. Only the 3-week treatments of 30 mg/kg of food yielded populations that contained a few (1%) females.

Arizona. Studies in the laboratory of the feeding behavior of threadfin shad confirmed inferences made in field studies that shad feed on plankton both selectively and by filtering. Threadfin shad selectively ate relatively large plankters (adult brine shrimp longer than 0.39 mm) and filtered smaller food items (nauplii of brine shrimp and phytoplankton). The amount of food eaten per unit of time during the selective feeding of the shad decreased as light intensities decreased. We inferred that selective feeding in this species is a visual process that takes place only when sufficient light is available. In the presence of microscopic foods, threadfin shad feed only by filtering, at all light intensities. Thus, under natural conditions, shad can feed by filtering at any time of the day if the food concentrations are sufficient to induce feeding. Filter feeding is probably triggered by chemoperception rather than vision. The circumstances that produce a specific type of feeding (selective or filtering) in shad are: (1) for selective feeding, a certain size of prey and a minimum light intensity; and (2) for filter feeding, a concentration of microscopic food sufficient to provide a chemosensory response in light or darkness. The combined feeding attributes allow threadfin shad to eat whichever plankton groups are most abun-

dant during different seasons of the year.

California. Pacific herring and northern anchovy populations were studied in Humboldt Bay to determine seasonal distribution and abundance. Controversy concerning proposed commercial fisheries on these two bay populations demonstrated a lack of adequate biological data for the support of management decisions. The density of spawned herring eggs on eelgrass, the primary spawning substrate, was determined for two winters and combined with herring fecundity data to estimate the biomass of herring in the spawning populations. Spawning occurred from early December to early March, primarily in north Humboldt Bay. Estimated herring biomass during the spawning season was 372 tons in 1974-75 and 241 tons in 1975-76. Humboldt Bay summer anchovy populations were sampled by purse and lampara seines and abundance estimates made by relating acoustical transect traces to net hauls. The incidence of other species, particularly salmonids, taken by commercial seining methods was noted. Anchovies annually entered Humboldt Bay in April and departed in late October or November. Age I fish were the dominant age group each year. Vertical and horizontal distribution of anchovies was influenced by tides. Weekly biomass estimates varied from 26 to 620 metric tons (mean, 154). Management recommendations for both herring and anchovy populations were made. The California Department of Fish and Game has used the recommendations in management of a commercial herring fishery in Humboldt Bay.

The use of small intermittent streams by spawning anadromous salmonids, the emigration of juveniles, the mortality of juveniles remaining in the intermittent stream, and the immigration of juveniles into intermittent streams during the wet season were examined. Specific intermittent streams were important habitat, particularly for spawning, depending heavily on rainfall patterns. The intermittent stream is a delicate system and most vulnerable to alteration from improper land-use practices.

Colorado. To make rational management decisions, a fishery manager must know the potential capacity of waters to produce fish. Because the primary productivity of a body of water (i.e., the basic foundation of a fish food chain) often reflects its ability to support fish, it can be used as an indirect surrogate measure of potential fish production. In an effort to determine the relation between fish production and primary productivity,

we measured these two factors in eight swimming-pool microcosms in which goldfish were stocked as fry. Fish production was 3.7% of the average gross primary production. Results of other comparable studies on the relation of fish production to primary production were similar, particularly when the effects of population density and the trophic level of the fish species involved were taken into consideration. The evidence seems to indicate that reasonably good estimates of potential fish production can be made from measurements of primary productivity.

A computerized fishery operations planning system developed for the State of Wyoming integrates projected angler use, management objectives, available resources, and state-of-the-art management capabilities. The heart of the system is a lake and stream classification scheme that identifies "best uses" for all available waters, based on descriptive fishery attributes. Meshed with the classification scheme is a management option component that allows the fishery manager to examine probable outcomes, in terms of angler days produced, of several management alternatives, strategies, and changing angler preferences and demands.

Because of frequent and extreme water level fluctuations, most irrigation reservoirs on the eastern plains of Colorado lack adequate forage fish populations and, consequently, game fish populations. The Mississippi silverside, a highly desirable forage species in more southern climes, was introduced into several reservoirs in northern Colorado in the hope that it would provide an adequate self-sustaining forage base for game fish. Although the silversides provided a temporary and heavily used source of forage, they failed to survive even relatively mild Colorado winters.

Georgia. To facilitate the study of fish physiology, we developed a transmitter that enables us to record heart rates of free-swimming fish in the laboratory. Measurement of changes in heart rate can be useful in studying the behavior of fish and can be a sensitive measurement of their reactions to various types of pollutants. The transmitter, which is about 3.5 cm long and 1.5 cm in diameter, contains a magnetic switch that can be turned on and off by passing a magnet close to the fish. Battery life is about 75 days if the transmitter is operated for about 1 hour each day. The transmitter, which is inserted into the body cavity of the fish, broadcasts on the standard FM radio band. By tuning each transmitter to broadcast on

a different frequency, heart rates of individual fish can be monitored. Also, by using the radio earphone jack, we can observe the heart rate visually on an oscilloscope, or make a permanent record on a chart recorder.

We conducted a study in Par Pond (a 1,120-ha cooling reservoir located on the Energy Research and Development Administration's Savannah River Plant, Aiken, South Carolina) to determine if an increased availability of prey fish contributed to the seasonal (winter) attraction of adult largemouth bass to the warmwater discharge area. This study is one of a series of studies carried out by the Georgia Unit to determine the effects of warmwater effluents on fish populations. Results of this study suggested that, although the standing crop of prey fish, as determined from rotenone sampling in coves, was almost twice as great in the heated as in the unheated area, there were fewer species in the heated area. In the summer the prey fish (primarily bluegills) tended to remain in the vegetation away from the discharge; in the winter, however, prey fish moved to the discharge and sought cover in the rocks lining the area. Blueback herring were attracted to the discharge when the effluent was at ambient temperature (27°-31°C), and preferred the discharge area, except when the discharged water was unheated. These data show that prey fish were most numerous in the warmwater discharge area during the winter, during the same season when adult largemouth bass were most numerous there.

Hawaii. A comprehensive classification of Hawaiian inland waters into 12 categories of natural and artificial ecosystems was prepared by drawing on data collected during 10 years of field studies by the Unit. It was done as a contribution toward the national habitat classification effort, and in support of the current State (Health Department) revision of water quality standards on the basis of ecosystems. Detailed descriptions of the ecosystems include environmental characteristics, representative biota, and distributions. Among systems amenable to tally, perennial streams (360) constitute the most numerous flowing-water type, and reservoirs (400+) the most abundant standing-water type.

In other Unit studies stream macrofaunal communities and species of native aquatic invertebrates were evaluated. Extensive collections at 16 stations in three study streams showed that native fauna is lacking in concrete inverts. Such greatly modified channels have low species diversities and



Hihiwai, limpet-like snails, occur abundantly only in remote Hawaiian streams partly because they are heavily used as an ethnic food. Study of the biology of this diadromous mollusk revealed striking differences in shell morphology between populations at different altitudes that apparently relate to environmental conditions. Large hihiwai exceed 5 cm in shell diameter. The white spots are deposited capsules, each containing more than a hundred eggs. Larvae escaping from capsules are carried passively to the ocean where they develop through veliger stages before reentering streams. *Hawaii Cooperative Fishery Research Unit photo.*

serve mainly as nursery habitat for introduced top-minnows. Ecological investigation of an endemic limpet-like snail, *Neritina granosa*, confirmed that exploitation (commercial and recreational) and habitat degradation have depleted it in most streams. A status survey of native Hawaiian damselflies (endemic genus *Megalagrion*), the first Statewide investigation of this unique aquatic insect group in 70 years, resulted in the finding of 13 of the 24 described species. Other species are either rare or extinct. However, one unusual form found in a remote swamp appears to be a new species.

Idaho. Demand for electricity in the Pacific Northwest is increasing pressure to generate more electrical power at Snake River hydroelectric dams, to supply power during high demand

periods. To maximize power production, the Corps of Engineers has proposed that discharge through the lower Snake River dams at night (2300-0700 hours) be reduced to zero during the summer and fall. During this period, discharge in the Snake River now ranges from 20,000 to 60,000 cfs, well below the 120,000 cfs needed to operate the turbines at each dam at full efficiency. Storage of water at night and discharge through the turbines during the day would best meet the demands for electricity, but fishery managers were concerned that such flow regulations would interfere with the upstream migration of adult salmon and steelhead.

During 1975 and 1976, we assessed the effects of zero nighttime flows in lower Snake River reservoirs on the upstream migration of adult chinook



Chinook salmon tagged with an internal transmitter, used in tests to determine effects of shutting off dam flows at night on the upstream migration of anadromous salmonids in the Snake River. Opercle punch identifies test run in which this fish was used. *Photo by K. McMaster.*

salmon and steelhead trout. In the first phase of the study we used radiotelemetry and mark-recapture techniques to evaluate response of test fish to the reduced flows. Adult salmon and steelhead were tagged with internal transmitters or magnetic wire and transported to release sites. Individually identifiable radio-tagged fish were monitored 24 hours a day from a boat or pickup truck during 7-day alternating test periods of 0 to 10,000 cfs nighttime flow. Magnetic- and radio-tagged fish were recaptured as they passed through a magnetic detector in the fish ladder. From July to October 1976, flows were controlled on a 2-day rotating schedule of 0 to 20,000 cfs nighttime flow. Effects of these flows on upstream migrating salmonid populations were evaluated by monitoring fish passage at all lower Snake River dams related to the particular nighttime test flow condition.

After evaluating data collected during the 2 years of the study, we concluded that zero nighttime discharge had no observable effect on behavior or rate of migration of adult chinook salmon or steelhead trout. The results of this study will be used by the Corps of Engineers to use water for power production at lower Snake River dams efficiently without adversely affecting the upstream migration of anadromous salmonids.

