Fisheries and Wildlife Research

1982

Activities in the Divisions of Research for the Fiscal Year 1982

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Noel Snyder, field biologist for the U.S. Fish and Wildlife Service, Condor Research Center, carries a travel case containing a California condor chick from the chick's nesting site northeast of Los Angeles. The bird was captured in August, after biologists determined that the parents were not feeding the chick regularly. The chick was taken to the San Diego Wild Animal Park to begin a captive breeding program for this critically endangered species. Dr. Phil Ensley, veterinarian for the Zoological Society of San Diego, accompanied Dr. Snyder on the capture operation. *Photo by H. K. Snyder.*

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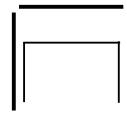
Foreword

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 1982 (October 1, 1981-September 30, 1982) 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

Research responsibilities within the Fish and Wildlife Service were carried out by the Division of Wildlife Ecology-Research, the Division of Fishery Ecology-Research, and the Office of Cooperative Units. During fiscal year 1982, these organizational entities and their field components 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 governmental 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 responsibilities, Research cooperates with agencies of the Departments of the Interior, Agriculture, Defense, and Health, Education, and Welfare; the Atomic Energy Commission; the Agency for International Development; the Environmental Protection Agency; and various State agencies, institutions, and private organizations. Completed research is communicated by talks and lectures, workshops, 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 12 major facilities, approximately 80 satellite field stations, and 50 Cooperative Research Units under the following programs: Environmental Contaminant Evaluation, Biological Services, Migratory Birds, Mammals and Non-migratory Birds, Animal Damage Control, Interpretation and Recreation, Fishery Resources, Endangered Species, and Cooperative Units. The planning, coordination, and administration of the research programs are centralized under the Office of the Associate Director-Research in Washington, D.C. Fiscal, personnel, property management, and other supporting services are provided to the field research facilities by the seven Regional Offices of the Service. By the end of fiscal year 1982, Research had 751 full-time permanent employees. The budget included approximately $36 million of appropriated funds and $7 million of other funds.

DENVER WILDLIFE RESEARCH CENTER

Sunflower Fields Protected from Blackbirds by 4-Aminopyridine Baits. In 1981, 4-aminopyridine baits, applied by hand in 20-foot swaths from baiting lanes, were evaluated for protecting ripening sunflowers from blackbird damage in six test fields in Ramsey and Benson counties, North Dakota. A split-field design (two experimental units separated by a buffer unit) and a 12-day test period (6 days pretreatment and 6 days treatment) were used.

In test fields with paired experimental units, untreated units lost 10,806 pounds of sunflower seed to birds during the 6-day treatment period, whereas baited units lost 5,143 pounds of seed, or 52% less. However, untreated units also had more damage during pretreatment periods and the adjusted losses on baited units were 43.6% less than expected during the baiting period.

Peak numbers of blackbirds damaging test fields ranged from 5,000 to 31,000 on individual fields during the test period. The species composition of feeding flocks was estimated to be 73% red-winged blackbirds, 20% yellow-headed blackbirds, and 7% common grackles. The estimated kill of 169 blackbirds was similar in composition. However, 30 of 34 birds seen giving distress displays were yellow-headed blackbirds. We found evidence that many redwings broke the chopped corn baits before consuming them. This lengthened response times considerably and contributed to lowered bait effectiveness.

Life History of Red-winged Blackbirds in North Dakota in Relation to Sunflower Damage. The problem of blackbird depredation on crops, particularly sunflowers in North Dakota, has stimulated the investigation of the life history of red-winged blackbirds in this area. Studies of food habits and molt of the redwing conducted by North Dakota State University under contract with the Fish and Wildlife Service (FWS) have recently been completed in Cass County, North Dakota.

The esophageal contents of 1,361 redwings, collected from mid-July through October in 1979 and 1980, showed that young-of-the-year birds consumed the same proportions of food items as second-year and older birds; males consumed more corn and sunflower seeds than females, but females consumed more weed seeds, especially foxtail. From 9 September to 6 October foxtail seeds made up 37% of the male and 75% of the female diets. Use of sunflower seeds by redwings was highest between 26 August and 6 October (the major sunflower damage season), when 71% of the male and 57% of the female diets were sunflowers.

Redwings collected for food studies were also examined for phenology of molt (N = 3,795). Second-year males were found molting in the second week of July, 1 week earlier than older males. After-hatching-year (AHY) females began molting the third week of July; by the last week of September some of these had completed molt. Hatching-year birds likewise began to molt in the third week of July, but some of these birds had not completed molt until the first week of October.

Start of molt among AHY birds may be related to nesting activities. Second-year males, generally nonbreeding, began to molt first, whereas breeding males tended to leave their territories before the females completed nesting. Breeding males also molted earlier than females. Molt progress indicates that by late September most of the local redwings have migrated and birds remaining in southwestern Cass County during October are transients.

The food habits findings point to some useful sunflower damage management strategies: diversification of crops to include those less attractive to redwings, planting less susceptible crops close to historic roosts, retention of stubble fields until crop harvest is completed, leaving foxtail stands in noncrop areas, and reducing foxtail in crop fields to minimize their attractiveness to blackbirds.

Bird Damage to Sunflowers in the Sacramento Valley, California, is Low. Sunflowers are grown in California primarily for use as seed and are therefore worth four to five times more per pound than sunflowers grown for processing. Large seasonal concentrations of blackbirds, and therefore the potential for an economically important bird depredation problem on ripening sunflowers, exist in the Sacramento Valley. To quantify the extent and severity of this problem and to provide a basis for any eventual research and management strategies,

an extensive survey of bird damage in sunflower fields was conducted in Butte, Colusa, and Glenn counties during 1980 and 1981.

Damage caused by birds to ripening sunflowers was evaluated in 60 fields (about 70% of all planted fields). Overall monetary losses in the sampled fields were about $6,800 (24 fields) and $7,400 (36 fields) in 1980 and 1981, respectively. Losses estimated for the individual fields were low, ranging from 0 to 5.4% of the crop; in about two-thirds of the fields, losses were <0.5%. For the 12 fields with the highest (1.0%) damage, the average per acre monetary loss was about $18. Damage levels within local areas were relatively constant between the two years. Although several species of birds caused damage, house finches were apparently most important. Their foraging behavior differed from that of blackbirds, which fed extensively on insects in addition to sunflowers. The presence of large numbers of blackbirds or finches in fields was not always an indication of bird damage.

Surveys of Bird Damage to Sunflowers Define Magnitude of Losses and Reveal Influential Environmental Factors. During recent years, sunflowers have become a major field crop in North Dakota, South Dakota, and Minnesota. The acreage peaked at about 5.3 million acres planted in this three-State area in 1979, then declined to 3.9 million in 1980. Along with the great expansion in sunflower acreage has come an increasing number of complaints of seed losses caused by blackbirds, primarily the red-winged blackbird. To evaluate the overall extent and severity of these losses, as well as to assess the influence of various environmental factors on the presence of bird damage, we initiated a 3-year damage survey throughout North Dakota, South Dakota, and Minnesota in 1979.

Based on a sample of 933 fields, about 56.8 million pounds of sunflower seed were destroyed by birds in the three States in 1979. A sample of 555 fields resulted in an estimated 75.3-million-pound loss in 1980 - a 33% increase over 1979. Only Minnesota showed a decline in bird damage from 12.1 million pounds in 1979 to 7.0 million in 1980. In South Dakota, however, the estimated loss increased from 3.9 million to 4.8 million pounds and in North Dakota, which had the largest sunflower acreage (2.3 million acres harvested in 1980) of the three States, the loss increased from 40.8 to 63.5 million pounds.

The large increase in losses for both North Dakota and the three-State area was primarily due to a particularly large loss of 21% of the crop in Stutsman County, North Dakota, in 1980. The loss in this county, estimated at 43.9 million pounds, amounted to 69% of the North Dakota loss and 58% of the three-State loss. Except in Stutsman County, which lost only 0.3% (1.0 million pounds) of its sunflowers to birds in 1979, bird damage actually declined overall in 1980.

The dollar loss for the three-State area increased by 75% from an estimated $5.0 million in 1979 to $8.7 million in 1980. Losses in 1979 and 1980 were $3.6 and $7.3 million, respectively, in North Dakota; $1.1 and $0.8 million in Minnesota; and $0.3 and $0.6 million in South Dakota. The increased dollar losses were due not only to the increased loss of sunflowers to birds but also to the higher (about one-third) value of sunflower seed in 1980.

From the results of these two field surveys, four counties were identified as having consistently high losses. To better evaluate the severity of the losses in such high-damage regions, we intensively surveyed 49-50 fields per county just before harvest in 1981. By measuring damage on a large number (250) of sunflower heads in each of the fields, more precise damage estimates were obtained than during either of the two previous surveys.

The field with the highest loss to blackbirds - about $81 per acre - was located in Benson County in north-central North Dakota. Within nearby Bottineau County, the two most heavily damaged fields each had losses amounting to about $25 per acre. In Brown County, South Dakota, about 200 miles to the south, the highest loss to a field was about $22 per acre.

Such high losses were the exception rather than the rule, however. Of the 199 total fields surveyed, only about 13% had losses that exceeded $6 per acre. Most (77%) of the fields had losses ranging from a few cents to a few dollars per acre and, in about 10% of the fields, there was no damage detected.

These results demonstrated once again that even in small regions where overall blackbird damage is relatively high, most of the sunflower growers have low losses, whereas a few have losses that range from moderate to very severe.

As part of the same 3-year survey, we attempted to relate certain environmental features of the fields to damage levels. In addition to measuring bird damage in each field, the following environmental factors were measured in an attempt to quantify their relationship to losses: field size, average plant height, average head size (area), distance between rows, average weed density in the field, the presence

A grackle, equipped with a leg-hold radio transmitter, is ready for release. The signal from the transmitter will allow researchers to follow the movements of the bird for up to 4 weeks. *Photo by J. F. Heisterberg.*

A cannon net is used to capture blackbirds for banding. Band returns will provide information on the nesting and wintering areas of these birds. *Photo by J. F. Heisterberg.*

or absence of certain habitat types, and the presence or absence of nearby marsh areas.

In 1979 the presence of a marsh close to the field was strongly associated with increased damage in the field. Wide row spacing and the presence of adjacent plowed fields, in the absence of a marsh, also contributed to higher damage. In 1980 the presence of a marsh was again strongly related to higher damage, whereas the presence of adjacent pasture land appeared to reduce damage. In 1981 only the interaction of weed density with the presence or absence of adjacent trees had a significant influence on damage in the fields. When trees were present, fields with low weed density had increased damage, fields with moderate weed density had reduced damage, and fields with high weed density again resulted in greater damage. It is noteworthy that although the presence of marsh areas strongly influenced damage in 1979 and 1980, it was unimportant in 1981, when the survey was conducted in only four counties of traditionally high damage. Apparently, blackbird populations are so large in such areas that they exert pressure on fields regardless of proximity to roost sites. Identification of habitat factors related to damage should help sunflower growers to better assess the need for bird control measures in their pest management plans.

Millions of Red-winged Blackbirds Marked by New Mass-marking Technique. In mid-March 1982 the first large-scale operational use of an aerial mass-marking technique, developed at the Denver Wildlife Research Center (DWRC), for birds was successfully conducted in northwestern Missouri. Objectives of the spray operation were threefold: (1) to determine the seasonal movements of red-winged blackbirds as they relate to fall sunflower damage in the Dakotas and Minnesota, (2) to map the overall distribution of redwings in the north-central United States and Canada as they dispersed from the marking sites, and (3) to evaluate the operational use, practicality, and durability of the markers for blackbirds.

Two cattail roosting marshes on and near Squaw Creek National Wildlife Refuge that contained an estimated 15 million redwings were sprayed by helicopter on two separate evenings, each with a different colored marker. The marker, a fluorescent resin particle which is a talcum powder-like substance visible only under long-wave ultraviolet light, was formulated in diesel fuel and boiled linseed oil. Redwings collected immediately following the spray operation indicated about 60% (9 million) were marked.

In May and June numerous cooperators from Federal, State, and Canadian wildlife agencies collected territorial male redwings and mailed the wings and tailfeathers to DWRC for examination. States in which collections were made included all or parts of North and South Dakota, Minnesota, Wisconsin, Iowa, Missouri, Kansas, Nebraska, Montana, Wyoming, Michigan, Illinois, and portions of the four central Canadian provinces. Several cooperators in States south of Missouri were asked to send samples as controls.

By early October 1982 about 3,000 of the 5,000 samples received had been examined; about 23% showed markers. Marked birds were recovered from as far north as Grand Prairie, Alberta, central Manitoba, and western Ontario, Canada. Each State listed above had a scattering of marked birds with the highest concentration in the Dakotas. This sampling indicates that birds congregating in a spring migration roost may subsequently disperse over at least a 700,000-square-mile area. Furthermore, the longevity of the marker is now known to be at least three months in the field.

Proadifin HCl Identified as a Synergist for Chemicals Administered to Birds. Since the early 1950's personnel at DWRC have been charged with the responsibility of developing methods for preventing damage caused by wild birds. One of the most important areas of research has been the development of chemicals for bird damage control. More than 2,000 chemicals have been tested as potential bird repellents, stupefacients, or toxicants, and several of these have been developed for use in circumstances where damage is severe and control is practical. The intent of this study was to determine if the biological activity of chemicals known to produce immobilization in many bird species could be enhanced by combining them with a synergist, such as Proadifin HC1. A synergist is a chemical that, when combined with another chemical, produces a response greater than the sum of the individual responses to each chemical administered alone. If synergism could be demonstrated, it would provide a method to reduce the amounts of potentially hazardous chemicals introduced into the environment. Demonstration of the synergism of the immobilizing or lethal activity of these chemicals would also suggest that additional research with toxicants and repellents might be warranted.

Probit analysis of our data showed that Proadifin HC1, administered orally and concurrently with each of four test chemicals (phencyclidine, nicotine sulfate, *alpha*-chloralose, and chlordiazepoxide) sig-

nificantly lowered the LD50 or TI50 responses of coturnix quail to these agents. Proadifin HC1 (100 mg/kg) lowered the LD50 of phencyclidine 2.35-fold, and the TI50 27.5-fold; it lowered the LD50 of nicotine sulfate 4.10-fold and the TI50 2.98-fold; and it lowered the LD50 of *alpha*-chloralose 1.56-fold and the TI50 2.03-fold. The LD50 for chlorodiazepoxide was apparently not affected (1,000.0 mg/kg), but it did lower the TI50 2.47-fold.

This study shows that the LD50 or TI50 of some immobilizing chemicals can be manipulated by the use of a synergist such as Proadifin HC1. The ability to manipulate these or other biological responses of birds to chemicals could have important implications in the development and use of chemicals in bird damage control.

Denver Wildlife Research Center-U.S. Department of Agriculture Cooperate on Testing Insect Repellents on Wild Birds. Scientists from DWRC and the Biologically Active Natural Products Laboratory of the U.S. Department of Agriculture (USDA) initiated an informal joint research program in 1979 to determine the repellency of a number of chemical insect repellents to wild birds. Following a progressive testing regimen designed to compare structure-activity relationships, 55 chemicals were tested through fiscal year 1982 for acute repellency and toxicity to red-winged blackbirds.

The bird repellent activity of most of the chemicals tested was less than the test method could detect and none of the chemicals were toxic to redwings at 100 mg/kg; therefore, meaningful structure-activity information was not obtained. However, 2 of the 55 compounds tested showed some potential avian repellent activity. One of the active compounds was trans-asarone, a natural component of wild ginger tubers and the other was safrole, which is a natural component of sassafras.

This cooperative effort has led to another informal research program to evaluate the bird repellent activity and toxicity of a new series of insect molt inhibitors developed at USDA laboratories.

Carbaryl Application Fails to Deter Blackbirds Feeding on Ripening Rice. A recent Ohio test showed that the insecticide carbaryl could be effective in reducing blackbird numbers in fields of sweet corn, probably by reducing insect populations that attract birds. Carbaryl is also registered for insect control in rice, a crop that sometimes is severely damaged by blackbirds, and for which no chemical bird repellent is registered. To test the effect of a carbaryl application on blackbirds feeding on ripening rice, we aerially sprayed a portion of an Arkansas rice field undergoing consistent feeding by red-winged blackbirds and brown-headed cowbirds with the chemical at the maximum registered rate of 1.7 kg/ha. Bird use of the treated area did not lessen after the application. Insect numbers appeared not to decline, although composition of the population changed. Further trials of insecticides to reduce bird numbers in rice fields are planned.

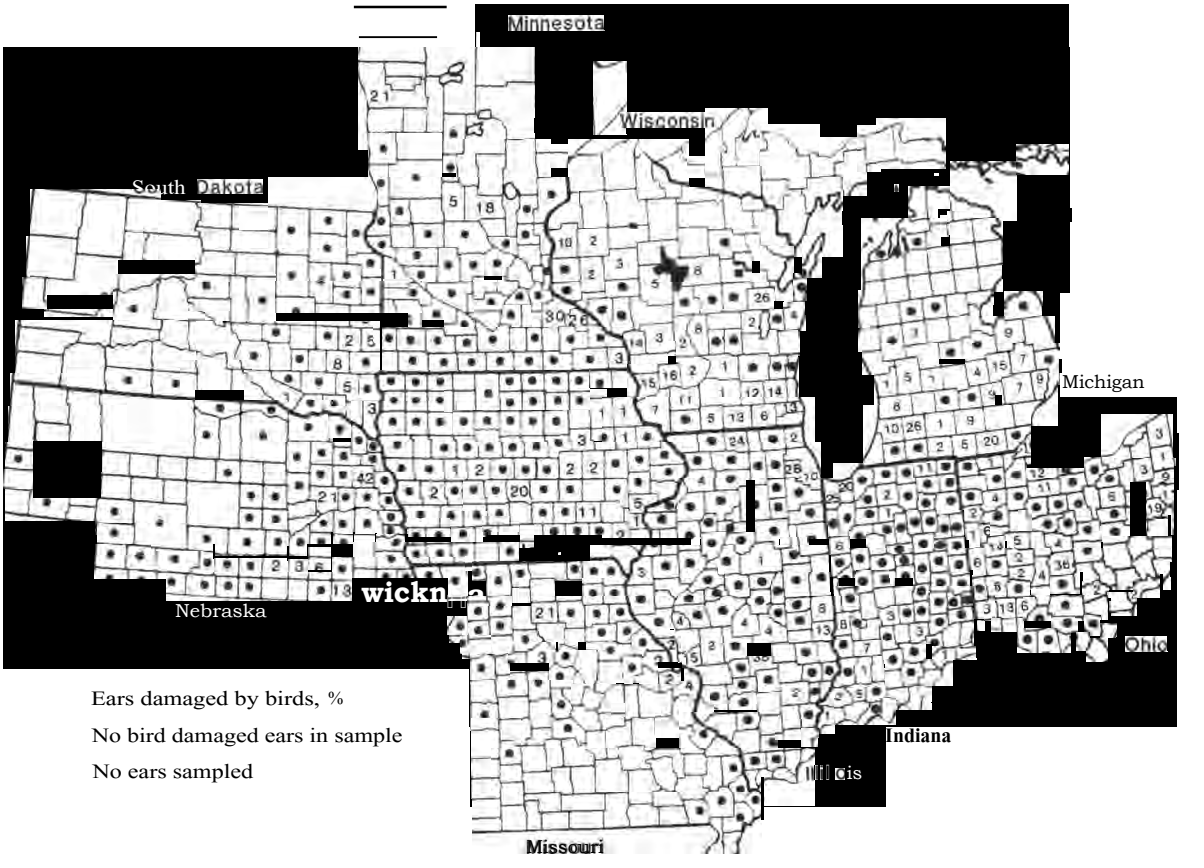
Bird Damage to Corn Increases in Past Decade. In 1981, in cooperation with the USDA, the third survey of bird damage to ripening corn was conducted in major corn-producing States. Previous surveys were conducted in 1970 and 1971.

The estimated loss to birds in the 10 States that grew 59.3 million (79.4%) of the 74.7 million acres in the United States in 1981 was 0.1293 (± SE 0.0174) bushels per acre. Total bushel loss, estimated to be 7.7 million bushels in 1981, was significantly greater than the estimated 3.1 million bushels lost in these States in 1971. The percentage of ears damaged in the 10 States in 1981 was 2.2 times greater (2.4% vs. 1.1%), and the percentage of fields damaged 2.1 times greater (18.5% vs. 8.7%) than in these States in 1971. At the November 1981 price of $2.60 per bushel of corn, the estimated loss in the surveyed States amounts to $20 million.

Populations of red-winged blackbirds and common grackles, the two blackbird species causing most of the damage to corn in the 10 States surveyed in 1981, have not increased at the same rate as damage to corn during the past decade. One can speculate that the increased use of herbicides and insecticides and the decreased acreages of small-grain stubbles, hay lands, and noncultivated lands have increased the proportion of corn in the blackbird diet.

Environmental Factors and Cultural Practices Influencing Bird Damage at Tennessee Feedlots Identified. Losses due to wintering blackbirds and starlings are reported in cattle and swine feeding operations from various locations in the United States. In the Southeast this problem is of particular concern because most winter roosting blackbirds and starlings are concentrated in this area.

Data collected on blackbird and starling damage, environmental factors, and management practices at 313 Tennessee livestock farms inspected during winter 1979-80 were analyzed for possible associations between the presence of bird damage and various farm management practices. Results indicated that farmers feeding grain (usually shelled corn) on the ground, over an area of at least 100 square feet and within 9 miles of a blackbird-starling roost,



Frequency of damage by birds to sampled ears of corn in counties of the 10 major corn-producing States of the United States.

were most likely to receive blackbird damage. Blackbirds were almost exclusively associated with ground feeding and normally gleaned grain particles from livestock manure and spillage on the ground, whereas starlings preferred feed troughs or feeders.

Starling damage occurred more than twice as often as blackbird damage and was most likely to occur at a livestock operation on days with snow cover or below freezing temperatures. Snow cover and frozen ground probably limited starling probing for soil insects, forcing the birds to search elsewhere for food. Farmers feeding at least 150 animals or a minimum of 500 pounds of grain or grain products throughout the day also were more apt to receive starling damage. Herd size and feed exposure data suggest that starlings selectively seek out farms with the largest sustained food supply within their foraging area. Farms that had at least 500 pounds of grain or grain products exposed all day were most likely to receive consistent damage throughout the winter, independent of weather conditions. This suggests that these operations may provide a food base for at least some of the local wintering starling population.

Results of this study suggest possible control strategies by pointing out the conditions in which damage is likely to occur. The best long-term strategy to reduce starling and blackbird damage would be to change feeding practices to limit the exposure of feed to these birds. Selective control of roosting starling populations may be warranted where a number of damage-susceptible operations are within the foraging area of these populations.

Methiocarb Fails as an Effective Roost Repellent. Although a variety of auditory and visual devices are available for dispersing problem roosts of blackbirds and starlings, effective use of these devices is time-consuming and can be costly, especially when one is purchasing firework-type devices or equipment for broadcasting bird distress calls. A technique to reduce these costs and possibly expedite dispersal would be to spray the birds or roosting vegetation with a repellent material. One chemical,

Analysis of factors influencing bird damage to livestock feed confirms that snow cover and related weather conditions greatly influence the incidence and severity of starling damage at many livestock operations. However, large operations with sustained feed exposure may provide a food base for wintering starlings and therefore may suffer consistent damage problems independent of weather conditions. *Photos by D. J. Twedt and J. F. Glahn.*

Of the various sizes of livestock feed, the use of a ⅜-inch-diameter pellet and granular meal was found most effective in reducing feed loss to starlings. *Photo by D. J. Twedt.*

methiocarb (Mesurol 75 WP), has shown excellent bird repellent properties when applied to a variety of food crops including grains and soft fruits.

Methiocarb was evaluated in two separate tests at a 1.2-ha Scotch pine planting in Tennessee containing about 650,000 roosting blackbirds and starlings. A total of 27.2 kg of Mesurol 75 WP was applied by aircraft to the roosting vegetation during the day while the birds were away foraging; 3 weeks later the same amount was applied after dark on the roosting birds. Although little feeding takes place at the roost site, it was hoped that the birds would come in contact with sufficient quantities of the chemical to cause dispersal through preening activities, inhalation, or skin absorption.

Results of bird population counts throughout the test periods showed that neither chemical application affected the roosting population. Based on results of this evaluation, further tests of methiocarb as a roost dispersal agent do not appear to be warranted. Nevertheless, the search for improved roost relocation techniques, both chemical and mechanical, will continue to have high priority in the ongoing effort to solve problems associated with winter roosting blackbirds and starlings.

Determining Livestock Feed Losses to Starlings—A New Approach. Livestock feed losses to wintering starling populations is a widespread problem throughout the United States. However, reliable estimates of these losses have been difficult to obtain due to the lack of a practical assessment method applicable to a wide range of field conditions. Past studies have indicated that starling populations at livestock operations may not be a good index of damage because starlings utilize a variable amount of livestock feed in their diet depending on the availability of alternate food and weather conditions. Thus, research efforts have focused on assessing feed lost by studying starling utilization and behavior at livestock troughs and relating this to feed consumption. Livestock-excluded troughs, containing several types of livestock feed, were placed at a livestock feeding operation and monitored with time-lapse photography and observers to sample starling trough use.

Results of this study indicate that starlings eat about 1 to 2 g of feed per visit to a trough, depending on feed type. Thus, based on an average consumption rate of 1.5 g per starling visit, a daily

projection of 1,000 starling visits would equal a loss of 1.5 kg of feed per day. In addition, reliable estimates of starling trough visits and feed consumption were obtained by an observer estimating the number of starlings that landed at a feed trough during four half-hour observations per day. Seasonal loss can therefore be estimated by sampling starling trough utilization for a number of days throughout the winter damage season.

The use of this trough visit method should provide researchers and farmers with a reliable method of determining feed loss to starlings, and therefore allow an accurate determination of the cost-benefits of proposed control measures.

Losses of Livestock Feed to Starlings Reduced by Changing Feed Size. Livestock producers have long considered the presence of starlings at livestock feeding areas (feedlots) to be a major economic problem because of the feed they consume. Research has shown that these feed losses can be reduced by changing the size of feed offered to livestock. In cage trials, captive starlings consumed lesser quantities of feeds compressed into 3/8-inch-diameter or larger pellets than pellets 1/4 inch in diameter or smaller. Feeds fed as granular meal were also consumed in lesser amounts than the smaller amounts of 3/8-inch-diameter pellets and granular meal compared with 3/16-inch-diameter pellets. Therefore, when feeding livestock in situations where feed is accessible to starlings, feeding granular meal or pellets 3/8 inch in diameter or larger can reduce feed losses to these birds.

Blackbirds and Starlings Change Winter Roost Sites Often. Concern by people living near a large blackbird and starling winter roost and by farmers within flying distance of the birds often results in requests to reduce bird-related problems. An important consideration when developing bird management control strategies at a winter roost is the stability of the roosting population. This study was conducted to determine the frequency with which birds changed roost sites, the location of these sites, and some of the factors affecting movements of birds among these sites.

From 1977 to 1981 studies of blackbird and starling movements among winter roosts were conducted in nine different areas in Arkansas, Kentucky, and Tennessee. Miniature radio transmitters attached to the birds' tails were used to follow the movements of 74 grackles, 58 starlings, and 34 red-winged blackbirds captured at nine different roost sites. The 166 birds subsequently used 82 different roost locations up to 45 miles from the roost where they were originally captured. Roosts used on consecutive nights by radio-instrumented birds were located up to 26 miles apart (average of 4 miles). Individual birds were radio-tracked an average of eight nights during which time they changed roosts an average of one out of every four nights. The frequency of roost changes did not differ among the three species, and birds were twice as likely to change roosts when snow covered the ground than when snow was absent.

The intermittent use of a roost by birds, the large number of different roosts in a given area, and the probable wide overlap of feeding areas of birds using these roosts all can negatively impact the effectiveness of lethal roost-control methods. Given these factors, lethal control at a single roost may only temporarily reduce agricultural losses to birds within the feeding area of the treated roost.

Despite movements which could be expected to cause repopulation of roosts, an effective control operation can sometimes result in a sustained reduction in bird numbers at a treated site and occasionally abandonment. Twelve of 34 bird-control operations with the avian stressing agent PA-14 in Kentucky and Tennessee from 1974 to 1981 resulted in an immediate 50 % or greater reduction in bird numbers at the roost site. Bird numbers at 11 of these 12 sites remained at or below posttreatment levels for the remainder of the winter and birds abandoned at least 4 of these sites within 2 weeks after treatment. We suspect that dead and dying birds at the roosts, as well as the repellent effects of PA-14 on surviving birds, kept populations from rebuilding and in some instances led to roost desertion.

Rodent Control in the Philippines—It Works. In the Philippines, national preharvest losses to rodents between 1971 and 1975 were 3.7% annually. In 1976 new, improved rodent-control methods were made available for small rice producers. The control strategy involves baiting rice paddies with low concentrations of chronic rodenticides throughout the entire growing season. This type of continuous control maintains a relatively low rodent population and thus reduces losses. Since the introduction of these methods, annual losses have dropped to 0.5% and Filipino farmers have produced more rice, valued at $266 million, which otherwise would have been lost to rodents.

Vertebrate Pests Cause Major Losses of Corn in Haiti. This study was undertaken to determine what percentage of corn grown in Haiti was taken by vertebrate pests before harvest. Also, we wanted to de-

Woodpecker damage to maturing corn in Haiti. *Photo by G. Clay Mitchell.*

termine if the same pest species caused the same degree of damage in different parts of the country. The main vertebrate pests in corn are Norway rats, Hispaniolan parakeets, African village weavers, and Hispaniolan woodpeckers.

Field corn is the largest single crop produced in Haiti. Some corn is grown in the mountains (above 300 m), but most is grown in the Port-au-Prince and Les Cayes regions (0-300 m). In these two regions, 20 fields were surveyed. Thirteen of the 20 fields have been sampled near Port-au-Prince. In each field, 10 hills were sampled along each of five transects. Preharvest losses in these fields were 5.6% to Norway rats, 6.4% to parakeets and weavers, and 1.7% to woodpeckers. Near Les Cayes, 20 fields were sampled. Preliminary results show heavy damage by woodpeckers and only moderate damage by parakeets, weavers, and Norway rats.

Control of Bird Damage to Wheat in Bangladesh. Wheat is quickly becoming an important grain crop in Bangladesh. In 1976, 215,000 long tons were harvested, whereas in 1981 1,075,000 long tons were harvested. As would be expected, bird damage to newly sown wheat fields has increased accordingly. The main pest birds in the fields are rock pigeons, ring doves, Indian myna, and pied myna.

Two chemicals, methiocarb and copper oxychloride, were evaluated as bird repellents with sprouting wheat. Wheat seeds were treated before planting at levels of 0.5 and 0.25% for methiocarb and 1.2% for copper oxychloride. Methiocarb, at 0.5%, gave an increase in plant density of 77% over the reference plot. This was followed by 0.25% methiocarb with an increase of 45% and by 1.2% copper oxychloride at an increase of 16%.

Even though 0.5% methiocarb gave the best results, it is not recommended because of toxicity to domestic pigeons. No bird mortality was observed in 0.25% methiocarb-treated or copper oxychloride-treated fields.

The cost effectiveness of copper oxychloride, as compared with methiocarb, makes it the material of choice as a bird repellent in Bangladesh. Copper oxychloride has a cost:benefit ratio of 1:27 as compared with a ratio of 1:7.5 for 0.25% methiocarb.

Radiotelemetry Studies on Red-billed Quelea and Village Weavers in Ethiopia. Radio transmitters, developed at DWRC and weighing 1.8 g, were attached to 17 red-billed quelea and four village weavers in southwestern Ethiopia during May and June 1981 to evaluate the feasibility of this technique for rapidly locating quelea nesting colonies and following the local movements of both species. Movements of both species were monitored from the ground and from a helicopter. Quelea, which weigh 18-22 g, probably are the smallest birds to which external radio transmitters have been attached. Four nesting colonies were located by following radio-equipped birds with a helicopter. Three of these colonies were in the nest construction stage, a stage which occurs during the first 3 days of colony establishment. Colonies in this stage are not normally found when conventional survey methods are used. Radio-equipped quelea normally foraged within 3 km of the colony at the nestling and fledgling stages.

While feeding nestlings, village weavers, which weigh 35 g, generally obtained food in the same location each day and in proximity (within 1 km) to the colony. Females made more than 35 feeding trips per day to their nests. The males of this species are polygamous and assist in feeding nestlings. Adults (males and females) dispersed immediately when the young fledged and formed roosts that were adjacent to ripening maize fields.

The studies demonstrated the usefulness of radio transmitters for obtaining information on colony formation, feeding patterns, and postbreeding dispersal movements of these species, which are serious pests to ripening grain in Africa; village weavers also damage crops in Hispaniola. These kinds of information are needed to develop efficient crop protection strategies.

Quelea Marked With Fluorescent Particles in Ethiopia. An estimated 1.2 million red-billed quelea were marked with aerially applied fluorescent particles in southwestern Ethiopia during June 1981. Thirteen of the marked birds were later recovered during August and September from four nesting colonies and one roost in the Awash River Valley, up to 100 days after spraying and between 500 and 700 km from the original marked colonies. These recaptures confirm the hypothesized migration route in the Ethiopian Rift Valley and are the first direct evidence for itinerant breeding of quelea in Africa.

Nesting colonies associated with the Awash River Valley were spread over a distance of more than 300 km; their establishment was staggered over a 2-month period, coinciding with local differences in availability of seeding grasses. This dispersal might enhance the reproductive potential of itinerant breeding by further reducing the impact of locally unfavorable conditions. Recoveries were segregated by both marking area and sex, suggesting group cohesion by sex from nesting to nesting. Colonial nesting in quelea may facilitate itinerant breeding through information transfer about the location and timing of traditional nesting sites. Postnesting group cohesion may provide a means to maintain the integrity of group information.

The mass-marking technique appears to be potentially valuable for studying the movement and dynamics of large aggregations of birds. The particle markers, however, are transient, and their use is limited by feather molt and the ability to collect and examine birds under ultraviolet light.

Assessment of Forest-Animal Problems and Control on Bureau of Land Management Lands in Oregon. A cooperative agreement was signed in 1982 with the Bureau of Land Management (BLM) providing for the assessment of forest-animal damage control problems in western Oregon by Service researchers. The Bureau reforests thousands of acres of highly productive forest lands in coastal Oregon. Most conifer seedlings planted on these lands require protection from animals for survival and growth.

Information to date shows that intensive tree damage and mortality is caused by mountain beavers and elk, and that other species—principally deer, hares, rabbits, meadow mice, and livestock — are causing less intensive but widespread damage and growth delays. The problem is being compounded by increasing elk herds and inadequate forage to divert animal feeding pressure from trees. There is a growing need to protect high valued, genetically improved trees being developed for increased wood production.

Phase I of the assessment will result in a state-of-the-art document on forest-animal problems and control on BLM lands in western Oregon. Phase II will include field studies to provide cost-effective data and recommendations for efficient methods and materials to reduce wildlife-reforestation conflicts on BLM lands. Overall results will benefit the forest industry throughout coastal Oregon, Washington, and California.

Golden-mantled Ground Squirrels Adversely Affected by Baiting for Pocket Gophers. Underground baiting with strychnine-treated oats is the most common method of controlling pocket gopher damage to conifers in western forests. Previous studies indicated low hazard potential of gopher baiting to species such as chipmunks and grizzly bears, but a major concern still exists about the effect of baiting on other wildlife species.

During 1982 a radiotelemetry study was conducted to identify the hazards of gopher baiting to golden-mantled ground squirrels. Golden-mantled ground squirrels are a desirable nongame species in many western States. In addition, they are often associated with pocket gophers and are an important prey species for several avian and mammalian predators.

The study was conducted on two large U.S. Forest Service plantations in central Oregon. Ninety-three ground squirrels were equipped with radio transmitters 1 week before operational baiting and followed for up to 2 weeks after baiting for pocket gophers. In addition, ground squirrel abundance was estimated during the pretreatment and post-treatment observation periods.

Radio-tracking showed that golden-mantled ground squirrels commonly used underground systems made by gophers and consumed poisoned bait directed at gophers. Over 42% of the radio-equipped animals on one area and over 48% of those on the other area were found poisoned. Although some ground squirrels were found underground at bait sets, food caches, and nests of pocket

Although mountain beavers are turning their backs on newly designed, small-diameter tree protectors in the Pacific Northwest, foresters probably will not. The new tubes, expected to be commercially available in 1983, will result in a substantial saving of money for materials, shipping, storage, and installation compared with larger, more expensive barriers now being used for forest-animal control. *Photo by S. R. Olmstead.*

For many years big game animals have browsed this established Douglas-fir plantation on Bureau of Land Management land in coastal Oregon. This browsing and other types of damage by wildlife result in a substantial loss of potential timber production affecting the national economy. Guidelines are being developed to reduce this loss. *Photo by D. L. Campbell.*

gophers, most (77%) of the poisoned squirrels died above ground. Four radio-equipped ground squirrels were preyed upon below ground by badgers and several instances of avian predation on non-radioed ground squirrels by goshawks were observed.

Overall, ground squirrel numbers decreased 77% during postbaiting observation periods on treated compared to untreated plantations. Yet to be determined are the long-term impacts on the golden-mantled population and the potential for the inadvertent poisoning of predators that feed on strychnine-killed ground squirrels.

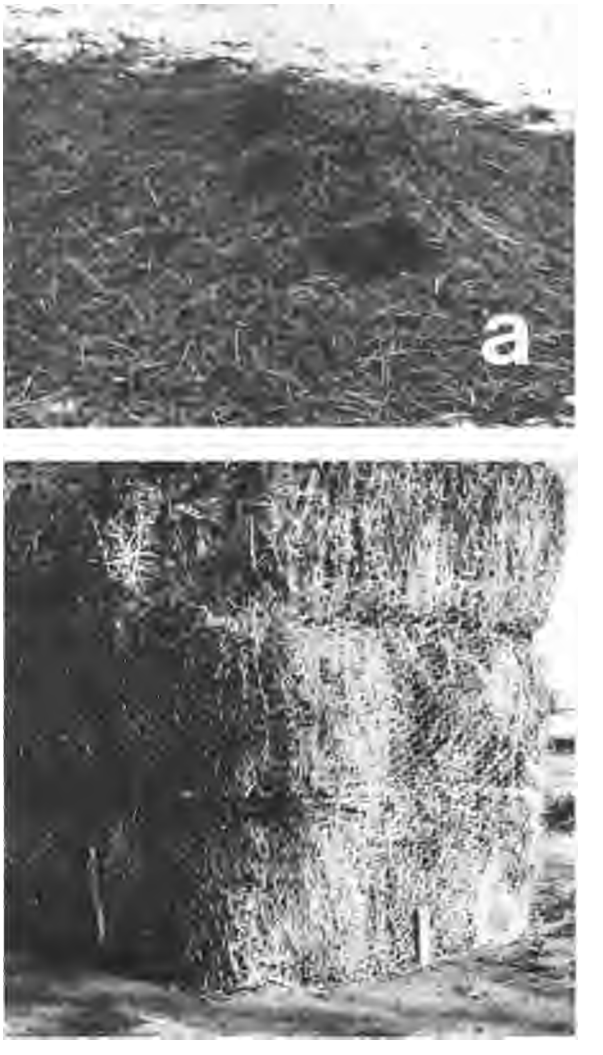
Zinc Phosphide Appears Promising as a Pocket Gopher Toxicant on Christmas Tree Plantations. A toxic bait with little nontarget hazard potential is needed for controlling pocket gophers in Christmas tree plantations, particularly ones accessible to household pets and locally sensitive wildlife species. Based on favorable laboratory tests and a pilot study, a 0.75% zinc phosphide-carrot bait registered for nutria control and a standard 0.5% strychnine-oat bait for gophers were compared for efficacy against pocket gophers on Christmas tree plantations in the Pacific Northwest. Individual pocket gopher systems were baited with 1-cm wedges of carrot bait or a spoonful of oat bait. Seven days after baiting, all systems were examined for gopher activity. Results showed that the zinc phosphide-carrot bait equalled strychnine-oat bait for controlling pocket gophers. This, plus other data, indicates that the 0.75% zinc phosphide-carrot bait would be a favorable substitute for strych-

nine baits for pocket gopher control in local areas where special attention is needed to help ensure safety to wildlife and domestic animals.