Iowa. Energy development proposals in the Midwest have focused on increased use of stripable high-sulfur coals. The Iowa State University Coal Project, focusing on efficient strip mining, sulfur removal, and restoring of mined lands, gives the Unit an opportunity to assist in protecting the associated aquatic environment. A bibliography on the potential effects of processing or conversion of Iowa coal on aquatic resources was

developed. Finding only limited published data on the potential effects of possible discharge of magnetite-slurry used experimentally to reduce sulfur and other waste products from Iowa coal, we conducted static 96-hour bioassay tests with fingerling channel catfish. Mortalities observed were more directly related to low pH or high oxygen demands in waste waters than to other factors. Studies on the effects of crude oil on the developmental stages of the Japanese medaka (an extended-spawning oviparous killifish) showed that premature hatching of older embryos could be attributed to stimulation of the hatching mechanism by water-soluble components of the crude oil.

Louisiana. Descriptive limnology and estuarine ecology of rivers, swamps, and marshes have been emphasized during the past 6 years. We have been involved in surveys of base-line conditions in a 10-mile reach of the lower Mississippi River, and in the 1,800-square-mile Atchafalaya River basin. Results which may prove important to such Service-wide programs as stream alteration, power plant siting, and wetlands inventory are as follows: (1) Temporal changes in water quality and biotic communities are large and not easily predicted. (2) Water quality changes in these riverine heterotrophic systems are seldom caused by the biota, unless water stages are very low. (3) Estimates of standing stocks of primary producers and first-level consumers are highest in the portions of the Atchafalaya basin most influenced by land-clearing and agricultural development. (4) Estimates of standing stock of fish are most diverse, and highest for desirable species, in the regions of the basin least affected by man's activities. (5) Spring, summer, or fall fish kills occur commonly during low or falling river stages, when storms circulate organic materials high in oxygen demand throughout the water column.

In an attempt to determine the growth rate of brown shrimp, we injected more than 16,000 with fluorescent pigment and released them in the coastal marsh nursery from which they were captured. Although growth rate of marked shrimp ranged from 0.52 to 0.87 mm/day, the returns were too few to provide reliable estimates of average growth.

Maine. Restoration of Atlantic salmon to rivers in New England is a major objective of the Service and various State agencies. Our studies of model salmon rivers have shown that huge problems must be overcome to achieve full restoration: Dams block salmon runs and impoundments

cause warming of water; introduced smallmouth bass and chain pickerel prey on fry and compete with older fish; and pollution is still a problem, although abatement has resulted in substantial improvement in water quality. A computer analysis of hatchery records did not reveal bad practices during rearing or stocking that contributed to failure of the fish to return as adults. There was, however, a correlation between the amount of living space in the hatchery (which contributed to the quality of juveniles) and the number of salmon that returned 1 or 2 years later.

Spraying of vast tracts of forests for the control of spruce budworm could adversely affect fisheries in the Northeast. Our studies showed that streams were quickly contaminated from spraying of adjacent forests but that lakes outside the spray zone received only a small dose. Because the pesticides used (Dylox and Orthene) are short-lived and were applied in a responsible manner, there were no measurable effects on fish or fish-food animals. Public demand for application of pesticides directly into streams for blackfly control is another potential problem. We found that the carrier chemical of a blackfly pesticide repelled Atlantic salmon, suggesting that repeated application could impede upstream migration of salmon.

Prevention of the maturation of the gonads could result in several advantages: prevention of the development of overcrowded, stunted populations; avoidance of the naturalization of introduced species; circumvention of mortalities associated with reproduction; and enhancement of growth by the shunting into flesh production the energy otherwise expended for the production of sex products. Natural sterility in brook trout was found to be caused by cells that had extra chromosomes. An identical condition was induced in Atlantic salmon by treating eggs with an antibiotic.

Massachusetts. The shortnose sturgeon in the Holyoke Pool of the Connecticut River, Massachusetts, is endangered and is the only nonanadromous population known in the world. We are studying the basic biological and population characteristics of this species and are attempting to determine the possible effects of the construction of a proposed twin thermonuclear power plant intake in the Pool.

Gill-net and trotline fishing and monitoring of the Holyoke Dam fish lifts during 1976 and 1977 yielded 229 shortnose sturgeons 325 to 1,071 mm long, weighing 200 to 5,750 g. Recapture data from tagged fish yielded a total population esti-



Shortnose sturgeon from an endangered nonanadromous population in Holyoke Pool, Connecticut River, Massachusetts: recently hatched larva (above) and juvenile, 304 mm long (below). *Massachusetts Cooperative Fishery Research Unit photo.*



mate of 450 fish longer than 460 mm. Radio-tracking and recapture information showed that the fish have small (1-3 km) summer ranges and that they either return to the same area every year or stay within the same section of the river throughout the year. Although the shortnose sturgeons in the Holyoke Pool are trapped between two dams and are considered primarily nonanadromous, one marked fish lifted over the Holyoke Dam is known to have moved to the lower Connecticut River.

In 1977, seven larval shortnose sturgeon were captured in plankton nets set at the bottom in the spring. The larvae were caught between 179 and 190 km above the river mouth. During May and June, 102 sturgeons were caught in gill nets, of which 11 were ripe males and 4 were ripe females. All ripe males were caught from river km 190-190.1, between May 4 and May 9. During spawning, temperature ranged from 10° to 14°C and water velocities from 12,000 to 50,000 cfs. The

substrate within the spawning area was mostly gravel and rubble, with some large boulders. The current was relatively fast and water depth was 3 to 15 m. Insofar as can be determined all shortnose sturgeon reproductive activity during 1977 was confined to an area about 1 km above the proposed nuclear power plant intake.

Missouri. The overall goal of the Missouri Unit program is to promote optimum sustained yield as a concept in fishery management. To achieve that goal, Unit researchers seek to develop 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.

The Proportional Stock Density (PSD) is an index of the percentage of fish of quality size in a stock. Stock and quality size have been defined as 20 and 30 cm, respectively, for largemouth bass

and 7.5 and 15 cm for bluegills. Desirable ranges of PSD for balanced populations are 40-60% for bass and 20-40% for bluegills. Values outside these ranges may indicate functional or environmental problems and a need for management measures. A new approach to regulating harvest of largemouth bass, calling for the release of all bass 30 to 38 cm long, has been shown to improve the PSD of bass and bluegill stocks.

New indices of condition or well-being are based on the development of a standard weight-length relationship. A new index of condition, Relative Weight (W_t) is expressed as the actual weight as a percentage of the standard weight. Optimum values for largemouth bass in small midwestern impoundments in the fall appear to be 95-100%. Values outside this range are considered to be suboptimal. The concept of a standard weight has also been applied to develop indices of feeding and fecundity.

Indices of fishing quality have been developed that incorporate variable angler values for the species, size, number, and diversity of fish caught, as well as values for the fish that are caught and released. All of these indices can be used to evaluate the need for management, the effects of environmental modifications, or the benefits of a management program.

Montana. Studies were undertaken to determine the effects of heavy metals from old mining and milling sites on the trout populations and aquatic insects of the Boulder River. The number of trout in two study sections receiving metals were only about 38 and 11% of the number in a comparable control section without metals. The total weights of trout collected in the two polluted sections were only 59 and 15% of those in the control section. At a sampling station about 6 km below the metals sources, the average total number, average total weight, and average number of subordinal taxa in the aquatic insect community were only 33, 71, and 40%, respectively, of those in the control section. State resource agencies will use these studies in an attempt to force removal of the metal sources.

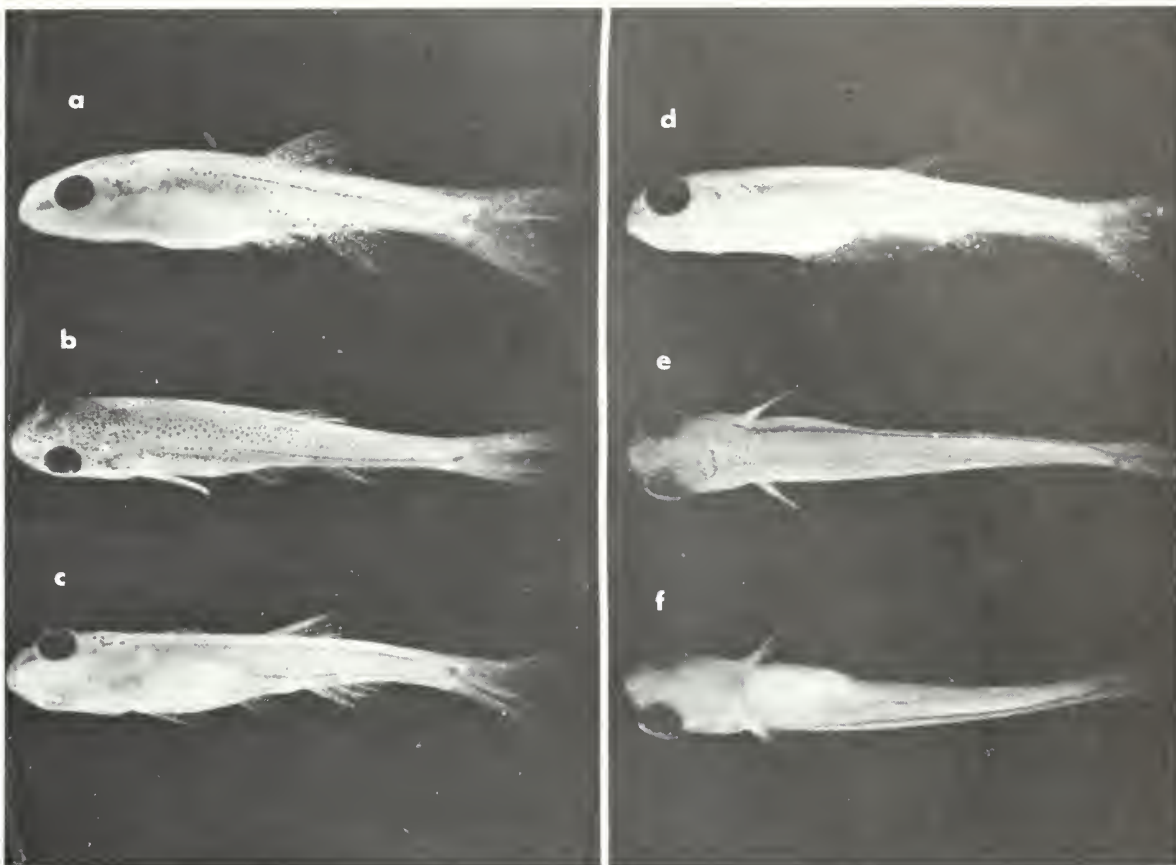
Bass population characteristics were studied during the summers of 1975 and 1976, before expansion of surface coal mining adjacent to the Tongue River Reservoir. Although the spawning population of smallmouth bass was much larger than that of largemouth bass, largemouth bass fingerlings were more abundant in both years. Growth and length-weight relationships were good

for both species, for a northern water. Population estimates obtained during 1976 with boat electrofishing gear indicated a fall smallmouth bass population (fish 1 year old or older) of 13 fish/ha and a standing crop of 2 kg/ha, which represented 80% of the total black bass population and 84% of the standing crop.