Wire Fencing Helpful in Controlling Jack Rabbit Damage. Jack rabbit damage and control in Idaho became an international affair in 1982. Loss of hay and crops to jack rabbits amounted to millions of dollars and control of rabbits by clubbing and poisoning was highly criticized both in the United States and abroad. Service biologists showed that simple use of lightweight fencing was a very acceptable way of helping to prevent jack rabbit damage. This information was promptly provided to the State of Idaho for early release to the public in a popular-type, illustrated pamphlet entitled "Wire Fencing for Controlling Jackrabbit Damage."

Nontarget Hazards Not Detected in Evaluation of Candidate Fire Ant Control Chemical. Hazards to nontarget wildlife were evaluated following the aerial application of a 0.75% nifluridide bait for controlling the imported red fire ant. Bird species and individual birds were counted on 12 transects (6 treated and 6 control) pretreatment and posttreatment. The abundance of small mammals was estimated by livetrapping before and after treatment. The rate of bait disappearance was measured for three different densities of fire ant mounds.

Overall, more birds and small mammals were counted posttreatment than pretreatment. Cardinals, dickcissels, and indigo buntings, moving in to establish nesting territories, accounted for most of the increase. Eight bird species that had recognizable territories before treatment declined after treatment, but the differences were not statistically different from controls. However, the disappearance of well-documented individuals of three low-foraging insectivorous species (white-eyed vireo, Swainson's warbler, and common yellowthroat) occurred at or shortly after time of treatment. Small mammals increased on five of six plots and decreased on one. No carcasses were found during the posttreatment searching period that were attributed to treatment.



Jack rabbits seriously damage agricultural commodities such as hay (A) in western United States. A simple wrap of poultry netting around haystacks **(B)** economically reduces this type of damage. (Note rabbit droppings, indicating heavy use.) Wire fencing of other crops is also socially accepted as a biologically sound way of controlling jack rabbit damage. *Photos by P. L. Hegdal.*

Annual Cycle of the Richardson's Ground Squirrel Determined. Richardson's ground squirrels are considered serious pests in Colorado and Wyoming because they consume agricultural crops and range forage that would otherwise be available to cattle. Extensive efforts have been made to reduce ground squirrel populations with poisoned bait in areas where economic losses occur. Any application of poisoned bait should occur when the highest number of animals are active above ground. However, the annual cycle of the Richardson's ground squirrel has not been adequately studied. Therefore, during 1979 and 1980 a study was conducted to determine the annual cycle and population dynamics of the Wyoming ground squirrel. Ground squirrels were trapped twice a month and individually marked. Radiotelemetry was used to determine hibernation dates.

Wyoming ground squirrels were individually marked with black dye to study their movement patterns and hibernation dates. *Photo by K. A. Fagerstone.*

Long-tailed weasel with field mouse from a ground squirrel burrow in a field scheduled for poisoning ground squirrels. This predator-prey relationship, coupled with increased field use of household rodenticides, points to a growing need to determine toxic effect to target and nontarget wildlife. *Photo by G. D. Lindsey.*

The study revealed that, although ground squirrels were seen above ground from late March through September, each individual was active for only 3 to 4 months and hibernated for the remaining 8 to 9 months. Adult males emerged from hibernation in late March or early April, followed 1 to 3 weeks later by adult females and yearlings. Breeding occurred as soon as females emerged from hibernation and young were born 24 to 27 days later. Juveniles appeared above ground in early June, about 4 weeks after birth. Adults began entering hibernation in late June; average hibernation dates were 18 July for adult females and 31 July for adult males. Juveniles remained active into September.

Any application of poisoned bait must be closely keyed to this annual cycle. Baiting appears to be most effective in late June or early July when both adults and juveniles are active above ground.

Vocalization Differences Between Wyoming and Richardson's Ground Squirrels May Be Indicative of Two Species. In the past, Wyoming and Richardson's ground squirrels have been considered one species. However, recent chromosomal evidence indicates that they may actually be different species. During 1981 a study was conducted to document the types of vocalizations emitted and to determine if a significant difference occurred between vocalizations of Wyoming and Richardson's ground squirrels.

Vocalizations were recorded of Wyoming ground squirrels from Kremmling, Colorado, and from Encampment, Wyoming. Vocalizations were recorded of Richardson's ground squirrels from White Sulphur Springs, Montana, and from Picture Butte, Alberta. After recording vocalizations, sonagrams (a graph of frequency in hertz versus time) were made of each call.

Both Wyoming and Richardson's ground squirrels emitted the same five types of vocalizations: growls, squeals, tooth chatters, churrs, and chirps. Growls, squeals, and tooth chatters were similar between the ground squirrels but alarm calls (churrs and chirps) were significantly different. Chirps of Wyoming ground squirrels contained seven notes, whereas chirps of Richardson's ground squirrels consisted of only one long note that declined rapidly in frequency. Churrs of Wyoming ground squirrels contained an average of 12 short notes compared with 5 longer notes in Richardson's ground squirrels. Discriminant analysis accurately differentiated between the calls of the two ground squirrels. Vocalizations therefore appear to support the idea that Wyoming and Richardson's ground squirrels are two species.

Radios Better Than Recaptures for Monitoring Black Rats in Sugarcane. A pilot study of the use of radio transmitters on black rats demonstrated that this technique will succeed where livetrapping might fail in monitoring roof rat populations during rodenticide field tests. During a 2-year (1974-1976) capture-recapture study of rodent populations in Florida sugarcane fields, recapture success for black rats was poor, averaging about 1.4 captures per individual. Because radio-tracking requires only one livetrapping occasion per individual, it would be an ideal approach provided the radio collars cause no

short-term detrimental effects on the rats, rat movements are not generally beyond the range of signal reception, and dead rats can be located and recovered. In May 1982,21 black rats were radio-collared in two Florida sugarcane fields, and an attempt was made to locate each one at least once daily for 14 days. Eighteen rats were successfully located daily during the tracking period. Two were not located on 2 days each, but were again located on subsequent days. Only one rat died before the end of the radio-tracking period, and it appeared to have been the victim of an avian predator. Ten rats were recaptured or dug out of shallow burrows following the tracking period, and all appeared to be in excellent condition with no sign of neck abrasion. Most of the radio-collared rats stayed within 60 m of their original capture location over the 14-day tracking period. Two rats moved a considerable distance (> 270 m) and only one left the field. Radio-tracking appears to be a highly suitable technique for determining the fate of black rats in sugarcane over a short time period.

Secondary Hazards of Anticoagulants to Owls Evaluated. A new highly potent anticoagulant rodenticide is attracting considerable interest for field rodent control throughout the world. This material has been registered in the United States for controlling rats and mice in urban areas and around farmsteads and industrial areas. A study started in 1980 indicates that the use of TALON rodenticide (Brodifacoum) probably has minimal secondary hazard potential to barn owls.

During fall and winter 1981-1982, we evaluated the potential secondary hazards to screech owls of VOLID rodenticide (Brodifacoum) for controlling orchard voles. Thirty-eight screech owls were radio-equipped and monitored before, during, and after the rodenticide treatment. Of the 25 screech owls that were radio-tracked in orchards after treatment, 6 were found dead under circumstances that indicate secondary poisoning was the most likely cause of death. Results of residue analysis and necropsies on these birds also tend to support secondary poisoning as the probable cause of death. In addition, four of six owls collected alive for residue analysis 2 months after treatment contained Brodifacoum residues at levels near the levels of owls that died. During the study two screech owls were killed by vehicles, four apparently by predators, and one died of unknown causes.

The use of Brodifacoum rodenticide bait for controlling rats and mice in urban and industrial areas and around farmsteads appears to present only minimal secondary hazards to barn owls. However, the use of Brodifacoum bait for controlling voles in orchards has resulted in several screech owl mortalities. Any proposed use of this rodenticide for controlling field rodents should be carefully evaluated if the target species is a significant food item in the diet of avian or mammalian predators.

Factors Contributing to Predation on Sheep and Goats Examined. High (over 5%) and low (0-5%) predation intensities were compared among 95 sheep or goat producers in five States to determine if differences between the two groups were evident. Data were compared between the two groups for the following features: losses to predation, flock size, type of ranch operation, management practices, predator indices, prey indices, use of U.S. Animal Damage Control (ADC) program, private control efforts, predation history, timing of predation, and presence of other sheep or goats nearby.

Overall, 45% of the producers had predation losses of their lambs or kids, and percent predation tended to decrease with decreased flock sizes. Feeder lamb and range operations were predominantly in the low-loss category, but sheep, cattle, and goat operations were mostly in the high-loss category because of predation on goats. A variety of management practices was used by both groups; however, lower indices for natural prey and predators were reported for low-loss producers. A majority of producers used the Federal ADC program and private control, although fewer low-loss producers than high-loss producers used both types. Rough, bottom, and brushy grazing lands, historic predation problems, and high predator indices characterized many of the high-loss categories. Good habitat for predators in proximity to young livestock increased the opportunities for contact with predators and for predation.

Indirect Costs of Predation on Sheep Determined. The objective of this study was to identify, rank, and assign monetary values for the indirect costs of predation on sheep. Most previous studies on sheep predation have dealt with direct costs, but have ignored the indirect costs of predation; thus, total costs of predation were unknown. This work was funded by the U.S. Fish and Wildlife Service, DWRC, administered by the Cooperative Fisheries and Wildlife Research Unit at the University of Wyoming, and conducted by the Department of Water Resources (Economics), University of Wyoming.

Personal interviews were conducted during March 1982 with 107 sheep producers in five geo-

Because coyotes are attracted to livestock carcasses, such carcasses have long been used to dispense toxicants to coyotes. The Denver Wildlife Research Center currently is planning studies of efficacy and environmental hazards of toxic, single-dose coyote baits placed near nontoxic carcass "draw" stations. *Photo by G. Connolly.*

Coyotes typically kill sheep and goats with throat bites. In such attacks, the coyote's teeth often damage one or both of the prey animal's jaw bones. This jaw, from an angora goat killed in Texas, shows six punctures or marks made by coyote teeth. On weathered carcasses, these marks are evident long after other evidence of predation has vanished. *Photo by G. Connolly.*

graphic divisions of Wyoming. Producer samples were selected by numbers of sheep owned and assigned to four size categories from 50 to over 5,500 sheep. Thirty-three sources of indirect costs of predation controls were identified and ranged from llamas to electronic shepherds. Indirect costs of predation increased as flock size increased. Average cost per breeding ewe in the 50-199 sheep category was $0.97, $1.46 for 200-999 sheep, $1.70 for 1,000-5,499 sheep, and $3.17 for over 5,500 sheep.

When replacement costs of sheep killed were not considered, the total indirect cost of predation for this sample was $619,199. Total indirect costs for individual producers ranged from a low of $2.62 to a high of $183,385. This study emphasizes that some sheep producers incur substantial indirect costs of predation that must be considered when

A technician examines a domestic lamb killed by coyotes on a high-elevation summer sheep range. Such losses are frequently severe and means of controlling predation are restricted on public grazing allotments. The Denver Center is evaluating the use of portable sound- and light-emitting frightening devices as a way to keep coyotes from killing sheep on bedgrounds located in these areas. *Photo by S. B. Linhart.*

assessing the total impact of predation on livestock.

Coyotes Prey Selectively on Kids in Mixed Lamb-Kid Flocks. In attempting to develop coyote predation control methods selective for individual coyotes that kill livestock, we developed and sought registration for a prey-mounted control device and are studying others. One of the most important problems with livestock-mounted control devices has been in directing coyote attacks toward animals wearing the devices. If we can learn to direct coyote attacks toward certain animals or groups of animals within flocks, we can make most livestock-mounted control devices more effective.

Some ranchers feel that coyotes prefer kids over lambs if the coyotes have a choice between the two. The concept was tested in pens at the predator research site near Logan, Utah, in order to exploit this possibility in coyote predation control.

Two coyotes (A and B) were presented a lamb and a kid simultaneously. Two other coyotes (C and D) were allowed to "choose" their prey from a small flock of 8 to 11 various-size lambs and 1 to 2 medium-size kids. All four coyotes were tested individually. Before testing, the first two coyotes had no experience killing sheep or goats, whereas the second two had both killed one or two lambs.

The results showed that coyote A killed six kids and no lambs. After three kills the coyote attacked a large adult male goat but was unable to kill it. During the goat attack, the alternate prey was a

Under a Cooperative Agreement with the Mexican Fish and Wildlife Service (Fauna Silvestre), studies of the impact of coyote predation on deer and pronghorn antelope fawns are being initiated in northern Mexico. Left: A Mexican wildlife technician is setting a coyote trap on one of the study areas. Service biologists are training Mexicans in the use of research and predator control techniques. Below: A Mexican biologist records data from a coyote taken from an area in San Luis Potosi where white-tailed deer fawn survival is exceedingly low. One of the factors believed responsible is coyotes preying on newborn fawns. *Photos by S. B. Linhart.*

lamb only half the size of the goat; this lamb was mostly ignored. Coyote B killed three kids, one goat, and one lamb. The coyote attacked other lambs, but the goats were almost always killed before lambs. Coyote B's preference for goats was most strikingly shown during the final test. The :oyote went over and around a 23-kg lamb in his attempts to kill a 30-kg goat. Coyote C killed the 2 kids from a flock of 11 various-size lambs and 2 medium-size kids. Coyote D first killed a small lamb, then killed two kids.

The results indicated a definite preference for kids over lambs in both one-to-one and small-flock choice tests among captive coyotes with little or no sheep-killing experience. Field tests with kids wearing control devices in sheep flocks appear desirable to confirm the pen-study results.

Prey-mounted Bait Collars Fed Upon by Coyotes. Tests with toxicants were initiated based on coyote food choice tests and on preliminary observations of coyotes showing frequent feeding on bait collars made from sheep mesentery fat. Bait collars, if effective, would have two advantages over the present liquid-filled rubber collar: they should be cheaper to manufacture and would require much less toxicant.

During tests, 2- x 6-inch sheep hide collars covered with 50% sheep mesentery fat and 50% corn oil containing 5 mg of sodium monofluoroacetate were tied around lambs' throats. Lambs were released into 1-ha field pens containing individual coyotes or a pair. Coyotes died in five of six tests in which the lambs were killed and the bait collars were eaten. The coyote that survived cached vomitus soon after feeding extensively on the lamb and probably eliminated the collar during caching.

Three points were of particular interest: (1) in all tests, at least one coyote ate the collar; (2) when a coyote began eating a collar, it was entirely consumed; and (3) no coyotes showed fear or aversion to collars. It appeared, from these results, that bait collars merit further developmental work as a specific delivery method for toxicants.

Cooperative Predator Research Studies Initiated by United States and Mexico. The USA−Mexico Joint Committee on Wildlife recently approved initiation of studies in northern Mexico to determine the impact of predators, primarily coyotes, on productivity and survival of pronghorn and white-tailed deer.

Four study areas in the States of San Luis Potosi, Chihuahua, and Baja California Sur have been identified. After visiting these areas DWRC staff and biologists of the Mexican "Fauna Silvestre" will begin developing plans to investigate coyote-pronghorn and coyote-deer interactions. Local populations of these ungulates number less than 100 individuals and observations indicate that fawn survival is poor or nonexistent. Research will focus on obtaining base-line natality and survival rates in the absence of coyote control and later reducing local coyote populations to determine if increased fawn survival and population growth results. Mortality radio transmitters will be used to monitor predation rates on one of the areas. Capturing newborn fawns and rearing them in captivity for later release back into the herd has already been shown to be a promising technique. It is expected that the results of these studies will identify major causes of fawn mortality. If predation is a significant factor, cooperative research to determine appropriate ways to manage predators will be mutually advantageous.

Field Tests of Sodium Cyanide Ejectors for Coyote Control Completed. The M-44 sodium cyanide ejector is an important method used by the Fish and Wildlife Service's Animal Damage Control Program to control coyote damage. In recent years, increasing numbers of ADC program field workers have reported the M-44 to be ineffective because of excessive malfunctions. Accordingly, the Service appointed an M-44 study team to document and resolve this problem. The team, which includes participants from both research and operations, carried out a field test of **M-44** and other NaCN ejectors in Texas early in 1982. The results substantiated field reports of ineffectiveness.

Coyote getters, M-44's, and M-50's were tested. The coyote getter, which ejects NaCN by detonation of a small pistol cartridge primer and small powder charge, was used with good success in the ADC program for about 30 years. It was replaced for ADC program use in 1970 by the M-44 which ejects by means of a spring-driven plunger and therefore is believed to be safer than the coyote getter. The M-50 is a redesigned M-44. Introduced in 1979, the M-50 was expected to eliminate several inherent and chronic causes of malfunction associated with the M-44. However, the M-50 proved even less dependable and was not favored by most field men.

In the present experiment, 600 ejectors were set in a fenced plot and subsequently pulled and reset at either 7-day or 21-day intervals. Any unit that failed to eject or required over 8 pounds pull force for ejection was deemed to have malfunctioned. In addition, units that could not be reset because of

The M-44 sodium cyanide ejector is an important tool for removing coyotes from livestock ranges. About two-thirds of all Animal Damage Control program use of M-44's is in Texas. Because current M-44 ejectors frequently malfunction, research is in progress to improve the performance of this tool. *Photo by G. Connolly.*

Biologists measure the force required to trigger an M-44 sodium cyanide ejector. The test apparatus protects observers from contact with the ejected NaCN. The desired pull force is 3-4 pounds and units that do not eject at pull forces below 8 pounds are considered to be defective. *Photo by G. Connolly.*

Caking or decomposition of sodium cyanide currently is reducing the effectiveness of M-44's used by the Animal Damage Control program. In this capsule, the powdered NaCN mixture has solidified into a hard mass (right). If ejected into a coyote's mouth, this "pill" would be spit out before the toxicant could take effect. The "educated" coyote would probably never pull another M-44. Because caking or decomposition of NaCN results from moisture inside the capsule, improved sealing of capsules is expected to solve the problem. *Photo by G. Connolly.*

tality patterns, the influence of transmitter collars on general behavior patterns was studied among a group of captive animals. All 28 jack rabbits in two breakage, wear, or corrosion were tallied as malfunctions and withdrawn from the experiment. The incidence of caking or deterioration of NaCN within ejector capsules also was studied.

The 42-day test demonstrated substantial rates of failure for both ejectors and capsules. Ejector malfunctions were most frequent with M-50's and least frequent with coyote getters. For ejectors pulled and reset weekly, cumulative failure rates after 6 weeks were 100, 70, and 2%, respectively, for M-50's, M-44's, and coyote getters. The performance of M-44's was improved by shortening their plungers either 1/8 or 9/16 inch. Neither M-44 nor M-50 capsules appeared to be effectively sealed against moisture, as the contents of 47% of M-44 capsules and 20% of M-50 capsules were found caked after 6 weeks of field exposure.

Based on these results the study team recommended that the M-50 be discontinued and the M-44 improved by further research and development. Priority will be given to modification of the capsule or capsule loading procedures as needed to achieve effective seal. In addition, the prospects for development of a safer coyote getter are being explored.

Radio Transmitters Affect Activity Patterns and Mortality of Penned Jack Rabbits. Before initiating a telemetric study of black-tailed jack rabbit mor-

2-ha pens were given unique markings by means of a commercial hair lightener. Half were then equipped with a simulated transmitter package of the size and configuration to be used in later field studies. The rabbits were then released into the same pens in which they had been held for the previous

year. Behavioral observations were made routinely over the ensuing 31 days.

Throughout the observation period, instrumented jack rabbits spent more time grooming and less time sitting than jack rabbits without transmitters. No other consistent differences in behavior were noted.

Coincidentally, a golden eagle attacked and killed several jack rabbits in one of the pens. Eight of the twelve rabbits in the pen eventually succumbed to avian predators. Although statistical analysis did not indicate a significant difference in vulnerability between jack rabbits with and without the simulated transmitters, five of the first six animals killed carried transmitter packages. After behavioral observations were complete, a coyote was released into one pen. He ultimately killed all 16 rabbits in the pen in random fashion without regard to the presence or absence of the transmitters. Curiously, although the coyote took 2 weeks to catch all the rabbits, he killed the last seven in a single night. Weather may have created conditions that were advantageous to the coyote and fatal to the jack rabbits.

High-density Coyote Population Related to Abundant Food. Dynamics of a naturally regulated, high-density coyote population in southern Texas were monitored between 1976 and 1981. Indices of coyote abundance for this region, obtained through the annual survey of predator abundance over the past 10 years, have been consistently higher than elsewhere in the western United States. Natural prey is usually abundant in the dense shrub vegetation and exploitation of the coyote population by humans is relatively light compared with most other regions.

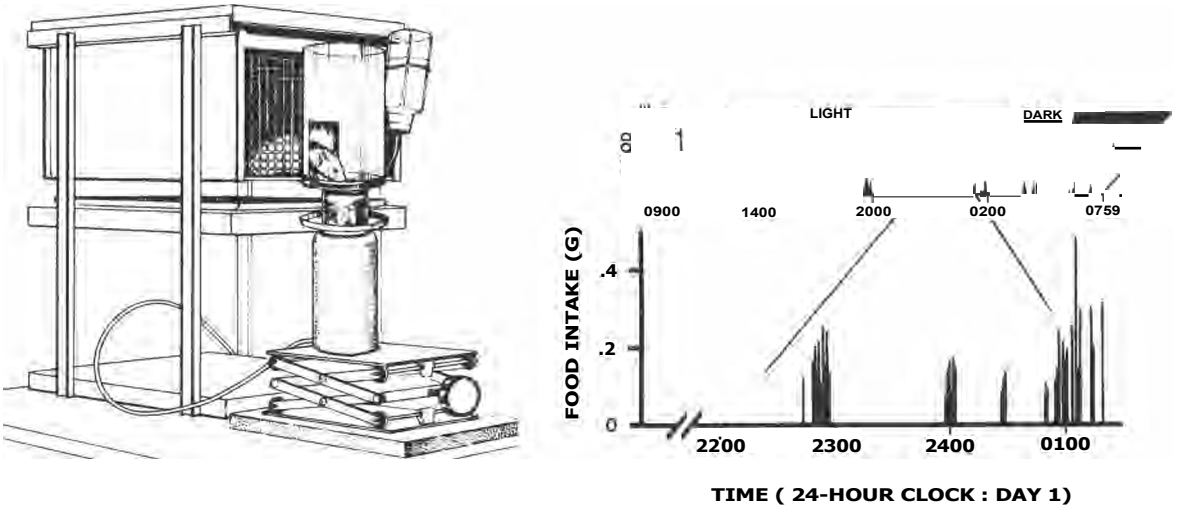
During the study period, the average number of young produced each year ranged from 4.3 to 6.2 per adult female. First-year females, however, were essentially nonreproductive since only 1 of the 91 examined during the study produced a litter and only 4 had even ovulated. Ovulation and pregnancy rates of females in their second year fluctuated considerably between years and typically were lower than older adults. Among older adults, ovulation rates, pregnancy rates, and litter sizes were generally similar among years. Hence, total reproductive output in the population was relatively stable during the 6-year period because the proportionate contribution by younger females was small.

Studies with captive coyotes and research on populations in other regions have documented that females in the first and second years of life are capable of much higher rates of ovulation and pregnancy than observed in South Texas. Concurrent monitoring of the abundance of prey on the study area indicated that sufficient natural food was consistently available for coyotes. Suppressed ovulation among the younger females may result from social mechanisms, perhaps involving competition for space, operating in a coyote population stabilized at relatively high densities.

Winter Mortality of Jack Rabbits Determined by Telemetry. A study to directly measure the rate of total and predator-induced mortality of adult black-tailed jack rabbits in Curlew Valley, Utah, by using mortality-sensing radio transmitters was continued during winter 1981-82. A total of 91 jack rabbits were captured, fitted with radio transmitters, and released. Transmitters were monitored daily from December through March to determine the status of each animal. Dead radio-tagged rabbits were usually recovered within 24 hours of death and cause of death was determined. Of the 91 jack rabbits instrumented, 57 (63%) were recovered during the study from jack rabbit mortalities, 30 (33%) were collected at the end of the study from surviving jack rabbits, and 4 (4%) were lost during the study due to transmitter malfunctions or movement of radio-tagged animals from the study area. Of the 57 observed jack rabbit mortalities, 13 (23 %) were killed by predators with no extenuating circumstances. Twelve (21 %) mortalities were from undetermined causes (5 of these may have been predator-induced but were devoured to a point where a judgment was not feasible), 11 (19%) were hunter kills, 1 (2%) died from disease, 1 (2%) was a road kill, and 19 (33% of the transmittered sample surviving at that time) died during a 2-day period in February either directly (15 animals) or indirectly (4 rabbits apparently were killed by predators but not eaten) from severe weather conditions.

About 40 cm of snow had accumulated in the study area, and on 5 and 6 February we experienced winds up to 95 km per hour accompanied by temperatures of - 30° to - 40°C. At the end of the windstorm, most of the snow was packed hard and crusted with drifts to 100 cm. Many of the 19 dead, transmitter-equipped jack rabbits were found frozen in a sitting position under sagebrush; others were found in large drifts, often accompanied by one or more dead jack rabbits not associated with the telemetry study.

This is the first time a quantitative measure of weather-induced mortality of jack rabbits has been documented. We think mortality directly related to weather as observed during those 2 days is uncommon in Curlew Valley. Conditions as extreme as



Denver Center studies of rat feeding patterns utilized microcomputer hardware to monitor the minute-by-minute intake of baits. Data showed that bait is consumed mainly during several bouts of eating—largely during the nocturnal portion of each day. Results of these laboratory studies should guide development of more efficient baiting practices for controlling troublesome species. *Photo by S. E. Gaddis.*

those on 5 and 6 February are rare. Though much of the rest of the winter was as harsh as usual, no other observed mortalities were judged to be directly weather-induced.

Lowest Concentration Determined for 1080 Baits. Early in 1982 pen trials were initiated to determine the lowest amount of 1080 that could be applied effectively to develop single lethal dose coyote baits. Tallow baits containing 3, 4, or 5 mg of 1080 were offered to coyotes for voluntary consumption. Based on 10 to 12 adult coyotes per dose level, only the 5-mg baits caused 100% mortality, whereas 80% mortality was achieved at the two lower concentrations. Plans to field test the 5-mg single lethal dose are being made.

Methomyl (DRC-6702) Not Promising as an M-44 Toxicant. Ever since the coyote getter (M-44) was introduced more than 40 years ago, there have been chronic reports of failure due to caking or decomposition of the sodium cyanide (NaCN) mixture. Therefore, a potential replacement toxicant was evaluated under laboratory and field conditions. Methomyl-loaded M-44's were pen-tested in 1981 and compared in field tests with NaCN early in 1982 in three Texas Animal Damage Control districts.

Total recoveries from 93 discharges (2,355 unit nights) of methomyl-loaded M-44's included 8 coyotes, 18 opossums, 8 skunks, and 2 raccoons. With NaCN, 20 coyotes but no other animals were recovered from 26 discharges (722 unit nights). Coyotes pulled one methomyl unit per 71 nights, compared to one NaCN unit per 29 exposure nights.

Eighty percent of coyotes that pulled NaCN ejectors were recovered, compared with only 24% for methomyl. Average recovery distances were 26 and 105 yards, respectively, for NaCN and methomyl. Coyotes may have been repelled and opossums attracted by M-44's that contained methomyl. We concluded that methomyl offers little promise as a replacement predacide in the M-44 devices.

Ultrasonic Rodent Repellent Devices Show Marginal and Short-term Effects. Laboratory and field research was initiated in October 1981 to evaluate the repellent effects of several commercial devices. This was part of an interagency agreement between the U.S. Environmental Protection Agency and the Fish and Wildlife Service. All sample devices had been previously analyzed for physical ultrasonic characteristics by the Food and Drug Administration's Winchester Engineering and Analytical Center laboratory.

For laboratory tests, a rodent infestation was simulated in a 740-square-foot building. Twelve wild Norway rats were released into a central enclosure area (38 square feet) containing food, water, and shelter boxes. Rats were allowed to exit from this central enclosure to obtain supplemental food from small packets of rolled oats in two isolated 350-square-foot rooms within the building. The ani-

mals were adapted for 2 weeks so that packet damage was equalized in both rooms. The test consisted of successive 3-week periods in which an ultrasonic device was alternately activated in each of the 350-square-foot rooms. This entire procedure was then repeated with a new group of 12 animals.

Results showed that a 30-50% reduction in rat damage and activity occurred for 1 week or less during the 3-week periods. Subsequently, the rats habituated to the ultrasonic stimulation and no reduction in food packet damage was noted in either test room.

For the field tests, four devices were assessed for repellency effects in seven buildings varying in size (100 to 2,500 square feet) and construction (metal versus wood). All buildings contained high levels of Norway rat or house mouse infestation. Tracking tiles, rolled oat packets, and photocell activity measurements indicated that the infestations were only temporarily or partially reduced during successive 3-week periods with the devices alternately switched on and off. Not once, however, was there a complete alleviation of rodent problems. Data collected represent a clear and valid operational assessment of efficacy and can be used for ranking repellency among devices.

Blackbird Damage to Sunflower Fields Greatest Near Marshes and River Drainage Systems. A second annual wide-area assessment of blackbird damage to sunflower fields was conducted near Sheyenne Lake, North Dakota. Thirty-eight of 143 available sunflower fields within a 144-section area surrounding Sheyenne Lake were sampled for blackbird-caused damage in October 1981. Additionally, bird-habitat utilization was monitored throughout August and September. This marked the second in a series of preharvest surveys to assess year-to-year variation in roost, flightline, crop-planting schemes, and sunflower damage patterns associated with blackbird migrations within the Dakotas.

Results generally confirmed those reported for 1980. Estimates of damage for the 38 sampled fields ranged between 1% and 27%, with the distribution of losses highly skewed (i.e., a few fields received extensive damage, but the vast majority of fields suffered less than 5% loss). Six of the seven fields that again received greater than 10% loss of seed were within 2 miles of the Sheyenne River. Blackbird habitat measurements suggested that sunflower foraging by red-winged blackbirds increased sharply in late September — coincident with the southward migration of this species.

Evaluation and Control of Postharvest Food Losses to Vertebrate Pests. As the world's population grows, increasing the food supply becomes an ever more urgent priority. One vital step toward this end is to reduce food loss occurring between harvest and consumption. On a worldwide scale, postharvest food losses are reported to be millions of tons per year, valued at billions of dollars. Losses may be due to a variety of factors and come in several forms such as physical loss of food, reduction in quality, or loss in nutritive value.

Until recently, vertebrate problems have not received as much emphasis as microorganisms, insects, storage methods, and engineering. Yet, most experts agree that vertebrates have a significant impact. For example, 200 black Bandicoot rats in a godown (small storehouse in India) will consume enough rice in 1 year to feed a human for 11 years. In the Philippines, birds enter through openings in large warehouses, peck holes in sacks, and consume or contaminate significant amounts of grain.

Although vertebrate pests consume large amounts of food, even larger quantities are contaminated. For example, most estimates show that rats contaminate 10 times more food than they eat. In addition, scattered grain is often swept up and mixed with clean grain, resulting in contamination of larger batches. Hair, feathers, urine, feces, ectoparasites, disease organisms, and even dead animals contaminate stored foods. These conditions increase the potential for human disease and result in lower prices at the marketplace.

An increased emphasis is being placed on postharvest food losses to vertebrate pests at DWRC. The Center's experience with preharvest projects, domestically and abroad, makes an extension to postharvest problems a natural one. Overall plans have been made and work is under way to develop accurate methods of food loss assessment both in the laboratory and in key countries, to improve methods of control, and to train nationals to manage their own problems.

Analytical Method for 1080 Residue Analysis Proves Highly Reliable. One of the major concerns regarding the use of 1080 as a toxicant is the potential environmental hazard to nontarget animals that scavenge on the tissues of poisoned target species. One means of assessing the hazard is to determine the residue levels of 1080 in the tissues. The development of a sensitive and reliable 1080 analytical method has greatly facilitated this assessment. The analytical method was extensively evaluated in a study to determine the precision of the

method measuring 1080 residues in tissues of poisoned coyotes and to test the stability of 1080 residue in muscle tissue stored under various conditions. Residue in the muscle tissue from coyotes dosed with the same amount of 1080 (5 mg 1080 per kilogram body weight) varied from 1.8 to 3.1 ppm. Assuming these concentrations apply to the entire coyote carcass, the residues represent about 36 to 62% of the dose administered. Residue concentrations did not change with storage, indicating that 1080 is relatively stable. Essentially the same amounts of residues were found in tissue samples analyzed fresh and in samples either stored frozen for 30 and 60 days or kept at ambient temperature for 28 days. Analyses of these samples in replicates indicated satisfactory precision of the analytical method. Average coefficients of variation showed that better precision was found with fresh samples (coefficient of 5.8%) than with ambient, 30-day frozen, and 60-day frozen samples (coefficients of 27, 12, and 14%, respectively).

How Do Rodenticides Taste to Rodents? Most experts on control agree that rodents have an exceptional sense of taste when compared with humans and that taste is an important consideration that influences bait acceptance and palatabilty. Bait formulations sometimes include flavorings (e.g., chicken or fish) to attract rodents, masking agents to "hide" undesirable taste qualities of the rodenticide, and enhancers such as sweeteners to encourage maximum consumption by the rodent pest. More recently, taste qualities have been recognized as cues by which rodents protect themselves from dietary poisoning. Some rodenticides are inherently avoided, presumably because they taste bitter to the rodent. Bitter tastes generally signal the presence of natural toxins to rodents and encourage avoidance. Furthermore, rodents often learn to associate the taste of food with post-ingestional malaise after just one experience, and will subsequently avoid similar-tasting foods.

But how do rodenticides taste to a rodent? We are using a recently developed animal psychophysical method to provide new insights into this question. The method does not tell us exactly how the rodenticide tastes to the rodent, but it does tell us which tastants are similar to the rodenticide flavor in terms of generalized aversion. More specifically, rodents are first allowed to taste a small amount of rodenticide, followed immediately by a drug-induced malaise by LiC1 injection. After recovery, the rodents are presented an array of tastants representing sour, salty, bitter, and sweet. Differential consumption between an experimental rodent (rodenticide, then LiC1 injection) and its yoked control (distilled water, then LiCl injection) is considered a measure of aversion to the tastant. The experimental rodent is assumed to be most aversive to tastants that most closely resemble the taste of the rodenticide.

Results from a series of such tests with laboratory strains of Norway rats suggested that strychnine was principally bitter (i.e., conditioned aversions to the taste of strychnine generalized to quinine sulfate and sucrose octoacetate); thiosemicarbazide was principally bitter and sweet (i.e., aversions generalized to quinine sulfate and sucrose), and scilliroside was sour and bitter (i.e., aversions generalized to dilute hydrochloric acid and quinine sulfate). The results of tests following pairing of arsenic and warfarin with LiC1 were less clear and will require additional studies before conclusions can be drawn.

With further development and modifications, we hope to extend the method to include a wider array of tastants, solid rodenticides, and complex bait formulations. The method may have potential applications that include improvement of prebaits, selection of bait-pairs for use in serial baiting, empirical evaluation of masking agents and microencapsulating techniques, and ultimately, systematic development of more effective bait formulations.

Environmental Contaminant Evaluation

COLUMBIA NATIONAL FISHERIES RESEARCH LABORATORY

Monitoring National Trends in Contaminants. Monitoring trends of contaminants in fish involves three tasks: (1) the measurement of temporal and geographic trends of organochlorine pesticides, PCB's, and seven heavy metals, (2) the identification of locations where unusually high concentrations of routinely measured contaminants occur, and (3) the determination of unidentified contaminants detected during routine screening The present report is confined to tasks (2) and (3). Interpretation of the most recently conducted analyses in terms of temporal and geographic trends would be premature because collection of samples is on a 2-year cycle (about half the stations being sampled each year), and we are now midway through the current cycle.

Toxaphene was detected for the first time in fish from Alaska. Pooled samples of rainbow trout and Dolly Varden from the Kenai River near Soldatna, Alaska, had toxaphene concentrations exceeding 200 ng/g — levels comparable to those commonly measured in samples collected from areas of low toxaphene use. Since use of toxaphene in this area of Alaska has not been reported, we are unable to identify the source of the residues.

Mirex, an insecticide, is routinely found in fish collected in the southeastern United States and was recently detected for the first time in striped bass. One adult striped bass collected in 1981 from the Cooper River, South Carolina, contained mirex residues of 30 ng/g, a level comparable to that measured in other fish species in the Southeast.

Lindane is an insecticide analyzed routinely in the monitoring program but is rarely detected in concentrations greater than 30 ng/g; however, this year the residue was 700 ng/g in a largemouth bass collected on the Loxahatchee National Wildlife Refuge, Florida. Yellow bullheads captured with the bass at the same site had no detectable lindane residue. The insecticide is used on citrus crops and in cattle dipping; however, these activities do not occur near the Refuge. Since the compound is short-lived, one would suspect that the largemouth bass received very localized acute exposure.

Striped mullet collected from the Colorado River near Yuma, Arizona, bore total DDT concentrations of 2,900 ng/g, of which 36-40% was an isomer most prevalent in the applied insecticide. This isomer usually composes only about 10% of the total DDT concentrations measured in fish from other locations in the United States. The high percentage of this isomer indicates that the fish were recently exposed to the applied pesticide, and probably reflects the continued use of DDT for agriculture in Mexico.

Endrin is another routinely analyzed insecticide that is infrequently encountered in concentrations exceeding 30-40 ng/g except in the Southeast. However, this year the highest endrin concentration measured (111 ng/g) was in a bloater from Lake Michigan. In 1982, unlike past years, measurable amounts of endrin were detected in all fish samples from Lake Michigan. The rising endrin levels may result from atmospheric deposition of aerially transported compounds.

Among the trace elements, selenium was the only metal occurring in unusually high concentrations where normal geologic background levels are fairly low. Residues measured in largemouth bass and bluegills from cooling reservoirs associated with coal-fired power facilities in North Carolina were generally 10 times higher (or more) than the nationwide geometric mean of about 0.5 $\mu g/g$). The elevated levels were attributed to atmospheric fallout of selenium from stack emissions, and discharges of dissolved selenium from ash disposal ponds into the reservoirs. Concentrations of selenium measured in mosquitofish from a reservoir in the Central Valley of California were the highest we ever measured in fish (25-30 $\mu g/g$). The reservoir is used as a disposal facility for tile-drain water from irrigated fields and is part of a National Wildlife Refuge. Causes of the high selenium levels have not been determined.

A number of contaminants were identified that had previously been unreported in routine sampling.

Polychlorinated diphenyl ethers and polybrominated aromatic compounds were identified in a quillback (a member of the sucker family) from the Cape Fear River near Elizabethtown, North Carolina. This is the first time we have found polyhalogenated aromatics in 5 years of screening for these compounds. Chlorinated diphenyl ethers are used as heat exchange media for electrical equipment, and polybrominated aromatics are used as fire retardants in clothing. Screening for polynuclear aromatic compounds in samples from a limited number of locations was begun this year. The compounds were found in samples of white catfish from the Connecticut River near Windsor Locks, Connecticut; they are associated with contamination by fossil fuels and petroleum derivatives used in industry, and cause concern because many of them are potent carcinogens.