New York. Studies on largemouth bass have shown for the third consecutive year that spawning time can be controlled and spawning season greatly extended by controlling the water temperatures to which adult bass are exposed. Mature fish taken from natural (wild) populations in April and maintained in running water averaging 16°C, spawned within 5 days after being stocked (in groups of six to eight fish) in small ponds averaging 23°C. Spawning was induced by this method through early July and could have continued into September as in 1976, but was terminated in July at the completion of the project. As in previous years, number of eggs per female, fertilization rate, and hatching success were comparable between spawnings from "controlled" fish and fish allowed to spawn naturally. This method of spawning manipulation is simple and requires no special equipment or facilities beyond those available at most fish culture and research stations. Control of the timing and duration of the bass spawning season expands bass culture flexibility and opportunities for research by lengthening the kind of availability of young bass.

Accurate identification of larval fishes is essential to the determination of the environmental impact of any development which affects aquatic ecosystems. Suckers are important components of most freshwater ecosystems in northeastern United States, but have not been studied in great detail. We reared sucker larvae in laboratory units and collected them from various streams, and analyzed various detailed morphometric, meristic, and pigmentation characters that could be used to accurately identify larvae to species at various stages of development. No single character was found that would discriminate among all species; however, identifications based on a combination of morphometric measurements were about 90% accurate. Although such accuracy in identifying larval fishes to the species level is impressive, a series of tedious measurements are required.

Culture of *Daphnia magna* populations in a flow-through system fertilized with animal wastes produced substantial reductions in the concentration of particulate organic matter in the water.



Closely related larval fishes look so much alike that detailed comparisons are required for their identification. Shown here are a 16-mm-long longnose dace (a-c) and a 12-mm blacknose dace (d-f). *Photo by L. Fuiman.*

Total nitrogen and phosphorus concentrations were also reduced, and a large “crop” of live daphnids was produced. If the observed production could be maintained through a year-long cycle in a hectare-sized unit, about 16,400 kg of raw animal protein per year should be produced. Flow-through daphnid culture seems to have potential as a means of supplementing animal protein sources, at least in animal diets and for improving the quality of waste-water effluent from certain waste-water treatment facilities.

North Carolina. Primary subjects of research in 1977 were studies of American eel and largemouth bass, the relation of a power plant to fish, and studies of the genetics of warmwater fish. American eel postlarvae (elvers) enter streams in the northeastern part of North Carolina a month later than in streams farther south in the State. The numbers of elvers in 1977 appeared to be fewer than in previous years—possibly a result of the extremely cold winter in 1977. Efforts to determine

the effects of Eurasian watermilfoil on largemouth bass populations in North Carolina’s Currituck Sound were begun during the year. Watermilfoil was introduced to the Sound during the 1960’s and dense growths now occur in 60 to 75% of its area. Sampling demonstrated that, although largemouth bass are plentiful, many of them are heavily parasitized and are not in good condition. Phylogenetic studies of North American catfishes and armored catfishes by karyological and DNA techniques supported the concept that primitive fishes generally have higher amounts of DNA than do less primitive groups. Chromosome number, number of chromosome arms, and chromosome area were not correlated with DNA content of the cells. Trawl and gill-net samples in and near the intake canal of a power plant at the estuary of the Cape Fear River showed that there are significant changes in species and sizes of fish during an annual cycle. The major species caught were spot, Atlantic croaker, bay



The color of rearing units for walleye fry was shown to be important in studies conducted by the New York Cooperative Fishery Research Unit. Walleyes in neutral or dark-colored units were evenly distributed throughout an experimental trough and fed normally (left photo), whereas those in white or partly white units (right photo) were so strongly attracted to the white surfaces that they ignored all feeds offered. Uniformly lighted troughs of a dark or neutral color appear to be essential for the intensive culture of walleye fry. *Photos by L. Corazza.*

anchovy, and Atlantic menhaden.

Ohio. A 3-year study of the effect of channelization of warmwater fish populations in five Ohio streams was completed. Generally, stream channelization resulted in a reduction of diversity of species and shifts in community structure for both macroinvertebrates and fish. Macroinvertebrates, as represented in benthos and drift collections were dominated by riffle species such as hydropsychids, heptageniids, and elmids in the natural control areas, whereas slow-water forms such as oligochaetes and chironomids were dominant in channelized sections. Sunfishes, crappies, basses, and to some extent, catfishes, were all relatively abundant in control areas, but suckers and

minnows predominated in channelized areas. A series of artificial riffles constructed of large limestone boulders in conjunction with 2.5-m-deep excavated pools in the Olentangy River served to reduce stress on aquatic biota induced by channelization. Relative abundance, standing crop, and community structure of macroinvertebrate and fish populations in this area approximated those in the control area, and a successful sport fishery was provided. Drought conditions during the study period resulted in complete desiccation of the beds of some smaller streams that had been channelized, whereas control areas retained water. Fish and invertebrate populations seemed to recover to nearly normal conditions within a year if

refuges from the desiccated conditions were immediately accessible.

Oklahoma. Emphasis was on relations between certain aspects of reservoir ecology that can be artificially manipulated and the population dynamics of fishes, particularly largemouth bass. A computer model of the largemouth bass population in Lake Carl Blackwell was developed on the basis of data collected over 10 years, and changes in population structure were correlated with physical conditions in the reservoir. It was found that water levels at spawning and fluctuations before the spawning season were major factors in determining year-class strength of largemouth bass. (The possibility of strengthening chronically weak year classes of centrarchid basses was initially investigated, through studies of competitive interaction in ponds.)

Floating breakwaters constructed of used tires are commonly used to dissipate wave action and reduce shore erosion. Since high winds and the resultant turbulence have been shown to limit survival of eggs and fry of largemouth bass in Oklahoma reservoirs, the effects of floating breakwaters on the production of fingerling largemouth bass are being assessed. Wave height, surface and bottom currents, and apparently suspended solids and sedimentation rate were altered behind breakwaters, although the ultimate effects on populations of aquatic plants, benthic invertebrates, and fish are still not clear.

In other projects we investigated the influence of a heated effluent on northern and Florida largemouth bass and of artificial destratification on the dynamics of five species of fish. In both studies, conditions in the artificially altered areas had marked effects on growth and distribution (and probably survival) of fishes, even though fish apparently moved freely into and out of the modified areas.

Oregon. In laboratory experiments, both hatchery and coastal wild cutthroat trout had similar median survival times when exposed to constant and fluctuating lethal temperatures, such as those perhaps encountered in streams with clear-cut watersheds. Constant-temperature bioassay information was found to be useful in predicting the consequence of exposure to fluctuating temperatures. Standards of the Environmental Protection Agency appear to be satisfactory when applied to situations where fish are exposed to fluctuating lethal temperatures.

A biochemical genetic evaluation of steelhead trout and chinook salmon from the Rogue River basin indicated that gene frequencies did not differ between year classes and that there are no marked differences between races of salmonids within the Rogue system. In investigations of the adaptive significance of certain enzyme polymorphisms in steelhead trout, we found that resistance to high temperature or low dissolved oxygen appears to be a heritable trait correlated to



Floating tire breakwater used to improve recruitment of young largemouth bass in a wind-swept cove (to the right of the photograph) of an Oklahoma reservoir. *Oklahoma Cooperative Fishery Research Unit photo.*

isocitrate dehydrogenase and perhaps lactate dehydrogenase. Such differences may account for the predominance of some phenotypes in interior stocks of steelhead in Oregon.

Underwater surveys, creel censuses, and scale analyses were used to evaluate the wild trout sport fishery on a fork of the Willamette River, Oregon. Size restrictions were found to be the most useful means of selectively limiting trout harvest. The North Fork can continue to support a catch rate of 0.3-0.5 trout per hour.

In selective breeding, heritability, and evaluation-of-performance studies with steelhead trout and salmon, we found that the time of return of winter adult Alsea Hatchery steelhead had shifted to an earlier run. Selection for size had increased the average age at maturity of steelhead in a summer run. Steelhead under intense selection had reduced survival. Steelhead from the Alsea River, Oregon, are phenotypically more similar to adjacent stocks than to distant ones, and this relationship is linear with distance. Artificial selection could be used to increase the number of sockeye salmon that can tolerate infectious hematopoietic necrosis. We also found that inbreeding, as perhaps occurs in hatcheries, did not affect survival, growth, feeding efficiency, or resistance to gas bubble disease. Behavior tests indicated that hatchery fry may be more aggressive, be more attracted to cover, and have smaller territories than do wild fry.