Dioxins and Dibenzofurans Found in Fish from the Great Lakes and Eastern Seaboard. Analyses for polychlorinated dibenzofurans and polychlorinated dibenzodioxins in fish were completed for sample sets gathered from five important river and lake systems: the Great Lakes; Hudson River; eastern seaboard rivers and estuaries supporting populations of striped bass (especially Chesapeake Bay); Black River, Ohio; and the Housatonic River in Connecticut and Massachusetts. The levels of residues found in fish tissues varied from a few parts per trillion (ng/kg) to a few parts per billion (ng/g) among the 20 sampling sites, and are apparently associated with industrial pollution. The most highly contaminated samples were taken from the Tittabawassee and Saginaw rivers, Michigan, and the Niagara River, New York. The furans were generally found in higher concentrations than the dioxins.

Somewhat surprisingly, the residues of furans and dioxins in Great Lakes fish were composed mainly of the most toxic isomers of these chemicals. In most samples, more than 50 % of the total dioxins (of which there are 75 isomers) were accounted for by the most toxic isomer — 2,3,7,8–TCDD. The occurrence of this isomer appears to be most prevalent in regions of Lakes Huron and Ontario adjacent to areas where the intermediate chemical, 2,4,5-trichlorophenol, was produced during the manufacture of herbicides and pharmaceuticals. Residues of 2,3,7,8-TCDD in fish from these two regions generally exceeded the advisory limit of 25 ng/kg established by the Food and Drug Administration and the guideline of 20 ng/kg set by the Canadian government. Two samples of common carp from the Niagara River contained 53 and 417 ng/kg of 2,3,7,8-TCDD and two samples from the mouth of the Saginaw River contained 81 and 94 ng/kg. A limited number of determinations of residue levels in river sediments (Hudson and Housatonic) were made and may provide complementary data on the factors controlling the distribution of the various isomers in aquatic ecosystems.

The impact of these contaminants on the fishery resources cannot be evaluated because data on the toxicity of these materials to fish and food organisms are lacking. However, this study established that these chemicals are present at levels that are well above detectable trace concentrations, and that they are widely distributed in the Great Lakes — particularly Lakes Huron and Ontario. These data are a prerequisite for an assessment of their hazard to aquatic organisms, and studies are being planned to determine their toxic effect on fish.

Bait for Fire Ant Control Evaluated. Amdro, the first fire ant insecticide approved by the Environmental Protection Agency for limited application since mirex was banned in 1978, was tested by using representative species of warmwater and coldwater invertebrates and fish. Technical Amdro (97.7 % active ingredient) was highly toxic to invertebrates; the EC50's (concentrations causing immobilization within 48 hours) were 130 µg/L for daphnids and 140 µg/L for midge larvae. Technical Amdro was also highly toxic to fish; the LC50's (concentrations [Ag/L] causing 50 % mortality within 96 hours of exposure) were 76 for rainbow trout, 75 for fathead minnows, 70 for channel catfish, and 120 for bluegills When the field formulation of Amdro (a pelleted bait containing 0.88% active ingredient) was tested at an estimated concentration greater than 100 µg/L active ingredient, it did not readily dissolve in the dilution water and most of the bait settled to the bottom of the test containers. Apparently little, if any, Amdro leached into the exposure water, and no mortalities occurred in invertebrates or fish after 96 hours of exposure.

Apple Snails versus Copper-Diquat. Apple snail populations have declined since 1970 in the canals surrounding Loxahatchee National Wildlife Refuge in southern Florida. This decline is of particular concern because the apple snail is the only food of the endangered snail kite (formerly known as the Everglade kite). Management of habitat for this kite is directed primarily toward providing suitable habitat during adverse drought conditions when the canals provide much of the open-water habitat for apple snails and the primary feeding areas for the

kite. The use of copper, a known molluscicide, in combination with diquat for the control of hydrilla (*Hydrilla verticillata)* in the canals surrounding the Refuge was suspected of being the agent responsible for the decline in apple snail populations.

The acute toxicities — concentrations lethal to 50% of test organisms in 96 hours — of copper, diquat, and copper in combination with diquat to apple snails were determined in laboratory tests. Concentrations of Cutrine-Plus and Komeen (chelated formulations of copper) toxic to juvenile snails were 22 and 24 μg/L, respectively. Adult snails were less sensitive to copper than juveniles; the concentration of komeen toxic to adults was 57 μg/L. Diquat was toxic to juvenile apple snails at 1,800 μg/L. The toxicity of the copper-diquat combination was similar to that of copper alone, indicating that copper was the toxic agent in the combination.

Copper residue levels in plants, detritus, and mud collected along transects established on the Refuge were significantly higher in samples from the canal than in those collected from the interior of the Refuge. Mean copper concentration in plants, detritus, and mud from the canal were 9.8, 33.9, and 12.4 μg/g, respectively, compared with 5.0, 9.7, and 5.4 μg/g in samples from the interior of the Refuge. Copper concentrations in the water ranged from 5 to 9 μg/L, and did not differ significantly in the canal and interior.

The influence of copper associated with detritus on apple snails was evaluated in the field by using caged snails and tank bioassay procedures. Mortality of caged adult apple snails placed for 8 weeks at four locations on the Refuge, each having different copper residue levels (27, 16, 12, and 8 μg/g copper in detritus), differed little among the sites. There was also no significant difference in the mortality of juvenile snails reared for 12 weeks in tanks containing detritus from the canal (26 g/ g copper), detritus from the Refuge interior (3 μg/g copper), and detritus from the Refuge interior treated with copper-diquat (150 μg/ g copper).

Mortality of caged juvenile and adult apple snails was not affected by a single field application of copper-diquat. Copper was rapidly taken out of solution by plants and detritus; however, at the end of 1 week, snails contained 90 pg/g of copper.

Thus laboratory studies showed that copper at low concentrations in the water was acutely toxic to apple snails, but field evaluations indicated that copper was rapidly taken out of solution by plants and detritus, that copper associated with detritus showed no detrimental effect on survival of snails, and that survival of juvenile and adult snails was not affected by a single application of copper-diquat. Although the influence of repeated applications of copper-diquat and the long-term effects of high body-burdens of copper in snails are not known, copper does not appear to have been responsible for the decline of apple snail populations in the canals surrounding the Refuge. Application of copper-diquat at recommended rates should pose no threat to apple snails in the highly organic waters of southern Florida.

Waste Transformer Oil More Toxic to Trout than Technical PCB's. Last year we reported that used or waste PCB's contained in electrical transformer oils were more toxic to trout than pure technical PCB's. Growth rates of rainbow trout were severely reduced within 30 days of exposure to 1.5 μg/L of waste PCB's, whereas technical PCB's had no effect on growth until 90 days after exposure at a concentration of 6.0 μg/L. In addition, mortality of fish exposed to waste PCB's at 6 μg/L was more than double that of fish exposed to technical PCB's (82% and 37%, respectively) at 90 days.

This year the study was continued to determine if rainbow trout stressed by exposure to PCB's were more susceptible to disease. Serum cortisol in fish exposed to waste PCB's (3-6 μg/L) was at least twice that in controls and in fish exposed to technical PCB's, indicating that the waste PCB caused severe stress. Fish were challenged with the enteric redmouth bacterium (ERM) by flush exposure (bacteria poured into aquarium water) and by intraperitoneal injection. Ninety days after challenges by flush exposure, fish were more resistant to ERM at 1.5 to 6.0 μg/L waste and technical PCB's than at lower concentrations and controls. However, when ERM was injected, fish in waste PCB's died sooner than did fish in technical PCB's, or controls. Disease mortality trends disappeared when fish were placed in fresh water after PCB exposure. Histopathological examination of the gills indicated that the secretion of excess mucus caused by exposure to PCB's may have been a physical or chemical barrier to bacteria in the flush disease challenges. Inhibition tests with sensitivity disks, and incorporating PCB into ERM media, indicated that the PCB materials were not directly inhibiting the ERM bacteria. Collectively, these results suggest that PCB exposure prevented the ERM bacteria from entering the fish. We also observed that, although exposure concentrations were essentially identical for both PCB formulations, fish exposed to transformer oil

accumulated fewer PCB's than did fish exposed to technical PCB's. This anomaly is believed to be related to the effects of petroleum hydrocarbons in the transformer oil on PCB solubility.

Trace Metals in the Big River, Missouri. An investigation of trace metals in the Big River, Missouri, was completed this year. The study was designed to evaluate the distribution, transport, mobility, accumulation, and biological effects of trace metals originating from mine tailings and was supported with funds provided by the St. Louis District of the U.S. Army Corps of Engineers. The Big River drains an area in southeastern Missouri known as the "Old Lead Belt," which was formerly the world's leading producer of lead. Tailings from abandoned mines occur in huge piles throughout the region and represent a potentially significant environmental hazard because they contain high concentrations of toxic metals. About 50,000 cubic yards of sediment enriched with lead, cadmium, and zinc entered the Big River in 1977, when a severe thunderstorm caused the collapse of an unmaintained tailings pile situated adjacent to the river.

An initial survey of trace metal residues in rooted aquatic plants, attached algae, crayfish, mussels, and fish from the Big River indicated elevated concentrations as far as 60 miles downstream from the tailings break. Trace metal analyses of river water samples confirmed that most metals were transported in the solid phase, that metal concentrations in the suspended load increased with flow, and that bed-load transport occurred during high flow. These results highlight the importance of floods in the movement of solid-phase metals.

No cogent chemical explanation for finding the elevated residues of lead, cadmium, and zinc in virtually all biological forms inhabiting the stream could be found. Conventional wisdom held that metals originally present as sulfides in the tailings should be insoluble under the alkaline (pH greater than 8.0), hard water (100-300 mg/L), and well-oxygenated conditions typical of streams draining the limestone-rich Ozark Plateau. Using a laboratory procedure that attacks the metal-containing particulate material with a series of progressively stronger reagents, we showed that relatively little of the potentially toxic metal residue present in the tailings and in the bottom sediments of affected reaches is in tightly bound chemical forms. Rather, the metals appear to be loosely associated with the surfaces of fine-grained sediment constituents derived from the area's dolomitic limestone bedrock, and hence are readily available for biogeochemical cycling. These laboratory findings were confirmed in the field when living, uncontaminated pocketbook mussels containing about 1.0 μg/g lead and less than 0.20 μg/g cadmium accumulated up to 120 μg/g lead and 20 μg/g cadmium in their soft tissues after being moved to contaminated stream areas for only 8 weeks. Based in part on these findings, we recommended to several State and Federal agencies that the contaminated particulate material not be contained in a proposed deep impoundment where summer de-oxygenation would occur. The reducing environment of the reservoir's hypolimnion would probably result in the further mobilization of metals from the sediments.

Wood Preservatives May Adversely Affect Fish and Food Organisms. Wood treated with the preservatives creosote or pentachlorophenol (PCP) is used in or near a variety of aquatic habitats — e.g., pilings for marinas, posts for walkways in marshy areas, and structures for streambank stabilization. Concern about the gradual release of contaminants or impurities (chlorinated phenols, chlorinated dibenzodioxins, and dibenzofurans) into water has led at least one State agency to ban the use of wood treated with creosote or PCP from State waters. In response to these concerns, we initiated acute toxicity tests (96-hour) to compare the relative toxicity of four wood preservatives — tetrachlorophenol, copper chromium arsenate (CCA), PCP, and copper PCP — to several species of fish and invertebrates. Tetrachlorophenol tested against daphnids, rainbow trout, fathead minnows, channel catfish, and bluegills was highly toxic; LC50's ranged from 85 to 170 μg/L for these organisms. Toxicity of CCA was moderate, as concentrations causing acute toxicity to channel catfish and bluegills were 1.8 and 12.5 mg/L, respectively. Rainbow trout were more sensitive to CCA (LC50 = less than 32 μg/L) possibly due to its copper component. The acute toxicity of various formulations of PCP, including a highly purified PCB, to daphnids did not differ significantly; EC50's ranged from 180 to 410 μg/L. The acute toxicity of a new copper PCP formulation was also similar to that of PCP for daphnids and channel catfish. Seemingly the addition of copper does not increase the toxicity of PCP.

Previous studies of PCP, a commonly used wood preservative, indicated that the toxicities of the industrial grade formulations were influenced by the amounts of impurities they contained. A relatively pure formulation containing less than 500 mg/L of impurities significantly reduced the growth of fathead minnows after 60 and 90 days of exposure to

concentrations of 85 µg/L or greater. During a 90-day exposure, PCB formulations containing up to 28,000 mg/L of impurities reduced growth of minnows at a concentration of 13 µg/L and reduced survival at 67 Ag/L. To further determine the toxic influence of impurities, we prepared a "pure" form of PCP containing less than 850 ng/L of total impurities. Fathead minnows exposed to the pure PCP for 90 days showed no adverse effects on growth or survival at concentrations up to 150 µg/L. These studies clearly show that the toxicity of PCB formulations to fish is greatly increased by associated impurities.

Our tests with PCP and CCA indicated that CCA would be preferable until further chronic toxicity tests with treated wood can be conducted. The presence of biologically active "impurities" in both creosote and industrial grade PCP represent potential long-term hazards to aquatic communities.

Dust-control Oils Can Pose a Hazard to Salmonids. Previously, the U.S. Forest Service routinely sprayed oil on unpaved roads to control dust in the Pacific Northwest. It has been estimated that as much as 75 % of the oil applied to the road may be translocated by dust transport and runoff. The greatest loss of oil from road surfaces is during rainstorms that occur shortly after application. Considering the proximity of many roads to National Forest streams, there was concern about the amount of oil runoff and the impact on salmon and trout. One official of the Forest Service reported that the water in a Montana stream might potentially contain 14 mg/L of oil after the first rainfall on a newly oiled road.

Streams in the Pacific Northwest provide habitat for resident and anadromous salmonids and their food organisms. This resource is of high priority to the Fish and Wildlife Service and the Northwestern States. Past studies have shown that short-term exposure (96 hours) of six different salmonid species to total oil concentrations of 2.7 to 4.4 mg/L resulted in extensive mortality. Exposures of 90 days adversely affected development and growth of salmonids at concentrations as low as 40 µg/L.

Recently completed studies at the Jackson (Wyoming) Field Research Laboratory addressed the potential for impact of road dust oils on resident trout and their food organisms. Intermittent exposure of cutthroat trout to simulated conditions of rainfall and runoff of road oils resulted in reduced growth of the trout. Exposures occurred for 48 hours in the 1st, 3rd, and 5th week of the 9-week study. Oil concentration in water during the 1st week of exposure reached a maximum of 51 µg/L total naphthalenes and corresponded to a tissue accumulation of 2.4 mg/L total naphthalenes. Subsequent exposures at the 3rd and 5th week resulted in 8.0 and 4.0 µg/L total naphthalenes, respectively, in water. Naphthalene concentrations in tissue were 1.7 mg/L at the 5th week of exposure but dropped to 0.23 mg/L at the end of the study. At these low and intermittent concentrations, the survival and growth of cutthroat trout were significantly reduced.

We also evaluated the effects of dust oil on colonization and community structure of fish-forage invertebrates, using artificial plate samplers placed in streams for 16 weeks. Weekly increases in colonization, as indicated by total number of organisms and number of species, peaked at the 6th week for both the control and oil-treated samplers. Concentrations of saturated hydrocarbons were elevated on the treated plate samplers through the 4th week of colonization, but the aromatic hydrocarbons (naphthalenes) disappeared during the 1st week after contamination. The oil-contaminated substrates had no effect on the quantity or quality of colonization.

The studies showed that oil used to control road dust can be washed off the road surface and that the runoff oil will be both dissolved in the water column and adsorbed onto stream bottom materials. Although the dissolved fraction is present for only a short time as compared with the adsorbed fraction, it is the dissolved fraction that is the most biologically available and important in terms of trout survival and growth. After these studies were begun, the Forest Service discontinued the use of oils to control dust.

Contaminants may be Contributing to Declines in Striped Bass Populations. Research on the effects of contaminants on striped bass began in spring 1980. Initial efforts involved a comprehensive survey for multiple organic and inorganic contaminants in striped bass, and we are currently conducting toxicological studies to determine the biological significance of the residues detected. The surveys showed that striped bass adults, eggs, and young of the year contained varying quantities of a multitude of organic and inorganic contaminants. No single contaminant appeared to be in sufficient concentration or frequency to enable us to conclude that it could be causing, or at least contributing to, the decline of striped bass stocks. However, numerous organic contaminants (PCB's, organochlorine insecticides, dioxins, dibenzofurans, and petroleum

Seining for young striped bass near the point where the Elk River enters Chesapeake Bay, Maryland. Various organic and inorganic contaminants may be contributing to declines in populations of striped bass in this region. *Photo by T. Haines.*

hydrocarbons) and inorganic contaminants (selenium, arsenic, lead, cadmium, and copper) were frequently present in small quantities in fish collected from throughout the Chesapeake Bay and Hudson River areas. These chemicals represent only the fraction of the potential contaminants that current analytical methodology enables us to detect and measure. If the measured contaminants are affecting striped bass stocks, the effects are most likely sublethal and result in chronic mortality. The magnitude of contaminant-induced chronic mortality is difficult to predict in natural striped bass populations, but even small increases in mortality rates could be significant during early life stages.

Toxicological studies were initiated this year with early life stages of striped bass to determine the effects of a mixture of chemical contaminants on survival, growth, swimming stamina, and response to natural environmental challenges such as prey-predator relations and variations in water quality. Selection of contaminants for the mixture was based on our analyses of water from the Potomac, Choptank, James, and Elk rivers; from data obtained through other monitoring programs sponsored by the Environmental Protection Agency and State agencies; and from residues detected in young striped bass. The mixture included industrial organics (Aroclors 1248, 1254, and 1260), pesticides (DDE, Kepone, toxaphene, chlordane, atrazine, and simazine), petroleum hydrocarbons (perylene, fluorene, phenanthrene, anthrene, flouranthrene, pyrene, benzoanthrene, and chrysene), and heavy metals (arsenic, selenium, lead, cadmium, and copper). Concentrations of individual contaminants in the mixture represented environmental levels found in striped bass spawning habitats in the Chesapeake Bay area. Exposure concentrations to young striped bass ranged from four times to one-fourth of the mixture concentration. Tests were conducted in dilution waters simulating those encountered by early life stages of striped bass and included fresh water (250 mg/L hardness) and salt water at salinities of 2 and 5 ‰.

Survival of young striped bass decreased in fresh water and 2 ‰ salt water after 30 days of exposure to two and four times the mixture concentration, but not in 5 ‰ salt water after 90 days of exposure. However, the swimming ability and feeding of young bass was impaired after 30 days in the 5 °/oo salt water. After 60 days, swimming behavior was reduced in the more saline test water at half the mixture concentration and the vulnerability of the young bass to predation increased.

Striped bass larvae move from freshwater spawning areas to saline waters during their early life stages. The time needed to reach saline environments varies among striped bass populations, depending on the river, its flow characteristics, and spring rainfall. We tested the effects of entering salt water by subjecting bass that had been exposed to

contaminant mixtures in 5 ‰ salt water for 60 days to 33, 66, and 100% sea water (33 ‰ salinity) for 96 hours. Survival for all groups tested ranged from 90 to 100%, indicating that the osmoregulatory capacity of the larvae was not impaired by the contaminant mixture.

In summary, the toxicity data showed that the contaminant mixture can significantly decrease survival of striped bass larvae that remain in water of low salinity —2 ‰ or less — for several weeks. The contaminant mixture did not cause direct mortality of larvae in 5 ‰ salt water, but reduced their ability to swim and feed, which in turn increases susceptibility to environmental stress. In assessing the possible causes of the population declines of striped bass along the Atlantic coast, results of our studies suggest that chemical contaminants may be a contributing factor.

Environmental Research Exchange between United States and USSR. Scientists from this laboratory have actively participated with scientists from the Environmental Protection Agency in the USA-USSR Joint Agreement on Environmental Protection since 1975. This participation has included the development of joint symposia and the exchange of scientists to conduct joint research on hazards posed by contaminants in the aquatic environment. The objectives of the cooperative investigations are to develop techniques to be used as indicators of contaminant stress in aquatic communities and to assess and predict impacts of chemical contaminants on water quality that would be useful to the United States and the Soviet Union. These activities have resulted in about 70 manuscripts, of which 21 are co-authored by Soviet and American scientists.

One member of the staff participated in a symposium on the Geochemistry of Natural Waters that was hosted by the Hydrochemical Institute, Rostov on Don, USSR. Two other members of the staff conducted research relative to fish behavior and microbiology with Soviet scientists at the Institute of Biology of Inland Waters, USSR Academy of Sciences, Borok. They examined the influence of petroleum hydrocarbons, phenols, detergents, and an insecticide on the chemical senses of common carp, an economically important species in the Soviet Union. The use of Soviet electrophysiological techniques enabled us to characterize and compare neural messages that the olfactory system sends to the brain of the fish when the system is exposed to chemical contaminants, and when the olfactory system of chronically exposed fish is stimulated by food odors. It was found that phenol, sodium lauryl sulfate detergents, and diesel fuel stimulated the olfactory system, but did not induce avoidance reactions. Long-term exposure to Strobane, an organochlorine insecticide similar to toxaphene, greatly reduced olfactory reactions to food odors, and when diesel fuel was present, the neural responses to food odors were totally inhibited. The results suggested that the ability of fish to find food may be inhibited through impairments of the olfactory system by certain chemicals. The olfactory system mediates feeding responses, as well as reproductive responses, in many species. Information from these studies will be used in the design of experiments next year to assess the toxicity of crude oil fractions to salmonids. Three manuscripts on fish behavioral toxicology are being jointly prepared for publication in the United States and USSR.

The cooperative microbiological investigations were conducted to determine the impact of a simulated spill of diesel fuel on the trophic levels of a freshwater microcosm that contained native sediment, plants, water, and organisms from the Rybinsk Reservoir. Twenty variables were measured during the 14-day study. It was found that, immediately following a spill that simulated 1 μg/L fuel oil, populations of organisms at certain trophic levels — particularly algae and invertebrates — were significantly reduced. However, these groups rapidly recovered when the oil was removed or reduced. Functional and morphological changes (observed by electron microscopy) occurred among the sediment microbiota. The indigenous bacteria rapidly responded to oil, using it as a nutrient source. Bacterial oil degraders increased by 1,000 times and saprophytic bacteria (responding to dead plant and animal material) by 100 times.

Survival, Growth, and Reproduction of Fish Affected by Selenium. Selenium is a common trace element in coal, and is largely volatilized during combustion. In the stack it adsorbs onto small particulates, some of which are removed as fly ash and some of which escape. Ash pond effluent that is high in selenium has resulted in high selenium levels in fish from a number of cooling water reservoirs. In several of these, including Belews Lake and Hyco Reservoir in North Carolina, sport fish populations declined severely. This Laboratory's research is designed to determine residues of selenium in natural fish populations, what levels are associated with reproductive failure or other pathology, and the mechanism by which reproduction is inhibited.

Collections of male and female largemouth bass

and bluegills were made from three cooling water reservoirs — Hyco and Catfish in North Carolina and Sangchris in Illinois. A small multispecies collection was also made from Lake Hope, Ohio, which receives runoff from coal mines. Selenium levels were determined for both the gonadal tissue and for the rest of the body. Fish from Lake Hope had selenium concentrations (0.55 μg/g or less) in the range normally found in relatively uncontaminated water. However, fish from all three cooling reservoirs had mean selenium concentrations greater than 85% of those found in freshwater fish nationwide, as determined by the National Pesticide Monitoring Program from 1972 to 1979. The highest mean selenium residues (7.8 μg/g) were measured in male bluegills from Hyco Reservoir. Ovaries always contained significantly higher concentrations of selenium than did other body tissues. Seemingly, selenium was transferred from the parent to the maturing eggs and concentrated there. Residue levels in testes, however, were not consistently different from those in other body tissues.

Male and female bluegills were collected from Hyco Reservoir and Roxboro City Lake (a low-selenium site) for gamete viability and larval survival experiments. Preliminary results from cross-breeding experiments indicated that fertilization success was good with gametes from a population with high selenium residues (Hyco) or one with low selenium contamination. However, larvae from crosses involving a Hyco female appeared to develop abnormally and to have swimming and balance problems 6-7 days after hatching. The selenium level in males did not seem to affect larval development.

We also investigated the chronic toxicity of selenium (as selenite) to rainbow trout at concentrations similar to those measured in contaminated aquatic environments. Exposure of trout fry to selenium at concentrations of 50 or 100 μg/L resulted in significantly reduced growth and increased mortality within 60 days after exposure. After 90 days of exposure, 47% and 82% mortality were observed in trout exposed to 50 and 100 μg/L, respectively. The fish residue data indicate that the bioconcentration factors ranged from 10 to 100.

Contaminants in Northern Prairie Wetlands. Prairie wetlands of the north-central United States are essential for the production of many migratory waterfowl. The U.S. Department of Agriculture has estimated that 80 to 90% of the agricultural cropland within this area is treated annually with pesticides. Since wetlands are interspersed throughout much of this treated cropland, they are first in line to receive contaminants that are carried from the fields in runoff water and eroded topsoil. There currently exists a need for information in five categories: (1) factors that determine how much of a particular pesticide will be carried into a wetland from adjacent fields; (2) how a pesticide will be partitioned between the water and the particulate phase of the runoff; (3) how this partitioning affects bioavailability of the chemical; (4) effects of the available pesticide on important wetland biota (especially waterfowl food organisms); and (5) how rapidly the contaminant is degraded within the wetland into harmless substances.

A model laboratory system, composed of a runoff simulation device linked to a series of wetland microcosms, is being used to address the above questions as they relate to pesticides frequently used in the northern prairies. In this system the runoff simulator is loaded with topsoil from a wetland watershed that has been treated with a pesticide. Erosion of the topsoil with rainwater is simulated and the resulting "runoff" is transported into the microcosms that consist of important wetland plants and invertebrates growing in sediment and water obtained from a wetland. Samples are then taken at various points and times to determine which factors influence the quantity and distribution of the pesticide in the runoff, its availability, and its uptake by the various wetland components. The biological effects of these exposures on each wetland organism are evaluated and the time required for degradation of the pesticide in the wetland sediment under both aerobic and anaerobic conditions is also determined.

Studies completed to date have included a number of simulated runoff events involving the herbicides trifluralin and atrazine. Partly completed studies also involve Far-Go (triallate) and Dyfonate (fonofos). Initial results from microcosms exposed by way of simulated runoff indicated that normal use of trifluralin and atrazine has no acute or chronic effects on wetland invertebrates important to migratory waterfowl. Since the laboratory system can be used to screen a wide variety of chemicals in a relatively short period of time, with much less expense than that incurred in comparable field studies, it is anticipated that additional herbicides and insecticides will be studied.

Results from the runoff experiments indicate that pesticide formulation, soil properties (i.e., clay content, organic matter content, particle surface area, and moisture content), residence time, and method

of application (i.e., applied to surface or incorporated) greatly affect the partitioning (and thus the transport and fate) of the chemical in the runoff material. This information, along with data on the acute and chronic effects of bioavailable concentrations, will aid in providing recommendations of chemicals to be used and methods of application to minimize the hazard to waterfowl production.

Acidic Precipitation in the Northeast. Investigations to determine whether acidic precipitation constitutes a threat to surface water quality and fishery resources in the northeastern United States are continuing. Analyses of sediments from six remote lakes in Maine, New Hampshire, and Vermont showed that concentrations of certain potentially toxic metals — especially lead, zinc, and copper —began to increase above background concentrations about 100 years ago. The increases in the toxic metals accelerated 30 to 50 years ago, at the same time that calcium, magnesium, and aluminum concentrations in sediments began to decrease. It is believed that precipitation and lake waters became acidic and began to dissolve naturally occurring calcium, magnesium, and aluminum from sediments, simultaneously decreasing the amounts deposited in sediments while inputs of other metals to these lakes were increasing.

Fish from the acidic lakes contained higher concentrations of aluminum, copper, mercury, and zinc than did fish of the same species and size from nonacidic lakes. Concentrations of these metals in fish were most highly correlated with lake pH and concentrations of calcium and magnesium in lake water. Correlations of metal concentrations between fish and water were generally small.

A study to determine the proportions of headwater lakes and streams in New England that are vulnerable to acidification, and to locate sensitive areas, was completed. A total of 226 headwater lakes and streams were surveyed. These surface waters were chosen to represent a range of geographic areas, soil, and bedrock types, and to avoid areas directly affected by pollution from local sources.

Acidic lakes were found in each of the six New England States. In about 8% of the waters sampled the pH was less than 5, and in about 20% it was between 5 and 6. Proportionately more waters were very low in alkalinity, a measure of acid-neutralizing ability. About 25% of the waters had alkalinities of 1 mg/L (as $CaCO_3$) or less, and 25% had alkalinities between 1 and 10 mg/L. These waters are highly and moderately sensitive, respectively, to acidification. Waters sensitive to acidification generally occurred in areas where (1) bedrock was low in acid neutralizing capacity, (2) soils were low in base exchange concentrations, and (3) lakes had high calcite saturation indices. These three criteria have been proposed as indicators of vulnerability to acidification. Human disturbance of the watershed also affected vulnerability indices of lakes: Surface waters in disturbed watersheds were not vulnerable to acidification.

Historical pH data were obtained for 95 of the lakes surveyed. Of these, 34 had higher pH and 61 had lower pH in the present survey than previously. The mean pH declined from 6.07 historically to 5.37 now. This study demonstrated that a significant proportion of undisturbed headwater lakes and streams in the Northeast are vulnerable to acidification, that some are already rather strongly acidic, and that the majority of these waters have become progressively more acidic.

In an additional study, we are attempting to determine whether Atlantic salmon populations in the United States are now, or are likely to be, adversely affected by acidification. In southern Norway and southwestern Nova Scotia, where rivers were acidified, Atlantic salmon populations were adversely affected. Rivers used by Atlantic salmon in the United States drain areas that are both vulnerable to acidification and receiving acid precipitation (pH 4.2-4.4). Nine salmon streams, including major rivers, intermediate tributaries, and small spawning and nursery streams, were selected for study. Eight streams are in Maine and contain Atlantic salmon; one is in Vermont and is undergoing restoration of its salmon population. Water samples collected at frequent intervals were analyzed for pH, alkalinity, specific conductance, chloride, color, aluminum, calcium, magnesium, manganese, potassium, sodium, and sulfate.

The large salmon rivers in the United States had much higher pH's than did rivers in Norway and Nova Scotia where Atlantic salmon populations have declined. During snowmelt and spring runoff the streams underwent pH depressions ranging from 1.2 to 1.6 units. Small tributary streams had pH minima below 5.0, a level that may be toxic to fish. Aluminum concentrations in stream water increased during periods of pH depression and exceeded 400 $\mu g/L$ in small tributary streams. The combination of low pH and high aluminum concentration is especially toxic to fish. Atlantic salmon redds were located and marked in a small tributary stream and in a larger, third-order stream. One redd in each

stream was excavated after the eggs hatched, but before fry emerged from the gravel. Total egg and fry mortality was 11% in the small stream, which had a pH minimum of 4.9 and a maximum aluminum concentration of 360 µg/L. In the larger stream, where the minimum pH was 5.4 and the maximum aluminum concentration was 270 µg/L, total mortality was only 2%.

Chemical Analyses of Fishes from Acid and Circumneutral Lakes in Northern Wisconsin. Recent investigations of surface water and precipitation chemistry have aroused considerable concern about the potential effects of acidic precipitation on fishery resources in the north-central United States. In north-central Wisconsin, hundreds of lakes are poorly buffered, naturally acidic, and susceptible to acidification. Precipitation in this area is acidic; weighted annual mean pH ranged from about 4.5 to 4.7. To evaluate potential effects of acidification on fishery resources, we began comparative analyses of fish populations in six acidic (pH range, 5.1-6.0) and six circumneutral (pH range, 6.7-7.5) clear-water lakes in north-central Wisconsin during 1980. The two groups of lakes (here termed acidic and circumneutral) were morphologically and hydrologically similar, but differed substantially in pH, alkalinity, and related chemical characteristics. Dystrophic (bog) and winterkill lakes and lakes located on recently disturbed watersheds were excluded from the study.

The primary objective of this study was to determine whether fishes inhabiting naturally acidic lakes in this region exhibit signs of acid or metal stress. If stress is evident, it is likely that continuing additions of acids to these lakes will adversely affect fish populations. Selected characteristics of fish populations in the acidic and circumneutral lakes were compared. Differences between the two groups of lakes in serum calcium concentrations of bluegills and white suckers before spawning and in the accumulation of potentially toxic metals by bluegills and walleyes were compared and evaluated in terms of pH-related effects. Because many water chemistry variables (e.g., alkalinity, metal concentration and form, and calcium concentration) vary concomitantly with pH, it is emphasized that the acidic and circumneutral lakes differ mainly in pH-related chemical characteristics, and not solely in pH. This work was conducted with cooperation from personnel of the Wisconsin Department of Natural Resources and the U.S. Environmental Protection Agency, who are studying surface water and precipitation chemistry in this area.

Blood serum samples were collected from mature prespawning white suckers and bluegills from study lakes during spring 1981. Female white suckers were collected from a lake with neutral pH (7.0) and from two acidic lakes (pH 5.6). The mean serum calcium concentration was significantly higher in female suckers from the neutral lakes than in those from the acidic lakes, whereas mean concentrations in females from the two acidic lakes did not differ. Serum calcium concentrations in female bluegills from four acidic and four circumneutral lakes varied among lakes; however, no correlation between lake pH and serum calcium concentration in fish was apparent. In contrast, a strong negative correlation between mean serum calcium concentration and relative density of bluegills in the eight lakes was observed. Mean serum calcium concentrations in mature male bluegills, measured in samples from one acidic and one circumneutral lake, were substantially less than in females from the two lakes, which is the normal situation before spawning. These results suggest that white suckers, which are more acid-sensitive than bluegills, are experiencing pH-related stress in lakes with pH's of 5.6 or less. In acidified Ontario lakes, mature female white suckers exhibited depressed serum calcium concentrations that were associated with failure to produce viable eggs. Serum calcium concentrations may be a useful measure of pH-related stress in white suckers.

Dual composite samples of whole bluegills from five acidic and five circumneutral lakes were analyzed for aluminum, cadmium, copper, manganese, lead, vanadium, and zinc. All bluegill samples analyzed were composed of 4-year-old fish, with the exception of the samples from one acidic lake, which contained 6- and 7-year-old fish. Concentrations of cadmium, manganese, lead, vanadium, and zinc in bluegills varied significantly among lakes, whereas concentrations of aluminum and copper did not. Mean concentrations of cadmium and lead in bluegills from the 10 lakes were strongly (rank) correlated with hydrogen ion concentration. Mean concentrations of manganese, vanadium, and zinc in bluegills were unrelated to lake pH and did not exhibit the manifold variation among lakes shown by cadmium and lead. Concentrations of manganese, vanadium, zinc, and other essential trace elements in fishes appear to be homeostatically controlled and are consequently less variable than those of the nonessential elements cadmium and lead. The mean and maximum concentrations of cadmium and lead in whole bluegills from the acidic

lakes were similar to or exceeded values reported for whole bluegills from United States lakes and rivers contaminated by metal-containing industrial effluents and urban runoff. In contrast, cadmium and lead concentrations in bluegills from the circumneutral Wisconsin lakes were similar to values reported for bluegills from uncontaminated waters.

Mercury concentrations were measured in axial (edible) muscle tissue of 4-, 5-, and 7-year-old walleyes from two acidic and three circumneutral lakes. Mercury concentrations were substantially higher in walleyes from the two acidic lakes (range, 0.41 to 1.74 μg/g wet weight) than in walleyes from the three circumneutral lakes (range, 0.22 to 0.57 μg/g wet weight). About one-third of the walleyes analyzed from the two acidic lakes contained mercury concentrations in excess of the 1.0 μg/g U.S. Food and Drug Administration "Action Level" for human consumption. Given the remote location of the Wisconsin lakes, the proximity and geologic similarity of the watersheds of the acidic and circumneutral lakes, and the absence of direct (other than atmospheric) anthropogenic inputs of metals to the lakes, these findings suggest that cadmium, lead, and mercury in the acidic lakes are highly available to fish and perhaps to other aquatic organisms.

These studies indicated that the pH range of the acidic lakes studied (5.1-6.0) was stressful to sensitive fish fauna. Acid-sensitive fishes were rare or absent in acidic lakes, but were well represented in the circumneutral lakes. Serum calcium measurements revealed that white suckers were stressed in lakes with pH 5.6 or lower. Accumulation of the highly toxic metals cadmium, lead, and mercury by fish was substantially greater in acidic than in circumneutral lakes.

In studies of susceptible surface waters in Scandinavia and eastern North America, acidification of sensitive surface waters has generally been detected within one to two decades where precipitation pH was less than 4.6. The pH of precipitation falling in north-central Wisconsin is near this threshold value. Consequently, increased loadings of acids to susceptible lakes in north-central Wisconsin would probably increase chronic acid-related stress on fish populations. Piscivorous fishes in acidified waters might accumulate enough mercury in edible muscle tissue to render them unfit for human consumption.

Ecological Indicators of Contaminant Stress. The most pervasive class of environmental contaminants found in aquatic ecosystems originates from nonpoint sources such as agriculture, energy-related activities, surface mining, and urban development. These activities result in large-scale land disturbance, erosion, and transport of sediment into nearby aquatic ecosystems. Chemical contaminants generated by these activities are often sorbed onto soil particles and then washed into streams, rivers, and lakes. Small streams are often the first aquatic ecosystems affected by accelerated sedimentation and from non-point contaminants. Streams are extremely important as systems for processing organic material — both natural detritus and material generated by humans — from the surrounding watershed. Sediment profoundly affects the bioavailability and transport of organic contaminants within an aquatic ecosystem, as well as from one aquatic system to another.

In cooperation with the Environmental Protection Agency and the University of Missouri, this Laboratory is assessing the impact of sediment and triphenylphosphate (TPP) on artificial stream ecosystems. This compound is an industrial chemical and is a component of many compounds used as substitutes for PCB. Laboratory studies showed that the concentrations of **TPP** causing acute toxicity to scuds, midge larvae, and bluegills were 0.25, 0.36, and 0.75 mg/L. Neither pure clays nor locally obtained topsoil caused acute toxicity to these organisms at concentrations as high as 1 g/L. The acute toxicity tests also showed that the presence of clay or topsoil reduced the bioavailability and toxic effect of **TPP.** In other laboratory studies, we found that sorbed **TPP** resulted in a reduction of emerging midge larvae from lake sediments. Thus, sorption of **TPP** onto sediments can reduce its bioavailability and toxicity to fish **but** increase its toxic effect on benthic organisms.

To determine if similar results occur in more natural situations, and to compare the results of single species laboratory techniques with populations and community responses in natural systems, we conducted comparable studies in our artificial streams. The streams were exposed to sediment and a combination of sediment and TPP for 6 weeks. Preliminary examination of the data showed that sediment and sediment plus **TPP** reduced the magnitude of drift of algae and detrital leaf material in the streams but greatly increased the invertebrate drift, especially of mayflies and amphipods. Leaf degradation was also reduced in streams receiving each treatment — implying that the treatments resulted in invertebrate leaf processors being lost from the stream, which in turn reduced leaf processing. The overall effects of the treatment may be a reduc-

Hybrid grass carp x bighead carp feeding on aquatic plants in laboratory studies of feeding preference and behavior. Stocking of these infertile hybrids may reduce the need for herbicides (many of which are toxic to fish) to control aquatic vegetation in certain waters. *Photo by T. Jackson.*

tion of energy transfer through the food web to fish.

Hybrid Grass Carp May Reduce Herbicide Applications. Hybrid grass carp (female grass carp x male bighead carp) have been commercially produced in the United States since 1979 as a sterile alternative to fertile grass carp for aquatic plant control. Research interest in these fish stems from their possible role in reducing or eliminating the need for aquatic herbicides to control water weeds, particularly in western irrigation systems where applications of toxic herbicides kill hundreds of thousands of resident fish each year.