Pennsylvania. Studies of unproductive, naturally acidic trout streams of the Allegheny Plateau indicated that native brook trout have poor spawning success and reach maturity at small size. A prototype flow-through limestone device decreased acidity only slightly and had only minor effects on primary producer organisms (mostly diatoms) and invertebrate animals in the stream. In general, a more dense and diverse aquatic community was demonstrated in a similar but non-acidic stream nearby. When yearling smallmouth bass were exposed to increasing acidity, from pH 6.3 to 2.8 over an 8-hour period, there were no significant changes in cover use or swimming movements; however, coughs, gulps, rolls, and spasms increased during the first 4 hours. Rock bass ate the most abundant available zooplankton during the 1st year of life, but ate mostly mayfly nymphs during the 2nd year and then mostly crayfish. Intensive study of a "catchable-trout" stream fishery with multiple stockings of trout indicated that 83% of the trout stocked before the

season were captured, as compared with only 65% of those stocked during the season. Brook trout had the highest catchability, followed by rainbow and then brown trout. Nearly 25% of the total angler effort was expended on opening day, when 43% of the trout stocked before the opening of the season were captured. It was recommended that proportionally more brown trout be stocked to spread fishing pressure and opportunity. Preliminary observations indicated that natural coloration patterns may be used to distinguish individual wild trout for study of their use of time and space under natural conditions.

South Dakota. Construction of reservoirs on the Missouri River has greatly reduced the amount of spawning habitat for paddlefish in South Dakota. Artificial propagation of paddlefish will be necessary to maintain fishable stocks in some of these reservoirs. In 1976-77, one study conducted by the Unit was directed toward the development of techniques for the intensive culture of paddlefish. Two diets—the W-7 diet for cool-water fishes developed by the U.S. Fish and Wildlife Service and the commercial diet "Liv"—were tested. The W-7 diet was fed hourly and three times daily, and the Liv diet hourly. The average total length of fish after 40 days was 30.3 mm for fish fed W-7 hourly, 22.7 mm for fish fed W-7 three times daily, and 22.6 mm for fish fed Liv. Survival was significantly higher for fish fed the W-7 diet hourly than for those fed the W-7 diet three times daily or the Liv diet hourly. Among paddlefish reared at two water temperatures (15.6° and 21.1°C), survival and growth after 40 days were significantly higher for fish reared at the higher temperature. Total length of the fish averaged 118 mm at the higher temperature and 52 mm at the lower temperature. In an experiment conducted with different fungus control agents on incubating paddlefish eggs, eggs were treated daily with either formalin at a concentration of 1,667 ppm for 15 minutes or with malachite green at a concentration of 65 ppm for 2 minutes. Hatching success was significantly higher for eggs treated with malachite green, and survival of fry 23 days after swim-up was significantly higher for the fish hatched from eggs treated with malachite green.

Tennessee. Movement patterns of white crappies and striped bass were studied in J. Percy Priest Reservoir, Tennessee, by surgically implanting ultrasonic transmitters into the body cavity and tracking the fish with radio receivers. Crappie



The culture of paddlefish—fungus control, optimum temperature, food, and feeding rate—was studied to develop propagation techniques that will ensure the perpetuation of stocks whose natural spawning grounds in the Missouri River were greatly reduced by dam construction. *Photo by R. L. Brandt.*

movement depended on time of year, water level, and water temperature. Striped bass were usually found with a school of similar-sized fish, and movement patterns were mainly related to water temperature. Striped bass were least active during the summer, when water temperature exceeded 28°C. Individuals of both species tended to concentrate their activity within a limited home range.

Rates of angler harvest of largemouth bass, smallmouth bass, and spotted bass have been estimated for 2 successive years in Center Hill Reservoir, Tennessee. Numbered tags were applied to about 3,000 black bass, and tag returns were encouraged by offering rewards to anglers. Data indicate that about 20% of each species is harvested annually. This information, in conjunction with studies on other mortality factors, will be used to determine if additional creel or size limits should be recommended for the Center Hill bass

fishery.

Effects of a commercial fishery on striped bass and other sport fishes have been evaluated in Watts Bar and Chickamauga reservoirs, Tennessee. Gill nets and trammel nets were used for 12 months in a manner identical with that of commercial fishermen. Catches of striped bass were low in relation to those of nonsport species, indicating that commercial fishing probably does not seriously affect striped bass populations in these reservoirs.

Utah. The rivers within the upper Colorado River basin have been and will be modified by man's search for irrigation water, hydroelectric power, and energy-producing mineral deposits. The distribution, habitat requirements, and life history of fish must be known so that they can be protected in the changing aquatic environment. We have given special attention to four species



The squawfish, which is endemic to the Colorado River basin, is the largest minnow in North America. Weights of 100 pounds and lengths of 6 feet have been recorded. Photo by C. Berry.

which have suffered drastic population declines in recent years and are now considered rare: the Colorado squawfish, the largest minnow in North America (weight up to 100 pounds); and three large fish with unusual humped backs—the razorback sucker, the humpback chub, and the bonytail chub.

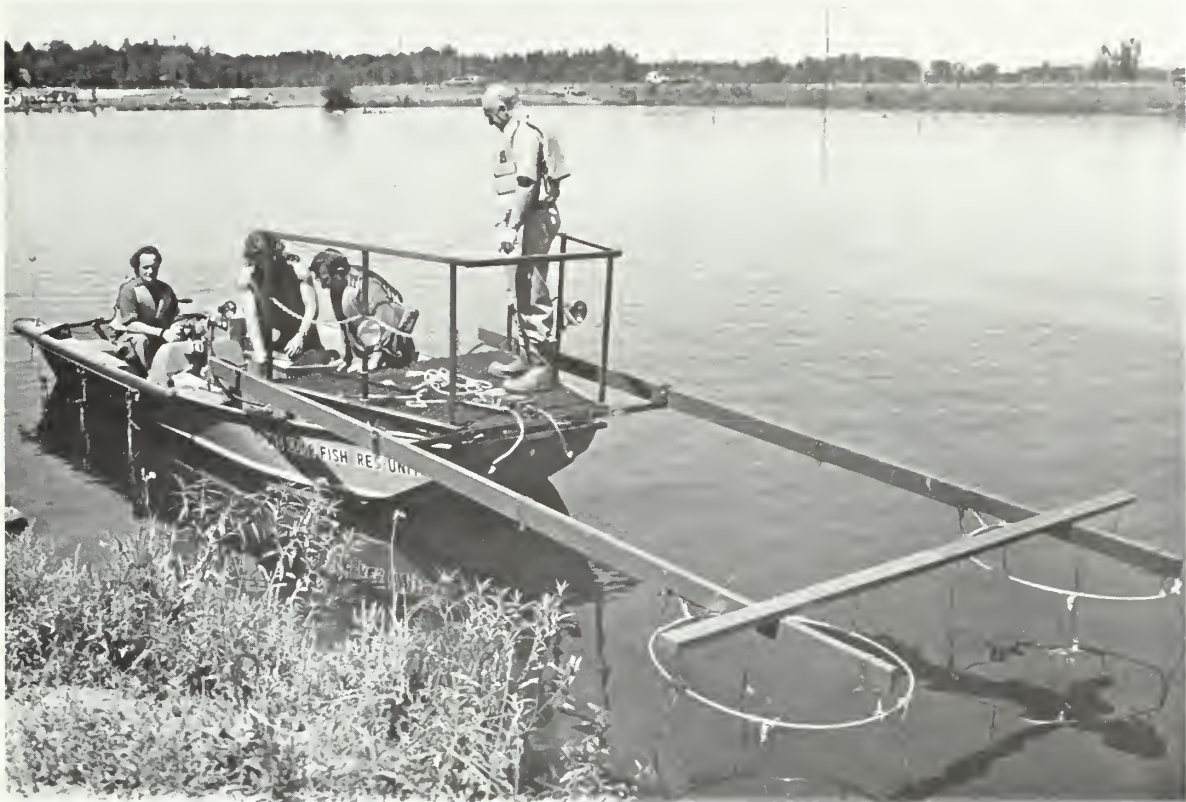


The razorback sucker is one of several humpbacked species of fish endemic to the Colorado River Drainage. Photo by C. Berry.

The fish were found only in the two largest rivers, the Colorado and Green, and at the mouths of major tributaries. So few specimens of the bonytail chub and humpback chub were found that no inferences on the biology of these fish could be made. Adult squawfish were found in pools and eddies over most bottom types. The razorback sucker was found in most river habitats. The reproductive success of each of these fish was considered poor.

An annotated bibliography of over 900 references, dealing with all aspects of the history and ecology of the Colorado River basin, was compiled. Information on habitat requirements of the fish fauna will be valuable in planning environmentally sound development of the resources within the basin.

Virginia. Water chemistry, physical characteristics, and fish populations were evaluated in five strip mine ponds on orphan mines in southwestern Virginia to determine whether the ponds offered possibilities for fishery management in an area where sport fishing opportunities are extremely limited. These representative ponds were slightly acidic and low in fertility; three showed indications of acid drainage pollution. All contained fish populations in various combinations of 11 species plus one hybrid sunfish. Growth of all sport fishes except largemouth bass was poor. Fish production in the ponds was low, as evidenced by a mean standing crop estimate of only about 60 pounds per acre.



The boom shocker, so named because electrodes hang from a boom in front of the boat, is commonly used in capturing fish for research. *University of Wisconsin-Stevens Point News Service Photo.*

In Virginia, stream channelization normally accompanies the construction of an upstream reservoir. Thus the downstream reaches are affected by both channelization and the presence of the reservoir. In four streams studied, the density of drift organisms tended to be higher, and that of benthic organisms lower, in channelized than in unchannelized streams. Densities of drift organisms increased markedly immediately below a small flood control impoundment (as a result of the influx of large numbers of organisms from the impoundment), but decreased rapidly as the distance downstream from the reservoir increased. Population estimates revealed that the biomass of both game and nongame fishes was only seasonally higher in areas with consistently high densities of drift organisms.

Washington. In the Pacific Northwest, intertidal mudflats and salt marshes at the mouths of rivers are often used for temporary storage of log rafts. These intertidal areas also produce large numbers of benthic invertebrates that are eaten by migrating juvenile salmonids and other fishes. For

this reason, the effects of log raft storage on intertidal benthos were studied on the Snohomish River delta near Everett, Washington, over a 2-year period. Invertebrate densities were determined under log rafts and in the same areas after the log rafts had been removed; densities in adjacent unrafted control areas provided a basis for comparison. About 80 to 90% of the log raft storage areas on the delta were on intertidal mudflats and marsh. This intertidal area had high populations of benthic invertebrates. Log rafts that settled on the substrate at low tides greatly reduced the number of species of benthos and their abundance. The rafts reduced the population of all the common species except *Anisogammarus confervicolus*, an actively swimming amphipod, within a few days. Recolonization of an area from which rafts had been removed occurred within 1 or 2 months. Rapid recovery from rafting events occurred both during winter and spring, although the process was slightly slower in the winter for some species.

Mass immunization of game fishes against dis-

ease agents has been one major goal of aquaculturists for the last decade. Achieving this goal has been delayed for a variety of reasons, one of which is the failure to develop a satisfactory delivery system that is economical. We recently completed a project dealing with an innovative method of hyperosmotic infiltration for immunizing rainbow trout that has potential commercial or industrial value for the immunization of fish against specific disease organisms. Bovine serum albumin (BSA) was used as a test antigen. BSA infusion could be achieved from a water-BSA solution, but about 10 times more uptake resulted when urea or NaCl was used at increased concentrations. The best BSA uptake was obtained by using Hank's balanced salt solution at 10X concentration. The longer the fish remained in the hyperosmotic solutions, the higher the plasma-BSA concentration. However, a 3-minute immersion was the upper limit which fish could tolerate. The lateral line was the primary target organ through which BSA entered the circulatory system, with somewhat lesser concentrations of BSA obtained via the gills. This process is currently being tested for commercial use.

Wisconsin. Among the 15 field and laboratory studies under way during the year was an assessment, by vertical starch gel electrophoresis, of the population genetic structure of the lake whitefish in Green Bay and northern Lake Michigan. Analysis of electropherograms of lactate, glycerol-3-phosphate, and malate dehydrogenase indicated that two populations exist in the study area. The Lake Michigan population included samples collected in two consecutive spawning seasons in Big Bay de Noc and at Seul Choix Point, Michigan, and the Green Bay population included samples collected during spring and summer in central Green Bay. Other samples, collected in North and Moonlight bays in Wisconsin waters of Lake Michigan, at Chambers Island in Green Bay, and in northern Green Bay, had allelic frequencies that overlapped those found at the other locations, and therefore appeared to contain fish of both populations. Both populations appeared to home to specific spawning grounds.

COOPERATIVE WILDLIFE RESEARCH UNITS

Alabama. The life history of the river otter was

studied through examination of 471 carcasses taken by trappers from 1972 through 1977 in Alabama and Georgia. Because relatively little was known about this economically and aesthetically important furbearer in the southeastern United States, the study was designed to determine reproductive parameters, sex and age structure, and major foods. Mean weights were 8.1 kg and 6.7 kg for adult and juvenile males and 6.7 kg and 6.3 kg for adult and juvenile females. Annulations in the dental cementum of canine teeth and the weights of dried eye lenses provided accurate indications of age. The baculum of the male, the degree of change in skull sutures, and the epiphyseal closures of the long bones were adequate only for distinguishing juveniles from adults.

River otters apparently breed in late winter through spring, implantation of fertilized eggs occurs from October to March, and parturition is believed to occur from late January through May. Ovulation rates in 59 females averaged 2.9 eggs per female, but the number of implanted fetuses averaged 2.6 (range, 1-4).

Analysis of 315 digestive tracts and 12 scats indicated that fish and crayfish were the principal foods. Fish, mostly sunfish, suckers, and catfish, occurred in 83.2% of the digestive tracts and 91.7% of the scats. Crayfish occurred in 62.5% of the digestive tracts and 58.3% of the scats. No evidence of significant predation on other vertebrates was found.

Eleven species of helminth parasites including five roundworms, three flukes, one tapeworm, and two acanthocephalans were found in the digestive tracts and the kidneys. Only four of these were considered naturally parasitic on river otters; the others were believed to be parasites of the ingested fish.

Sixty-five percent of the otters necropsied were males. The mean age of the otters, about half of which came from one trapper, was 5.4 years, with good representation in the older age groups up to 15 years of age. Life expectancies of otters in age classes 3, 7, and 11 were 3.4, 3.8, and 2.3 years, respectively, for males and 3.8, 2.6, and 1.9 years, respectively, for females.

Alaska. Breeding biology of the lesser sandhill crane was studied during 1975 and 1976 at Clarence Rhode National Wildlife Range on the Yukon-Kuskokwim Delta, the most important crane nesting area in Alaska. Breeding pairs and nonbreeding flocks of cranes were present by the 1st week of May in both years. Family groups re-

mained on territories through the brood season. Both breeding and nonbreeding cranes used wet areas extensively throughout the summer but increased their use of brushy tundra in August as berries ripened. Food items included a variety of plant and animal materials.

Two types of habitat dominate the study site: marshy areas with low shrubs and meadows of grasses and sedges. Twenty-six nests were found, mostly on slightly raised mounds in marshy areas and in grass-sedge meadows. Nests were usually constructed near open water from nearby dead vegetation.



This lesser sandhill crane chick was marked with a colored collar and leg bands to aid in determining migration routes and wintering areas. Photo by Cheryl Boise.

Nest densities of 0.54 nest per km² and 0.78 nest per km² were observed during 1975 and 1976, respectively. Nests were significantly closer together in marshy areas than in meadows. In marshy areas, ridges covered with low shrubs may function as visual barriers separating cranes, allowing closer nesting than in open habitats. Clutch size averaged 1.8 in 1975 and 1.6 in 1976. Predators took about 27% of the eggs in 1976, which may explain the lower clutch size that year. Hatching occurred from June 14 through July 1. In two-egg clutches, an interval of 1 or 2 days occurred between the hatching of the first egg and the hatching of the second.

Females devoted more time than males to feeding and attending chicks in one-chick broods, but

the two parents shared these duties about equally in two-chick broods. In 1975, 57% of the chicks survived to fledging, and 71% were fledged in 1976. Most chick losses probably occurred during the early rearing period. Chick losses in 1975 were probably increased by inclement weather and its adverse effect on food and feeding opportunities.

Ninety chicks and adults, captured with the aid of a helicopter, were marked with colored collars and leg bands. Nine resightings of color-marked birds were reported during fall migration and from wintering areas, and one banded bird was shot by a hunter. Information from resightings indicated that most birds from the Yukon Delta pass through southern Saskatchewan and winter in eastern New Mexico, northwestern Texas, and northern Mexico.

Arizona. White-tailed deer are common in most of the higher mountain ranges of southeastern Arizona. They are generally found at elevations where there is oak-woodland, pinyon-juniper, or other coniferous forest; they seldom inhabit desert areas. In 1976, the U.S. National Park Service contracted the Arizona Cooperative Wildlife Research Unit to study a relict white-tailed deer population living in the Ajo Mountains within the boundaries of Organ Pipe Cactus National Monument.

Field work on the project was completed in August 1977. The deer inhabit an extremely dry desert area unlike the remaining range of this species in the Southwest. Their existence seems to be made possible by natural *tinajas*, small water holes in the rocks. Although heavy grazing by cattle and feral burros is a major problem in the Monument, neither these domestic animals nor mule deer inhabit the same areas as the white-tailed deer. The only competing species in the whitetail range is the desert bighorn sheep.

The white-tailed deer in this desert area are present in very small numbers. The only recommendation made to help them is to curtail the use of the area by hikers.

An intensive study of nesting Harris' hawks in Pima, Pinal, and Maricopa counties was continued through its 2nd and final year. A total of 392 nesting attempts were recorded during the 2-year period (232 in 1977). Of this number, 305 (78%) were successful. When the final observations were made, 646 young were still alive and probably survived to fledging.

Nesting was largely restricted to the saguaro-palo verde vegetative zone. The robbing of nests

by falconers from California poses a serious problem for the hawks, but a greater danger is the destruction of their very limited habitat by the sporadic invasion of trailer towns.

The coyote is one of the few contemporary species that has extended its range and increased its numbers. The controversy attending the species stems in large part from a lack of ecological information. The objectives of this study were to: (1) delimit their home ranges, (2) estimate relative abundance throughout the year, (3) observe and describe their overt behavior, and (4) assess their sociability.

Coyotes were studied on the Santa Rita Experimental Range and adjacent areas from October 1973 to March 1975. Home ranges of 13 coyotes were estimated from radio locations, sightings, and capture sites. Home range areas were calculated with both irregular polygons and ellipses that averaged 21.0 and 29.3 square miles (54.4 and 75.9 km²) for adults and 2.6 and 3.7 square miles (6.7 and 9.6 km²) for immatures.

The relative abundance was estimated about every 4 weeks along a 14.7-mile (23.7-km) scent post route. Throughout the year the index varied; abundance was highest in February and lowest in May. The population appeared to be decreasing over the period of the study. The scent posts nearest a known high concentration of coyotes were visited most frequently.

Coyotes interacting at a concentration point, a cattle carcass dumping area, were observed for 171 hours; as many as 38 coyotes were seen at one time in this area. Home ranges appeared to have been extended to include the carcass area. Young animals used the area more than adults; perhaps it is important for pup survival.

Similar constant and abundant sources of food such as garbage dumps and hog carcass dumping areas may influence the distribution and population dynamics of coyotes in other areas. When these areas are near suburban developments, the problems associated with human-coyote interactions may be increased.