Recent field studies of hybrids demonstrated that survival and growth in weight were both high: 70% and 300 g after one growing season, and 50% and 900 g after two growing seasons. In addition these fish were shown to be herbivorous; fecal pellets of hybrids from a pond supporting large numbers of dragonfly and damselfly nymphs contained over 99% aquatic plant material.

Blood samples were obtained from these hybrids with an improved cardiac puncture procedure without mortality or adverse side effects. The more than 230 fish sampled covered a wide range in size (13 to 1,300 g). At peak proficiency, we weighed anesthetized specimens, measured total length, and obtained a blood sample in less than 90 seconds per fish. The Maine Cooperative Fishery Research Unit analyzed the blood samples for red cell DNA content and found that all fish were triploid, having 50% more chromosomes than the parent species. This finding was particularly encouraging because triploid hybrids have the greatest likelihood of being completely sterile.

Three-year-old hybrid grass carp x bighead carp, comparing a fish with a broken back caused by electrofishing (top) with a normal fish (bottom). The spinal column of the hybrid is often broken or displaced when the hybrids are collected with electrofishing gear. Most recover. *Photo by T. Jackson.*

Another encouraging result from this research is that no hybrids have been taken by hook and line in over 2 years from a completely controlled urban

fishery, despite a fishing pressure for trout of 5,000 to 7,000 man-hours per hectare per year.

A precautionary finding from this work is that the spinal column of hybrid grass carp is susceptible to displacement or breakage when fish are exposed to AC or DC electrical fields produced by conventional electrofishing gear. In one experiment, 90% of the hybrids exposed to pulsed DC electrofishing methods in ponds sustained broken backs but recovered to near-normal swimming and feeding activity and growth rates within about 8 months. By comparison, the vertebral columns of nonhybrid grass carp were undamaged among fish collected from a pond near Denver, Colorado, with the same equipment. In addition, medium-sized grass carp were most easily stunned and captured when low frequency (15-20 hertz) direct current was used at medium pulse width (40-50%), although their jumping behavior in response to this electrical field was both unpredictable and spectacular.

A surgical procedure for gelding and spaying fertile yearling grass carp was developed to provide small numbers of sterile fish for field comparisons with hybrid grass carp. Cautious surgical techniques were credited for the rapid recovery and low postoperative mortality (2%) among 280 sterilized fish. However, disturbance of internal organs probably caused the reduced growth but increased food consumption rates observed among treated fish when compared with the rates in fertile controls from the same stock. Fish weighing 200 to 300 g are ideal for surgical sterilization and can be successfully handled and transported 7 days after surgery, although 30 to 40 days is preferable. Yearling grass carp twice subjected to surgery over a 40-day interval completely consumed *Hydrilla verticillata* in 5 days in three southern California research canals. These results may accelerate research with grass carp and hybrids and eventually reduce or eliminate herbicide use for weed control in certain water management systems.

Fish Populations Influenced by Irrigated Agriculture. About 6.5 million acres in the Central Valley of California are intensively irrigated for agriculture. During the irrigation season (usually March through October), return flows from irrigated fields can make up most of the discharge in low-elevation rivers. Knowledge of changes in the river environment associated with irrigated agriculture and attendant changes in the fish populations may contribute toward a better understanding of potential ecological impacts from existing and future irrigation drainage projects elsewhere in the United States.

Field research was initiated on the San Joaquin and Merced rivers and Salt Slough (agricultural drain) in July 1980 and completed in November 1981. Monthly samples were collected at upstream "control" stations at the head of the irrigated valley floor and at downstream "experimental" stations receiving irrigation return flows.

Physical and chemical characteristics exhibited longitudinal (upstream to downstream) differences related primarily to irrigation activities. Turbidity, total alkalinity, conductivity, and concentrations of macronutrients (nitrates and phosphates) showed especially conspicuous increases at downstream stations. Fish faunas also differed between upstream and downstream stations: several species were primarily caught upstream (e.g., sculpins, green sunfish, redear sunfish, Sacramento squawfish, hardhead, and threespine stickleback); and other species were encountered only downstream (e.g., Mississippi silverside, white crappie, threadfin shad, fathead minnow, Sacramento blackfish, tule perch, and striped bass). Anadromous chinook salmon were observed from October through April in the Merced River.

The incidence of parasitic copepods (anchor worms), hemorrhagic fins, and fin erosion were determined for bluegills and largemouth bass. Copepods occurred much more frequently on bluegills and bass from downstream stations than from upstream stations. Bluegills, but not bass, had a higher incidence of hemorrhagic fins at the downstream stations. Fin erosion was not significantly higher at the downstream stations in either species. The incidence of copepods was significantly correlated with several water-quality characteristics, including temperature, turbidity, total nitrogen (bluegills only), orthophosphate, and total phosphorus. Seasonal effects were important, the incidence of copepods being highest in summer and lowest in winter. There were no significant correlations between the incidence of hemorrhagic fins in bluegills and water-quality variables.

The diets of bluegills differed between upstream and downstream stations; the differences seemed to be related to changes in the composition of benthic forage invertebrates. Growth rates and condition factors of bluegills were not significantly different.

These preliminary results suggest that, although certain physical and chemical characteristics of the river environment are modified by irrigation activities, the biological significance of the modifications is subtle and difficult to interpret.

Bald eagles are submitted to the Patuxent Wildlife Research Center for chemical analysis. In a recent study, the livers of a substantial number of those examined (7%) contained lead at levels indicative of probable lead poisoning. *Photo by H. Bourne.*

PATUXENT WILDLIFE RESEARCH CENTER

Mortality of Bald Eagles from Lead Poisoning. During the past 3 years, investigations to determine base-line residues of heavy metals in bald eagles have been carried out. Liver samples from 650 archived specimens have been analyzed for 12 metals.

A substantial number of the samples contained what appeared to be large amounts of lead. No data were available to interpret these levels, however, so captive bald eagles were dosed with lead shot to determine tissue lead residues associated with lead-shot poisoning and mortality. Four of the five dosed birds died and contained 11.5-27 ppm lead in their livers.

Forty-seven archived eagles contained liver lead residues ranging from 11 to 98 ppm wet weight, indicating that they probably died of lead poisoning. Necropsy findings for these eagles were generally compatible with lead poisoning as well. Birds were in poor condition and emaciated, had reduced fat deposits and atrophied pectoral muscles, and some had gastrointestinal tracts stained with bile. Six birds contained lead shot in their gastrointestinal tracts. All but 1 of the 47 suspected lead-poisoned eagles died between October and March; the highest number of deaths (18) was in January.

Chronic Low-Level Lead Exposure Does Not Affect Reproduction in American Kestrels. The release of peregrine falcons in cities where their prey are heavily contaminated with lead, and the exposure of bald eagles to lead from dead or crippled waterfowl has raised questions about the effects of sublethal exposure to lead.

American kestrels were fed 0, 10, or 50 ppm metallic lead powder mixed into their diet for 5-7 months to evaluate the effects of chronic exposure to lead. Lead levels were elevated in the bones and livers of birds receiving the treated diets, particularly in the 50-ppm treatment group. Differential assimilation of lead was evident between males and females; the higher levels were in the females. Lead

exposure did not affect survival, egg-laying, initiation of incubation, or fertility of eggs. Little or no lead was detected in egg contents, and levels in eggshells were highly variable and unrelated to treatment. Eggshell thickness was unaffected.

This study suggests that the chronic lead exposure that most raptors receive is unlikely to cause reproductive problems through the initiation of incubation. Also lead exposure should not be monitored through use of eggs or eggshells because there appears to be no relation between levels ingested and amounts present in the eggs.

Lead Exposure Affects Development of Young American Kestrels. American kestrels often live in or near urban areas with high lead availability. Tissue lead concentrations from other bird species from urban areas are often high. For example, pigeons have been reported to contain several hundred parts per million lead in their tissues. Potential food items for kestrels, such as shrews, also are contaminated by highway lead.

Hatchling kestrels were dosed daily for 10 days with inorganic lead powder at 25, 125, and 625 mg/kg. The intermediate level represents a highly probable level of exposure in the wild, whereas 625 mg/kg represents a possible but less likely level of exposure. Significant growth retardation occurred within 3-4 days of dosing in the intermediate and high dose groups, and the highest dosage resulted in 40% mortality. In addition, significant hematological effects occurred in the lowest dose group, including lower hemoglobin content and inhibited activity of the enzyme ALAD in red blood cells. Levels of several plasma enzymes, including alkaline phosphatase and creatine phosphokinase, were altered by lead exposure. These findings suggest that lead ingestion from either lead shot or tissues contaminated with lead could significantly impair normal development in nestling falcons.

Earthworms from Soil Containing Sewage Sludge May Be Hazardous to Wildlife Feeding on Them. Sewage sludge is sometimes spread on farmland as a means of disposal. The sludge conditions and fertilizes soil. Some sludges contain exceptionally high concentrations of metals, however, and are potentially a source of contamination of wildlife food. We collected and analyzed earthworms from farmers' fields treated with sludges known to contain high concentrations of metals and from paired control plots that had not been treated with sludge. Earthworms were selected for study because they are an important food of many wildlife species, they are widely distributed, and they are useful for monitoring soil pollution.

Earthworms from the four treated sites contained on the average more cadmium (12 times), copper (2.4 times), zinc (2.0 times), and lead (1.2 times) than did earthworms from control sites, but there were large differences between sites. Generally, cadmium and zinc were concentrated by earthworms relative to soil, and copper, lead, and nickel were not concentrated. At one site the soil contained only 2 ppm cadmium, but the earthworms contained 100 ppm cadmium, a level considered hazardous to wildlife. Liming soil decreased cadmium concentrations in earthworms slightly, but had no discernible effect on concentrations of the other metals studied. High zinc concentrations in soil substantially reduced cadmium concentrations in earthworms.

Applying some sewage sludges to land may enrich the soil, improve plant growth, and benefit wildlife. However, applying sludges heavily contaminated with metals to soil will contaminate some wildlife foods and increase the metal burdens carried by wildlife feeding in the vicinity.

Acid Rain Impacts on Aquatic Birds. Preliminary surveys of the wildlife of wetlands susceptible to acidification have indicated that diving waterfowl (hooded and common mergansers and ring-necked ducks) are characteristic of these areas and are likely to be affected by food reduction. Measurements of habitat characteristics and bird use of wetlands in susceptible and resistant areas of Maine were begun in the spring and summer of 1982. A total of 32 wetlands in the vulnerable area were sampled, and chemical analysis revealed that 29 of them were susceptible to acidification. Additional analyses confirmed that 28 of 29 wetlands examined in the nonvulnerable area were highly resistant to acidification.

Studies of the Effects of Fluorides on Birds. Fluorides are major industrial air pollutants resulting from aluminum reduction, steel manufacturing, coal-fired power generation, and phosphate mining and processing. Dental and bony lesions in deer have been reported in areas of high fluoride levels, but few data exist on other wild mammals or birds.

The tendency of fluorine to bind with calcium and to be stored in calcium-containing tissues suggested the need for investigations of the effects of fluorides on eggshells and growth of birds.

Preliminary studies on wild birds were conducted during 1982. Fledging weights of young screech owls were depressed when birds were given fluorides in amounts equivalent to low dietary doses to be ex-

pected in polluted areas; however, final conclusions must await further analyses. Additional work is under way to evaluate methods of realistically administering fluorides to wildlife in experimental studies.

Biological samples were collected from an area of industrial fluoride pollution in Tennessee. These samples are being analyzed for fluoride content. The data will be used to determine acquisition of fluorides by birds in heavily contaminated environments. These data will aid in the extrapolation of our experimentally derived results to field situations.

Tissue Residues Are Not Diagnostic of Dietary Chromium Exposure in Black Ducks. Chromium, a common by-product of industrial processes, is elevated in waters along the Atlantic seaboard. Waterfowl and other avian species that winter and breed in the area must be able to handle substantial quantities of the metal. Reproductive studies with black ducks have shown that although adults survive up to 50 ppm in the diet and reproduce as successfully as controls, young black ducks neither grow nor survive as well as controls on a similar diet.

Liver, kidney, and carcasses from controls and birds fed two treatment levels of chromium were analyzed, but there was no correlation between dietary exposure level and tissue residues. Egg contents showed no dose-related change in chromium residue levels. Only the long bones in the legs of adult females appeared to contain a dose-related amount of chromium. Because metals may be retained in certain portions of the bone for long periods, and because they may be accumulated throughout life, this tissue is probably not a good indicator of chromium exposure.

Indicators of Tissue Damage Evaluated. Measurements of enzyme levels are routinely used in human and veterinary medicine for predicting specific organ damage. When certain organs are affected by disease or toxins, enzymes produced by them may leak into the blood. For example, in mammals, elevated activity of a certain enzyme in the serum or plasma is considered a highly specific indicator of liver damage, and increased levels of another enzyme have been associated with kidney ailments. Before diagnostic criteria can be established for wildlife species, it is necessary to determine normal enzyme levels in blood and various other tissues. We recently completed a study in which relative levels of seven enzymes in liver, kidney, and blood plasma were established for mallards and black ducks. Unfortunately, none of the enzymes studied was organ-specific for liver or kidney. Differences among tissues were noted, however, and it appears that investigation of patterns of enzyme release from damaged tissues may provide data of use in diagnosing overt effects of environmental contaminants.

Black duck nesting in natural pen area at Patuxent Wildlife Research Center. Chromium, a common aquatic contaminant along the Atlantic seaboard, affected survival of ducklings in experimental *studies. Photo by T. Bunck.*

Comparative Uptake of Toxic Chemicals Measured. Studies were conducted in 1982 to compare absorption rates of toxic chemicals among several wild species. Uptake was measured by an in vivo intestinal perfusion technique. A saline solution containing the test chemical and a nonabsorbable volume marker (phenol red) was perfused through a measured section of intestine for fixed times and flow rates. Disappearance of the test material was measured by appropriate analytical means.

Northern bobwhites, screech owls, and American kestrels absorbed significantly more of each test substance (a PCB, dieldrin, and mercury) than did black-crowned night herons and mallards. Mallards in particular are known to be relatively resistant to the effects of toxic chemicals. Food passage time through their digestive tracts is about 3 hours. This rapid movement of ingesta, plus what appears to be poor absorption, may account for the relative resistance of this species to ingested petroleum, pesticides, and other toxic materials.

Toxicities of Formulated Pesticides May Not Be Predictable on the Basis of Active Ingredients. Commercially available pesticides are formulated with inert or relatively non-toxic ingredients to aid in packaging, application, or absorption by target species. It has generally been assumed that tests with wildlife should be conducted with the technical grade active ingredient. Assessments of the hazard of formulated products could then be based on projections by using the percent active ingredient in the

The intestinal absorption of toxic chemicals can be measured by using special laboratory techniques. Here the absorption of mercury from a perfusion fluid by a young kestrel is being measured in a study of the comparative uptake of toxic chemicals by several species of wild birds. *Photo by D. J. Hoffman.*

product. To test this assumption, we compared technical and commercial formulations of several pesticides. The mean lethal concentrations of single oral doses (LD50) were determined for each chemical and formulation as were their lethal concentrations when presented in the diet (LC50) for 5-day periods. By both measures, differences appeared that would not have been predicted on the basis of active ingredient percentages. Orthene, for example, is much more toxic to birds than its active ingredient, acephate, and formulated diazinon is more toxic than its active ingredient. Technical dimethoate is, however, more toxic than is its formulated product Cygon 2E on an active ingredient basis. Other pesticide formulations had more predictable toxicities, but these studies have pointed out a serious potential for erratic relations between actual and expected risks to wildlife resources.

Abate 4E Potentially Hazardous to Young Waterfowl. Abate 4E is a formulation of the organophosphate pesticide temephos. It is widely used in coastal mosquito control and its use coincides at times with waterfowl nesting and rearing. Concern over possible adverse effects prompted us to evaluate the effects of the chemical on waterfowl reproduction. Pairs of mallards were fed diets containing up to 10 ppm Abate through the reproductive period. Duckling survival to 21 days of age was lower in treated groups than the control group, but clutch size, fertility, hatchability, nest attentiveness of incubating hens, and avoidance response of ducklings to a frightening stimulus were not affected. No Abate residues were detected in tissues of exposed individuals or in eggs. Reduced survival of ducklings was an unexpected result of the tests. Further study is needed to determine the mechanism

of this effect and its possible implications for wild waterfowl populations.

Sublethal Exposure to Parathion Alters Incubation Behavior in Laughing Gulls. Parathion is known to be highly toxic to birds, but little is known about its sublethal effects on exposed avian populations. In 1982 we dosed wild laughing gulls at a Texas colony with a sublethal amount of parathion to determine if this treatment caused aberrant incubation behavior. Birds receiving 6 ppm parathion spent significantly less time incubating than did birds otherwise handled similarly but dosed with corn oil. By the afternoon of the third day after treatment, the effects of the parathion had subsided and nest duties returned to normal. These findings suggest that sublethal exposure of nesting birds to parathion and possibly other organophosphate insecticides may result in decreased nest attentiveness, making the clutch more susceptible to predation or egg failure. The effect could be especially great if both members of the incubating pair were exposed to the compound.

Measurement of Organophosphate Residues in Insects. Wild animals often become poisoned when they eat insects that have been killed or debilitated by insecticides. Numerous studies have been conducted on the toxicity of pesticides to various insects and on the occurrence and persistence of residues in plants, soil, and water. It is surprising, therefore, that residues of insecticides in affected insects have very seldom been reported. We conducted a test to examine the dynamics of diazinon residues in free-living insect larvae. Tobacco infested with hornworms was experimentally sprayed with diazinon and hornworms were collected at intervals after spraying. Residues decreased rapidly, nearly disappearing by 18 days postspray. The toxic metabolite diazoxon occurred only at insignificant levels.

Grasshoppers were also collected in sprayed fields to evaluate hazards to birds and other predators. Malathion spraying resulted only in low residue levels that disappeared rapidly. Acephate (Orthene) residues also declined rapidly — from nearly 10 ppm soon after spraying to 2 ppm 2 days later. A highly toxic metabolite, methamidophos, was found, however, at levels as much as ½ those of acephate. This observation illustrates the possible risk to wildlife posed when relatively safe insecticides are metabolized to more toxic products.

Wildlife Poisoning Incidents Evaluated. We are increasingly called upon to determine the cause of death of wild birds suspected of dying of acute exposure to chemical agents. In 1982, 121 specimens from 17 incidents were analyzed by Patuxent scientists when preliminary indications suggested possible poisoning by organophosphate or carbamate compounds. The causative agent was identified in all but four specimens. Eight chemicals were implicated and at least 12 species were impacted. In one instance an endangered species, the eastern brown pelican, was involved. Some other typical incidents are summarized below.

In mid-November 1981 over 220 waterfowl died on ponds adjacent to a feedlot near McNary National Wildlife Refuge in southeastern Washington. Six American wigeons were examined at the Patuxent Wildlife Research Center. Brain cholinesterase activity was inhibited by 60 to 85% in each of the six specimens when compared with controls. Gastrointestinal tract contents from the five specimens analyzed contained residues of coumaphos (Co-Ral), a potent cholinesterase inhibitor.

The morning of 18 April 1982 several alfalfa fields on Bosque del Apache National Wildlife Refuge in New Mexico were aerially sprayed with diazinon. After spraying, scaring techniques (cracker shells) were used to keep birds out of the fields. The fields were checked every 2 hours by Refuge personnel. **All** checks through 4:00 p.m. that day revealed only songbirds and ring-necked pheasants in the fields and no mortality; however, at 5:30 p.m., four Ross' geese were found dead in one of the sprayed areas. The next morning eight snow geese and one Ross' goose were found dead in a pond in one of the sprayed areas. Three Ross' geese and three snow geese were received at the Patuxent Center. Brain cholinesterase activity in all but one was significantly inhibited and all contained diazinon residues in their gastrointestinal tracts.

In May 1982 blue-winged teal and red-winged blackbirds were found dead in rice fields near Collegeport, Texas. Brain cholinesterase activity was inhibited an average of 85% and gastrointestinal tracts of the dead birds contained rice seeds. Scattered rice seeds collected along a ditch where the birds were found contained 950 ppm monocrotophos (Azodrin) and appeared to have been put out deliberately to kill birds.

Normal Cholinesterase Activities Determined for Four Avian Species. Anticholinesterase pesticides (organophosphate and carbamate compounds) have been responsible for the deaths of many non-target organisms. Cause of death in these instances is diagnosed by evaluating brain cholinesterase activity and correlating any significant inhibition detected

with residues of the chemical in ingesta of the animal or its tissues. Blood plasma cholinesterase activity is also used for monitoring exposure and has the advantage that animals can be sampled without killing them.

To establish normal cholinesterase levels, brain and plasma cholinesterase activities were determined for northern bobwhites and three species of passerines at four physiologically critical seasons of the year: breeding, postbrooding, premigration, and mid-winter. Mean levels of brain cholinesterase activity were characteristic for each species but were unaffected by sex and were constant year-round for starlings and northern bobwhites. In red-winged blackbirds, brain cholinesterase activity was depressed by nearly 15% during mid-winter compared with other seasons. During mid-winter, activity was elevated by about 14% in common grackles. Cholinesterase activity in blood plasma varied among the four species of birds, between sexes within species, and to a lesser extent among seasons of the year.

Overall, this study indicates that brain cholinesterase activity in birds is not affected by sex and is species dependent. Species base-lines can be developed for diagnostic uses. Observed differences related to season of the year are relatively minor, compared with differences considered to be of diagnostic significance; therefore they do not invalidate the establishment of normal activity levels to be used in diagnosis. Because of erratic plasma cholinesterase activity observed in this study, we recommend that concurrent controls continue to serve as the basis for detection of exposure when plasma is used as the indicator tissue.

Use of Chemical Oil Dispersants Could Benefit Aquatic Birds. Though chemical oil dispersants are used in much of the world to combat oil spills, their use is viewed with caution in the United States. To evaluate possible hazards of dispersant use, incubating female mallard ducks were exposed to Prudhoe Bay crude oil, crude oil sprayed with diluted Corexit 9527 dispersant (10 parts oil to 1 part Corexit), or diluted Corexit 9527 applied to water troughs in their pens. Although the dispersant failed to completely disperse the crude oil into the water column, the results permitted several conclusions about the use of chemical dispersants to protect birds from floating oil. (1) Crude oil-Corexit 9527 mixtures on the water surface probably pose the same threat to the hatchability of eggs of nearby birds as crude oil alone. (2) Incubation temperature and behavior of females toward eggs and young are unlikely to be affected by exposure to crude oil alone or crude oil sprayed with normal amounts of Corexit 9527. (3) Corexit 9527 alone in water at levels up to 53 ppm poses no threat to egg hatchability.

Ocean tests of chemical dispersants have shown that dispersion of 50% or more of surface oil is possible with proper application. A reduction in surface oil of this magnitude would probably reduce mortality from plumage oiling and reduce the opportunities for egg oiling and oil ingestion. However, the remaining undispersed surface oil would still be a threat. In addition, the environmental effects of chemically dispersed oil are unknown.

New **Chemical Methods Developed for Studies of Oil Pollution.** Assessments of the impacts on wildlife of chronic pollution in the Pennsylvania oil fields required the development of new or more efficient methods of chemical analysis. Early discovery of brominated organic compounds in fish from a polluted site led to the development of analytical methods for 2-bromotoluene, 2-bromoethylbenzene, 4-bromo-o-xylene, and 2-bromomesitylene in water, fish, and sediment samples. Additional research showed that the chemicals are neither highly concentrated nor widespread in environmental samples. The small amounts of the chemicals found may have originated from the practice of injecting halogenated oxidizing agents into oil-bearing rock strata as a biocide. The studies also required us to analyze sediments from streams near oil wells for petroleum hydrocarbons. A survey of the available methods for sediments showed that all were time-consuming and inefficient, owing to complex or difficult cleanup procedures. We developed an extraction-cleanup method using steam distillation that is both convenient and selective. Analysis of percentage recoveries of petroleum hydrocarbons in spiked sediment indicated acceptable efficiency.

Effect of Test Conditions Evaluated. Evaluation of the hazard posed to wildlife by environmental chemicals requires a series of tests conducted under tightly controlled conditions. Conditions under which the tests are conducted for acute toxicity, subacute toxicity, and reproductive effects were developed in the past. These standards, or protocols, had large input from the Fish and Wildlife Service and are now mandated by regulatory agencies. We were asked to evaluate test conditions that would be appropriate for a new test of about 30 days' duration. We hope that this intermediate-length test, using sensitive indicators of effects, will yield information formerly available only from the longer and

more costly reproductive test.

A series of six major tests were conducted with northern bobwhites to evaluate variables that might influence test results. These results, and those obtained from previous work, permitted us to make recommendations regarding the source of birds used, best age of test subjects, number of treatment levels required, number of replicates, number of birds per pen, nature and amount of solvents used to mix toxicants with feed, photoperiod, and length of tests that should be run. Other studies have investigated various types of observations (e.g., mortality, growth, blood chemistry) that might yield information capable of predicting effects in the environment.

Effects of Age of Breeding Mallards on Productivity. Large numbers of breeding mallards are studied each year to estimate the potential effects of various chemicals on birds in the environment. Wide variability in success of penned mallard breeding pairs makes large sample sizes a necessity. The expense of maintaining birds throughout this type of long-term study is great and any factor that may reduce the number of pairs required would be beneficial. One such factor is age of breeding pairs. As birds get older, their reproductive success is thought to increase. We tested this hypothesis using 1- and 3-year-old mallards in two different breeding protocols. One test was completed indoors with controlled light and heat; **all** eggs were artificially incubated and young were raised in large groups. The other test was completed in outdoor facilities in natural light, and hens incubated and brooded their own young.

Preliminary analysis of the data from each study indicates that although certain measures of reproductive success varied (fertility and survival of young in the study with artificial incubation, nest attendance, and adult weights in the study with natural incubation), neither the number of young produced per breeding pair nor the weight of those young at the end of the study were significantly different for 1- and 3-year-old pairs. These results show that there is no overall advantage in using any particular age of breeding mallard in chemical evaluation under these protocols, and less costly 1-year-old birds can be used.

Halogenated Diphenyl Ethers are Widespread Contaminants. Discovery of halogenated diphenyl ethers in wildlife from two separate coastal areas in 1981 led to additional investigations in 1982. Chlorinated and brominated diphenyl ethers were identified by gas chromatography-mass spectrometry; some compounds found could not be quantitated because analytical standards are unavailable. To date, some of the compounds have been found in three different species of fish-eating birds, including bald eagles. Specimens from Rhode Island, Virginia, Louisiana, Texas, Michigan, Ohio, and Ontario contained residues of the compounds. Concentrations in tissues have so far all been less than 1 ppm and their toxicity and significance to wildlife populations are unknown. Some of the compounds found may be used as bacteriostats, as flame retardants, or may occur as impurities in pentachlorophenol preparations. Their presence in environmental samples may be a cause for concern because polychlorinated diphenyl ethers are known to photochemically convert to the more toxic polychlorinated dibenzofurans.

Locations where halogenated diphenyl ethers (DPE's) have been found in tissues or eggs of fish-eating birds. (▲ Brominated and chlorinated DPE's; • chlorinated DPE's.) *Prepared by A. Krynitsky.*

Endrin Impacts Wildlife in Washington State Orchards. Evidence of serious adverse effects of endrin in aquatic systems was documented several decades ago; however, a study we initiated this year provides the first evidence of serious problems in terrestrial systems caused by this chemical.

Endrin is used as a rodenticide in northwest orchards where 1.2 to 1.6 pounds per acre are applied annually in the autumn. From October 1981 to August 1982, cooperators near our study area in Wenatchee found over 90 birds and mammals that died in or near orchards. Most mortalities occurred from November to March. Chukars and California quail made up 38% of the dead birds, and raptors, 29%.

Brains of 42 birds and one mammal were analyzed for residues of organochlorines; 18 of these contained lethal levels of endrin. Residues of endrin in a number of other specimens were high enough

Owls, such as this young wild long-eared owl, played an important role in determining the effects of organochlorine pollutants in field studies dealing with heptachlor and endrin in the Pacific Northwest and also in experimental studies. *Photo by R. A. Grove.*

to induce serious sublethal effects. Raptors were apparently impacted most seriously; five of seven examined contained lethal levels in their brains and a sixth had an elevated level. Of 11 accipiters found dead, four of the five analyzed died from endrin poisoning.

Several birds died as late as March and April— 4 to 5 months after the latest known spray dates. Eggs of some species contained levels of endrin that were higher than those that caused reproductive problems in screech owls experimentally fed endrin. Obviously, endrin persists in the orchard system for a long time after application.

Reproduction of Atlantic Coast Common Terns Unaffected by Organochlorine and Heavy Metal Contamination. In 1980 eggs of common terns were collected from nine Atlantic coast colonies from Rhode Island to North Carolina. **DDE** and PCB's were found in most of the samples and were at higher concentrations in the northern colonies.

Reproductive success of common terns was measured in three Rhode Island colonies that were con-

Chemist analyzing wildlife tissue for metal content using an atomic absorption spectrophotometer. The detection of contaminant residues in wildlife tissues contributes to the evaluation of contaminant effects on wildlife and their habitats. *Photo by H. Bourne.*

taminated with organochlorines and heavy metals. Eggs from one colony had higher concentrations of organochlorines (mainly PCB's) than those from any other site along the Atlantic coast. Heavy metal contamination around this colony was also among the highest along the Atlantic coast. Even though contamination was high, the number of young produced per nest was good both during 1980 and 1981, suggesting that existing concentrations of organochlorines and heavy metals along the Atlantic coast do not significantly affect common tern reproduction.

Reproduction of Caspian Terns in California Impaired. Caspian terns nest in several colonies in California. In 1980 incidental observations suggested that terns nesting in southern San Diego Bay were experiencing poor reproductive success. As a result, an intensive study of that colony was conducted in 1981. That year many eggs failed to hatch and some were crushed in the nest; chicks in others died while hatching. Overall, the terns produced about 0.79 chick per nest. Sample eggs collected for analysis contained high concentrations of DDE; the mean of 25 randomly selected eggs was 9.23 ppm. This amount of DDT is high, but has not been positively tied to all mortality factors observed in the study. Nevertheless, it is likely that the residues observed (up to 56 ppm in individual eggs) had at least some effect on the poor recruitment. The terns may accumulate some of the **DDE** from fish they catch in the San Diego area. However, these birds winter in Mexico and Guatemala where they may also be exposed to DDE and its parent compound, DDT.

Cursory observations in a tern colony in southern San Francisco Bay in 1981 indicated that reproduction in that colony might also be low. Thus, a study was conducted there in 1982. Reproductive success was greater than that of the terns in San Diego, and the birds fledged about 1.02 chicks per nest. However, some of the eggs (4.2 %) were crushed in the nests in this colony also; eggs are being analyzed to determine whether DDE (or other contaminants) may be implicated as a cause for these losses.

Organochlorine Contaminants in California Waterfowl. Concern about the quality of wintering habitat for waterfowl in California has been widespread, and habitat conditions in the Central Valley of California have been recognized as being of special concern. In 1980-81 we studied the significance of organochlorine contaminants in waterfowl from California to determine concentrations of organochlorines in pintails from five important waterfowl wintering areas, and to compare concentrations of organochlorines in species with different diets. We also sought to determine the relation between concentrations of organochlorines in wings and carcasses of pintails.

Wings of northern pintails, canvasbacks, and lesser scaup were collected from the 1980-81 Pacific Flyway survey of waterfowl productivity ("Wingbee"), and we shot a series of pintails and northern shovelers at the Sacramento and Delevan National Wildlife refuges (Sacramento Valley). Concentrations of all compounds in pintail wings were below 1 ppm (wet weight), but residues were higher in wings from pintails shot later in the hunting season than those shot early in the season, suggesting that accumulation of chemicals occurs while ducks are wintering in California. Highest concentrations were in wings from the southern regions and lowest in those from northern regions of the State. Wings of diving ducks were too few to enable statistical comparisons. Carcasses of northern shovelers contained residues of a wide array of organochlorines and had significantly higher mean concentrations of DDE than did pintails collected at the same time and place. On a wet-weight basis, concentrations of **DDE** and DDT in the wings of pintails were about half those in the carcasses. Thus, the carcasses of hunter-killed pintails from which we analyzed wings probably contained about twice the concentrations of organochlorines that were found in wings. Overall, concentrations of organochlorines were relatively low in all species and probably would have no effect on population survival

or reproduction. However, some individuals contained elevated and possibly harmful levels of certain chemicals.

Underfeeding or Elevated Temperature Does Not Affect Reliability of Brain Cholinesterase Activity as an Indicator of Exposure to Insecticides. We conducted a series of experiments to assess the extent to which noncontaminant-related environmental conditions might affect brain cholinesterase activity, and thereby confound the diagnosis of organophosphate and carbamate intoxication. Underfeeding (restricting intake to 50% of the amount control animals received for 21 days, or fasting for 1-3 days) or exposure to elevated temperature (36°C for 1 day) caused only slight reductions (10-17%) in brain cholinesterase activity in adult male Japanese quail. This degree of reduction in brain cholinesterase activity is considerably less than the 50% inhibition criterion employed in the diagnosis of insecticide-induced mortality, but nevertheless approached the 20 % inhibition level used as a conservative estimate of sublethal exposure to a known insecticide application.

Dieldrin-induced Mortality of Gray Myotis in Missouri. As reported previously, mortality due to dieldrin poisoning occurred during 1976-78 in two maternity colonies of the endangered gray myotis at Bat Cave No. 2-3 and Roaring Spring Cave, Franklin County, Missouri. Residues associated with the insecticide heptachlor also increased markedly to potentially dangerous concentrations in the bats in 1977 and remained elevated in 1978. The more severely affected colony disappeared in 1979 and was not present when the roost caves were visited in 1982.

Hunter and Devil's Icebox caves are transient gray myotis caves in Boone County, Missouri, each with 400-500 bats. On 23 July 1980, 18 dead bats were found at Hunter Cave and on 14 July 1981, 24 dead bats were found at Devil's Icebox Cave. Three of the dead from each cave were analyzed and all six contained lethal levels of dieldrin and high concentrations of heptachlor-related compounds. Bat mortality had not been observed in previous years even though both caves had been visited frequently.

The contaminants detected in bats from Hunter and Devil's Icebox caves are the same as those in dead bats recovered at the Franklin County caves. Aldrin (dieldrin's parent compound) was applied to cornfields to control cutworms (larvae of several moth species, family Noctuidae) until it was banned in 1974. Heptachlor was recommended by the State of Missouri as a substitute and used through 1981. We assume these uses are the sources of the observed residues.

The sudden appearance of lethal levels of these residues in bats at Hunter and Devil's Icebox caves is not understood. Devil's Icebox Cave is about 120 km WNW of Bat Cave No. 2 and extensive banding studies have shown virtually no interchange of gray myotis between the two areas. Therefore, we believe the sources of contamination for the bats from Boone and Franklin counties are geographically different and that the problem is of greater extent than previously recognized.

The bat deaths at Devil's Icebox Cave were associated with a die-off of macroinvertebrates in the outlet stream. These included amphipods, snails, and planarians. A sample of dead amphipods analyzed by the State of Missouri contained dieldrin, heptachlor-related compounds, and DDE at concentrations greatly exceeding the background levels measured during the previous 15 years. As of May 1982 there had been no improvement in these invertebrate populations.

There is no proof that the pesticide residues killed the invertebrates, and other causative agents are possible. However, we speculate that the source of the residues in the invertebrates was bat guano dropped into the water by bats or leached into the stream by runoff water within the cave. Guano from Bat Cave No. 2-3 colony in Franklin County contained 1.1 ppm dieldrin, 0.34 ppm heptachlor, and 0.40 ppm DDE.

DDE May Concentrate to Lethal Levels in Hibernating Bats. The so-called "brown fat" found in bats and other mammalian hibernators is an organ specialized for the storage and metabolism of lipids. By rapid metabolism of triglycerides, the brown fat produces heat that speeds arousal. Lipid reserves are maintained in the brown fat throughout hibernation in spite of declining overall fat reserves. Studies of ground squirrels indicate that nearly half of the fat stored in brown fat may be depleted in a single arousal, but that it is replaced within 2 days by lipids drawn from the white fat reserves.

Our experimental studies with active bats have shown that when food intake is restricted and fat reserves shrink, organochlorine residues stored in the remaining fat causes mortality.

These characteristics of hibernating bats and organochlorines suggest that pesticide residues could concentrate in the brown fat as hibernation progresses and late arousals then could liberate them rapidly into the circulation. If sufficient amounts

reached the brain, death would result.

To look at this potential problem, we collected hibernating bats from a site contaminated with DDE and analyzed the brown and white fat reserves. Big brown bats, little brown bats, and eastern pipistrelle bats were collected in mid-November from abandoned mine tunnels near Hancock, Maryland. Analyses revealed that brown fat lipids contained significantly more DDE (by 2801o) than white fat lipids. As expected, when fat was lost, DDE levels in the remaining fat increased exponentially while the absolute amount present remained constant. Calculations showed that if half of the DDE present in each of the 14 bats in our sample were mobilized during arousal and reached the brain, 3 of the 14 would die.

Organochlorines in Bald Eagle Eggs. During 1969-79 bald eagle eggs were obtained from 89 different nesting territories in 14 States and analyzed for organochlorines. An analysis of the results shows that levels of organochlorines in eggs from some populations have been declining in recent years and reproductive success has been improving. In Maryland, for example, average levels of DDE, **DDD,** dieldrin, total chlordanes, and PCB's were significantly lower in 1979-81 than in 1973-78, declining more than 55[0]10 for each contaminant.

Many of the contaminants in the eggs were highly intercorrelated statistically, making it difficult to determine which contaminants were having adverse impacts on shell thickness and production. DDE was most closely related to eggshell thickness and reproductive success; however, PCB's and the combined residues of **DDD** and **DDT** were also related to these factors. Five-ppm DDE was associated with about 9% shell thinning and a reduction in mean production to about 0.6 young per occupied nest, a level generally considered to be below that needed for population stability; 16-ppm DDE was associated with about 14% shell thinning and nearly complete reproductive failure. Although these results are based on a substantial number of eggs, they should be used with caution, especially when making comparisons with other species, because the eggs were collected after failure to hatch. A less biased sample including viable eggs might have had lower average residue levels.

Contaminants in Surrogates of the California Condor. Residues of **DDE** have been suggested as one possible factor in the decline of the California condor population through eggshell thinning and associated reproductive failure. Because little was known about the current exposure of California condors to contaminants, a cooperative study with the California Department of Fish and Game was initiated to help fill this gap. Wintering turkey vultures, breeding turkey vultures, common ravens, and eggs of these species were collected in 1981 within the range of the condor. These species are related to the condor or have similar food habits; therefore, useful information on the exposure of condors to contaminants should be available from them. Condor food items were also collected. All samples were analyzed for organochlorines and metals.

Four turkey vulture eggs contained an average of 7 ppm DDE and the shells were about 16 % thinner than the pre-DDT norm, an amount associated with reproductive problems in other species. Two of the eggs contained about 0.5 ppm endrin, a level associated with a reduction in reproductive success of captive screech owls fed a diet containing endrin.

There was no shell thinning in a sample of six clutches of common raven eggs, which contained considerably lower levels of **DDE** than the vulture eggs. However, one clutch of six eggs contained an average of 2.7 ppm total **DDT** and its metabolites (nearly 10 times the amount of DDE alone present in the clutch). Although none of the other raven clutches contained either **DDD** or DDT, very recent exposure of the one female to DDT, probably within its nest territory or associated feeding range, was indicated.

Organochlorine residues in vulture and raven carcasses were variable; DDE was the major contaminant present. Metal residues in liver, kidney, and bone were generally within ranges thought to be normal, except for a few samples that appeared to have slightly elevated levels of lead, cadmium, or chromium. Condor foods contained very low levels of organochlorines and lead, with a few exceptions, and no mercury; however, the residues in the surrogate species sampled cause concern regarding the possible effects of organochlorine pesticides on condors.