Colorado. Investigations of mortality and movements of juvenile white-tailed ptarmigan were conducted on 16.9 km² of alpine habitat along Trail Ridge Road in Rocky Mountain National Park, Colorado, from May 1975 through January 1977, with particular interest in causes and timing of juvenile mortality and fall dispersal movements. Nest success ranged from 60% (1975) to 54% (1976); all nest loss was attributed to

predation. Clutch size averaged 5.6 eggs, and 89% of the eggs in successful nests hatched. Movements to summer habitat averaged 35 m for seven broods with known nest sites. Repeated observations of nine broods indicated that summer movements were restricted within an average home range of 15.4 ha. Chick mortality approached 34% within 2 weeks posthatch; predation was a primary cause. After chicks reached 2 weeks of age, additional mortality was less than 10% until brood breakup. Early fall snowstorms provided the impetus for brood breakup and dispersal by causing broods to abandon summer habitat. Juvenile females moved significantly greater distances (up to 8.4 km) during fall dispersal than juvenile males.

Public agencies responsible for the management of mountain lions are faced with the problem of not having a formalized, quantitative, and objective method of evaluating the influence of various levels of lion harvest on the welfare of any given lion population. The objective of this study, initiated in 1976, was to develop a population model that would mimic the essential features of any given mountain lion population and provide information helpful in making harvest management decisions. The model (LIONPOP) is a modification of a generalized population model (Program ONEPOP) that is now being used in deer, elk, and antelope management programs in Colorado. LIONPOP was designed to fit the biological and life history properties peculiar to mountain lions. Such properties as birth of young at any time of year and immigration to or emigration from a population are provided for within LIONPOP. LIONPOP uses data on the reproduction, natural mortality, harvest, and dispersal of any given mountain lion population to simulate the population trend over time. Outputs of LIONPOP include information on population size, age-class structure, birthrates, and harvest statistics. This model can be used to determine which of several management alternatives might be most likely to attain a desired management objective for a population. The computer programs of LIONPOP have been made operational for both a batch and an interactive computing system.

The energy expenditures and heart rates of active mule deer fawns were measured to ascertain the relationship between heart rate and energy expenditure. The objective was to obtain improved estimates of the energy requirements of fawns. These estimates are used in predicting the carrying

capacities of critical winter ranges. The results would also be useful to investigators interested in using the telemetered heart rates of deer to quantify their physiological responses to man-caused disturbances.



This immobilized mountain lion is an average-sized adult female which weighed 77 pounds. Photo by E. G. Currier.

Energy expenditure was estimated by respiratory collections made with a face mask. The face mask was connected by a hose to a respiratory meter that measured the volume of expired air and took a sample for later oxygen analysis. Four fawns were hand-reared from birth and trained to wear a face mask and to accept the extensive handling required. Of the four fawns, three at 6-9 months of age were used for the experiments. One hundred ten measurements of energy expenditure were made during trials of 7-30 minutes, including 11 measurements on fawns fasted 48 hours or

more. Activity during trials included bedding, standing, walking, and trotting.

There were high correlations between heart rate and energy expenditure for individual deer over the range of activities and levels of feed tested, but a single relation did not hold for all deer. Heart rate could be used to predict energy expenditure for a specific deer for which the relation between two variables has been found, but such an equation could not be applied indiscriminately to other deer.

Idaho. The 1973 edition of *Threatened Wildlife of the United States* listed the wolverine under "Status-Undetermined Mammals." A status-undetermined species is "one that has been suggested as possibly threatened with extinction but about which there is not enough information to determine its status." Although the wolverine has a vast range in the northern latitudes around the world, few scientists have attempted to study wolverines in their natural habitat.

In 1973, the Unit initiated an investigation of wolverine populations in northwestern Montana. The research was designed to study wolverines by observing marked individuals in a free-ranging population. Wolverines were captured in live traps and immobilized with drugs; they were then individually marked, fitted with collars containing miniature radio transmitters, and released for future identification. By locating and following these radio signals, individuals were studied, undisturbed, through a season, from season to season, and year to year.

A total of 24 different wolverines were captured. Twenty of these have worn radio transmitters for continuous periods up to 30 months. More than 900 recorded radio locations have supplied information on range and movements, food habits, seasonal habitat use, and many other aspects of the wolverine's biology and ecology.

Concurrent with work on wolverines is an appraisal of their suspected food supply—small mammals. The numbers and kinds of small mammals such as ground squirrels, mice, and voles were investigated in different vegetative types.

It is hoped that this research will not only provide knowledge about this little-known animal, but will result in better management of the wolverine wherever it occurs.

Iowa. Questionnaires were mailed to 1,500 successful hunters and 1,500 nonhunters to determine their attitudes toward a variety of outdoor issues. Hunter responses were grouped for analysis under

the following headings: quail hunters, rabbit-squirrel hunters, waterfowl hunters, furbearer hunters, avid generalist hunters, and casual generalist hunters. Value judgments varied among different types of hunters, and meaningful subgroups exist. Quail and waterfowl hunters could be combined as bird hunters on the basis of their similarities. Furbearer hunters could be subdivided into fox-coyote and raccoon hunters. Hunters who limited their hunting to one species had generally started hunting that species before 16 years of age. Giving up hunting may span several years, and many of the casual general hunters may have been in the process of ceasing to hunt. Among nonhunters, 11% were against hunting, 10% against land-use regulation, 22% against trapping, and 33% against gun control. Percentages for the first three issues were 65, 51, and 66. Fewer people were neutral (16%) toward gun control and 51% favored it. Socioeconomic background, knowledge of wildlife management principles, and familiarity with publications related to natural resources were all interrelated with attitudes toward hunting. Prohunting groups favored the present system of game management; anti-hunting groups wanted more of their tax dollars used for wildlife conservation, placed greater emphasis on nonhunted wildlife, and favored an increase in the number of wildlife managers and biologists. Both groups agreed that more land ought to be purchased for wildlife, and this agreement can provide the basis for a common conservation effort.

Louisiana. From February to August 1976, a survey of gull, tern, skimmer, pelican, cormorant, anhinga, heron, egret, and ibis colonies on the Louisiana-Mississippi-Alabama coast was carried out. Both aerial and ground-based inventory techniques were employed. One hundred sixty-eight colonies, including over 847,000 breeding birds of 26 species, were found in habitats ranging from swamp forests to coastal marshes and barrier islands. Heronries were active from February through July; seabird colonies were active from April through August.

Reliability of the various census and sampling methods was evaluated as applied to the 26 species in diverse nesting situations. Aerial photography produced accurate censuses of incubating great egrets, sandwich terns, and royal terns. Randomly placed belt transects 2 m wide yielded representative samples of active nests on very large shrub heronries.

Only 18 of the 168 colonies were protected either by posting or by restricting human access.

Maine. The ecological impact of Interstate 95 on small and medium-sized mammals, songbirds, and white-tailed deer was studied in northern Maine. Total numbers of small mammals were greater near the highway than 300-400 m distant but catches of individual species differed. Small mammal diversity was also greater near the road than away from it. Track counts suggested that fishers avoided the highway, red foxes and coyotes were attracted to the right-of-way, and red squirrels, snowshoe hares, and weasels were unaffected. Observations indicated that woodchucks, raccoons, muskrats, beavers, and porcupines used or were attracted to habitats created by highway construction.

Breeding bay-breasted warblers, Blackburnian warblers, winter wrens, and blue jays were less abundant near the highway, whereas chestnut-sided warblers, common yellowthroats, white-throated sparrows, robins, wood thrushes, and Tennessee warblers were more numerous. Wintering birds in the areas near the highway were unaffected. White-tailed deer made less use of forest habitat within 100 m of the forest right-of-way edge than at greater distances.

Sixteen bird species were observed and seabird colonies were found on 310 of Maine's coastal islands. Common eiders, Leach's storm-petrels, herring gulls, cormorants, and great black-backed gulls were the most abundant nesting seabirds. The seabird colonies were photographed to document habitat types, disturbances, and locations. The majority of bird islands are privately owned. A literature review and a search of unpublished records clearly show the traditional use of many islands by nesting birds.

Massachusetts. Although in most years breeding activity in a beaver colony is confined to an adult pair, sexually mature male and female progeny are present and will reproduce if one or both adults are removed. To assess behavior and reproduction in progeny, one adult in each of 18 complete colonies was either surgically sterilized (tubal ligation or castration) or sham operated in summer 1975. Sham operations were performed in four control colonies. Behavioral and reproductive responses to these treatments were measured until August 1976. Reproduction was normal among the controls but 11 of 13 treated colonies did not reproduce; the 14th colony dispersed before parturition. The results suggest that breeding

behavior of progeny is affected more by the adults' presence than by their breeding condition (castrate or ligate).

In a second study, the impact of stream channelization on wildlife was documented on Vermont's White River watershed 1 and 2 years after riparian and stream habitats were altered. Birds were significantly reduced in total numbers and number of species, especially where removal of streamside vegetation had been excessive. Thrushes, vireos, and particularly the warblers, were significantly lower in number in channelized areas. So were shrews, jumping mice, and white-footed mice, although the latter (the most abundant small mammal) recovered rapidly the 2nd year. No gross differences were documented for the common furbearers. On the positive side, modification of the habitat provided open aerial feeding for swallows and beach-like habitat for sandpipers; these species increased in channelized areas. The American toad also benefited by the inadvertent creation of breeding pools behind bulldozed berms and piles of debris.

Missouri. An expandable collar fitted with a transmitter was developed to monitor movement and mortality of juvenile coyotes in Missouri. A mortality rate of 56% was estimated from May through December for yearling coyotes. Daily movements of coyotes 4 weeks to 9 months old averaged 0.24 km but increased with age. Coyotes were less mobile in dense cover than in row crops. The mean home ranges were 11.8 km² for juvenile females, 1.8 km² for juvenile males, and 8.7 km² for adult coyotes. Dens were usually situated on southerly slopes in relatively well-drained soil on creek banks, pond banks, and eroded gullies. The average distance between occupied dens was 1.2 km.

Seventy percent of 69 Canada goose nests located in 1974 and 1975 along the lower Missouri River were on river bluffs. Parent geese moved their broods from the bluffs to rearing areas that included islands, sandbars, or quiet-water areas. In summer, nonbreeding geese migrated to Ontario and Wisconsin to molt, returning in September. In fall and winter, geese frequented nearby private lakes and farmland. Expansion of the flock was limited by scarcity of nest sites and brood-rearing habitat. Management recommendations include an annual aerial census, protection of island and backwater brood-rearing areas and nesting bluffs, and the provision of rock ballast on railroad tracks to permit easier crossing by

goslings.

A set of criteria to evaluate terrestrial habitats was developed and presented in handbook form to use with the Habitat Evaluation Procedures of the Fish and Wildlife Service. Selected game species serve as evaluative elements on the basis of their food, cover, water, and reproductive requirements. A selected literature review is provided. Results of field tests indicate that use of the handbook, with its specific guidelines for scoring habitat quality, reduces variability in scoring and thus makes scoring repeatable. Recommendations include the development of a handbook for non-game species, evaluation of seasonal habitat needs, and further testing of habitat evaluation procedures.

Distribution of wintering bald eagles in southeastern South Dakota was influenced by the location of a food source and the availability of an area protected from the wind. Goldeye, gizzard shad, and white bass were the major fish species consumed. Mallards, rabbits, and pheasants were the most common species in cast pellets of bald eagles. Eagles preferred tree perches to all other diurnal perches and favored those in close proximity to the Missouri River. There were five roost sites, two of which were communal. Aerial counts and ground censuses of eagles yielded similar results.

Moist soil impoundments at Mingo National Wildlife Refuge provided important animal and plant protein for prenesting blue-winged teal. Invertebrates accounted for 69.5% of the female teals' diet and 60.0% of the males'. The major foods were snails, insects, and crustaceans. Most waterfowl used water areas 10-25 cm deep, but depth varied with the season. Shorebirds preferred water areas 1-5 cm deep interspersed with mud flats. Unflooded agricultural areas supported only 13% of the food species found on moist soil impoundments.

Within the last decade the Bachman's sparrow has established breeding populations in several southern Missouri glades. Thirteen territories averaged 0.62 ha, and dominant vegetation on these sites included little bluestem, black-eyed Susan, and eastern red cedar. The sparrows preferred areas where woody plants (shrubs and crowns of trees) covered less than 33% of the area and good grass cover was present. There is sufficient habitat for the expanding population. Management recommendations include maintaining the requisite balance between grassy and



Wildlife biologists field-testing and comparing systematized procedures for evaluating terrestrial habitat. *Photo by Thomas Baskett, Jr.*

woody cover by burning and light grazing.

Montana. To determine whether lead pellets in the rooting environment of aquatic plants cause them to assimilate and accumulate lead, aquatic plants were collected from wildlife refuges where large-scale lead poisoning of waterfowl had occurred. Also, aquatic plants were grown under controlled greenhouse conditions with artificial introduction of lead into the rooting environment. Lead from shot pellets appeared to transfer through the aquatic plant food chain under natural and laboratory conditions, and the levels of lead in rooted aquatic plants grown in areas of

high lead-shot accumulations were as much as 240% greater than control amounts.

Although fatal poisoning via food-chain accumulation of lead is not a certainty in hunted-over areas, the lead content of plants in the normal diet of wild waterfowl may conceivably be exacerbating existing toxicity from ingested lead shot.

A study of winter habitat selection by bighorn sheep in the Cabinet Mountains of western Montana indicated a preference for cliffs, areas with a slope greater than 80%, south aspects, areas within 300 m of steep terrain, shrubland-grassland



A recent study in western Montana indicated that bighorn sheep were seldom farther than 300 yards from steep terrain. The perpetuation of shrubland-grassland and open forest by prescribed burning near steep terrain was recommended for maintenance of optimum bighorn range. *Photo by Bart W. O'Gara.*

and open forest, and rockland-scrub. Measurements taken at a small number of bedding sites indicated that night beds may be associated with conifers. The perpetuation of shrubland-grassland and open forest by prescribed burning was recommended when canopy coverages warranted conifer removal on the winter range.

A survey of wolves within the historical range of the northern Rocky Mountain wolf indicated two subgroups in Montana. One was in the northern part of the State centered around Glacier National Park and the Bob Marshall Wilderness Area; the other was in the Beaverhead National Forest of southwestern Montana. Wolves of the southern group had more characteristics of northern Rocky Mountain wolf than those of the northern group. The survey indicated a possible minimum of 17 to 23 wolves in Montana and Idaho.

The behavior and ecology of Harlequin ducks breeding in Glacier National Park, Montana, were investigated between 1973 and 1976. Breeding success was directly related to the timing, duration,



The pileated woodpecker is very sensitive to timber cutting practices in the Northwest and can be considered an indicator taxon of how cutting is affecting cavity nesters. *Photo by Riley McClelland.*

and intensity of spring runoff. The birds fed almost entirely in running water and typically selected loafing sites in midstream. Only three

adult females were banded during 1974; all three returned to the study area for the breeding seasons of 1975 and 1976. Recommendations were made to preserve or recreate pristine conditions along breeding creeks and to formulate comprehensive plans for minimizing the impact of humans in sensitive areas.

A study of sheep mortality on a single ranch was terminated on 30 September 1976, after 2½ years, when the rancher sold his property because he felt that coyote predation made it impossible for him to raise sheep profitably in the Bitterroot Valley of Montana. Despite predator control during the latter half of the study, 1,272 lambs and ewes were killed by coyotes. Because coyotes are highly mobile, the elimination of coyote damage was impossible without an extension of control over an area much larger than the single ranch.

New York. A study of the effects of orchard pesticide applications on breeding robins has been completed. From 1966 through 1968, robins reproduced successfully in commercial apple orchards that were periodically sprayed with DDT, dieldrin, and other pesticides. Observations revealed that breeding robins obtained virtually all food for themselves and their nestlings from unsprayed areas adjacent to the orchards. Trapping in sprayed and unsprayed areas showed that invertebrates were 5 or 6 times more abundant in unsprayed habitat. Earthworms forced to live in sprayed orchard soil displayed significantly greater mortality than controls. Mean clutch size of robins in the study orchards were lower than those reported for robins in other studies, perhaps because of food shortages or increased foraging distances. Levels of DDT and its analogs in food items from robin foraging areas did not exceed 8 ppm (wet-weight basis). From late April to July, adult robins showed small but significant increases in DDE levels in all tissues examined as well as an increase in dieldrin in brains. Pesticides sprayed on the orchards had no direct demonstrable adverse effects on robins; productivity was high and adult mortality low.

Ohio. Yellow-crowned night herons were studied from April through August, 1975 and 1976, on Drum Island, Charleston County, South Carolina, to learn their breeding behavior patterns. Field techniques included observation from blinds, inspection of nests, color-marking and leg-banding of nestlings, and flight line counts. Breeding activity that began in early April included calling; flying; stretch, greeting, and forward dis-

plays; bill clapping; preening; stick-fidgeting; and copulation. Egg laying and incubation by the 150 adult pairs began in mid-April. Average clutch size was 4.2 in 1975 and 3.2 in 1976; hatching success was 66% and 68%. Sibling rivalry accounted for 44% of chick mortality in 1976. Juvenile growth rate was highest between days 20 and 25.



Weighing a nestling yellow-crowned night heron in a South Carolina heronry to determine its growth rate. Photo by Fred M. Bagley.

On randomly selected days from 1 September 1975 to 31 August 1976, 20,328 questionnaires were distributed and car counts made on 43 State wildlife areas in Ohio to learn the opinions, attitudes, and characteristics of users and to determine volume of use. Total estimated use was 2,633,321 ± 333,028 man-hours and was not significantly different in hunting and nonhunting periods. Fishing (53%) and hunting (23%) were the most common of 18 recreational activities. Most respondents (93%) purchased a hunting or fishing license, and 58% owned both. Visitor conflicts were not a significant problem.

Oklahoma. Sixteen coveys of bobwhites were



Nesting habitat of the woodcock is a subject of long-term study in central Pennsylvania. *Photo by George H. Harrison.*

followed during fall, winter, and spring in tallgrass prairie rangeland in east-central Oklahoma to determine home range size and habitat preferences within home ranges. All coveys showed preferences for specific cover types within home ranges. Birds spent most time during the day in shrubby cover. Grassland was used as roosting and nesting cover. Coveys did not abandon established home ranges when subjected to field trials. Fencing and adjustment of grazing pressure are the most efficient and economical methods of improving bobwhite habitat in tallgrass prairie rangeland.

Young white-tailed deer fawns were captured, fitted with radio transmitters, and followed in open grasslands and woody edges of the Wichita Mountains area of Oklahoma during 1974-75 to determine the fate of fawns in an unhunted deer population. Mortality rates for these fawns were 63% (1974) and 96% (1975). Losses to coyotes and bobcats, the major predators, were calculated to be 96.6% of the marked fawns for the 2 years. Coyotes were observed apparently searching for fawns in the vicinity of single does. Home range sizes were larger than those reported for fawns in other studies, which may indicate a reduced

nutrient base for deer. Succession of plant communities may be involved.

Eight types of guards designed to prevent beaver activity from plugging flow risers on flood control dams of the Soil Conservation Service were evaluated. Four of the types were unsuccessful in preventing plugging and subsequent flooding. The other four types prevented plugging. One type of guard was considered to be superior to the others and was recommended for further testing.

Individuals belonging to coyote sport-hunting organizations were surveyed in Oklahoma to assess the amount of recreation provided by the animal. Sport hunters surveyed owned an average of 9.7 coyote-hunting dogs and spent an average of \$2,516 and 87 days per year hunting coyotes.