Osprey Distribution and Abundance in the United States. The osprey has been studied throughout its breeding range during the last two decades because of its status as an indicator species of environmental pollution. A review of the present distribution and abundance of nesting ospreys at a national level seemed appropriate and was carried out in 1982 with support from the U.S. Army Corps of Engineers.

Nesting ospreys in the contiguous United States now number about 8,000 pairs. Five regional popu-

lations exist (in order of abundance): Atlantic Coast, Florida and Gulf Coast, Pacific Northwest, Western Interior, and Great Lakes. The States with the largest nesting populations (in order of abundance) are Florida, Maine, Maryland, Virginia, and North Carolina. In past years, pesticides severely impacted the populations in the northern portion of the Atlantic Coast (Boston to Cape May), and the Great Lakes, but both are now recovering. Low reproductive rates were never reported from the West or the more southern portion of the Atlantic Coast, although some populations may have been affected to a lesser degree.

During recent years in the West, especially in the Western Interior, reservoirs have been responsible for a range expansion, and perhaps a population increase. However, a strong fidelity to ancestral breeding areas has slowed the range expansion. An estimated 69% of ospreys nest within 30 km of their hatching place. Introductions to distant reservoirs are now being made in Tennessee and Pennsylvania and are being followed with intense interest.

Ospreys adapted to man, his structures, and many of his habitat changes but proved sensitive to his chemical pollutants. These characteristics make the osprey an excellent environmental indicator species.

Endangered Species

PATUXENT WILDLIFE RESEARCH CENTER

Record Year for Captive Breeding and Reintroduction of Whooping Cranes. Husbandry, behavioral management, and artificial insemination regimens for the captive whooping cranes at the Patuxent Wildlife Research Center were intensified during the 1982 breeding season. As a result, **all** five potential breeding pairs, including two pairs that had not laid previously, produced eggs. A total of 28 eggs were laid, of which 26 were fertilized by artificial insemination. Twenty-five of the 26 eggs (96%) were fertile—the highest fertility rate achieved thus far with captive whooping cranes. All eggs were incubated under "foster-parent" sandhill cranes until hatching or until they were transferred to the nests of wild sandhill cranes at Grays Lake National Wildlife Refuge (NWR) in southeastern Idaho. Fifteen eggs were retained at the Patuxent Center: 12 (80%) were fertile, 9 (60%) hatched, and 6 (40%) chicks were subsequently raised to fledging. Thirteen eggs were transferred to Grays Lake: 11 (85%) hatched and 4 (30%) chicks were subsequently reared to fledging by their sandhill foster-parents.

For the first time since 1974, wild whooping crane eggs from Wood Buffalo National Park, Canada, were transferred to the Patuxent Center to increase the genetic representation within the captive flock. Both eggs were fertile and hatched, and one chick was successfully raised. There are now 28 whooping cranes in captivity: 25 at the Patuxent Center; 2 at the San Antonio Zoo, Texas; and 1 at the International Crane Foundation, Baraboo, Wisconsin.

Cooperative Efforts Result in Production of Whooping Crane Chick. This spring, "Tex," a female whooping crane on loan from the Patuxent Wildlife Research Center to the International Crane Foundation (ICF) in Baraboo, Wisconsin, produced her first and only chick. This event was significant because Tex was the sole descendant of "Rosie," the last whooping crane from the non-migratory Louisiana population. The perpetuation of this genetic line will help reduce the risk of inbreeding and loss of genetic variability within the species.

Tex became heavily imprinted on humans as a young chick, and upon reaching maturity, refused to pair with other whooping cranes. Instead, she formed a rather unique "pair bond" with Dr. George Archibald at ICF. For the past several breeding seasons, Dr. Archibald has spent hundreds of hours performing courtship rituals and other activities with Tex in an effort to get her to reproduce. Early attempts resulted in the production of eggs which were either infertile or had defective shells, which prevented proper embryo development and hatch-

Newly hatched whooping crane, Gee Whiz (top). Gee Whiz at 3 months of age (bottom). *Photos by G. Archibald.*

ing. In 1982 an all-out effort by Dr. Archibald resulted in a single thin-shelled, but fertile, egg.

This accomplishment was attributable in part to the Patuxent Wildlife Research Center, which contributed both fresh and frozen semen samples for artificially inseminating Tex, since ICF has no other whooping cranes. For 2 weeks frozen-thawed semen samples were used to inseminate Tex; the third week, just before the egg was laid, one frozen and two fresh semen samples were used; the fresh samples resulted in the fertility of the egg.

On 1 June the egg hatched a small, healthy chick. Named "Gee Whiz" after Dr. George Gee at Patuxent, the chick is thriving and survives as a testament to the cooperative efforts that resulted in its existence, exemplifying the need for such cooperation in the recovery of endangered species. Just 3 weeks after the chick hatched, however, predators attacked and killed Tex, which makes the hatching of Gee Whiz even more significant.

California Condor Pair Loses Two Eggs. Five pairs of California condors were observed during the 1982 breeding season. One pair nested twice, giving the first conclusive evidence of replacement clutching in the species. The first egg laid by this pair was kicked over the cliff edge by the adults during a fight over incubation rights. The second egg was laid 40 days later and was destroyed by common ravens. The conclusive documentation of the ability of the species to lay replacement clutches raises hopes that establishment of a captive population of condors can be accomplished in part by taking the first clutch (egg) laid for artificial incubation and allowing the pair to lay a replacement clutch, thus minimizing stress on the wild population.

California Condor Population Size Estimated from Photographs. Previous estimates of the size of the California condor population were based primarily on simultaneous counts of birds in key areas and on assumptions regarding day-to-day movements and seasonal distribution of the species. The range of the remnant population, however, is too large, and the movements of the birds are too variable to allow a comprehensive, standardized census by simultaneous counts. Population estimates developed with this census technique have not been sufficiently rigorous to allow firm conclusions about short-term population trends, although the reality of a pervasive long-term decline is not in doubt.

During the past year, a new method of assessing the status of the wild population was developed that

Peter Bloom, National Audubon Society, and Phil Ensley, veterinarian for the Zoological Society of San Diego, hold the subadult male California condor that was trapped with a cannon net by the Fish and Wildlife Service in October. The bird was equipped with patagial tags and solar-powered radio transmitters and released near the capture site. Tracking the condor will allow researchers to determine habitat requirements and possible limiting factors of the species. *Photo by H. K. Snyder.*

In 2 weeks these newly hatched masked bobwhites will be shipped from Patuxent to Arizona for conditioning with "foster-parents" before being released on the Sonora Desert in Mexico. *Photo by R. Schmidt.*

may give more accurate information on short-term trends. This method is based on individual identification of condors through flight photographs taken throughout the known range of the species. Each bird replaces about half of its flight feathers during the spring-to-fall season. The patterns of loss and regrowth of feathers vary among individuals and allow continuous recognition and differentiation of individuals if enough photographs are taken.

Over 350 recent flight photographs, each representing a different bird, date, or location, were analyzed in September 1982; only 20 individual condors were found from analyses of these photographs. Seven of the condors were dark-headed (immatures) and 13 had orange heads (adults or subadults). In the last 2 months, the rate of discovery of new individuals has declined almost to zero and it is possible that few or no additional condors exist in the wild.

Masked Bobwhite Propagation and Release Efforts. The masked bobwhite was once a common inhabitant of the mesquite-grassland areas of the Sonora Desert in Mexico and southern Arizona. By 1900 the quail had been extirpated in its U.S. range and drastically reduced in Mexico due to the tremendous growth in the cattle industry and subsequent habitat destruction from overgrazing, which began in the late 1800's. Several years of severe drought contributed to the further decline of the species until only a few small, isolated populations remained.

In 1966-70 a captive breeding flock of masked bobwhites was established at the Patuxent Wildlife Research Center with 57 wild-caught birds from Mexico and some captive-reared birds from private breeders in Arizona. Beginning in 1970 offspring from this flock were released in Arizona in an attempt to reestablish them in their historic range. Although early releases were largely unsuccessful, by 1977 release techniques had been improved and captive-bred birds survived to reproduce in the wild.

For the past 3 years masked bobwhites produced at Patuxent have been released in Mexico as part of the U.S.-Mexico Agreement on Wildlife Conservation. A total of 2,850 birds have been released at three sites to bolster the steadily decreasing population in that country.

Researchers involved in this recovery program constantly strive to upgrade their techniques in an effort to maximize the production of viable birds for reintroduction to the wild. Genetically sound stock is maintained by the use of computer programs for pedigree records and mate selection. This prevents mating of related stock and eventual deterioration of the birds' reproductive capabilities and

viability from inbreeding. Current release techniques incorporate adoptions of young chicks by wild foster-parents and a "soft" release, where birds are acclimated to natural conditions before reintroduction to the wild.

With continued improvements in propagation and release techniques and with the current interest by the private conservationists and the Fish and Wildlife Service to acquire and protect additional masked bobwhite habitat in Arizona, the species has good prospects for an eventual comeback. No releases have been made in Arizona since 1979, yet birds have survived and bred there during the past 3 years. Continued release of captive-produced birds into Arizona could mean the reestablishment of the masked bobwhite within the United States.

Urine and Anal Gland Secretions of the Gray Wolf. Gray wolves, like other members of the dog family, communicate considerably by means of odors in their urine and anal gland secretions. Understanding the wolves' means of olfactory communication can provide valuable insights into their behavior, ecology, and social system and can lead to more efficient methods of capturing wolves and perhaps reduce their depredations.

Biologists are observing captive gray wolves to study the role of urine and anal gland secretions in the life of the wolf. Every 2 weeks about 30 wolves are anesthetized and their urine and anal gland secretions are collected. Chemical analyses have shown differences in urine compounds from male and female wolves, and 16 compounds have been identified, including 1 that seems to be the "essence of wolf."

Six fatty acids and 22 volatiles have been chemically identified in wolf anal gland secretions. The volume of secretions in wolf anal glands decreases during the breeding season, perhaps because of increased use at that time. Preliminary experiments indicate that secretions are sometimes left on feces, and that some members of a pack leave such secretions more often than others.

These findings suggest that gray wolves use these body compounds in an elaborate olfactory coding system to communicate their reproductive state and perhaps their social status.

Comparison of the Seasonal Condition of Gray Wolves in High and Low Population Densities. Seasonal changes in the nutritional condition and physiology of gray wolves must be determined to understand fluctuations in productivity and population size. This information can be gained from the weights of trapped animals and from assays of wolf blood and hormones. It is difficult, however, to capture wolves and it is especially difficult to recapture them to obtain frequent samples. Therefore, a collar that facilitates recapture has been designed.

The capture collar darts and drugs a collared wolf upon command by a coded radio signal from an aircraft. The capture collar has been tested successfully on captive wolves, including a member of a captive pack. After as long as 2 weeks with packmates, a test wolf was drugged by a signal from an aircraft 915 m above him. The capture collar is now ready for testing on free-ranging wolves.

Success with the capture collar in the field would greatly reduce the cost of wolf recaptures and would enable biologists to gather a wealth of nutritional, physiological, and energetics data never before available for free-ranging animals of any species.

Population Trends of Gray Wolves in Minnesota. Biologists of the Minnesota Field Station have monitored the trend in numbers of gray wolves in the eastern half of the Superior National Forest since winter 1966-67 to obtain data that will describe and explain natural fluctuations in wolf populations. Aerial radio-tracking and observation of the sizes of an average of eight contiguous packs per year yielded population-trend data and information on wolf movements, territoriality, productivity, spacing, dispersal, and the number of white-tailed deer killed. Since winter 1975-76, deer numbers in the same area have been counted by aerial observation and radio-tracking.

By studying interactions among wolves, deer, and winter severity in this protected wilderness ecosystem, biologists can determine expected wolf populations under varying conditions in areas with a low wolf density, such as newly colonized areas or areas where wolves might be reintroduced. The wolf population in the study area peaked at a density of about 15 per 259 km^2 in winter 1969-70. The previous winter was the most severe in Minnesota's history, and deer were greatly weakened. Because of the increased kill of deer by wolves during that winter and in a series of severe winters that followed, deer numbers declined through winter 1975-76 to about one per 2.6 km^2. By then, wolf numbers had dropped to almost half of the density in winter 1969-70.

The decreased predation by wolves halted the deer decline, but wolf numbers in the study area continued to drop. By winter 1981-82 they had reached a density of only four wolves per 259 km^2, a decrease of about 70% since their 1969-70 peak.

Deer numbers have remained low but seem poised for recovery when winters become less severe.

Record Bald Eagle Production in Bicentennial Year. On 20 June 1982 we celebrated the bicentennial anniversary of the bald eagle as part of the Great Seal of the United States. Ironically, the bald eagle also is a symbol of rare and endangered wildlife in our country. Although once threatened with possible extinction from the use of DDT and other pesticides that found their way into its food supply, the eagle is now on the long road to recovery due to the prohibition of these substances in the United States.

In an attempt to hasten the expansion and population growth of the bald eagle, captive-bred eaglets produced at the Patuxent Wildlife Research Center have been adopted and "hacked" out to many States. In 1982, this production reached record levels; a total of 13 eaglets were translocated to seven States. This was much higher than any previous attempt to breed bald eagles in captivity and was five more than the previous year's output at Patuxent.

Two methods for raising eaglets are practiced. First-clutch eggs are removed from the nest and artificially incubated. Most pairs then re-lay and are allowed to keep their second clutch. Chicks hatched from first-clutch eggs are hand-reared to 3 weeks of age and fostered to wild eagle pairs. Eggs incubated in the nest remain there through hatching, and the eaglets are brooded and fed by the parents. At about 8 weeks of age these parent-reared birds are sent to hacking sites, this year in Tennessee and Georgia.

Expansion of the breeding flock from 8 to 12 pairs, plus added production from pairs that were too young or newly formed in 1982, should greatly enhance bald eagle propagation efforts in future years. Several States in addition to those that have received eaglets in the past have requested birds for release, indicating a continued and growing need for captive-bred eaglets. An increase in the number of breeders at Patuxent and continued research to improve propagation techniques should help satisfy this demand as well as decrease the recovery time for this species.

Mississippi Sandhill Crane Propagation and Reintroduction Continued. Five pairs of Mississippi sandhill cranes at the Patuxent Center produced a total of 33 eggs, of which 22 (66%) were fertile. For the first time, three fertile eggs were transferred to the Mississippi Sandhill Crane NWR in southeastern Mississippi and were fostered to wild pairs whose own eggs were infertile or addled. Two of these eggs hatched, and one chick was apparently raised successfully by its foster-parents.

Of the 19 fertile eggs retained at the Patuxent Center, 17 (89 %) hatched, and 9 (53%) chicks were subsequently raised by sandhill crane foster-parents. Although two of these chicks were retained at Patuxent to increase the size and genetic representation of the captive flock, the remaining seven chicks have been transferred to Mississippi for release into the wild. At the present time, all seven of the birds are being held in a large, natural enclosure at the Mississippi Sandhill Crane NWR to acclimate the birds to their new environment before they are released. In addition to these birds, 7 of 14 birds released previously still survive in the wild. All seven birds have successfully made the transition from captivity to the wild, and one bird appears to have already paired with a wild conspecific. These "soft" releases, which are being conducted in cooperation with the Louisiana Cooperative Wildlife Research Unit, will undoubtedly influence future management and conservation strategies for the Mississippi sandhill and other species of endangered cranes.

There are now 19 Mississippi sandhill cranes in the captive flock at the Patuxent Center. An additional four birds are currently on breeding loan to the National Zoological Park, Washington, D.C.

Predation on Endangered Bats at Gated and Fenced Caves. Human disturbance is thought to be one of the most important factors in causing the gray myotis, Indiana myotis, Townsend's big-eared bat, and Virginia big-eared bat to become endangered species. The entrances to many of the caves used by these species are gated or fenced to reduce this disturbance, but several observations have been recorded of predators using these structures to capture endangered bats as they exit or enter the cave.

A study of gated, fenced, and unmanaged summer caves used by endangered bats was performed in Alabama, Arkansas, Kentucky, Missouri, Tennessee, and West Virginia. Only one incidence of predation, a domestic cat at a gated Virginia big-eared bat maternity cave, was observed. A black rat snake was observed on a gray myotis maternity cave gate, but no bats were taken. Four owls were observed close to three gated and fenced gray myotis caves, but no avian predation occurred at these managed entrances. Based on these preliminary data, the gating and fencing of these entrances of caves used by endangered bats does not appear to increase the incidence of predator loss at summer caves.

Shearwater Aid Stations Successful. The shearwater aid stations that were established in 1978 at fire stations on Kauai, Hawaii, have been extremely successful in increasing the survival of endangered and threatened fledgling seabirds that are attracted to and crash into lighted areas. Over 50% of the Newell's shearwaters fledged each year probably are involved in the fallout around unshaded lights. From 1967 to 1977, conservation agencies appealed to the public to pick up the birds and release them into the ocean.

Public response was good, but the magnitude of the fallout problem was not known until 1978, when the public was asked to turn in the birds at shearwater aid stations. In the past 4 years, 5,130 Newell's shearwater fledglings, 17 endangered dark-rumped petrels, seven white-tailed tropicbirds, 20 wedge-tailed shearwaters, and five rare Harcourt's storm-petrels have been brought to the aid stations; an additional 586 Newell's shearwaters are known to have died on highways. If public response and fallout rate were equivalent during 1967-77, then the program has been responsible for returning about 19,000 Newell's shearwater fledglings safely to the sea.

Light Modifications Reduce Seabird Mortality. One-third of the light-related fallout of Newell's shearwaters occurs around one large hotel on Kauai, Hawaii, that has unshaded mercury vapor and high-intensity incandescent floodlights.

This situation provided a unique opportunity to study methods of reducing bird mortality around lights. In fall 1980 and 1981, biologists from the University of Wisconsin, under contract to the U.S. Fish and Wildlife Service and with financial assistance from the New York Zoological Society and the Nature Conservancy, shaded the hotel's major floodlights on alternate nights in October and November. Fallout was reduced by 39 % when the lights were shaded, even though extraneous light from the hotel could not be controlled; 273 birds were attracted to the hotel on nights when the lights were shielded, compared with 444 birds when lights were not protected. The Nature Conservancy in Honolulu has initiated a project, "Operation Shades," to seek $70,000 for the purchase of shades for the 2,500 street lights on Kauai. The shades could be installed economically when the power company converts the lights from mercury vapor to sodium vapor.

Hawaii Water Birds Evaluated. The historical record and 7 years of systematic field observations on water birds were analyzed in 1982. The data indicate that the endangered Hawaiian coot has increased in numbers in the last 20 years, although the population has shifted from the windward to the leeward side of the Island of Hawaii. The endangered Hawaiian gallinule was extirpated, and the Hawaiian stilt had reestablished a stable population of about 30 birds.

The number of migratory waterfowl visiting the State had declined during the last 20 years, but the number frequenting the Island of Hawaii appeared to have remained constant. Loss of habitat was identified as the reason for the statewide decline in numbers of migratory waterfowl.

Two Nature Conservancy Preserves Established in Hawaii. Surveys of forest birds in Hawaii from 1976 to 1981 provided data on the distribution, abundance, and habitat correlates of Hawaii's forest birds. This information, as well as that contained in forest bird recovery plans, attracted The Nature Conservancy (TNC) to Hawaii. They have developed a 5-year Endangered Forest Bird Project to protect significant forest reserves on each major island in the Hawaiian Archipelago. Patuxent wildlife biologists, among others, assisted TNC in determining the best locations for a system of proposed reserves.

Once key areas were identified, TNC acted quickly to obtain conservation easements on two key parcels. A conservation easement on a 6,700-ha Kamakou Preserve on Molokai was purchased and an option on a key 2,100-ha Waikamoi Preserve was obtained in September 1982. These two preserves harbor habitat for seven endangered species.

The Nature Conservancy hired a biologist (a former Service research team member) to develop a management plan for the Kamakou Preserve; this plan was completed in September 1982, and active management of this area will soon begin.

These two acquisitions result from immediate uses of the research data obtained during the forest bird surveys. These actions clearly demonstrate the value of research information in promoting recovery of endangered species and typify the successful interaction among research biologists and the members of the private conservation sector.

Captive-produced Parrots Experimentally Released into the Wild. To develop techniques for future releases of the endangered Puerto Rican parrot, we experimentally released captive-raised Hispaniolan parrots in the Dominican Republic, where substantial populations were still found. Releases of captive-produced Puerto Rican parrots are needed to bolster the Luquillo Forest population

and to reestablish the species in other parts of Puerto Rico.

One group of Hispaniolan parrots (n = 18) was not preconditioned to the release area or provided with food subsidies. The other group (n = 18) was held in a field aviary on the release site and provided wild foods to condition the birds to the habitat. Upon release, members of the conditioned group were allowed to return to the field aviary for shelter and food.

The conditioned group showed better survival than the unconditioned group and eventually exhibited good foraging and integration with wild parrots. Eighteen of the released birds were fitted with radio transmitters to test the applicability of telemetry to wild parrot research. An antenna-collar attachment proved suitable for most of the birds and provided a strong directional signal. After further tests, these techniques will be applied to the Puerto Rican parrot to determine factors affecting post-fledging mortality, movements, and habitat utilization.

Egg Production of Captive Parrots Experimentally Increased. By experimentally bolstering clutch size through sequential removal of eggs, captive Puerto Rican parrots produced an average of 9.3 eggs per female (range, 5-17 eggs per female), a 1.6- to 5.7-fold increase above normal clutch sizes for those females. Five of the eggs hatched, and four chicks fledged. Two of the chicks were fostered into the nests of wild parrots, and the other two were retained in the captive flock, which now numbers 17.

Hispaniolan parrots, which are used as surrogates to the endangered Puerto Rican species, were also experimentally induced to increase egg production. Five female Hispaniolan parrots laid an average of 10.8 eggs per female (range 5-19 eggs per female), an average increase of 215% above normal clutch sizes. Of the 57 Hispaniolan eggs laid, 59% were fertile, and chicks fledged from 33% of the eggs.

Production of Wild Puerto Rican Parrots. Four pairs of wild Puerto Rican parrots produced 10 eggs, but those at two nests failed to hatch. Captive-produced Hispaniolan parrot chicks were fostered into the two failed nests to maintain adult interest until suitable Puerto Rican parrot chicks could replace the surrogate species. Eventually, three captive-produced Puerto Rican parrots were substituted into the nests, and two of these chicks fledged. The wild population was estimated at between 25 and 27 birds after addition of the seven chicks.

Great Lakes Fisheries

GREAT LAKES FISHERY LABORATORY

Bloater Populations Continue to Rebuild in Lakes Huron and Michigan. The deepwater ciscoes (commonly called chubs by commercial fishermen) are endemic to the Great Lakes, where, together with the closely related lake herring, they have provided forage for lake trout and other native predators and supported widespread commercial fishing since the 1800's. However, severe declines in populations over the past two decades have resulted in lakewide bans on commercial harvest in U.S. waters, subsequent intensified interagency assessment of the various stocks, and (recently— on the basis of rates of recovery and accrual of sufficient fishable surpluses) the projection of total allowable catches in some waters.

The cisco populations in Lake Huron proper began to decline in the 1950's due to overfishing and competition by the exotic alewife, which was rapidly assuming nuisance proportions. By 1970 the cisco populations (by then largely limited to bloaters) were perilously low and the commercial fishery was closed. During surveys in 1973, the average catch of adult ciscoes was less than 0.2 per unit of effort (a 10-minute tow of a standard trawl), and we estimated that the trawlable stock in U.S. waters was less than 200 metric tons. It was not until 1979 that the populations showed any discernible improvement. The average catch of adults per unit of effort was 1 in 1977, 5 in 1979, and nearly 11 in 1981. We estimate that the trawlable stocks have shown a corresponding increase over the 8-year period to over 3,000 metric tons in 1981. Nevertheless, the agencies concerned agree that the populations

should be allowed to continue rebuilding in Lake Huron before commercial fishing is again permitted.

In Lake Michigan, the decline of deepwater ciscoes was not as severe as in Lake Huron; nonetheless the population (composed almost entirely of bloaters) fell steadily through the 1960's and early 1970's to low levels of abundance by the mid-1970's. The Lake Michigan Chub Technical Committee of the Great Lakes Fishery Commission recommended restrictions on commercial harvest, and a lakewide ban was finally established in 1976. Since 1977, survey catches have demonstrated an increase in abundance. The catch per unit of effort increased steadily from 2 in 1977 to 14, 50, 96, and 217 in 1978-81, and the estimated trawlable stock increased from about 6,800 metric tons in 1973 to 14,000 in 1980. Commercial fisheries have recently been reopened in Illinois and Wisconsin waters under conservative quotas based on projections of total allowable catches.

Standing Stock of Lake Trout and its Forage Requirements in Lake Michigan. Young lake trout have been stocked in Lake Michigan since 1965 at an average rate of 2.3 million per year, in an attempt by cooperating State and Federal agencies to reestablish the species after it was exterminated in the late 1940's and early 1950's, mainly by overfishing and sea lamprey predation. Resource agencies now need to know the size of the standing stocks of lake trout and other salmonid predators, what impact they are having on the forage base (composed mainly of alewives, rainbow smelt, and sculpins), and the total predation that can be sustained without the forage supply itself being adversely affected. We have therefore intensively sampled forage fish and lake trout populations since 1972 off Saugatuck, Michigan, and Port Washington, Wisconsin, in an attempt to supply the needed information.

On the basis of an estimated total annual mortality rate of 48%, in combination with known stocking rates and calculated rates of growth, we estimated that the standing stock of lake trout in Lake Michigan at the beginning of 1979 was about 1,600 metric tons, and that 1,100 tons of trout flesh were generated by the stock during the year. Although all ages of trout up to XIII were present, 85% of the biomass was produced by ages Ito V.

Next, using age-specific rates of production, seasonal data on the diet of lake trout by geographic area, and food-conversion efficiencies obtained from laboratory feeding studies, we estimated that slightly more than 3,000 tons of forage fish were eaten by the trout during their 1979 growing season (i.e., 15 May–1 December), a period that should account for most of the total forage consumed during the entire year. Alewives accounted for 71% of the total weight consumed, rainbow smelt for 18%, and slimy sculpins for 11%. Considering that an estimated mean standing stock of 384,000 tons of alewives alone existed in Lake Michigan during 1979, we concluded that current levels of forage fish consumption by the lake trout are not adversely affecting the stocks of prey. However, steadily increasing numbers of coho and chinook salmon and rainbow and brown trout have also been planted in Lake Michigan during the past decade, causing concern over the continuing ability of the lake's forage base to support these predators. In 1980, the total plants of salmonids (including lake trout) amounted to 16 million fish. If consumption by lake trout is combined with the total consumed by all other salmonid predator species, the amount may be large enough to have a significant impact on the productivity of the stocks of prey species. We are therefore attempting to develop estimates of consumption by these other trout and salmon, so that we can more fully evaluate the status of Lake Michigan's predator-prey system and forecast the maximum additional lake trout predator biomass that the system can safely sustain.

Relation of Aquaculture to the Restoration and Maintenance of Coregonines in the Great Lakes. Various agencies have attempted for decades to augment or restore populations of coregonines (primarily lake whitefish) in the Great Lakes by stocking hatchery-reared fry. However, there is no clear evidence that stocked fry have contributed to the rebuilding of any population. Therefore we conducted a review of worldwide literature and ongoing programs on the use of coregonine culture to augment natural reproduction of depleted wild stocks, to attempt to determine what techniques might be successful in the Great Lakes.

The results of large-scale plantings in Europe have indicated that stocking intensities for coregonine fry need to be much greater than those that have been applied in the Great Lakes if natural reproduction is to be detectably augmented. The largest annual planting of lake whitefish in Lake Ontario (1940-60) amounted to only 154 fry/ha, and the average was only 20 fry/ha. Somewhat heavier stocking in Lake Erie (1920-40) by six agencies included a maximum annual planting density of 228 fry/ha and an average of 107 fry/ha. No correla-

Rebuilding self-sustaining populations of lake trout in the Great Lakes is the ultimate goal of several lines of field and laboratory research. Principal obstacles to its attainment are environmental contaminants, heavy fishing pressure, and predation by sea lampreys. These adult lake trout are being used at the Great Lakes Fishery Laboratory to study the role of pheromones in spawning site selection. *Photo by E. Meves.*

tion was found between the number of fry planted and the size of subsequent commercial catches in those lakes. In contrast, stocking intensities in European lakes range from several hundred to several thousand fry per hectare per year, and represent a significant proportion of total fry production in the stocked lakes. These findings suggest, for example, that about 1.1 to 2.6 billion lake whitefish fry would be needed annually for Lake Ontario and 1.5 to 3.6 billion for Lake Erie to make the stocking effort a measurable success. Research on the Bodensee in Western Europe has revealed that hatchery production must exceed 10% of the annual hatch of fry in the lake if the eventual contribution of the stocked fry to the fishery is to be detectable.

Research Findings Aid Department Officials in Treaty Fishing Negotiations. Recent court decisions affirming the right of three northern Michigan Indian tribes to fish without State regulation, within treaty-ceded waters of the upper Great Lakes, have resulted in several user groups competing for limited fishery resources — Indian commercial fishermen and anglers for lake trout and yellow perch, and Indian and non-Indian commercial fishermen for lake whitefish and bloaters. To aid the joint trustees in preventing overexploitation of these fragile resources, the Great Lakes Fishery Laboratory played a leading role in the work of a Tripartite (State-

Tribes-FWS) Technical Working Group to assess annually the status of the resources and recommend total allowable catches that could be withdrawn without damaging the productivity of those resources.

Using the Laboratory's data base of historical catch records and creel survey records of the Michigan Department of Natural Resources, we were able to tabulate catch and effort statistics for the major species from 1965 to 1981 as a basis for assessing the current status of the stocks in Michigan's treaty-ceded waters of Lakes Superior, Huron, and Michigan. By combining data on growth, age composition, and catch per unit of effort obtained from our recent resource surveys with complementary data furnished by the State and Tribes, we developed new or revised estimates of total mortality, standing stocks, and total allowable catches (where appropriate) for lake trout, lake whitefish, and bloaters.

The results of our assessments, together with those for other species prepared by State or Tribal biologists, were assembled at the Laboratory into the 1982 Annual Report of the Tripartite Technical Working Group. This and earlier reports serve as the technical basis for formulation of Tribal fishing regulations and for interagency negotiations aimed at a permanent settlement of issues involving treaty fishing rights.

Growth, Food Consumption, and Conversion Efficiency in Large Lake Trout. Laboratory data on rates of food intake, growth, and food conversion by large lake trout fed natural forage and held at simulated lake temperatures are needed for incorporation in a general predator-prey model currently being developed by the Great Lakes Fishery Laboratory in conjunction with State natural resource agencies. This model will be used to predict the capacity of Great Lakes stocks of prey fish to sustain mixed populations of lake trout and other salmonids. To obtain the requisite data, we maintained 1974 and 1977 year classes of lake trout of the Marquette Hatchery strain on forage fish (rainbow smelt and alewives) from October 1980 to November 1981 at three ration levels (ad libitum, or 0.25 or 0.50% of body weight per day), at simulated lake temperatures. During the first 4 months of the study, smelt or alewives were fed to the trout on alternate days. We observed, however, that both year classes of trout fed ad libitum showed a marked preference for smelt over alewives, whereas trout fed either of two restricted rations did not exhibit such a preference. Consequently, we modified the rest of the study to evaluate each forage species independently and to eliminate the confounding effect of food preference. All trout were fed only smelt from February through August 1981; their diet was then changed to alewives until completion of the experimental period in early November 1981. Preliminary statistical analysis of growth data collected during the period when trout were fed either smelt or alewives exclusively showed no significant difference in specific growth rate between the two year classes for fish fed the 0.25 or 0.50% ration. However, for trout fed ad libitum, the specific growth rate of the 1977 year class was significantly higher than that of the 1974 year class. In addition, ration and temperature had a significant effect on specific growth rate for both year classes. Data on food consumption, food conversion efficiency, and caloric content of test trout and forage fish are also being analyzed.

Toxaphene in the Great Lakes. As a result of several years of cooperative investigation with the Columbia National Fisheries Research Laboratory and the U.S. Environmental Protection Agency, toxaphene was identified and confirmed as a major contaminant of fish from the upper Great Lakes. This chlorinated camphene insecticide is used mainly on cotton and has only limited use in the Great Lakes region. It is produced commercially by the chlorination of camphene and has a typical empirical formula of $C_{10}H_{10}Cl_8$, with 4,380 theoretical compounds. Gas chromatographic analyses suggest, however, that less than 200 compounds are actually formed and present in technical grade toxaphene, and that less than 40 of these compounds are present in Great Lakes fish.

Analysis of lake trout from Lakes Superior, Michigan, and Huron for technical grade toxaphene have shown that fish from these lakes contain many of the compounds present in toxaphene. Although the toxaphene components being detected in fish have undergone several changes, probably as a result of environmental weathering and metabolism, resemblance is sufficient for the compounds to be called toxaphene. Concentrations of toxaphene measured in lake trout generally varied with lake, location, and size of fish. Large lake trout (whole fish) from Lake Michigan, for example, contained 6-11 $\mu g/g$ toxaphene, and lake trout of similar size from Lakes Superior and Huron generally contained 3-5 $\mu g/g$. However, these values represented only a few composite samples from a single location in each lake. We expect to conduct additional analyses of fish from all of the Great Lakes to assess

more fully the presence of toxaphene in other species and areas. Atmospheric transport of toxaphene from southern U.S. cotton-producing States, combined with some use and production of the pesticide in the basin, is the probable source of toxaphene in the Great Lakes. The confirmation of elevated toxaphene residues in Great Lakes fish was a major contributing factor to a recent decision by the Environmental Protection Agency to further restrict the production and use of toxaphene.

Review of Bioaccumulation of Toxic Substances During Dredging Operations. Dredging operations in the Great Lakes move over 10 million cubic meters of sediment annually, causing potential harm to the biota through disruption of the habitat and resuspension of sediments often contaminated with toxic organic and inorganic chemicals. Laboratory studies have shown the potential bioavailability of both organic and inorganic contaminants from resuspended sediments. However, procedures used to determine bioaccumulation from sediment vary widely, and little information is available relating the accumulation of contaminants by organisms to overall effects on the ecosystem.

To provide a basis for recommending criteria for testing and evaluating proposed dredging and disposal operations, we completed a literature search and report entitled "Bioaccumulation of toxic substances during dredging." The report is the result of an interagency agreement between the Great Lakes Fishery Laboratory and the Environmental Protection Agency's Great Lakes National Program Office in Chicago, addressing the effects of dredging activities on aquatic organisms and methods used to determine these effects. The report summarizes information from 104 literature citations.

Some general conclusions and recommendations resulting from the literature search follow: (1) In bioassessment tests, flow-through bioassays of whole sediment should be used. (2) Bioassays should be conducted for at least 10 days. (3) To represent worst-case conditions, organisms should have direct contact with sediment during the bioassay. (4) The availability of contaminants to test organisms during the bioassay is affected by contaminant type and by physical characteristics of the sediment, such as organic content and particle size. (5) Bioassays should be conducted with at least one vertebrate and one invertebrate. (6) Standard bioassay procedures for testing contaminants in sediments must be readily available to groups responsible for evaluating dredging operations.

Toxicological Evaluation of Recently Identified Contaminants in Great Lakes Fish. Previous studies at the Great Lakes Fishery Laboratory resulted in the tentative identification of 476 organic compounds in fish of the Great Lakes. To evaluate initially the potential harm of these compounds to fish of the Great Lakes, we reviewed published and unpublished information on the toxicity, bioaccumulation, environmental occurrence, and potential sources of the compounds. Aided by this information, we placed about two-thirds of the compounds into one or more of 50 chemical categories and provisionally ranked these categories as follows in order of descending potential hazard to aquatic biota: complex, chlorinated polyaromatic hydrocarbons (e.g., endrin); arene halides (e.g., PCB's, DDT); chlorinated camphenes (toxaphene); alkyl halides (e.g., 3-chloro-l-propynylcyclohexane, lindane); polyaromatic hydrocarbons and reduced derivatives; complex polyaromatic hydrocarbons; phthalate esters; heterocyclic compounds; monocyclic terpenes; sulfur-containing compounds; phenols; and cyclic ethers. Many of the compounds that ranked below these (e.g., fatty acids, alcohols, and alkanes) may be natural components of wild fish as well as having anthropogenic sources.

We are currently testing extracts of lake trout from southeastern Lake Michigan that are similar to the extracts used to detect 167 of the 476 organic compounds found in fish from all the Great Lakes. Static acute bioassays of the cladoceran *Bosmina longirostris* at 17°C with fish extract (1 g tissue per milliliter of extract) and a solvent blank (ethanol) revealed that the fish extract was toxic to *Bosmina.* Based on the known concentrations of *p,p'*DDT in this fish tissue, the 48-h EC50 of the total extract was calculated in terms of p,p'DDT to be 0.57 μg/L (n = 2). Earlier acute bioassays of pure p,p'DDT with *Bosmina* gave a 48-h EC50 of 0.63 ± 0.03 jig& (± SE, n = 7), suggesting that the toxicity of the p,p'DDT in the extract was only slightly increased by the presence of the other organic compounds present in the extract. Alternatively, some compounds in the extract may play an antagonistic role relative to the more toxic compounds present. As the next step, we are preparing fractions of the extract for acute bioassays to estimate toxicity of groups of compounds in the fish extract.

In addition to testing the fish extract and fractions of the extract, we are testing specific compounds that rank high in a priority listing of the 476 compounds. One of the contaminants of concern as a potential threat to the health of the aqua-

Biologists assembling traps (upper photo) used to collect lake trout swim-up fry on spawning reefs in northwestern Lake Huron. Each trap consists of an inverted wire mesh funnel to which is attached an opaque polyethylene jar. The traps are set on rock-rubble substrate where spawning is known to have occurred. When newly hatched swim-up fry emerge from the substrate they are guided into the polyethylene jar at the apex of the trap where they are retained until the trap is retrieved (photo at left). Fry taken in these traps in 1982 provided the first evidence that hatchery-reared lake trout planted in Lake Huron are reproducing successfully. *Photos by D. W. Schloesser.*

tic biota is toxaphene, which is widespread in Great Lakes fish. Acute bioassays of technical grade toxaphene in reconstituted hard water resulted in 48-h EC50 values of 1.4 µg/L (n = 2) for *Bosmina* and 12.0 ± 3.4 µg/L (SE, n = 3) for *Daphnia magna,* indicating that toxaphene is only slightly less toxic than p,p'DDT. The value for toxicity of toxaphene to *D. magna* may be compared with earlier tests on *D. pulex* in softened well water, which resulted in a 48-h EC50 value of 2.67 ± 0.17 Ag/L p,p'DDT (± SE, n = 4). From these results, technical grade toxaphene may be considered acutely toxic to cladocerans, an important component of the invertebrate forage base of Great Lakes fish.

Evaluation of Fish Spawning and Nursery Habitat in Great Lakes Nearshore Waters. The reestablishment of self-sustaining stocks of lake trout in the U.S. waters of Lake Huron would be facilitated if information were available to show which portions of the spawning and nursery habitat used historically by this species are still capable of supporting the production of viable swim-up fry. This information would provide improved guidance for the ongoing Lake Huron brood stock rehabilitation program by pinpointing the best sites where lake trout stocking efforts could be focused and where refuges designed to protect the brood stocks of this species could be established. This information

Limnologist preparing to deploy a probe designed to measure dissolved oxygen and hydrogen sulfide under ice, within the interstices of rock-rubble substrate used historically for spawning by lake trout in Lake Huron. The probe has been used successfully to obtain interstitial water quality measurements as deep as 30 cm beneath the surface of the substrate. An underwater television camera (not shown) is used to assist in positioning the probe at the desired level within the substrate. *Photo by J. K. Hiltunen.*

would also aid in the development of explicit strategies designed to protect the remaining potentially productive spawning and nursery habitat from the adverse effects of various water-use practices.

During fall 1981 we began a study in the nearshore waters of northern Lake Huron near Rockport, Michigan, to investigate the feasibility of using an underwater television camera to survey historically used lake trout spawning and nursery habitat and to evaluate its present potential to produce viable swim-up fry. Images of the substrate were recorded on videotape at locations where we were able to collect fertilized lake trout eggs from the lake bottom by pumping. Study of these videotapes indicated that three major substrate types were present: type 1 — clean, angular, broken cobble, 30-60 cm in diameter; type 2 — clean, round rubble and cobble, 20-100 cm in diameter, interspersed with pockets of sand and fine gravel; and type 3 — large, angular boulders, 100-300 cm in diameter, interspersed with or covered by smaller, broken, angular rubble and cobble, 20-30 cm in diameter.

During spring 1982 we fished 18 emergent traps continuously for 49 days on the various substrate types composing the reef and caught 19 swim-up fry of lake trout, 24 to 27 mm long. Fry were captured only between 10 May and 1 June and only in traps set on type 1 substrate. All but four of the fry were alive when they were removed from the traps. These catches provide the first tangible evidence that hatchery-reared lake trout planted as juveniles in Lake Huron have spawned naturally and produced viable swim-up fry. This information, coupled with the fact that two of these fry have been held in Lake Huron water (at the Hammond Bay Biological Station) for about 4 months and have grown to a length of about 100 mm, suggests that survival of naturally spawned fry to the size at

which hatchery-reared juveniles are usually planted is possible and may now be occurring in some portions of Lake Huron.

Effect of Increased Nutrient Loading on Fish Spawning and Nursery Habitat in Great Lakes Nearshore Waters. Self-sustaining stocks of lake trout, once common throughout most of the Great Lakes, are now known to exist only in Lake Superior. Various hypotheses, including overfishing, predation by sea lamprey, and degradation of spawning and nursery habitat, have been advanced to explain why this species disappeared from much of its former range in the Great Lakes. One such hypothesis is that increased nutrient loading — which causes accelerated production of plankton and benthic algae, and subsequent degradation of interstitial waters on spawning grounds when these organisms settle out and decompose — may partly explain why lake trout have failed to reestablish themselves, despite costly stocking programs that have been followed for many years to accomplish that goal. To test this hypothesis, we began a limnological investigation in October 1981 at four widely separated locations used historically for spawning by lake trout in nearshore waters of Lake Huron: North Graham Shoal in the Straits of Mackinac, Bell Shoal near Rockport, North Point near Alpena, and Point Au Gres in Saginaw Bay.

In February 1982 we measured interstitial dissolved oxygen under the ice at depths of 10-30 cm within the rock-rubble substrate at each of the four study locations. The measurements were made in February because we believed that the biological oxygen demand of sediments present on the spawning grounds would be greatest during the period of ice cover, when water movement through interstitial spaces where eggs of lake trout incubate during winter would be at the seasonal minimum. At each location, we found a gradient in dissolved oxygen; values were high (12-14 ppm) in the overlying waters, and moderately high (5-13 ppm) in the interstitial waters. Although dissolved oxygen concentrations in the interstitial waters were equal to or above that required for normal development of lake trout embryos (5 ppm), the oxygen gradient within interstitial spaces of the substrate indicates that decomposition of organic matter settling on these historical spawning grounds does reduce water quality to a measurable extent. We also collected samples of interstitial water at each location to determine whether dissolved hydrogen sulfide, a gas lethal to fish eggs and larvae at very low concentrations, was present. Analysis of these water samples showed that dissolved hydrogen sulfide was present at all four locations, but that concentrations were high enough at only two locations (Point Au Gres, 1.3-5.4 μg/L and North Point, 0.9-1.8 μg/L) to impair normal development of lake trout embryos. These preliminary results suggest that water quality is adequate to permit embryonic development and the production of viable fry on historical lake trout spawning grounds in the relatively unpolluted waters of northern Lake Huron, but not in the southern waters of the lake, where water quality has been degraded by accelerated eutrophication. Research to further test this preliminary appraisal is under way.

Bioavailability of Precipitation-borne Phosphorus to Phytoplankton in the Upper Great Lakes. Precipitation, aside from its innate life-sustaining property, now poses a serious, long-lasting threat to water quality in the upper Great Lakes because it is acidic and contains high concentrations of phosphorus, the nutrient that most limits primary production in these waters. Because nearly all forms of phosphorus are hydrolyzed to phosphate — the form of phosphorus most readily used by plants— at rates that are proportional to the acidity of the solution, the increasing acidity of precipitation over the upper Great Lakes may be increasing the biological availability of phosphorus added to these waters by the atmosphere and tributaries. The impact of such an increase on fishery resources in the upper Great Lakes could be great because it would accelerate eutrophication — one of the prime environmental concerns of the U.S. and Canadian governments for many years. Eutrophication has been implicated in the demise of salmonid stocks in the lower Great Lakes and may pose a similar threat to self-sustaining fish stocks in the upper Great Lakes.

To test the hypothesis that phosphorus in rainfall is made more available for biological production by acidic hydrolysis, we analyzed samples of water from melted snow, tributary runoff, and lake water from the littoral zone in northwestern Lake Huron for phosphate phosphorus. Preliminary results of these analyses, which were performed in collaboration with the Great Lakes Environmental Research Laboratory in Ann Arbor, showed that more phosphate phosphorus was present initially in tributary runoff (up to 7 μg/L) than in water from melted snow (3 μg/L) or littoral waters (1 μg/L). After treatment with dilute hydrochloric acid, however, more phosphate phosphorus was present in the snow and rain water (each 15 μg/L) than in tributary runoff (13 μg/L) or littoral waters

(7 μg/L). To further demonstrate that phosphorus in acidic precipitation is biologically available, we also performed bioassay experiments in which epilimnetic waters from southeastern Lake Michigan containing phytoplankton were enriched by the addition of acidic precipitation or known amounts of phosphate phosphorus. The addition of the acidic precipitation stimulated increases in phytoplanktonic growth (^{14}C assimilation and chlorophyll concentration) closely approximating those caused by the phosphate phosphorus additions. These findings are consistent with the hypothesis that phosphorus in precipitation is made more biologically available by mild acidic hydrolysis and that acidic precipitation is potentially a large source of biologically available phosphorus to the Great Lakes.

Inland Fisheries and Reservoir Management

GAINESVILLE NATIONAL FISHERY RESEARCH LABORATORY

The mission of the Gainesville National Fishery Research Laboratory is to conduct a national research program on exotic species that are established in the Nation's waters or are likely to become established in the future, and to evaluate the potential beneficial or harmful characteristics of fish that are being considered for release.

A recent national survey supported by the Laboratory revealed that 39 species have established breeding populations in U.S. waters. These fish, under consideration for aquaculture, sport fishing, weed control, insect control, or aquarium use, escaped or were purposely released into open waters. An additional 59 exotic fish species that have not established self-sustaining populations have also been taken from these waters. None of the species were environmentally evaluated before introduction. The Gainesville Laboratory is preparing a protocol or set of procedures to serve as guidelines in evaluation of the potential beneficial or harmful characteristics of exotic species before they are introduced into open water environments.

A Service contract with James Deacon, University of Nevada, supported a detailed survey to determine the distribution, status, and impact of exotic fishes in southwestern United States from California to Texas. A total of 41 exotic species were taken from open water environments; of these, 12 are now established, 5 are possibly established, 6

The grass carp (above) and the grass carp x bighead carp (below) are exotic forms now being studied throughout the United States for use as weed control agents. *Photo by J. A. McCann.*

A typical unsorted seine haul of exotic fishes — mainly Mozambique tilapia (all of the larger fish shown), spotted tilapia, and black acara — established in the canal systems of southeastern Dade County, Florida. Only a few native fish—probably bluegills — are shown. The rule at center foreground is 14 inches long. *Photo by R. S. Dial.*

have localized populations, and 11 others have been taken at least once from open waters. At least six tilapia species or their hybrids have developed significant populations in the lower Colorado River. The effect on native fishes of established tilapia populations in the lower Colorado River, the Salton Sea, and along the southwestern coast of California is unknown, but of concern to fishery biologists.

Florida is particularly susceptible to the introduction of exotic fish species because of its subtropical climate, extensive environmental disturbance, and abundance of ornamental aquarium fish farms. The blue tilapia is an exotic cichlid of paramount concern in Florida. It now has the most extensive distribution of the exotic fish species established in the State, having already invaded at least 23 counties. It is capable of attaining high densities and has been implicated as being detrimental to native fishes. Research on the biology of this species is imperative to predict its potential range, understand its ecology, and evaluate its effects on native fishes.

The thermal biology and life history of the blue tilapia were investigated, as were some of the ecological concerns posed by the species. The fish survived water temperatures of 12°C indefinitely (> 60 days), but died in an average of 15 days at 10°C, 8 days at 8°C, and 1 day at 5°C. Salinity had little effect on the lethality of low temperatures. Blue tilapia moved into warmwater runs of a stenothermal spring in winter, reaching peak abundance there in December, when temperatures in nonspring waters were at their annual minimum. Reproductive activity of this multiple-spawning species peaks during summer. Scales and otoliths were collected from several hundred blue tilapia taken throughout the year for age and growth analyses. Experiments were conducted on the trophic biology of the species, competition for nesting sites between it and native centrarchids, and its suitability as forage for native piscivorous fish species.

LA CROSSE NATIONAL FISHERY RESEARCH LABORATORY

Development of Fish Control Methods. Salicylanilide I (2′,5-dichloro-3-tert-butyl-6-methyl-4′-nitrosalicylanilide) has been shown to be highly toxic to fish under a wide variety of conditions and to detoxify rapidly. Tests for efficacy and degradation rates were conducted in small ponds in cold and warm water, clear water, and water containing heavy blooms of planktonic algae and crustaceans. Concentrations of 50 to 70 µg/L (ppb) were effective against most species of fish under all conditions tested. Common carp and bullheads were among the more sensitive species but bowfins, gars, and goldfish were uncommonly resistant and survived exposure to more than twice the concentration that killed other species. The chemical degraded slightly faster in clear water than in turbid water, suggesting that sunlight may accelerate the rate of degradation. Degradation rates also were somewhat faster in warm water than in cold water. Degradation became evident after as little as 6 hours and was usually complete in less than 36 hours. If favorable results continue in other tests, Salicylanilide I should be a viable candidate fish toxicant.

Antimycin Residue Detection. Antimycin, a registered fish toxicant, has been used by fish managers for total reclamations of natural waters, as well as for some selective fish removals. The chemical is used at very low concentrations, from 10 ppb to less than 1 ppb. In the past, these concentrations were not analytically detectable. The development of analytical procedures to determine minute quantities of antimycin residues in fish tissues was pursued at the La Crosse Laboratory.

High performance liquid chromatography was used for the separation and quantitative determination of fluorescent derivatives of the piscicide. The method is sensitive and specific for antimycin and gives a recovery greater than 75 % for fish tissue samples fortified with the piscicide at concentrations as low as 0.45 µg/g. This method will make it possible to determine residue dynamics in fish after exposure to antimycin and to follow possible accumulation in nontarget organisms or in the environment.

Rotenone Residues. The continued registration of rotenone as a fish toxicant requires determination of the persistence of rotenone residues in fish tissues and in other portions of the aquatic environment. A rapid high performance liquid chromatography method has been developed that enables the detection of as little as 0.005 mg/L of rotenone in water. The analysis of treated water to determine concentrations applied and to follow dispersion patterns can be done rapidly and will make it possible to monitor persistence of the compound in the environment.

A high performance liquid chromatography method has also been developed for the analysis of rotenone residues in fish. Rotenone residues as low as 0.02 µg/g can be detected in fish muscle samples

This rainbow trout has been surgically prepared for the injection of radiolabeled rotenone into the dorsal aorta for studies to determine distribution and elimination. *Photo by L. L. Marking.*

after the extracts are cleaned up by silica gel chromatography. Recoveries of rotenone from fish tissue fortified with 0.05 to 2.0 Ag/g ranged from 84 to 93%. Muscle tissue of channel catfish and largemouth bass exposed to 0.1 mg/L of purified rotenone until they were moribund or dead contained 0.084 and 0.078 $\mu g/g$, respectively. Muscle tissue of channel catfish, largemouth bass, bluegills, and redear sunfish exposed to 2.0 $\mu L/L$ of Noxfish (5% rotenone) until they were moribund or dead contained 0.067, 0.065, 0.067, and 0.072 $\mu g/g$ of rotenone, respectively. The method is practical and will make it possible to continue research on the environmental fate of rotenone after its application to natural waters.

Tissue and Subcellular Distribution of Rotenone in Rainbow Trout. Rotenone is extremely toxic to fish and is important in fishery management as a general fish toxicant. As part of efforts to ensure that rotenone is an environmentally safe chemical, the Fish and Wildlife Service is currently conducting a series of studies to support the registration of this compound with the U.S. Environmental Protection Agency.

To evaluate the relative tissue and subcellular distribution and elimination of rotenone in a representative teleost, we administered radiolabeled rotenone to adult rainbow trout through a dorsal aortic canula. Samples of blood, bile, excreta, and selected tissues were collected from groups of fish at times ranging from 1 to 72 hours. Samples were oxidized to $^{14}CO_2$ and activity was quantified by liquid scintillation counting.

Elimination of rotenone from the body occurred in two discrete phases, an initial rapid phase having an estimated half-life of about 8 hours and a slower secondary phase having a half-life of 70 hours. Greatest relative tissue activities were found in tissues that are highly dependent on aerobic metabolism (atrium and ventricle of the heart, lateral line

red muscle). Activity was intermediate in most soft organs and was lowest in mature gonads from both sexes. Results of subcellular fractionation studies of four tissues (white muscle, red muscle, liver, kidney) revealed that more than half of the activity was associated with the mitochondrial fraction and lesser amounts with the nuclear, microsomal, and supernatant fractions. The results of these studies indicate that, although rotenone is readily accumulated in tissues that are highly dependent on aerobic metabolism, it is eliminated from all body compartments in a relatively short time. The relatively rapid elimination of rotenone from fish tissue supports the contention that rotenone is an environmentally safe chemical.

Fish Control in Garrison Diversion. A plan to divert water from the Missouri River watershed into the Red River system, which flows into Canada, has been developed by the U.S. Bureau of Reclamation. Known as the Garrison Diversion, this plan would provide water for agricultural and industrial purposes throughout a large part of North Dakota and would enhance fish, wildlife, and recreational resources. Canadian officials have expressed concern that certain species of fish that are not present in their waters may immigrate through the diversion and become established despite mechanical barriers already incorporated into the system. The species causing the objections are gizzard shad, rainbow smelt, common carp, and Utah chubs.

Under a Cooperative Agreement with the Bureau of Reclamation, the La Crosse Laboratory tested various chemical toxicants that might be effective for controlling eggs and larval forms of the problem fish species. Candidate chemicals included acrolein, sodium cyanide, sodium fluoride, sodium nitrite, ammonium chloride, calcium hypochlorite, potassium permanganate, and rotenone. Eggs and larvae of rainbow smelt were exposed to the chemicals in standardized laboratory tests to determine the LC50's (concentrations calculated to produce 50% mortality). All of the candidate chemicals proved toxic to eggs and larvae, but eggs were consistently more resistant than larvae. Three of the chemicals — calcium hypochlorite, potassium permanganate, and rotenone—showed good potential for use in solving the problem because low concentrations were effective and there was little difference in the concentrations required to eliminate either life stage. Chlorine (from calcium hypochlorite) destroyed eggs and larvae at 0.3 mg/L and its toxicity was least affected by water temperature, hardness, and pH. Toxicities of potassium permanganate and rotenone were less consistent and were influenced more by water characteristics.

Bar Formulation of Lampricide. A soluble bar formulation of the lampricide TFM (3-trifluoromethyl-4-nitrophenol) continued to show a high degree of effectiveness against larval sea lampreys in small streams. The bars consist of TFM incorporated into a water-soluble matrix. Each bar treats 0.5 cfs of water at a concentration of 1 ppm for 8 to 10 hours, depending on water temperature. Field trials were conducted in a tributary of the Sturgeon River in Upper Michigan. In the first treatment, the bars were placed in a location where the current velocity was 0.35 foot per second. The bars dissolved in 6 hours instead of the predicted 8 hours and failed to maintain a lethal concentration for the required length of time in the lower reaches of the stream. When the stream was re-treated, the bars were placed at a site where the velocity was only 0.2 foot per second. This treatment provided the proper concentration for the required time and resulted in the elimination of larval sea lampreys. The field trials have shown that the application point must be carefully chosen and limited to sites where water velocities are 0.2 foot per second or less. All field trials in which such sites have been used have resulted in total kills of sea lampreys.

An application is being prepared for registration of this new type of formulation by the Environmental Protection Agency. The bar formulation is expected to result in substantial reductions of manpower formerly expended in monitoring of mechanical pumps for application of the lampricide in liquid form.

Binding of TFM by Soil. Soil binding (adsorption/desorption) studies were run to help determine the environmental fate of the lampricide TFM and its metabolites. The potential for TFM to become bound to sediments not only affects the efficacy of the chemical but also its availability to nontarget organisms.

The adsorption of ^{14}C-labeled TFM and one of its metabolites (reduced TFM) was evaluated against bottom sediments from the Cedar, Ford, and Tahquamenon rivers in Michigan. Reduced TFM was more strongly adsorbed to the sediments than TFM, and its binding was influenced little by pH. However, TFM was more than 5 times more strongly adsorbed to sediments at pH 6 (un-ionized) than at pH 9 (ionized). Silty sediments adsorbed significantly more of each chemical than did sandy sediments.

Development of Methods for Sterilizing Spawning-run Sea Lampreys. The Great Lakes Fishery Commission has endorsed the development of an integrated sea lamprey control program that will include continued application of selective larvicides where appropriate, plus other methods that may prove effective in attaining the desired level of sea lamprey control. A control method now being developed and evaluated at the Hammond Bay Biological Station involves the release of artificially sterilized, sexually mature male sea lampreys into streams containing spawning populations of lampreys. In principle, these sterile males compete successfully with fertile males for mates, thereby reducing the reproductive success of the spawning population. A basic requirement for the successful application of the technique of releasing sterile males is the development of a method of inducing sterility without serious adverse effects on the mating behavior or competitiveness of the males.

Laboratory tests have shown that bisazir (p,p-bis[l-aziridinyl]-N-methylphosphinothioic amide) sterilizes lampreys; however, it is a mutagenic compound and is considered to be a potential human health hazard. Studies with labeled (radioactive) bisazir at the La Crosse Laboratory showed that residues of the chemical declined rapidly within a few days after treatment, but that quantities of radioactive residues remained in tissues for up to 10 days.

Evaluations of several other chemicals were largely unsuccessful. The injection of male sea lampreys with a dose of 1,000 mg/kg of methallibure, a chemical inhibitor of pituitary activity, or immersion in a 1,000-mg/L suspension of methallibure, for 24 hours had no sterilizing effect. Immunological and radiological methods of sterilization offer certain advantages over chemosterilization because neither method involves the use of chemicals that would have to be registered. However, antisera (made in rabbits) to antigens derived from lamprey sperm injected into male lampreys had no sterilizing effect.

Lampreys exposed to various doses of cobalt-60 and cesium-137 were partly sterilized. The irradiation technique may ultimately be useful if 100% sterility can be achieved and if further tests show that the treatments have no adverse effects on lamprey spawning behavior and competitiveness.

Water Chemistry of the Upper Mississippi River and Some Tributaries. Water quality monitoring provides important information for evaluating the effects on river systems of such factors as navigation, dredging, barge fleeting, construction, wetland development, agricultural practices, urbanization, and industrial waste discharges. Water chemistry characteristics have been monitored in selected tributaries and at sites on Navigation Pool 7 and in the upper end of Pool 8 of the Upper Mississippi River since January 1972. Sampling sites include two on the Mississippi River, three on the Black River, one on the La Crosse River, one on Halfway Creek, and one on Lake Onalaska.

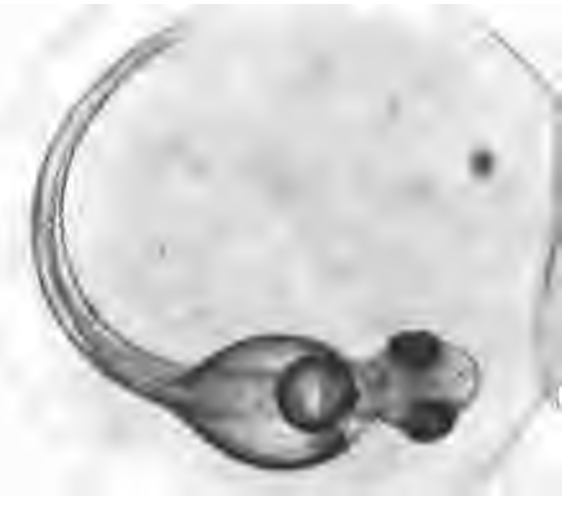
Several characteristics have demonstrated seasonal trends. Nitrate is generally lowest in summer, especially during August; however, nitrite is highest in summer. Ammonia concentrations are highest during winter, especially during periods of heavy ice and snow cover. Total phosphate is slightly lower in winter but is significantly elevated during August. Dissolved oxygen concentrations drop slightly during warmer periods, but generally remain between 75 and 100% of saturation. The greatest differences among years were observed during spring and could be related to periods of flooding. Annual changes in the overall water quality at any of the sites were usually small during the 10-year study period.

Probably the most critical problems observed during the study were excessive loads of suspended solids and nutrients, both of which contribute to accelerated eutrophication. Data developed through this monitoring can be used to identify detrimental effects on the resource and should reflect improvements as these impacts are mitigated.

Fish Abundance in the Upper Mississippi River. Fish density, diversity, and species composition are known to differ in the various habitats of the Upper Mississippi River as a result of physical characteristics and biological requirements. Backwaters, side channels, and the main channel in Pool 7 were sampled to identify the species and determine the abundance of fish in these habitats.

Paired hoop nets and experimental (graded-mesh) gill nets were set simultaneously in the three habitats at 2-week intervals from February to August. Each set was checked after 24 hours, numbers were recorded, and fish were released. A total of 36 species were captured in 26 net sets. Twenty-four species and 14% of the total number of fish were collected from the main channel, 30 species and 33% of the total from side channels, and 28 species and 53% of the total from backwaters. Among the sport fishes, northern pike and black crappies were most abundant in backwaters; northern pike and rock bass in side channels; and rock bass, saugers, and yellow perch in the main channel. The

Structures (dark lines) visible in the cleared and stained head of a larval northern pike illustrate the characters used to identify larval fishes. *Photo by L. E. Holland.*



Fish eggs reared in the laboratory are useful for identifying age and species of specimens collected in the field. This yellow perch embryo is about to hatch. *Photo by L. E. Holland.*

most frequently caught species were not limited to a particular habitat, although the difference in numbers and species in the three habitats were significant.

Larval Fish Assemblages Associated with Various Border Habitats in the Upper Mississippi River. Border habitats or "edge" areas provide the greatest diversity and abundance of flora and fauna in most ecosystems, especially lotic systems and particularly for larval fishes for which shore and littoral zones are important nursery areas. Previous studies have shown that larval fishes are surprisingly abundant in main channel border habitats of the Upper Mississippi River. Commercial navigation directly affects these border areas and therefore may significantly affect the survival of a larger portion of larval fishes than previously believed. However, few base-line data are available on which to judge the overall effects of navigation on recruitment. A study was begun in spring 1982 to determine the specific kinds of border habitats that maintain specific populations of larvae. The physical and chemical characteristics of the study areas were analyzed for their role in attracting larval fishes.

The abundance of larval fishes did not appear to be influenced by the type of border sampled. Catches from riprapped areas, dredge spoil, unaltered borders, or borders with submerged river training structures did not differ significantly. However, significantly more larvae were seen at stations that received flow from nearby backwater areas. Catches at stations receiving sediment-laden tributary waters were drastically lower. Species-specific analyses may provide more detailed information on differences between border habitats.

There are significant indications that most main channel border areas can be treated as a unit in an analysis of the effects of river traffic on larval fishes. Most importantly, it is evident that the integrity of backwater areas must be maintained to guarantee larval recruitment into the main channel, and that study of the backwaters and their associated downstream main channel border sites should be emphasized.

Guide to Early Life History of Fishes in the Upper Mississippi River. Increases in commercial navigation and recreational use of the Upper Mississippi River have made it necessary to manage fisheries in the system more intensively. One of the major gaps in information needed for such management is related to specific spawning habitat requirements, nursery site identification, and early life history needs of commercial and sport fishes. Both State and Federal interests in the river have agreed that without a basic understanding of the factors that affect recruitment into exploited fisheries of the area, efficient resource management is unlikely. One specific high-priority need was for the development of a regional guide to the identification of larval fishes in various stages of development.

Literature and field data have been analyzed to compile the information in the form of a guide to the early life histories and identifications of larval fishes common to the Upper Mississippi. The guide includes descriptions by family, with accounts on distribution, general morphology, and larval characteristics. Species descriptions include adult char-

acteristics, distribution, and ecology. An easily accessed outline of spawning sites, season, temperature, and substrates, as well as of egg, larval, and juvenile characteristics is provided. Available illustrations from previously published studies and new photographs of osteological structures are included. **In** addition, analyses of cartilage and bone development have been used to identify species that were previously unidentifiable by traditional meristic and morphometric methods.

Relative Plasma and Packed Red Cell Volumes in Two Strains of Rainbow Trout. The toxicity of many chemicals to fish can be partly explained by the manner in which chemicals are distributed to and accumulated in specific tissues. These processes are influenced by the relative volumes of blood in the individual organs and tissues and the rate at which they receive blood from the heart. Knowledge of the relative blood volumes of specific tissues is therefore important in understanding how chemicals are distributed within the various body compartments of an animal.

The relative body masses of 21 tissues and organs were established for two important hatchery strains of rainbow trout (Kamloops and Wytheville). In addition, the relative total blood volume, packed red cell volume, and plasma volumes were determined for 15 tissues within the two strains by the simultaneous injection of a suspension of ^{51}Cr-labeled trout erythrocytes and ^{125}I-bovine serum albumin into the dorsal aorta of surgically prepared animals.

Significant differences were found between the strains in 9 of 22 relative tissue and organ weights and in the relative total blood volume and plasma volumes for 5 of 15 tissues. The mean relative brain weight of the Wytheville strain was twice that of the Kamloops strain, but the relative weights of the kidney, small intestine, spleen, and white muscle were significantly greater in the Kamloops variety. Differences between strains in relative total blood and plasma volumes were most obvious among tissues having a high volume of blood, such as the anterior and posterior kidney, liver, stomach, and small intestine. The relative volume of blood in the lateral line red muscle of the Wytheville strain was 1.5 times greater than that in the Kamloops.

These observations indicate that significant differences exist in the relative size of organs and the relative volume of the vascular space in the same tissues or organs from different strains of fish. The results of these studies demonstrate basic physiological differences between strains that may influence the manner in which environmental contaminants, therapeutic agents, and fishery management chemicals affect different species.

Malachite Green: Detection of Residues and Search for an Alternative Fungicide. Malachite green has been used in fish culture for many years to control fungal infections on fish and fish eggs. Control of pathogenic aquatic fungi is essential in fish culture operations. In the development of data to support the registration of malachite green, mammalian safety tests showed that the chemical has the potential to cause birth defects. This finding greatly decreased the possibility of obtaining a registration.

As part of the continuing study of malachite green, we attempted to develop methods for the detection of the chemical in tissues of treated fish and to improve methods for its detection in water. The chemical produces color in solution with maximum absorbency at 615 nm. Muscle tissues can be extracted with ethyl alcohol, formalin, and acetic acid (85:10:5) and residues measured by colorimetry. This method is selective, specific, and sensitive for malachite green, and should be useful for developing information on residues of this therapeutant.

Rainbow trout exposed to 0.1 mg/L of malachite green for 24 hours were placed in fresh water and sampled and analyzed during 144 hours of withdrawal. Residues as high as 2 μg/g in the muscle of fish immediately after the exposure had declined to an apparent residue of 0.5 μg/g after 144 hours of withdrawal. Untreated control fish showed a "background" reading of 0.3 μg/g.

In a search begun for new fungicides to replace malachite green for use against aquatic fungi, we tested nearly 40 chemicals (mostly agricultural fungicides) in vitro by applying solutions to agar plugs containing actively growing aquatic fungi. The activity of each chemical was compared with that of malachite green. One promising chemical, Du-ter, which showed a high degree of activity against fungus cultures, was subjected to more definitive testing against fungal growths on live rainbow trout eggs. Du-ter controlled the fungus but proved to be highly toxic to the fish eggs. The lowest concentration tested (1 mg/L) caused nearly 50% mortality of the eggs.

Preparation of ^{14}C-Labeled Hyamines and Analysis for Presence of Nitrosamines. Quaternary ammonium compounds (Hyamine 1622, Hyamine 3500, and Roccal) are widely used disinfectants and are needed in fish culture for the control and prevention of diseases. As part of regulatory requirements, the persistence of residues of applied chemi-

cals in tissues of exposed fish must be determined. In addition, metabolism studies are required to determine the distribution and fate of the chemical in fish. We prepared ^{14}C-labeled Hyamine from commercial Hyamine for use in the development of residue detection methods and metabolism studies.

Inasmuch as quaternary ammonium compounds are potential precursors for the formation of nitrosamines (chemical carcinogens), we analyzed samples of commercial Roccal, Hyamine 1622, and Hyamine 3500 by gas chromatography for the presence of nitrosamines. The samples showed no detectable contamination with nitrosamines. The absence of nitrosamines in commercial samples of these therapeutants alleviates concern about the use of quaternary ammonium compounds in fish culture.

Anesthetics for Fish. Anesthetics are used by fish culturists in the handling of brood stock salmon during sorting of the fish and during spawn taking. Unfortunately, all currently used anesthetics leave residues in treated fish. Because of the residues, the Food and Drug Administration does not permit the use of the carcasses of spent fish for animal feed. Data have been developed that indicate that it should be possible to reduce the withdrawal period after use of MS-222 from 21 days to about 72 hours. A submission to Food and Drug Administration requesting this change is nearing completion.

Benzocaine has been suggested as an alternative to MS-222. It is an effective anesthetic for fish but few data are available on residues in fish after they are exposed to the anesthetic. Rainbow trout were exposed to 50 mg/L of benzocaine for 15 minutes, transferred to anesthetic-free water for withdrawal, and sampled periodically during 24 hours of withdrawal and analyzed by colorimetry and gas chromatography for residues of the anesthetic. Residues of benzocaine were detectable (above background readings) by colorimetry in fish after 4 hours of withdrawal and by gas chromatography in fish withdrawn from the anesthetic for 8 hours. These results suggest that benzocaine presents residue problems similar to those posed by MS-222.

Official Registration of Formalin. On 9 April 1982 the Food and Drug Administration (FDA) accepted Fish and Wildlife Service (FWS) data submissions as adequate evidence that fishery uses of formalin were effective and did not pose a significant hazard to human health or to the environment. This ruling cleared the way for private industry to file submissions that would permit them to label and sell formalin for fishery uses as a parasiticide and fungicide. The net effect of the FDA ruling is that fish culturists can legally use formalin but commercial firms must go through a procedure of registering with FDA before they can label and sell formalin specifically for fishery uses. A number of firms are now investigating the potential market in response to the Service's announcement of the FDA ruling.

Formalin has been known to fishery workers since 1909, when it was used to control parasites on rainbow trout. In time, the compound became the most widely used chemical in the treatment of fish disease because of its versatility and effectiveness. Use of the drug was lawful until the Federal Food, Drug, and Cosmetic Act was amended in 1972 to require registration of all drugs and chemicals used on food animals.

The registration of formalin culminates 9 years of effort by FWS to comply with FDA requirements. Formalin-related research has been guided by the La Crosse Laboratory. Studies were designed to answer a broad range of questions about the possible drawbacks of its use. Potential side effects that were ruled out included birth defects, cancer, and chromosomal damage that could cause mutants. Other research concerned the amount of residue in treated fish, the compound's effects on plants, and chemical interactions with pollutants and other products in the water. No test showed that formalin was unsafe or ineffective when used as directed. As part of its efforts to get formalin registered as a fish disease control agent, the Service drafted instructions for its use that manufacturers can include on package inserts and labels.

With this registration, formalin can be lawfully used by Federal, State, and private fish culturists to control parasites of trout, catfish, salmon, largemouth bass, and bluegills, and to control fungal infections on the eggs of salmon, trout, and pike.

Negotiations with the Environmental Protection Agency Regarding Rotenone. Officials of FWS and the Environmental Protection Agency (EPA) met on 16 June 1982 to discuss the remaining studies and data requirements to support reregistration of rotenone. Before rotenone can be reregistered, the research done must satisfy the concerns of four branches of EPA: Ecological Effects, Environmental Fate, Toxicology, and Residue Chemistry.

The Ecological Effects Branch suggested that FWS formally submit basic data and request accession numbers and validation of these data. The Branch indicated that data now available may be adequate to support an application for a waiver of

certain studies, but that the data must be provided for evaluation. The Environmental Fate Branch stated that the studies completed and in progress should meet its basic requirements. Available data and rationale may also be sufficient to support FWS requests for waivers for studies concerning irrigated crops, field accumulation, water dispersal, and field dissipation in nontarget organisms. The Toxicology Branch stated that the mammalian safety studies completed and in progress on rotenone should meet its basic requirements. The Residue Chemistry Branch indicated that further consideration of the use pattern of rotenone and the amount of preliminary data regarding residues, metabolites, and mammalian safety data may warrant issuance of a waiver for a study of metabolism in goats originally required.

The Fish and Wildlife Service agreed to officially submit copies of completed studies on ecological effects, environmental fate, and mammalian safety, for assignment of formal accession numbers and for validation by the respective branches. The Service submitted copies of completed studies on the ecological effects of rotenone on birds, fish, and invertebrates to the official files at the EPA, with the request that these studies be assigned formal accession numbers and validation by the Ecological Effects Branch of EPA.

Negotiations with the Environmental Protection Agency Regarding TFM. An update of the registered label for TFM was requested by EPA in February 1982 to meet current registration requirements. The supplemental label that covered the combined use of Bayluscide-Lamprecid (the new registered name for TFM) was incorporated into the draft label. The Service has received verbal confirmation from EPA that the draft label submitted on 20 May 1982 is acceptable.

On the basis of data provided by the La Crosse Laboratory, EPA established the following tolerances for TFM: 0.05 ppm in potable water, 0.1 ppm in milk and meat, and 20 ppm in fish.

Dimethylformamide (DMF), when used in formulations of TFM, now has an exemption from a requirement of a tolerance. This ruling, issued by the EPA on 10 March 1982, removes one of the last barriers to the establishment of tolerances for TFM in potable water, fish, meat, and milk. A teratology study in a second mammalian species begun in fiscal year 1982 should complete the requirements of EPA.

The La Crosse Laboratory submitted a Canadian TFM photodegradation study to EPA for review to determine if it would meet requirements for data on environmental fate. Further information was requested by EPA, which we hope to obtain from the Canadian investigators.

Report of the Technical Advisory Group on Fishery Chemical Needs. The 1982 report of the Technical Advisory Group for fishery chemical needs in FWS was completed. Although the 48 chemicals listed in this report do not reflect a significant change from 1980, the order of priorities has changed. Primary emphasis in 1982 was on needs for chemotherapeutic agents (antibiotics, antibacterial drugs, sanitizing compounds) and parasiticides. In 1980, priorities indicated the need to have at least one registered chemical or drug for use in meeting problems in each major category.

Of the top 30 compounds listed in 1980, 15 now have FDA or EPA registrations for aquatic or fishery uses. Thirteen of the compounds on the 1982 list (many of which appeared on the 1980 list) also are approved for fishery or aquatic uses. Some of the repeat listings of compounds already registered reflect a desire on the part of fish culturists to use chemicals for purposes other than those specified on the label. **If** a compound has a GRAS ("generally regarded as safe") classification, there is no need to register fishery uses. Unless the new or added purpose represents a major use that is significantly different from the labeled use, there should be little need to invest funds and manpower to obtain a new label.

The major subjects of concern include the following: viricide to disinfect the external surface of eggs (povidone-iodine compounds), fungicide to replace malachite green, control for bacterial gill disease (Hyamines), control of bacterial kidney disease (erythromycin), control of enteric redmouth disease (Ro5-0037), and resistance of disease organisms to chemotherapy.

Comments on Threshold Assessment and Target Animal Safety Guidelines. The Division of Fishery Research of FWS provided comments to FDA on "Criteria and procedures for evaluating assays for carcinogenic residues: Guidelines for threshold assessment." The Service suggested that FDA not finalize the guidelines at this time, but extend the comment period to end at the same time as the comment period for the "sensitivity of the methods" procedures. Otherwise the threshold assessment guidelines will have undergone publication, review, and approval before draft guidelines on sensitivity of methods are ready. The Service contended that both sets of guidelines must be considered together to

Research requires fish that are free of stresses that may be caused by problems in the water supply. These column aerators developed at the La Crosse National Fishery Research Laboratory are highly efficient for producing nitrogen and oxygen levels that are suitable for fish culture and testing. *Photo by T. D. Bills.*

develop a logical and workable system.

The Service asked FDA to consider establishing two sets of guidelines regarding permissible residue levels in cultured fish. One set would apply to juvenile fish produced in hatcheries for release in natural waters, where they eventually grow to the size harvested by anglers and commercial fishermen. The other set would establish separate tolerances or withdrawal periods for cultured fish reared to marketable size for human consumption. In addition, FWS requested that a correction factor for the residue score for fish be established and that it should be similar to that for beef, pork, sheep, and poultry where various tissues and muscles are considered. The correction factor should represent the percentage of fish as compared with the percentage of major food animal species consumed in the American diet.

The Service requested that FDA formulate testing guidelines to aid sponsors of fishery chemicals in developing protocols for experiments to satisfy FDA animal safety requirements for drugs used to treat fish, and also asked FDA whether the draft guidelines recently revised by FWS on the safety and efficacy for food fish are sufficient to meet the Target Animal Safety Guidelines for New Animal Drugs, and the General Food Safety Provisions of the act as they relate to toxicity.

These changes should provide a more realistic set of guidelines to govern minor-use drugs and chemicals.

Supersaturation in Well Water. Nitrogen gas concentrations in well water at the La Crosse Laboratory range from 130 to 140% of saturation. The high nitrogen content causes gas bubble disease in some fish species and stress in others. Various aeration methods were investigated initially with only partial success. A vacuum degasser was installed soon after the Laboratory was put into operation. That system effectively removed nitrogen gas but also decreased the oxygen to critical levels. A search for methods to alleviate the problem led to an evaluation of column aerators and a comparison of alternatives.

The column aerators and the vacuum degasser were compared to determine the efficiency of the

two systems separately and in combination, to determine their effectiveness for producing water suitable for culturing fish, and to evaluate cost factors and energy consumption.

The degasser, the column aerator, and the combined systems effectively reduced nitrogen gas from about 133% to near 100% of saturation. However, the vacuum degasser also decreased the dissolved oxygen from 27 to 22% of saturation, whereas column aerators increased the oxygen level to over 91% of saturation. The vacuum degassing system has been abandoned in favor of column aerators because they are easy to construct, are reasonably inexpensive, require little maintenance, consume no energy other than head pressure, and are highly efficient for altering concentrations of nitrogen and oxygen to levels suitable for fish culture.

The principle of aeration columns is ideal for treating water used for fish cultural purposes because oxygen is more soluble than nitrogen in water. The process corrects disequilibrium and causes both gases to stabilize at near 100% saturation.