Oregon. The influence of summer haying and winter grazing by cattle on the production of ducklings at Malheur National Wildlife Refuge was studied during the field seasons of 1974 and 1975. Some earlier studies indicated that light to moderate grazing had little effect on production of ducks, but more recent investigators concluded that production was reduced when vegetation was removed before the nesting season. Both livestock interests and conservationists have criticized



This pronghorn is being rewarded after completing a training session. The animal is being trained for use in a study of pronghorn nutrition. *Photo by Sandy Amazeen.*

refuge management.

Three fields were selected and three management plans were applied to the fields: (1) traditional use—hayed and grazed; (2) hayed but not grazed; and (3) neither hayed nor grazed. These three management methods did not affect distribution of breeding pairs. Nests were most abundant when both haying and grazing were excluded and least abundant when both haying and grazing occurred. The most important characteristic of nest sites was the amount of the preceding year's vegetation that was present at the beginning of the nesting season. Over twice as many ducklings were hatched on the field where haying and grazing were prohibited as on the field that was hayed and grazed.

Pennsylvania. A study conducted in central Pennsylvania in 1971-75 provided new information on the nesting habitat of American woodcock, their fall migration, and the characteristics of the State's woodcock hunters and their hunting effort. The study of nesting habitat was an initial phase of a long-term study of habitat-woodcock coactions in central Pennsylvania. The need for current biological information on woodcock has become more urgent as man continues to affect land-use patterns, plant succession, and woodcock mortality (through hunting).

Marked differences in certain habitat features were observed between 30 nest and 15 control sites. Average shrub stem densities were 394 per acre on nest sites and 236 per acre on control sites.

Average densities of sapling-sized trees were 22 per acre (nest sites) and 29 per acre (controls).

Band returns from 813 woodcock banded in Pennsylvania during 1939-74 numbered 63, a 7.7% recovery rate. Seventy-eight percent of the recoveries were within the State, which suggests that woodcock remain on the local breeding grounds during the summer and that they strongly tend to reuse these grounds during subsequent years.

The onset of migration from local breeding grounds occurred between 18 November and 8 December for nine radio-tagged woodcock. Two birds, each radio-tracked by aircraft for at least 1 hour, traveled 22 and 28 miles per hour, air-speed. Both birds migrated in a south-southwest and southwest direction.

In 1971-73, an average of 292 hunters made 3.9 hunting trips for woodcock per season, flushed 15.1, and harvested 5.1 woodcock per year. Eighty percent of the hunters bagged at least one woodcock each year.

Data provided by 246 woodcock hunters in Pennsylvania indicated that the average hunter is a male, 31-40 years old, who has had 16-20 years of hunting experience, but has hunted woodcock only 6-10 years. It was apparent from this study that woodcock in Pennsylvania provide a significant recreational opportunity for hunters.

South Dakota. The Missouri River has been greatly affected by water development. At present, only a 65-km section below Fort Randall Dam, South Dakota, and a 95-km section between Gavins Point Dam, South Dakota, and Sioux City, Iowa, remain unchannelized and unimpounded. The value of the undeveloped sections of the River to wildlife was measured, and habitat changes were determined from aerial photos taken in 1944 and 1974.

In 1974 farmlands and urban communities occupied 60% of the land area within 1 km of the unchannelized and unimpounded river. Six habitat types that made up the remainder of the area were sampled to determine vegetative composition and to evaluate their importance to wildlife. Cattail marshes with monospecific stands of narrow-leaved cattail were valuable to all wildlife, especially aquatic furbearers, waterfowl, other water and marsh birds, and herptiles. Areas where eastern cottonwood, red osier dogwood, and poison ivy grew were important for terrestrial fauna (except herptiles). Cottonwood-willow stands with clumped distribution of eastern cottonwood and

various willows supported big game and upland game birds. Elm-oak habitat was used by most types of wildlife, but its value was reduced by overgrazing of the understory and ground cover. Sand dunes were of fair value to most species of terrestrial wildlife.

Habitat changes that occurred from 1944 to 1974 included an increase in the ratio of water to land, an increase in the percentage of land under cultivation, and a decrease in the acreage of non-developed areas. Agricultural encroachment on wildlife habitat claimed 133 acres per year (1.7%) in the 30-year period. Channel expansion by erosion of shorelines converted 134 additional acres per year into water area or low transient sandbars. Sand dunes are the most endangered wildlife habitat measured in this study because the loss from erosion can only be replaced by major flooding. Management action is needed to preserve the wildlife habitat in the unchannelized and unimpounded section of the River.

Utah. Work continues on new methods to estimate population size from capture data. Several successful approaches have been developed to allow variability in capture probabilities. Methods of estimation have been evolved to allow changes



Over 500 newborn white-tailed deer fawns have been captured, marked, and released in studies conducted jointly by the Virginia Cooperative Wildlife Research Unit and the Denver Wildlife Research Center. Photo by R. L. Downing.



Profile view of a lioness in Tanzania, Africa.

in capture probabilities by time or by individual animal. Other methods allow for “trap-happy” and “trap-shy” animals in populations. Extensive test procedures were devised to permit selection of the most appropriate method of estimation. A large computer algorithm has been completed for easy and inexpensive analysis of capture data.

Virginia. Deer kill data collected over many years on State game management areas have been poorly utilized by deer biologists. Recent computer modeling developments provide a vehicle for the examination of these data. An attempt was made to demonstrate the usefulness of minimum population reconstruction in defining those populations that best contrast different harvest strategies. Buck-only deer hunting was compared with either-sex hunting on two similar areas.

To determine whether harvest in southeastern deer herds and hunter participation are altered by variables such as weather, we tested 25 individual

variables. Precipitation before the hunt and higher than normal temperatures before and during the hunt were positive contributors to harvest. Hunt days that followed nights of full moon also demonstrated a positive but generally weak association with kill.

The size of the deer population on an area and the number of hunters that participated were the most powerful contributors to overall deer harvest. An evaluation of vegetative density indicated that buck hunting was most successful on comparatively open areas, whereas doe harvest was highest on areas of denser vegetation.

Most surface coal mines that were worked before the passage of reclamation laws in the mid-1960's have now developed productive wildlife habitat through the processes of natural succession. A detailed analysis of the factors influencing vegetative succession on orphan mines by personnel of the Denver Wildlife Research Center and The Vir-



Male lions with small manes are indigenous to an area in Tanzania where competition between Masai cattle, zebras, and wildebeests for forage and water is under study.

Family groups of lions are often indifferent to human disturbance. *Photos by Burd S. McGinnes.*



ginia Cooperative Wildlife Research Unit revealed that chemical properties of the soil, primarily high acidity and a lack of potash, are the primary deterrents to the establishment of vegetation. Physical properties, such as slope, aspect, color, and particle size, were all less influential than chemical properties. Analysis of mines of different ages and of soils at different depths indicates that weathering is a slow process and, therefore, that reshaping and regrading the present surface of orphan mines will not make them more difficult to reclaim. Regrading should be avoided when possible, however, because of the hazard of increased erosion and stream siltation.

Evaluation of the wildlife use of 12 of these mines showed that approximately the same number of species of small mammals was present on 4 poorly vegetated, 4 medium-vegetated, and 4 well-vegetated mines. However, the number of individuals captured in 3 nights of trapping was related to density of vegetation; 57, 81, and 99 individuals were caught on the three types of mines, respectively. Populations of small mammals apparently are low on any orphan mine since only about one or two *Peromyscus*, the most abundant species, were caught per 100 trap-nights. In contrast, 11 to 13 were caught per 100 trap-nights on mines that had been reclaimed with sericea lespedeza. These early results of our study indicate that small mammals and the raptors and carnivores that feed on them will benefit from the reclamation of orphan mines if dense vegetation is successfully established.

On the other hand, songbirds were found in greater variety and abundance on poorly vegetated

and medium-vegetated orphan mines than on well-vegetated and reclaimed mines. It therefore seems unlikely that reclamation will benefit songbirds. Study areas contained 1.3 ha of mine and 0.6 ha of edge but had 21 and 34 species of songbirds. Bird watchers may find that orphan mines afford the greatest variety of birdlife within the entire Appalachian coal region.

Wisconsin. The relative precision and efficiency of 12 strip-sample methods were compared in songbird surveys in 79 deciduous woodlots in southeastern Wisconsin. Relative accuracy was calculated by comparing strip-sample estimates of songbird densities in six woodlots with the densities estimated by the international mapping method. All of these strip methods provided reasonably precise and accurate estimates of songbird densities and required only a quarter of the time necessary to obtain an estimate by the international mapping method.

An analysis of songbird communities in farm woodlots in southeastern Wisconsin revealed that physical characteristics of the vegetation accounted for 6 to 29% of the variation in woodlot avifauna. Disturbances such as grazing, lumbering, and the presence of human residences in woodlots had minor impacts, primarily indirect (changes in vegetation), on avifaunal characteristics. Size of the woodlot was the most important factor affecting the avifauna. In stepwise regression equations, woodlot size and physical attributes of the vegetation accounted for almost 50% of the variation in density, number of species, and bird species diversity.

Publications

Listed below are titles of articles published from October 1, 1976 to September 30, 1977 and a few papers published that were not listed in previous annual reports. The articles were published in technical and scientific journals, magazines, proceedings, transactions, and other media.

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Before initial development for a coal strip mining operation at East Decker, Montana. *Photo by Dean E. Biggins.*



After initial development for a coal strip mining operation at East Decker, Montana; coal storage silos in the foreground. *Photo by Dean E. Biggins.*



The black crappie (above) is a species whose spawning season coincides with that of the black basses in Bull Shoals Lake. *Photo by L. Voegelé.*

The largemouth bass (below) is one of the major sport fishes whose spawning habits are being studied underwater in Bull Shoals Lake. *Photo by L. Voegelé.*