Water-stable Diet for Aquatic Invertebrates. Many kinds of aquatic invertebrates are used in fishery research. Suitable diets are needed for the culture of aquatic invertebrates used for assessing physiological effects and potential environmental impacts, and to provide food for culturing young fish. Such preparations must support growth and reproduction, should not adversely affect water quality, and should be water stable to accommodate slow and intermittent feeders. Since most organisms require at least daily feeding, it would be more convenient to incorporate nutrients in a binder that would disintegrate slowly and provide nourishment for several days to a week.

A diet was prepared in 1 liter of water with the following components (amounts in grams): Trout Chow, 35; dehydrated alfalfa, 15; Pervinal vitamin-mineral tablets (crushed), 4.5; and leaves of sugar maple, 10. The nutrient mixture was heated to 75°C for 5 minutes with stirring, and then 30 g of Difco Bacto-agar were slowly added, with constant stirring to prevent lumping of the agar. The resulting mixture was poured into a flat pan and cooled in a refrigerator at 4°C. The gelled cake was cut into bars of appropriate size to provide food for the invertebrates for several days.

The diet was fed to amphipods, snails, caddisfly nymphs, and crayfish. The organisms survived and grew in fiberglass tanks for up to 1 year in flowing water at 12°C. Amphipods and snails reproduced while on the diet. The preparation remained stable for 1 week in water at 12°C and provided a constant source of food for benthic organisms that feed slowly and intermittently.

LEETOWN NATIONAL FISHERIES CENTER

The National Fisheries Center directs programs of the National Fish Health Research Laboratory, Fisheries Academy, and other components at Leetown; the Tunison Laboratory of Fish Nutrition, Cortland, New York; the Fish Farming Experimental Station, Stuttgart, Arkansas; the Southeastern Fish Cultural Laboratory, Marion, Alabama; and the National Fishery Research and Development Laboratory, Wellsboro, Pennsylvania.

Among the activities at Leetown components not reported separately in the accounts that follow, the Center's Fish Genetics Section conducted the second national survey of trout brood stocks used by State fish management agencies during the year. This partly completed survey has identified different trout strains that are being used in State fishery programs with production information on each strain that includes breeding history, disease tolerance, stress tolerance, hatchery performance, and (to some extent) field performance. Nineteen States have reported 108 brood stocks divided among five species: 43 rainbow trout, 18 brook trout, 18 brown trout, 23 cutthroat trout, and 6 lake trout. The first edition of the Trout Strain Registry was distributed to fishery managers during the year. Studies to evaluate the relative potential of strain crossing and inbred line crossing as breeding methods for producing fish population that express hybrid vigor in captive and non-captive environments were continued. These studies demonstrated that both methods are capable of producing hybrid vigor in progeny. Inbred line crossing offers the higher potential for improvement in future performance, but this improvement will require considerable effort and time to be achieved. Alternatively, the strain crossing approach offers a lower potential gain, but that gain could be achieved quickly once the specific strain combinations yielding superior performance are identified.

The Aquaculture Production and Demonstration Station cooperated with the West Virginia Department of Natural Resources and the Fisheries Academy in an accelerated growth project with tiger muskellunge (hybrids of muskellunge x northern

Eggs being stripped from a rainbow trout at the Service's Aquaculture Production and Demonstration Station. The progeny from individual fish are raised separately, in attempts to identify genetically superior parents that will produce future "prize catches." *Photo by H. M. Stuckey.*

pike). Feeding on fathead minnows as forage, fingerling tiger muskellunge stocked in two ponds in late June more than doubled in length in 3 months. The highly popular Fishing Area for the Handicapped, managed by the Station, posted a new season record for use, with 862 anglers fishing 3,042 hours and catching 1,129 fish. In addition, 210 handicapped youngsters who participated in a Fall Fishing Derby caught 57 fish. Rainbow trout and channel catfish were the predominant species caught. The Station provided 26,497 rainbow trout and brook trout fry, fingerlings, and adults, and 146,537 rainbow trout eggs to various Federal, State, and private agencies and universities, principally for research.

At the Fisheries Academy, 14 trainees completed the Fish Hatchery Managers Course on 28 May. Fish and Wildlife Service Director R. A. Jantzen delivered the graduation address, which emphasized the growing importance of aquaculture in this country.

Nineteen short courses were presented at the Academy on subjects such as genetics and brood stock selection; fish health; culture of coldwater, warmwater, and coolwater fishes; Pacific salmon culture; electrofishing; bio-statistics; aquatic chemicals; nutrition; and water quality. A total of 1,334 days of training were given to 185 short-course participants. Five contract courses were presented. Two video training courses, "Fish marking" and "Preparing fish for shipment to diagnostic stations," were made available. Single copies of each were distributed to each Regional Office, and a brochure describing the tapes was given general distribution. Fourteen tapes have been sold to non-FWS user groups.

A Heath hatching tray system, jar battery, and catfish hatching trough have been constructed at the Academy and used for teaching. Two closed-system production tanks incorporating biological filters have been constructed. New fyke nets were built and used as training aids. A tank pad for demonstrating various aquaculture procedures has been built and tanks installed. An environmental assessment of the impact that will be caused by the renovation of the existing hatchery ponds was completed during

Awo Otisi (Nigeria) and Helene Drouin (Quebec, Canada) inspect normally pigmented and albino channel catfish with instructor Don Kuntzelman during the Fish Hatchery Managers' Course at the Service's Fisheries Academy. *Photo by H. M. Stuckey.*

the year. We propose to fill in the ponds adjacent to the holding house to provide space for above-ground aquaculture production systems, and to divide the remaining ponds into smaller, more manageable units.

FISH FARMING EXPERIMENTAL STATION

Developments in Chemotherapeutants to Control Fish Pathogens. Legal constraints on the use of some chemicals and drugs, and the development of organism resistance to others call for continuous research to develop better treatment methods. A replacement chemical for malachite green for fungus control is a high-priority need. Replicated treatments of four fungicides (diquat, 25 ppm; Du-ter, 5 ppm; copper sulfate, 1 ppm; and Argentyne, 100 ppm) against a natural fungus infection on channel catfish eggs gave promising results. The eggs were exposed to the chemicals for 10 minutes each day for 4 days. Diquat and Du-ter both appeared to be very effective. Because of the extreme toxicity of Du-ter to fish, however, later tests were conducted on only diquat. Results indicated that diquat (25 ppm) applied 3 times per day for 4 days was apparently not toxic to eggs and seemed to be

nearly 100% effective in preventing fungus infections. Diquat at 25 ppm for 10 minutes did not appear to be toxic to channel catfish fry.

New Distribution Records for Fish Parasites. Fish and Wildlife Service and university researchers, in collaborative efforts, have identified several new fish pathogens in the United States. Proliferative kidney disease (possibly *Marteilia* sp. of rainbow trout) has been found for the first time in North America. It is agreed among the investigators that this entity is the same as that causing this disease in Great Britain and in Europe. Although it is possible that the disease was confused in the past with early stages of ova of *Sanguinicola* in the kidney and gills, we believe that the parasite that causes proliferative kidney disease is new to our continent.

A lesion-producing sessile stalked peritrichous ciliate has been observed by aquaculturists in the southeastern United States for many years. It is fairly common on the fins of channel catfish in water reuse systems and on the fins of green sunfish in Arkansas. It has been diagnosed on the fins and scales of bluegills as far away as South Carolina and California. A new species and genus of a ciliate, which now appears identical to our form, was described as *Heteropolaria colisarum* in West Germany in 1977. A similar parasite reported from goldfish epizootics in Japan was identified as *Epistylis longicorpora,* but needs to be compared with *H. colisarum.* If it, too, proves to be *H. colisarum,* the parasite has a nearly worldwide distribution.

Technique for Diagnosing the Ovarian Parasite in Golden Shiners. The culture of golden shiners for bait is a $70 million industry at the fish-farm level. Culture of these fish depends on the availability of good quality brood fish from which large numbers of eggs can be obtained. However, the ovarian parasite *Pleistophora ovariae* can significantly reduce the number of eggs obtained. The ovaries of some fish can be so severely damaged that the fish are sterile. Commercial fish farmers and State and Federal hatcherymen who culture golden shiners for bait or forage need a fast, reliable method to diagnose for the presence of the ovarian parasite in developing brood stock. This information can provide for the retention and sale of good brood fish, as well as prevent the spread of this parasite into wild populations, or to parasite-free farms and hatcheries. Previous methods of ovarian examination were of questionable value because it is difficult to isolate and distinguish the spores in the presence of large amounts of ovarian tissue. Of the several methods tested, the most promising diagnostic technique consisted of homogenizing 5 g of the ovarian tissue in 40 mL of water in a Pyrex No. 7727 tissue grinder, centrifuging the homogenate in a 50-mL centrifuge tube at about 1,500 *g,* and counting a diluted sample of the centrifuged pellet on an American Optical Bright Line Hemocytometer. Since the tissue is subdivided into particles smaller than the spores, the spores show up as round bodies in the bright field, and thus can be easily identified and counted.

New Findings about Endangered, Threatened, or Exotic Fishes. *khthyophonus hoferi* has been found in the brain and optic nerves of the endangered Gila topminnow by FWS cooperators. The organism seems to lack host specificity, occurring in many fish species, usually marine, but experimentally has shown host specificity. Subsequent to the *Ichthyophonus* epizootic, large peculiar whitish lesions appeared on the ventral surface and fins of humpback chubs but no evidence of *khthyophonus* could be found in the lesions. In the present situation we found it in the brain and optic nerve of the Gila topminnow, where the massive growth caused extreme exophthalmia resulting in blindness and finally starvation. The parasite has also been found in the brain of the Comanche Springs pupfish, and scattered in the viscera of razorback suckers. This ubiquitous parasite is a threat to the attempts to save the Gila topminnow and pupfish from extinction.

The findings of metacercariae of *Ornithodiplostomum ptychocheilus* in the brain of Comanche Springs pupfish is a new record.

Bothriocephalus opsarichthydis, the world-traveling Asian tapeworm (previously known as *B. gowkongensis* and *B. acheilognathi),* has moved on to New Mexico to the cultured Colorado squawfish. The infected squawfish were 13 to 16 inches long and did not appear to be greatly harmed by the tapeworms. It is possible that they acquire the larvae from copepods that forage fish have recently eaten. The Asian tapeworm is more dangerous for fry and small fingerlings that feed on infected copepods. Only surveillance is recommended for the time being.

A number of interesting parasites are being identified in the exotic fishes. These fishes make up the bulk of the aquarium fish trade, having a retail value of about $250 million. Many of these fishes are being cultured in the United States, but others are being made available from foreign sources. *Euclinostomum heterostomum,* closely related to the

American yellow grub, has become a serious pest of angelfish in Florida. Control measures such as those used for yellow grubs were recommended.

Pleistophora hyphessobryconis (Protozoa: Microspora), the muscle-destroying microsporan of ornamental tropical fishes, has been referred to us for verification. We also received a similar, but not identical, *Pleistophora* that attacks the visceral organs. Its exact identity is not known.

Warmwater Technical Services. Requests for technical and professional assistance increase as aquaculture gains in importance in the United States. Sales of dressed channel catfish are expected to increase 40 % over last year; total farm level sales would then exceed $250 million. Interest is growing in the production and sale of polyculture fishes such as buffaloes, common carp, and Chinese carps. With the increase in travel costs, sales of baitfish for sport fishing are increasing. A narrowed profit margin has brought about a reassessment of techniques and procedures, and closer attention to husbandry needs. Aquaculturists are looking to technical assistance personnel for aid and advice. During fiscal year 1981, Station personnel responded to 4,535 requests for extension assistance from citizens.

The Fish Farming Experimental Station Diagnostic Laboratory processed 61 referral cases of disease. These cases provide an overview of the problems confronting the aquaculturist in the United States and abroad. Among the cases reviewed, *Ichthyophonus hoferi* continued to be important, the latest problem involving unknown whitish lesions in humpback chubs. Others of interest include a second report of *Myxosoma scleropercae* in the eye of yellow perch of New York; a second report of a "milk scale" organism, *Myxosoma hudsonis,* under the scales of banded killifish in Maine; *Myxobolus kisutchi* from the brain of spring chinook salmon; unknown egg clusters on the skin of a gourami; *Dermocystidium* from between the fin rays of brown trout of Maine; a probable new species of intestinal monogenean from the marine butterfly fish; a huge new species of *Myxobolus* from the brain of the Central American knifefish; the metacercaria of *Ornithodiplostomum ptychocheilus* from the brain of the endangered Comanche Springs pupfish (a new host record); *Diphyllobothrium cordiceps* larvae from rainbow trout in Montana (a new geographical record); proliferative kidney disease in Idaho rainbow trout; *Bothriocephalus opsarichthydis* (Asian tapeworm) from Colorado squawfish of New Mexico; an unknown large ciliate attacking larval cui-ui in Nevada; and *Triaenophorus nodulosus* in fathead minnow fry in New York.

NATIONAL FISH HEALTH RESEARCH LABORATORY

Striped Bass Studies. Preliminary results of a study of bacterial contents of intestine, liver, and kidneys of adult striped bass from Long Island and the Hudson River indicated that the same types of bacteria were predominant in fish from both locations. Determinations are being made of seasonal variations in numbers and types of bacteria. Experiments are also being conducted on the effects of a metal mixture of lead, mercury, zinc, and cadmium (all common environmental contaminants) in predisposing striped bass to infection with bacteria that are known to infect these fish. Experiments completed to date indicate that the metals protect the fish, rather than predispose them to disease. Additional experiments are in progress to verify protection by the metal mixture.

Tissue Levels of Drug Used in Furunculosis Control. The experimental drug Ro5-0037 has been used for several years to control furunculosis in searun prespawning Atlantic salmon. Data are being accumulated that will enable the Food and Drug Administration to consider registration of the drug. In 1982 we compared absorption of Ro5-0037 in salmon administered the drug by intraperitoneal injection or by insertion into the intestine. (Insertion poses less threat to injury than injection.) At least 3 times more drug was present in the blood sera of the injected salmon. Injection thus should provide better control of furunculosis. Studies are under way to determine how long Ro5-0037 remains in muscle, skin, and scales after injection.

Injection of Salmon with Erythromycin May Prevent Vertical Transmission of Bacterial Kidney Disease. During fiscal year 1981 we found that eggs from adult female salmon that had been injected with erythromycin, to prevent prespawning mortality from bacterial kidney disease (BKD), retained erythromycin far longer than did eggs from noninjected females that had been water-hardened 1 hour in 2 ppm erythromycin. In 1982 we determined the minimum inhibitory concentration of erythromycin for cultures of *Renibacterium salmoninarum,* the cause of BKD. Tubes of BKD medium alone, or

containing 1.5, 0.75, 0.375, or 0.19 ppm erythromycin, were inoculated with cultures of *R. salmoninarum*. Samples were removed from each tube 3 hours, 24 hours, and 1 week after inoculation and placed in BKD medium containing no drug. The tubes of medium were incubated 3 weeks and examined for growth. None of the test concentrations had inhibited growth of ***R. salmoninarum*** in 3 hours or 24 hours after incubation, but all concentrations — including the lowest (0.19 ppm)— had inhibited growth after 1 week. The 0.19-ppm level was present well beyond 1 week after spawning, and provides evidence for efficacy of erythromycin in preventing vertical transmission of **BKD** when females are injected with erythromycin before spawning.

Furunculosis Vaccines. Because furunculosis, caused by the bacterium *Aeromonas salmonicida,* is a serious disease among cultured and feral populations of fishes, major research efforts were expended at the National Fish Health Research Laboratory to develop a method of controlling this disease. After a careful antigenic analysis of the bacterium was completed, a breakthrough was made toward practical, economical, and efficacious vaccination of fish against furunculosis. Fish were immunized by immersion for 60 seconds in cultures of living avirulent bacteria. Mortality in Atlantic salmon that were so vaccinated was only 12%, whereas that in salmon that were not vaccinated was 88%. Because vaccination depended on immersing fish in cultures of living bacteria, we also studied ways to chemically inactivate the bacteria and yet maintain antigenicity. Mortality of Atlantic salmon that were immunized by immersion in chloroform-inactivated vaccines was 7%, whereas that of unvaccinated salmon was 94%. The vaccine also immunized fish against natural field challenges, but further studies are needed to increase the duration of immunity. However, these are the first successful reports of immersion vaccination of fishes against furunculosis and the data provide a basis for the commercial development of a practical vaccine.

Goldfish Ulcer Disease. Atypical variants of *Aeromonas salmonicida* cause severe problems in certain coarse fishes by establishing external infections that create large and unsightly dermal lesions. We tested the virulence of the atypical strains of *A. salmonicida* that especially cause goldfish ulcer disease, to determine if they pose a potential threat to cultured salmonids. A spot inoculation of fish with the atypical *A. salmonicida* produced lesions and mortality in 25% of the experimental brook trout and Atlantic salmon, but did not affect rainbow trout. The results indicated that atypical variants of *A. salmonicida* may cause disease in salmonid fishes if the bacteria opportunistically invade damaged skin. Additional studies were conducted to investigate the immune response of goldfish exposed to these atypical variants of *A. salmonicida.* Essentially, we found that antibody-like substances are evoked in the mucus of fishes exposed to this disease. A vaccine was delivered orally to promote this antibody development and field-tested in local hatcheries. In these studies, mortality was 3% among orally vaccinated fish and 51% among fish that were not vaccinated. The vaccinated fish were not only protected against *A. salmonicida* but also showed a higher resistance to systemic infections caused by the related pathogen *A. hydrophila.*

Studies of the Immune Response in Trout. We are attempting to define the kinetics or the initiation and progression of immune response in rainbow trout by immersing fish in a vaccine preparation and then monitoring the cellular and humoral antibody response. Spleen cells are sampled 9 days after immersion to show which cells are producing antibody. The cells are demonstrated by a special technique, passive hemolytic plaque assay, developed in our laboratory. Then we demonstrate how the antibody builds up in the blood and levels off, lasting for more than 4 months. Using this model, we are experimenting with the effect of outside influences in altering this normal immune response. For instance, the injection of corticosteroids suppresses the immune response; in contrast, the injection of certain other agents can heighten the response. Low concentrations of phenol in water suppress the number of splenic antibody-producing cells, whereas certain adjuvants and variations of immunization regimens can heighten the immune response. In addition, the immune response to certain antigens such as the dinitrophenyl hapten can be boosted by attaching dinitrophenyl to a molecule that is a strong immunogen. Knowledge gained from these experiments is applicable to making field vaccination of fish more successful.

Growth of Infectious Pancreatic Virus in Suspension Culture. Suspension cultures of chinook salmon embryo cells (CHSE-214S) are being used to produce large quantities of infectious pancreatic necrosis virus (IPNV) at less cost and effort than in traditional monolayer cultures. Cultures are grown in siliconized flasks as large as 2 L, rather than in stirred suspension. This change in culture

methods appears to be responsible for increased susceptibility of cell line to virus and production of IPNV. The cultures require more virus to initiate infection and 1 or 2 days longer for maximum titer to develop.

Epithelioma Papillosum Cyprini Cell Line. A latent virus has been visualized by electron microscopy in the epithelioma papillosum cyprini (EPC) cell line. In sucrose gradients, the virus is typical of the cornaviridae in appearance and particle density. In EPC cultures incubated above 25°C, the viral effect is seen as the formation of giant cells. The virus appears to produce no cytopathic effect in other cell lines; however, no cell culture system is available for assay. The effects of this virus on the EPC cell line, when used in diagnostics, are unknown and efforts are continuing to define them.

American Shad Cell Line. Cells from the American shad (AMSH) are continuing well in culture. The cell line is susceptible to viral hemorrhagic septicemia virus and infectious hematopoietic necrosis virus, and to a lesser extent to infectious pancreatic necrosis virus. The AMSH cell line has a chromosome number of 48 and is passaged every 2-3 weeks at 1:4. It has been used to survey populations of shad but no evidence of virus has been found.

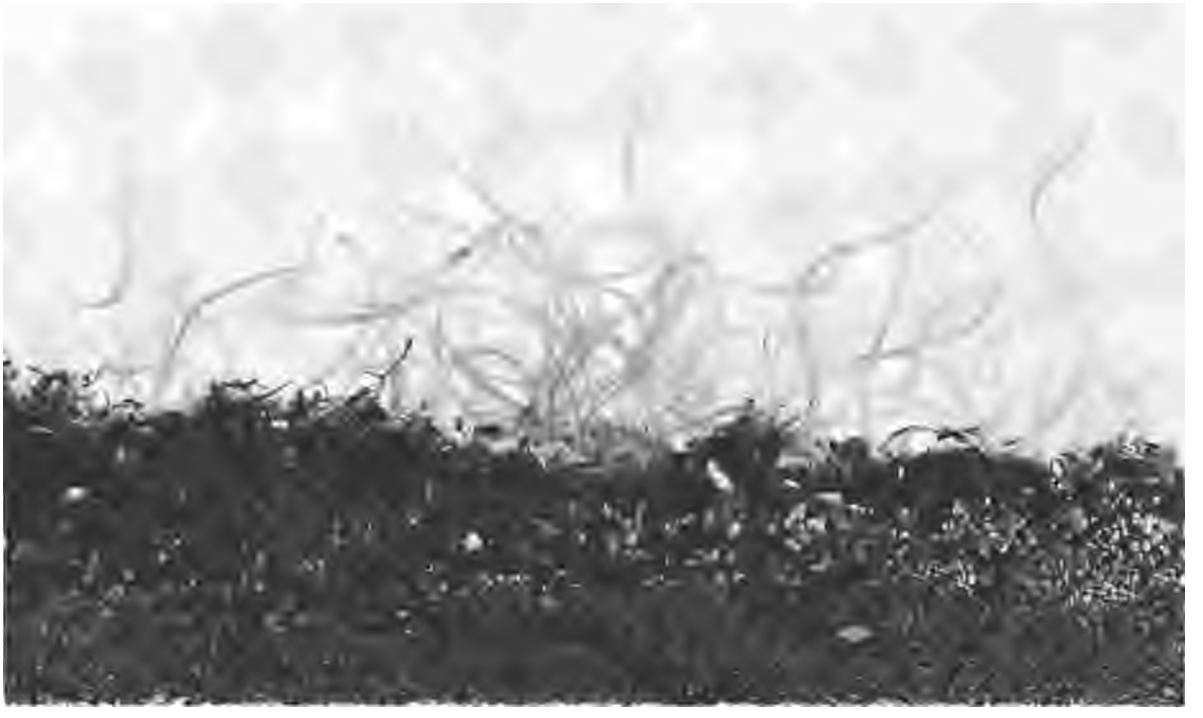
Enzyme Characterization of Cell Lines. We have completed a study to determine the profiles of the major enzymes found in seven fish cell lines. We characterized BB, BF-2, CAR, CHSE-214, EPC, FHM, and RTG-2 for 10 enzymes. A group of characteristics for each cell line allows their identification. Also, the profiles permit confirmation of species and tissue of origin for cell lines.

Golden Shiner Cell Line. When existing cell lines were evaluated for sensitivity to golden shiner virus (GSV), no line was found superior to the fathead minnow (FHM) cell line. A cell line has been developed from golden shiner as an alternative to FHM. The cell line (golden shiner fin [GSF]) is more susceptible than existing lines but not superior to the FHM. Sensitivity is increased when samples assayed are taken from diseased golden shiners rather than from virus grown in cell culture. The GSF cell line may provide more efficient detection of GSV than the FHM cell line now used.

Infectious Pancreatic Necrosis Immunization. Infectious pancreatic necrosis (IPN) is a serious viral disease that causes high mortality in young salmonid fish. Avoidance is the most effective method for disease control, but because of practical considerations, conditions required for effective avoidance, such as secure water supplies and virus-free fish, are infrequently met. Consequently, alternative methods must be developed. Inasmuch as immunization effectively controls certain human and animal diseases and some bacterial diseases of fish, we evaluated several candidate vaccines to determine if IPN can be controlled by immunization. These studies also defined host factors that influence susceptibility to infection and factors that influence the lethality or virulence of the virus. Brook trout were infected by placing them in water containing the virus. Critical elements of virus concentration and exposure time were determined so that the experimental infection or challenge would be standardized. Natural resistance to lethal infection increased with age; fish 16 to 20 weeks old were no longer susceptible. Nutrition seemed to influence susceptibility only during the first 80 days after hatching. Virulence of the IPN virus decreased when it was repeatedly grown in cell culture. Reduced-virulence and killed IPN virus preparations were used as candidate vaccines. The fish could be vaccinated by adding vaccine preparation to the water. The reduced-virulence preparation protected brook trout from lethal infection. Repeated vaccinations did not increase the level of protection.

Clues to Improved Brood Stock Management Obtained from Computer Models. Computer modeling allows insights into many biological processes in which experimental data are insufficient, not easily manipulated, or difficult to obtain. We used computer simulations to examine factors affecting genetic variability in cultured trout populations. Genetic diversity is important because it is the basis for biological change that is demanded by environmental change. However, little information (other than a few "rules of thumb"), has been available to assist the hatchery manager in maintaining genetic variability and stability in hatchery strains. From the computer models we are developing innovative and practical breeding techniques to improve hatchery strains. We have particularly emphasized that year-to-year variation in a population can be very large as a result of some common breeding practices. Consequently, year-to-year vf,riation in research results can be predicted if such populations are used in experiments.

Studies of Genetic Variability in Fish. Variation is present in all animal species in traits such as disease susceptibility and other important attributes for survival and growth. The basis for this variability is due to both genetic and environmental factors; consequently gross visual inspection usually fails to



Tubifex worms, common inhabitants of earthen ponds and raceways used in aquaculture, have been shown by researchers at the National Fish Health Research Laboratory to be necessary hosts in the life cycle of the protozoan *Myxosoma cerebralis,* the cause of salmonid whirling disease. *Photo by H. M. Stuckey.*

adequately describe the reasons and extent of these differences. Insights into genetic differences and reproductive relationships within and among fish strains have recently been clarified by examining enzymes with a simple genetic basis in a molecular sieve, i.e., by electrophoresis. We have electrophoretically described the rainbow trout strains currently reared at the Fish Genetics Station to gain insight into the reasons for important characteristic differences between strains and between year classes and lots within a strain.

We also are developing alternative techniques such as mitochondrial DNA and immunological differences to complement the data obtained by electrophoresis. We succeeded in cloning rainbow trout mitochondrial DNA into the bacterium *Escherichia coli.* The purpose of this effort is to enable rapid definition of genetic similarity of mitochondrial DNA in different strains and species. We also purified rainbow trout albumin by two techniques. Antibody to the albumin was obtained from rabbits. The reactivity of the albumin of fish in other strains to this antibody reagent provides us with another measurement of genetic relatedness to this reference rainbow trout strain from which the albumin was obtained. As differences between strains become better defined, the reasons for their differences in important attributes such as disease tolerance should be better understood.

Measurement of the Responses of White Blood Cells of Fish to Foreign Substances. The first line of defense against a disease largely involves the engulfment and destruction of the foreign cellular material by certain white blood cells (phagocytes). We purified, in the living state, several types of white blood cells to enable the measurements of their metabolic performance (an indication of the ability to resist disease). We found quantifiable differences in the response of individual fish to a variety of bacterial products, identified cellular products that influence the response level, and characterized response differences of different cell types in rainbow trout and goldfish. The differences seen in cellular response in different fish before exposure to disease suggests that the differences persist during a disease outbreak. If the outcome of disease exposure can be predicted (as we anticipate) the crea-

tion of disease-tolerant brood stocks would appear to be attainable.

***Tubifex* Worms Essential for Development of Whirling Disease.** Whirling disease is a chronic and serious infection notably of rainbow trout, but also of other salmonids. The condition commonly results in impaired swimming capability, and severe cases culminate in death. The causal organism, *Myxosoma cerebralis,* is a myxosporidan parasite that was first described in Europe in 1903, but which has since been accidentally introduced elsewhere, including the United States (in 1956). As with all myxosporidans, the life cycle has been an enigma; little has been known except that the spores must undergo an aging process of 3 to 4 months in the aquatic environment in order to generate infectivity. However, neither the biology of the process nor the size and shape of the infectious form have been identified.

A key answer to the puzzle of how infectivity is generated has been obtained, but that breakthrough capped a sequence of studies that began 8 years ago. First, methods were developed to release and concentrate spores of the parasite so that specific antiserum could be produced. The antiserum was then coupled to a fluorescent dye, providing a serological probe for detecting and identifying previously unrecognized forms of the parasite. Aging tests with spores in natural and inert aquatic environments showed that infectivity was not an endogenous process, but that an external factor was involved. Insight into the nature of such a factor was found when the infectivity of soils from hatcheries with whirling disease were found to be associated with aquatic annelid worms, which additionally showed serologic evidence of harboring *M. cerebralis* and, when fed to trout, produced whirling disease.

Definitive identification of the exogenous factor of aging and specific aquatic worm was obtained from tests with four genera of annelids that were planted in pasteurized trout hatchery soil to which *M. cerebralis* spores were added. After the required 4 months of aging, rainbow trout fry were added to assay for infectivity. Whirling disease occurred only in the presence of *Tubifex* worms, not in soil without worms or in soil that had been planted with aquatic worms of the genera *Aeleosoma, Dero,* or *Stylaria.* Trout feed on *Tubifex* worms, and we have shown that *Tubifex* worms ingest spores of *M. cerebralis.* Thus, a critical factor in the life cycle of the whirling disease organism has been revealed. Results probably have applicability to other problem myxosporidans, such as *Ceratomyxa shasta* of salmonids and *Henneguya exilis* of catfish.

Production and Distribution of Fish Biologics. Over 700 vials of antisera, antigens, and other reagants used for the detection and identification of fish diseases were produced and distributed to U.S. Fish and Wildlife Service fish pathologists and other qualified personnel. These biologics are especially important for rapid and accurate identification of disease agents. They are increasingly used for sophisticated immunological tests such as enzyme immunoabsorbant assay and immunofluorescent antibody techniques.

The Biologics Section maintains more than 30 rabbits for the production of antisera, and has become a well-recognized source for a supply of products that are difficult to produce.

NATIONAL FISHERY RESEARCH AND DEVELOPMENT LABORATORY

Acute Toxicity and Histopathology of Aluminum. For many years, aluminum had been considered a rather innocuous metal; however, recent studies have shown it to be toxic to aquatic life in some acid waters. When soils become acid, as may occur with acid precipitation, aluminum is mobilized and may leach into streams and lakes.

The information available on toxicity of aluminum to aquatic organisms is limited, but it has been established that if the pH of the water is 5.5 or lower, aluminum can be toxic to fish. This study was undertaken to evaluate acute toxicity and the histological effects of aluminum on brook trout.

Brook trout of 1 to 2 g were exposed to a range of aluminum sulfate concentrations giving active aluminum ion levels of 0.1 to 16.0 mg/L in waters of pH 5.6, to determine the 96-hour LC50's. Because of the protective effect hard water often has on the toxicity of metals to aquatic animals, we included three categories of water hardness in the study. In tests of median survival time, brook trout showed no gross signs of stress and none died in water at pH 5.6 without aluminum. The 96-hour LC50 of aluminum increased progressively (i.e., it became less toxic) with water hardness: 0.37, 3.40, and 6.53 ppm at 2, 18, and 40 ppm hardness.

Fish dying during the test period and three surviving fish from each treatment at the end of the

test period were examined for histopathology. Observed changes in all fish were edema in gills and muscles; cellular swelling; and vacuolation and necrosis in gills, skin, lateral line canal, liver, and kidney. Survivors kept in well water without aluminum recovered within 3 months, as judged by periodic histological examinations.

Although the specific mode of action of aluminum toxicity was not investigated, the data and observations were compatible with a general breakdown in osmoregulation and oxygen transport.

Atlantic Salmon Diets. Growth and survival were compared for first-feeding fry of Atlantic salmon fed a closed-formula commercial preparation, BioDiet, or FWS high nutrient density diets 398 or 406, for 14 weeks. Growth of fry fed BioDiet for 2, 3, 4, or 6 weeks from first feeding and then diet 406 for the rest of the 14-week study was also examined. Growth was fastest in fish fed diet 398 or 406 exclusively for 14 weeks, or BioDiet for 2 weeks followed by diet 406 for 12 weeks; survival was about 68, 82, and 92%, respectively, for the three groups. Thus the feeding of BioDiet for the first 2 weeks of feeding and then changing to diet 406 provided both rapid growth and the highest survival of Atlantic salmon fry.

A study of the growth, survival, and fin condition of Atlantic salmon fed one of seven diets indicated a dietary effect on fish quality. Test diets being fed included BioDiet and Silver Cup commercial diets and open-formula Abernathy salmon and GR trout diets, and an experimental high protein-energy diet (406). At the end of the first 9-month phase, fish fed either the semi-moist commercial BioDiet or the FWS open-formula diet 406 were significantly larger than fish fed other diets.

Oxygen Consumption of Fishes. Resting metabolism was measured for non-feeding Atlantic salmon held in a closed respirometer at 5°C. The hourly oxygen consumption rate ranged from 44.8 to 70.9 mg/kg for salmon weighing 13 to 90 g. The energy requirement for maintenance metabolism for salmon at this temperature was estimated to be about 0.2% of body weight per day.

Invertebrate Culture. The use of live feeds has expanded beyond the traditional use of brine shrimp and daphnids as initial feeds for fry of walleyes, striped bass, shad, and other delicate fishes. Rotifers *(Branchionus rubens)* have been successfully cultured in outdoor ponds, and progress is being made in the intensive rearing of rotifers in cultured algal solutions. Cyclopoid copepods have been isolated and are being intensively cultured on a trial basis. The food base for all of the intensive invertebrate culture systems under study consists of cultured algae grown in 100-L solar tubes with inorganic fertilizer.

Food Choice. Observations on the movement of walleyes 47-74 days old in a Y-shaped chamber when various visual and odor-producing stimuli were added to one of the wings indicated that this species is clearly attracted to certain types of odor and movement. In visual tests in which no odor cues were present, walleyes were most strongly attracted to brine shrimp, least attracted to non-moving food items, and moderately attracted to daphnids. Water containing odors from slurries and washings of brine shrimp were preferred over water containing similar preparations of daphnids. Of all items tested, brine shrimp—although not found in the walleye's environment—appear to be the food of choice for young walleyes. In other tests we observed that walleyes were strongly attracted to odors from slurries of whole walleyes but were indifferent to odors from slurries of commercial fish pellets. Results from such studies should provide information that will be useful in the development of formulated feeds that attract and stimulate young fish to feed.

SOUTHEASTERN FISH CULTURAL LABORATORY

Seasonal Changes in Body Composition of Channel Catfish. An increasing number of channel catfish producers are using grading seines to selectively harvest the larger fish from ponds periodically throughout the year. Frequently smaller fish are stocked back into the pond before all of the larger fish have been removed. This study was designed to determine the seasonal changes in the body composition, and thus changes in the quality, of channel catfish harvested at different times of the year.

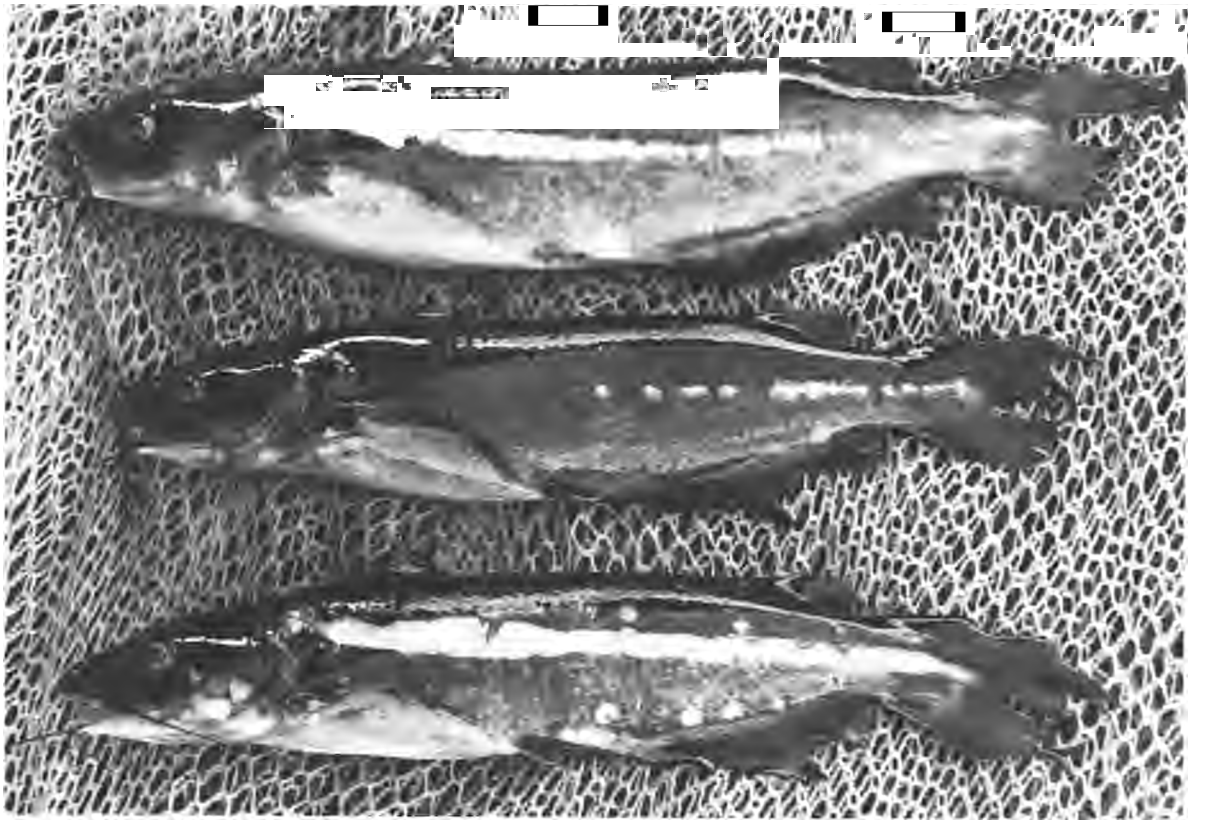
In January 1980, eight 0.02-ha ponds were stocked with channel catfish at a density of 50,000 fish per hectare. Fish stocked in each pond ranged from about **10-15** cm to 20-30 cm in standard length at stocking. Fish in all ponds were fed an estimated 3% of body weight per day during the prime growing season, and less during winter. All ponds were equipped with continuously operated aerators to prevent stratification and to provide supplemental oxygen.

A grading seine with a mesh size designed to remove fish weighing 350 g or more was used eight times during the year to selectively harvest fish from all ponds. Small fish (10-15 cm long) were returned to the ponds on a one-to-one basis to replace fish removed by the grading seine; the number of fish in each pond thus remained nearly constant throughout the year.

The average size of fish selectively harvested increased from 304 to 824 g during the 12-month study. Dress-out weight was highest in September (59% for both sexes) and lowest in November (52% for males and 50 % for females). This seasonal difference of 7 to 9 percentage points in dress-out weight, which was not solely a function of gonadal state but apparently an accumulation of smaller differences related to other body changes, translates into a considerable difference in the price of fish to the retailer and consumer. Seasonal changes in the water and lipid content of muscle may also produce changes in texture and flavor of processed fish.

Field Testing of Pond Aeration Equipment. Hatchery and production ponds often become stratified, and inadequate levels of dissolved oxygen may limit growth and survival of fish. During the past few years we have been investigating methods of destratifying ponds to provide a uniform mixture

Fountain and spray-type floating agitators are used to provide emergency aeration in warmwater fish ponds. The device mounted above the water at left is a demand feeder, which delivers food when the rod extending from the can to the water is moved by the fish. *Photo by M. A. Suttle.*



These striped channel catfish, which lack a layer of pigmented cells in the whitish areas of the skin and have irregularly shaped fins, have been crossed with normally pigmented fish to determine if these characteristics are a result of genetic mutation. If the characteristics are inheritable, they may be useful as a genetic marker in future studies of channel catfish. *Photo by N. C. Parker.*

Channel catfish are weighed in a lift net as they are removed from a pond that was used by researchers to investigate the effects of aeration devices on fish production. *Photos by M. A. Suttle.*

of oxygen throughout the pond. Airlift pumps effectively destratified our small ponds. In addition, the pumps were easy to assemble and install, and economical to operate.

We increased the capacity of our airlift pump system and installed the pond aeration equipment at Edenton National Fish Hatchery, Natchitoches National Fish Hatchery, and San Marcos National Fish Hatchery and Development Center. Ponds equipped with the airlift pumps and the replicate control ponds at these hatcheries ranged from 0.04 to 0.32 ha. An additional system was installed in a 2-ha pond at the Southeastern Fish Cultural Laboratory.

The aeration systems consisted of continuously operated airlift pumps, 7.6 cm in diameter, which each moved 132 L of water per minute. The systems were designed to operate 25 airlift pumps per hectare. Regenerative blowers were used to supply the air and each airlift required 85 L of air per minute. Daily operational cost for the regenerative blower and airlift pump system was about $2.50/ha, based on cost of electrity of $0.05 per kilowatt hour when regenerative blowers were used at the rate of 2.5 horsepower per hectare.

Benefits of pond aeration included increased dissolved oxygen in the ponds and the elimination of pond stratification. More fish were produced and survival of fish was higher in the aerated than in the unaerated ponds. Hatchery managers reported fewer or no incidences of disease in aerated ponds stocked with largemouth bass and striped bass.

Detection and Quantitation of Steroids in Blue Tilapia. Steroid hormones have been used in aquaculture for enhancing fish growth and as sex-reversal agents for producing mono-sex fish populations. Treating sexually undifferentiated blue tilapia with methyltestosterone has consistently produced mono-sex populations of this potential food fish. However, the action of the hormone within the fish and the residual tissue levels over time are unknown. Such information is essential if these sex-reversed fish are to be used for human consumption. Studies were begun to develop reliable methods of estimating levels of methyltestosterone and testosterone in tissues of blue tilapia, and to determine the residual tissue levels of these compounds. Optimum detection conditions were developed by using high pressure liquid chromatography. The lowest limit of testosterone and methyltestosterone that could be resolved and separated by high pressure liquid chromatography was 5 ng per compound. Extraction procedures have been developed that optimize recovery and quantitation of these steroids from spiked samples of tilapia muscle. The metabolic fate of radioactively labeled testosterone (^{3}H-testosterone) fed to tilapia in the diet indicated that, 1 hour after feeding, ^{3}H-testosterone levels were higher in the liver and kidney than in other tissues. Radioactivity peaked 3 hours post-ingestion in the proximal intestine and 6 hours post-ingestion in the distal intestine. The gallbladder contained the highest radioactivity of all tissues measured 12 hours post-ingestion. This pattern of isotope incorporation suggests excretion by way of the liver and bile, as has been previously shown for salmonids and carp. These techniques should enable us to quantitate residual levels of methyltestosterone in the tissues of blue tilapia.

Content of RNA and DNA in Fish Muscle Tissue. Growth in fish and invertebrates can be defined as protein synthesis of new cells and tissues within a specified time. Biochemically, the amount of ribonucleic acids (RNA) present in the cells and tissues reflects these rates of protein synthesis. Since the deoxribonucleic acid (DNA) content is nearly constant within cells, the RNA/DNA ratio has been proposed as an index of growth in fish and invertebrates. Unfortunately, few investigators have reported recovery rates of known amounts of RNA and DNA standards from spiked tissues when a particular extraction procedure was used. Consequently, we evaluated several modifications of the Schmidt-Thannhauser method (developed in 1945) for their precision and accuracy in separating and extracting nucleic acids from muscle tissue of striped bass. Orcinol-indole sugar reactions and UV absorption spectrophometry were used in conjunction with the extraction methods to determine RNA and DNA content. In the procedure deemed best, we used sample volumes of 6 mL, with a final concentration of 0.2 N perchloric acid, and 0.3 N NaOH as the alkali. After the hot-acid extraction of DNA, the determination of nucleic acids was made by UV absorption. Recovery of DNA was improved by the addition of nucleic acid-free bovine serum albumin to the muscle and spiked tissue samples. Hot-acid extraction and UV absorption yielded highly reproducible estimates for DNA, and recoveries ranging from 72 to 100%. Recovery of RNA determined by UV absorption provided reproducible estimates, but recovery rates were 13% or less. Additional work will be required to improve the RNA recovery rate if it is to be of value as an indicator of fish growth.

Chemical Induction of Zooplankton Growth and Reproduction. In previous research we identified a 4-week period, 2 weeks before and 2 weeks after stocking fish, as an especially critical time during which the culturist must establish and maintain crustacean zooplankton populations in striped bass rearing ponds. Fish culturists fertilize the ponds to provide nutrients for the phytoplankton and food for the zooplankton. The zooplankters must be produced at a rate greater than the rate of removal by predation of larval fish. With the goal of increasing the growth and reproductive rates of zooplankters, we studied the cladoceran *Daphnia pulex* when exposed to several concentrations of the steroid estradiol 17-β. Young daphnids (neonates) were exposed to low concentrations of ethanol (controls) and estradiol 17-β dissolved in an ethanol carrier. Daphnids were examined daily for growth, numbers of viable and nonviable eggs, abortions, and numbers of young produced. Test solutions were renewed and daphnids were fed daily about 10 cells of the green alga *Chlamydomonas reinhardi.* All daphnids that were fed algae and exposed to estradiol were larger after 21 days and produced more eggs than did the controls fed the same algae. Furthermore, the control organisms exposed to ethanol produced more young than did organisms not exposed to ethanol. Application of these findings may improve the control and manipulation of zooplankton reproduction and growth enhancement by biochemical means.

Zooplankton Production in Fertilized Striped Bass Rearing Ponds. Previous research at this Laboratory indicated that striped bass rearing ponds fertilized with combinations of liquid inorganic and organic fertilizers and inoculated with crustacean zooplankton produced more striped bass per hectare than did ponds fertilized with only organic fertilizers. In a cooperative research project with the Marion Hatchery of the Alabama Department of Conservation and Natural Resources, we evaluated combinations of liquid inorganic fertilizers, organic fertilizers, and zooplankton inoculation during a 4-week period. Ten 0.04-ha ponds were fertilized with liquid inorganic fertilizer, inoculated with a mixed population of cladocerans and copepods, and fertilized with either cottonseed meal (five ponds) or chicken manure-chicken litter (five ponds). All ponds were stocked with 7-day-old striped bass fry. Fish survival and production averaged 63% and 50 kg fish/ha in ponds fertilized with cottonseed meal, and 46% and 26 kg fish/ha in ponds fertilized with chicken manure-chicken litter. Zooplankton samples indicated that ponds fertilized with cottonseed meal produced significantly more crustaceans (cladocerans and copepods) than did ponds fertilized with chicken wastes. However, weekly zooplankton analyses indicated that levels of both organic fertilizers were insufficient to maintain enough food to support crustacean reproduction over the 28-day period. These results and our previous work indicate that management effort should be shifted toward maximizing crustacean zooplankton foods during the period 2 weeks before and 2 weeks after the fish are stocked.

TUNISON LABORATORY OF FISH NUTRITION

Nutritional Cataracts in Hatchery Fish. From time to time a problem in fish hatcheries has been the development of cataracts in large numbers of young fishes. The problem has economic significance, in that fish with impaired vision do not feed as efficiently as normally sighted fish, and consequently do not grow as rapidly. Therefore, the various causes of cataracts in fish have warranted investigation. Cataracts develop predictably in fish on diets deficient in methionine, tryptophan, or riboflavin, or on diets high in mineral content. In view of this relation to diet, fish could be used as a model for the study of the mechanism of cataract formation in general.

It has been found that cataracts can be prevented in various salmonid fishes by adding zinc to practical diets that contain high levels of minerals. The content of calcium in such diets is usually about 3% of the diet.

To assess a possible interaction of calcium and zinc relative to cataract formation, we studied rainbow trout (initial weight about 1.5 g) that were fed semipurified diets (casein-gelatin) with various levels of calcium. Each diet contained 0.1, 0.5, 1.0, 2.0, or 3.0% calcium supplied by steamed bone meal. The zinc levels in all five diets were in the range of 15-30 ppm, which is within the normal limits established for rainbow trout. After 22 weeks more than half of the trout on each of the five diets had developed opacities of the lens. Most opacities were in the anterior cortical region just beneath the lens capsule. There was slight to severe involvement of the deeper anterior cortex of the lens. Since fish on low, medium, and high levels of calcium in the diets

developed cataracts, the suggestion is that there may not be a simple direct interaction between zinc and calcium in the diet. Other considerations include possible interactions of zinc and other minerals besides calcium; possible effects of very low calcium diets, irrespective of the zinc levels; and the possibility that the effects of the minerals in the diets are modulated by some factor or factors in semipurified diets not present in practical diets.

Future studies in trout may answer these questions and contribute to our knowledge of how diet affects the development of cataracts. This one study with different concentrations of calcium and zinc did not resolve the original question about how calcium and zinc interact (if at all) relative to cataract development in rainbow trout.

Branch-chain Amino Acid Requirements of Fish. Since the costs for protein (35-55% of the diet) can represent 40% or more of the cost of fish production, the reduction of those costs could result in substantial savings. Efforts to replace the relatively expensive fish meal protein in salmonid diets with other less costly protein sources of either animal or plant origin have not been altogether successful, primarily due to a paucity of knowledge of amino acid requirements and interactions. We are attempting to fill a portion of this void for salmonids.

We conducted a series of studies to determine the dietary requirements of lake trout for leucine, isoleucine, and valine. Growth studies showed the requirement for leucine was 2.74-3.66% of dietary protein; isoleucine, 1.54-2.06%; and valine, 1.77-2.23%. Feeding lake trout a diet low in leucine, isoleucine, or valine impaired growth and feed conversion efficiency. The protein content of the carcass was also lower in fish fed the low isoleucine diet than in control fish, indicating that isoleucine might be limiting for protein synthesis.

Feeding excess leucine caused a reduction in growth and feed conversion efficiency but had no effect on free amino acids in plasma or muscle. Excess dietary isoleucine did not depress fish growth or feed utilization unless the diet was supplemented with leucine. Addition of supplemental valine relieved the depression in both instances. Growth and feed utilization efficiency were also reduced in fish fed excess valine, but this reduction could not be overcome by added leucine or isoleucine. Tissue composition analyses showed a diminution in energy stores of fish whose growth was impaired, although protein levels were relatively unaffected. The studies indicated that dietary excesses of leucine or isoleucine are antagonistic toward valine and cause an increase in the valine requirement. The inability of leucine and isoleucine to remove the effects of excess dietary valine is interpreted as an amino acid toxicity rather than as an antagonism caused by excesses of leucine and isoleucine.

Effects of Phosphorus in Hatchery Feeds on Water Pollution. A report on a study in Michigan indicated that the discharge of phosphorus (originating from fish feed) from a salmonid hatchery into a small lake significantly hastened the eutrophication process. Therefore we conducted an experiment with rainbow trout to try to reduce the level and forms of dietary phosphorus not well retained by trout. Two commercially prepared diets tested were the salmon diet used in Michigan and a Swedish diet (Ewos T40) purported to reduce waste. Two new experimental diets were formulated by computer to contain no excess or unavailable forms of phosphorus. They were identical except that one contained dicalcium phosphate (Dical) and the other deflorinated rock phosphate (CDP). The CDP supposedly is highly digestible but dissolves only slightly in water — a possibly beneficial property in reducing water pollution.

After the diets were fed for 12 weeks, growth and survival were best in trout fed the Swedish diet. The Michigan salmon diet supported good growth, at a rate of 73% of that for the Swedish diet. The Dical and CDP diets supported growth equal to 86 and 93% of that supported by the salmon diet. Chemical analyses of phosphorus in feeds, carcasses, and sludge (feces and solid wastes) showed significant differences in the fate of phosphorus among diets, although about 0.45% phosphorus remained in all carcasses, regardless of diet. The percentages of dietary phosphorus remaining in the sludge were 30, 23, 13, and 33 for the salmon, Swedish, Dical, and CDP diets, respectively. Thus it appears that more phosphorus from the less-soluble CDP diet was retained in the sludge, thereby reducing the pollution of the effluent water.

Effluent data showed that 1,000 pounds of the salmon diet would leave 12.4 pounds of phosphorus in the effluent water, whereas the Swedish, Dical, and CDP diets would leave only 6.4, 5.4, and 4.5 pounds, respectively. Thus pollution by diet was reduced by 64% when the CDP diet, rather than the salmon diet, was fed.

Because the salmon diet was far less costly than the others, still another experiment was conducted. It showed that CDP (and another product with similar potential to reduce pollution) could successfully be included in a new economical diet that supports

good growth; however, the pollution benefits remain to be determined.

NATIONAL RESERVOIR RESEARCH PROGRAM

The National Reservoir Research Program (NRRP) continued intensive efforts to describe and quantify the environmental factors that determine sport fish production in 1,600 large reservoirs (over 500 acres in area), which now provide about 30% of all freshwater fishing in the United States. The synthesis of data produced by its several field research units and by other State and Federal fishery agencies yielded an integrated body of information on which to base improved management techniques and measures designed to protect or enhance fishery resources.

During fiscal year 1982, a staff of 36 professional and support personnel addressed problems ranging from heated water effluents in reservoirs to minimum flow requirements in tailwaters below dams. The studies have yielded answers to immediate management problems, as well as broad findings concerning reservoir ecology. The findings have been communicated to managers and other users by the publication of technical papers; by illustrated talks at workshops, seminars, and regional and national meetings; by correspondence and telephone; by personal visits; and by field demonstrations of equipment and techniques.

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

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

In 1974, NRRP and the Environmental Effects Laboratory, U.S. Army Engineers, Waterways Experiment Station, began a cooperative study on the effects of varying the outlet depth of the dam on the ecology of DeGray Lake and its tailwater. Coordinated field studies are under way to test and provide verification for elaborate ecological simulation models currently being developed by the Environmental Effects Laboratory. Research for 4 years during which water was released from the epilimnion has been completed, and 4 years of study during which water is released from the hypolimnion will be completed in 1983.

In a broad approach to reservoir operation as related to aquatic resources, NRRP and the Waterways Experiment Station entered into a 6-year coordinated research effort designed to locate and define conditions that optimize both coldwater and warmwater tailwater fisheries, the limits within which they can operate, and the immediate and long-term biological effects of various operational procedures. The program includes a synthesis of existing published and unpublished information on biological relations in tailwaters and field studies on nine tailwaters that represent widely used operational modes. Studies incorporate operational modification of reservoirs on an experimental basis. They include such objectives as determining criteria for establishing optimal minimum release, downstream effects of different depths of release of water from the reservoir, and effects of different hydropower operational modes on the tailwater biota. The effects of various operational modes on reservoir fisheries are also being evaluated.

Modeling Reservoir Ecosystems. Continued development of NRRP's trophic model has produced a new version that requires input of biomass data according to species and size classes of fish collected in August as opposed to four seasonal samples. The simplification was made possible by regressing the mean biomass of different functional groups of fish collected four times a year on their biomass in August. Consequently, we now can provide predictions for fishery managers who sample only in August. The new version of the model also includes revised food conversion efficiencies for young-of-the-year and older fish, resulting in more realistic estimates of food consumption.

Using an equation derived in a cooperative study

with Oak Ridge National Laboratory, we can now predict annual primary production from our estimates of fish production. Estimates of primary production enable classification of a reservoir as oligotrophic, mesotrophic, or eutrophic. Predictions of trophic state usually agree with the classification given in the National Eutrophication Survey, U.S. Environmental Protection Agency. Other predictions include mean monthly biomass of benthos and zooplankton and the total biomass of prey fish required annually by piscivores.

In another study, regression of fish standing crop and harvest data on data such as Secchi disc transparency, chlorophyll *a*, total phosphorus, total nitrogen, alkalinity, and 12 other physicochemical variables from 115 reservoirs has provided over 50 new regression models for predicting standing crop or harvest of fish in reservoirs. For example, the best single variable for predicting the total standing crop of fish was total phosphorus, which explained about 41% of the variation in crop among reservoirs. Roughly 52% of the variation was explained by a three-variable equation that included total phosphorus, total nitrogen, and chlorophyll *a*. In hydropower storage reservoirs, total phosphorus and alkalinity explained 61% of the variation in total crop.

The best single variable for predicting total harvest was chlorophyll *a*, but for 106 reservoirs this variable explained only about 17% of the total variation. For hydropower storage reservoirs, chlorophyll *a* explained up to 40% of the total variation and a three-variable model that included transparency, chlorophyll *a*, and mean depth explained 50% of the variation in total harvest.

Water-level Studies. Published literature on the effects of water-level fluctuations in reservoir ecosystems has been synthesized in a report that provides a literature review and conceptual model of operations to enhance reservoir fisheries. This report describes how changes in water levels can indirectly influence fish production and fisheries by altering both the physical environment (basin shape, bottom substrates, and habitat) and the chemical environment (nutrients and dissolved oxygen). It also describes the complex ways that water-level changes affect aquatic plants, zooplankton, benthos, and fish.

An intensive analysis of data on the effects of water-level changes on fish standing crops is under way. Data collected over a 75-year period on monthly changes in surface elevation, area, volume, inflow, and outflow have been collated for 11 reservoirs in Iowa, Kansas, Arkansas, Kentucky, Mississippi, Virginia, North Carolina, and Georgia. These data have been matched, by reservoir and year, with fish standing crop data furnished by State fishery agencies. Preliminary multiple regression analyses have begun to reveal the effects of magnitude, seasonality, duration, and rates of water-level changes on different species and sizes of fish. Such information should prove valuable in the development of water-level management plans.

Classifying **Reservoir Habitats on the Basis of Sport Fish Harvest.** In recent years, the Fish and Wildlife Service has devoted considerable attention to classifying terrestrial and aquatic habitats as an aid in assessing changes in fish and wildlife resources associated with changes in land and water use. In conjunction with this effort, NRRP developed multiple-regression equations relating environmental features and harvest of important coolwater and coldwater sport fishes in reservoirs. The equations are based on field data obtained mostly by State fishery agencies from 119 coolwater and 96 coldwater reservoirs, and have application to many reservoirs throughout much of the northern and western United States. Indexes of habitat suitability have also been developed to help biologists compare observed or predicted harvest with that from other reservoirs. The harvest of important sport fishes such as walleyes, yellow perch, northern pike, rainbow trout, brown trout, and coho salmon can be predicted from the equations.

EAST CENTRAL RESERVOIR INVESTIGATIONS

East Central Reservoir Investigations conducts studies to determine the influence of reservoir releases on water quality, invertebrates, and fish in tailwaters. Cooperative studies between the Environmental Laboratory of the U.S. Army Corps of Engineers Waterways Experiment Station and the Fish and Wildlife Service provide information on the effects of releases from flood-control and hydropower reservoirs on tailwater biota. The purpose is to develop and evaluate environmental criteria and operational methods that maintain desirable downstream aquatic habitat and associated biota. Base-line data for assessing the effects of reservoir releases on tailwater biota are provided by studies conducted on multi-level release flood con-

trol projects (Barren River Lake and Green River Lake, Kentucky; Gillham Lake, Arkansas; and Pine Creek Lake, Oklahoma) and hydropower reservoirs (Beaver Lake, DeGray Lake, and Lake Greeson, Arkansas; and Lake Hartwell, South Carolina).

Effects of Reservoir Releases on Water Quality of Tailwaters. Water quality studies have been conducted below flood control and hydropower reservoirs in southwest Arkansas and southeast Oklahoma to assess the effects of different releases on water quality of tailwaters and the associated biological community. Water quality in tailwaters of Pine Creek Lake, Oklahoma, and Gillham Lake, Arkansas (both flood-control reservoirs), were not affected by reservoir water release during unstratified periods. During summer stratification, however, the water quality in the tailwaters depended largely on the amount of water released and the release depth within the reservoirs. In Gillham Lake, where water releases during stratification were near the surface and above an anoxic hypolimnion, low flow releases from the reservoir had no adverse effects on the water quality in the tailwater. In Pine Lake, where the water-release depth during stratification was within an anoxic hypolimnion, aeration and the precipitation of various chemicals occurred immediately downstream from the reservoir during low flow releases (1.5 mVsecond). During increased reservoir releases (14 mVsecond), however, large amounts of anoxic water were carried farther downstream, increasing the distance downstream in which the tailwater biota would be stressed by elevated amounts of certain chemicals.

In the tailwater immediately below Lake Greeson, Arkansas, hydropower released produced considerable variation in water temperatures and total organic and inorganic matter. Benthic invertebrate communities immediately below the dam were stressed by hypolimnetic water released during power generation. Detrimental effects from altered temperature and variable release patterns had decreased 16 km downstream, where invertebrate communities were representative of less stressed environments.

Effects of Releases from a Flood-control Reservoir on Zooplankton and Macroinvertebrates in the Tailwater. Zooplankton abundance and distribution in tailwaters are largely functions of reservoir release patterns (outlet depth and release volume) and the composition and distribution of organisms in the reservoir. Studies of zooplankton abundance in the Barren River Lake tailwater have provided information on zooplankton population dynamics in tailwaters. Zooplankton in the tailwater of Barren River Lake varied seasonally, concurrently with changes in abundance in the reservoir, but densities in the tailwater were reduced. Plankton densities were highest near the dam and were progressively reduced downstream. Decreases in densities downstream were attributed to fish predation, physical destruction, and lack of suitable habitat. During summer when the reservoir was stratified, water released from low levels of the reservoir contained larger numbers of zooplankters than were observed in the reservoir hypolimnion, suggesting that water and associated organisms were drawn from a wide section of the water column. When the reservoir was unstratified, densities of zooplankton were lower in the tailwater than in the reservoir at the level of release, which indicated that zooplankton was concentrated above the level of discharge.

Macroinvertebrates in tailwaters of flood-control reservoirs are affected by the magnitude and variation of discharge. Altered temperatures and water quality, a function of the level of withdrawal, also influence the structure of the tailwater community. Discharges from Barren River Lake were categorized into three flow types: low-stable, high-stable, and fluctuating. Highest densities of tailwater macroinvertebrates were associated with low-stable flows (2.1 mVsecond for at least 20 days). Low densities of macroinvertebrates were associated with high-stable flows (flows greater than 80 mVsecond for more than 20 days), which resulted from heavy rains in the watershed and scheduled reservoir drawdown. Macroinvertebrate densities associated with fluctuating flows were more variable than those obtained during stable releases. Few macroinvertebrates were tolerant of all flow regimens and associated water-quality changes. Only tolerant forms were found in the immediate tailwater of Barren River Lake, where cool, deep releases and altered flows created stressful living conditions. The composition of macroinvertebrate collections 22 km downstream suggested that the stress had diminished but that recovery was still incomplete (on the basis of a comparison with conditions in the natural stream above the reservoir).

Fish Sampling in Tailwaters. Accurate sampling of fish standing crops in tailwaters is necessary to assess the effects of reservoir releases. The objective of this study was to develop techniques for quantitative sampling of tailwater fish populations. Two mark and recapture procedures were used to estimate fish standing crops; in the first we used only electrofishing to collect fish, and in the second

we used both electrofishing and application of rotenone.

The electrofishing mark and recapture method was unsuccessful because too few marked fish were recaptured to yield sound population estimates. The electrofishing plus rotenone method was more successful, but was influenced by handling mortality of small fish. Population estimates were therefore made only for fish longer than 100 mm, and thus were conservative measures of the tailwater fish standing crops. Standing crop estimates for fish populations were 361 kg/ha for Green River Lake tailwater and 759 kg/ha for Barren River Lake tailwater.

The electrofishing and rotenone procedure allowed comparison of the capture efficiencies of the sample methods. Capture efficiency for eight species ranged from 5 to 54% for electrofishing, and from 36 to 100% for rotenone.

Effects of Reservoir Releases on Tailwater Fish Abundance. Fish abundance in the tailwater of Barren River Lake, Kentucky, was compared with that in an unregulated tributary. The purpose was to determine the influence of reservoir releases on fish occurrence in the tailwater. Abundance was 2.5 times greater in the tailwater and was dominated by species common in the reservoir (gizzard shad, bluegills, and white crappies).

Reservoir stratification appeared to influence the number of fish in the tailwater. Using electroshockers, biologists caught 334 fish per hour when the reservoir was unstratified (October-May) and 108 fish per hour when it was stratified (June-September). Comparative catch rates in the tributary stream indicated little difference between the October-May and June-September periods (100 versus 75 fish per hour).

The greater abundance of fish in the tailwater during fall and winter was seemingly the result of fish leaving the reservoir during fall drawdown (75% of reservoir volume discharged) and winter flood releases. Movement of fish to the lower end of the reservoir, where they could be influenced by water currents near the discharge gates, is likely during fall and winter, when reservoir volume is reduced and temperature and dissolved oxygen concentrations are uniform. During summer the reservoir is stratified, and low dissolved oxygen concentrations at the level of water release and the relatively large volume of the reservoir reduce the likelihood of fish passage into the tailwater. A large fall and winter fishery for white crappies has developed in the tailwater and is apparently dependent on fish originating in the reservoir. We found no evidence of upstream movement of riverine fishes into the tailwater during fall and winter.

Influence of Reservoir on Tailwater Fish Populations. The influence of Green River Lake on the tailwater fish community was examined by comparing post-impoundment tailwater samples with pre-impoundment and headwater samples. Abundance of common reservoir species (white crappies and gizzard shad) after impoundment increased in the tailwater and was positively correlated with reservoir discharge. Riverine species (redhorses, minnows, and catfishes) declined after impoundment, apparently because water temperatures in the tailwater decreased. Our studies suggested that caution must be used in comparing headwater and tailwater samples. The headwater fish community may only partly represent pre-impoundment conditions because some species, particularly common carp and gizzard shad, migrate upstream out of the reservoir.

MULTI-OUTLET RESERVOIR STUDIES

Control of the depth at which water is released from a reservoir is a primary means of controlling water quality in reservoirs. Unfortunately, many biological effects of altering reservoir release depths remain poorly understood. Multi-outlet Reservoir Studies was established to evaluate the effects of changing outlet depth on reservoir fisheries and related aquatic resources. Field studies being conducted at DeGray Lake, Arkansas, include monitoring of trends in fish and invertebrate crops and production during 4 years in which water was released from the epilimnion (1975-78), followed by 4 years of release from the hypolimnion (1979-82). The DeGray Lake studies are part of a cooperative effort by several universities and State and Federal agencies to provide base-line information on physical and biological interactions in multi-outlet reservoirs.

Loss of Larval Fish. The development of multi-outlet release structures and knowledge of daily and seasonal patterns of vertical distribution of the larval fishes allows for selectivity in regulating the degree of entrainment. The experimental operation of the multiple release structure at DeGray Dam has enabled biologists to quantify larval fish losses from the lake and explore factors that influence those

Biologists using a boat-mounted electroshocker to collect fish in the regulating pool at DeGray Lake, Arkansas, as part of a study designed to compare the effects of water releases from the epilimnion and from the hypolimnion on downstream fish populations. *Photo by T. O. Duncan.*

losses. The loss of larval fish through DeGray Dam during periods of generation has varied annually since 1975. Annual losses are related to depth of outlet, differences in population density, amount of water discharged when the fish are small, and vertical distribution of larvae.

Estimated annual loss of larval fishes ranged from nearly 15 million in 1980 to more than 400 million in 1979; estimated loss of larval fish biomass ranged from 226 kg in 1981 to 1,644 kg in 1978. Using data from 6 years of larval entrainment studies, we have developed linear regression models to describe the relation between larval fish abundance above the dam and larval fish entrainment during both high-level (epilimnial) and low-level (hypolimnial) discharge regimens. The slope of the regression line predicting larval fish loss on the basis of reservoir fish density indicated a higher degree of entrainment during epilimnial release for the three principal taxa (shad, crappies, and sunfishes). Since our data indicate that larval fish loss is passive, the seasonal vertical distribution of the larvae vulnerable to entrainment and the outlet depth largely determine the percentage of larvae entrained.

Although millions of larval fish are discharged each year, it is the proportion of the reservoir standing crop entrained that is biologically important. Proportions of the standing crop of larval fish discharged (May through July) were indicated by comparisons of weekly estimates of entrainment with corresponding estimates of the reservoir population. During epilimnial release, estimated weekly percentages of the reservoir population lost ranged from 0.01 to 8.6 for shad, 0.0 to 3.3 for crappies, and 0.0 to 2.6 for sunfishes. During hypolimnial release, the weekly percentages were much lower for shad (0.0-1.1), but higher for crappies (0.03-10.6). Weekly percentages of the larval sunfish population lost were similar for both release regimens. We believe these losses have little effect on the total reservoir population, even though rates of entrainment were greater during epilimnial release.

Largemouth Bass Population Dynamics. The population of largemouth bass has been sampled intensively to evaluate possible effects of different

reservoir release depths on the population dynamics of this important sport fish, and to evaluate springtime electroshocking as a sampling tool for quantitative sampling. Studies conducted since 1975 have indicated that the population is dominated by fish of ages I and II. In 1982 the number of bass increased in three study coves, the increases ranging from 3% in the uplake section of the reservoir to 75% in the downlake section. Only the midlake portion of the reservoir showed a noticeable increase in large fish (longer than 250 mm). In 1982 the downlake study cove was sampled in March and again 1 month later. The length frequency of bass collected was similar, indicating little difference in the size distribution of bass near shore. This lack of difference suggested that population estimates of bass obtained in March and April were comparable.

Bass production was 14.9 kg/ha in 1980-81, and 18.5 kg/ha in 1981-82. Both of these values were below the average of 25.5 kg/ha for the period 1975-80. Largemouth bass reproduction, as measured by the number of young of the year in September rotenone samples, was slightly below average in 1982 — 188/ha, compared with 279 for 1981 and a 6-year mean of 254 (range 30-625/ha).

River Zooplankton. The abundance and distribution of zooplankton and benthos was studied downstream from DeGray Lake to determine the influence of this reservoir release on a large river system (Ouachita River). Zooplankton was sampled from areas below the DeGray Lake reregulating pool on the Caddo River, above the confluence of the Caddo and Ouachita rivers, and below the confluence. The DeGray Lake tailwater contained relatively high densities of reservoir-produced zooplankton, whereas the Ouachita River stations had extremely low densities of zooplankton. Most of the reservoir-produced zooplankton in the DeGray tailwater during minimum-flow conditions disappeared within 2 river miles downstream from the reregulating pool. Organisms found below this point were most often littoral types not commonly found in reservoir samples.

SOUTHEAST RESERVOIR INVESTIGATIONS

The management of the fisheries in large Federal reservoirs and tailwaters is a complex and continuing experimental process. Each reservoir has unique problems — some related to natural environmental differences and others to activities of man — but the integration of knowledge gained from limited studies contributes to our ability to understand these problems over a wide geographical area, to manipulate natural and man-made events for management purposes, and to ultimately predict an aquatic system's response to various environmental alterations. Southeast Reservoir Investigations' major role in this effort is to assess the impacts of various electrical power development projects on aquatic life in reservoirs and their tailwaters. Research has focused on conventional hydroelectric plants, pumped-storage hydroelectric systems, and nuclear-fueled steam generating plants. Headquarters of the Investigations are at Clemson, South Carolina, near a series of power reservoirs in the upper Savannah River watershed. Progressing downstream, the reservoirs are Jocassee (7,570 acres), Keowee (18,120 acres), Hartwell (56,400 acres), and Clarks Hill (71,500 acres). With the completion of Richard B. Russell Reservoir (29,340 acres) in 1984, a total of about 115 miles of river will be inundated.

Zooplankton Abundance. Keowee and Jocassee reservoirs have been influenced by a nuclear-fueled steam-electric power plant (2,600 MW) and a pumped-storage hydroelectric plant (610 MW) since late 1973. Operation of the nuclear plant moves large volumes of water (for condenser cooling) from a depth of 66-89 feet and returns it at a depth of 30-39 feet in Keowee Reservoir; pumped-storage operations exchange water between the two reservoirs at a depth of 43-66 feet. Southeast Reservoir Investigations sampled both reservoirs from 1973 through 1977 to document long-term changes in zooplankton distribution and abundance due to plant operation. Numbers of surface-oriented (0-49 feet) zooplankton declined 40% from 1973 to 1977 and biomass declined 56%. Over the same period, nutrient levels decreased and the population of a zooplankton predator (threadfin shad) increased. Both factors could have contributed to the decline in zooplankton density. However, changes in zooplankton abundance have been site-specific, whereas nutrient and predation pressure effects probably occur with equal intensity over the entire reservoir. Zooplankton declines were greatest in areas farthest from the nuclear plant in summer and nearest the plant in winter. The summer decline is attributed to movement of zooplankton from the surface to depths greater than 49 feet because of changes in the summer temperature profile of the

reservoir induced by the nuclear plant. Zooplankton numbers in winter probably are low because condenser cooling water (from 66-89 feet) is low in zooplankton and is displaced near the surface (30-39 feet). The Jocassee pumped-storage operation also has an effect on the northernmost area of Keowee Reservoir near Jocassee Dam. The densities in this area are not significantly different from those found in Jocassee Reservoir, and densities have not declined in either area as they have in Keowee Reservoir proper.

Similar species were present over the years of study in Keowee Reservoir, but population changes varied among species. Three major species increased over the years, or declined initially, but recovered to 1974 levels by 1977. Densities of four other species declined significantly from 1974 to 1977. Time of yearly maximum abundance changed significantly during the study period. For example, the dominant season for *Diaphanosoma,* a common plankter, occurred during summer in 1974-75, but in spring of 1976-77. Thus the nuclear plant operation appears to have affected abundance and seasonal dynamics of zooplankton over a wide area of Keowee Reservoir, although plant-induced mortality is not a significant factor. In contrast, pumped-storage operations have resulted in only limited changes in zooplankton density in Jocassee Reservoir and have stabilized densities in adjacent areas of Keowee Reservoir.

Life History Studies. Many steam-electric power plants use large multi-purpose reservoirs as a source of cooling water and as a means of dissipating waste heat. These cooling reservoirs sometimes have higher water temperatures and longer growing seasons than do nearby non-cooling reservoirs. The response of fish to elevated water temperatures and other subtle changes (e.g., changes in dissolved oxygen and flow regimens) in cooling reservoirs is a major concern of fishery managers, and the long-term studies by Southeast Reservoir Investigations are part of an effort to measure the effects of these changes on fish communities. The growth rates of three major sport fishes — bluegills, largemouth bass, and black crappies — in Keowee Reservoir were determined for the first 10 years of impoundment. During this period, the reservoir filled, water temperatures were increased by the heated effluent, and threadfin shad were stocked by the State with the hope of increasing predator growth rates. Threadfin shad may have improved the growth rates of 2-year-old largemouth bass and 2-, 3-, and 4-year-old black crappies. Growth rates of bluegills generally were fastest as the reservoir filled and declined significantly after the reservoir reached full pool. Elevated water temperatures had no measurable effects; fish growth was apparently regulated by the abundance and size of prey.

Redeye bass were collected along with numerous species of fish in Keowee and Jocassee reservoirs. This species is generally believed to be poorly adapted for lakes and reservoirs and is usually abundant in reservoirs for only a few years after the native streams are impounded. However, annual catches of redeye bass per 100 gill nets in Keowee Reservoir increased from 0.37 in 1973 (5 years after impoundment) to 13.75 in 1981 (13 years after impoundment) and catches in Jocassee Reservoir increased from 2.02 in 1977 (4 years after impoundment) to 17.50 in 1981 (8 years after impoundment). Growth rates for fish from Keowee and Jocassee reservoirs were considerably faster than those reported in streams, but somewhat slower than those reported in ponds. The increase in abundance and the rapid rate of growth of redeye bass in Keowee and Jocassee reservoirs suggests that this species may be better suited for some lake environments than previously believed.

Larval Fish Entrainment. Pumped-storage hydroelectric power plants use reversible pump-turbines and two reservoirs for power generation. Electricity is generated during periods of peak power demand, but during periods of low power demand the turbines are reversed and water is pumped into the upper reservoir where it is available for additional generation. The reuse of large volumes of water by pumping and generation increases the vulnerability of larval fish to passage through the power plant (entrainment) to mortality or relocation. We completed a study (1977-79) at Jocassee Pumped-Storage Station to determine operational effects on larval fish populations in the upper (Jocassee) and lower (Keowee) reservoirs. Information collected and used in a predictive model developed in conjunction with the Service's National Power Plant Team include annual production estimates, natural mortality rates, pumping and generation entrainment passage and survival rates, and volumes of water flows in and out of each reservoir. Adequate data were available for three major species. Threadfin shad were most vulnerable to generation and pumping. Pumped-storage operations reduced young-of-the-year shad in both reservoirs by about 40%. However, the production of shad in each reservoir differed, and pumped-storage operation resulted in a net gain of almost 18-fold in the upper

reservoir and a loss of about 48% in the lower reservoir by the end of the entrainment period. Reductions of young-of-the-year black crappies and yellow perch ranged between 0.5 and 3.0%. The relocation of black crappies resulted in a 100% net increase in the population of the lower reservoir and an 8% loss in the upper reservoir. The relocation of yellow perch resulted in no net gains or losses for either reservoir. This information is the first step in estimating long-term impacts on the size of adult fish populations.

Tailwater Fisheries. Factors controlling distribution and abundance of tailwater fish populations are poorly understood. Effects on tailwaters are most severe when water is released for power generation through discharge structures located near the bottom of reservoirs that thermally stratify in summer. This type of release results in low water temperatures throughout the tailwater. We studied Hartwell Reservoir tailwater (a peaking hydropower project) when flows ranged from 100 to 23,500 cubic feet per second during nongeneration and generation, respectively; maximum water temperatures rarely exceeded 68°F throughout the 8-mile study area; and dissolved oxygen concentrations periodically dropped as low as 3 ppm in the 1-mile section of tailwater immediately below the dam.

Estimates of fish distribution and abundance were obtained by electrofishing and sampling with rotenone. The collection of 43 species of fish indicated that this is one of the more diverse cold tailwater fish faunas in southeastern United States. Distribution of species was similar at all sampling locations, but abundance generally increased downstream. Major factors affecting fish abundance below Hartwell Dam appeared to be recruitment of fish from the reservoir, a reduction in habitat diversity just below the dam, water temperatures suitable for sunfish spawning, and the stocking of rainbow trout and brown trout.

WHITE RIVER RESERVOIR STUDIES

The acquisition of long-term records needed to identify various environmental and biological interactions remains the only effective approach to understanding the functioning of sport fish communities in reservoirs. The White River Reservoir Studies team conducted field investigations on Beaver and Bull Shoals lakes from 1963 to 1981 to document the development and evolution of the sport fishery in a new reservoir (Beaver) and to compare population trends with those observed in an older reservoir of similar morphometry (Bull Shoals). Field activities have yielded a unique data bank for fishery biologists to use in testing hypotheses concerning reservoir ecosystems. Sampling techniques developed by the White River Reservoir Studies team are widely used for studying reservoir fish communities.

Long-term Studies on Angler Harvest Document Reservoir Aging Effects. Estimates of angler use and harvest obtained from Beaver Lake during its first 17 years of impoundment have provided biologists with valuable insights into the potential for reservoir angler use. After closure of Beaver Dam in late 1963, sport fishing was exceptionally good for about 4 years (anglers caught more than 30 pounds of sport fish per acre annually). The harvest of most important sport fishes then declined through 1980, the 17th year of impoundment. Although there were substantial year-to-year fluctuations during the period, annual harvest of all sport fishes decreased about 80%. The catch of black basses and crappies showed similar declines. Fishing pressure peaked at about 110 hours/ha during the 4th year of impoundment and then slowly declined to about 25 hours/ha in 1979-80. This decline paralleled the decrease in harvest. The pattern of declining harvest on Beaver Lake is characteristic of that in other man-made impoundments as they age. Until recently, new reservoirs provided excellent sport fishing in most regions of the United States. With the decline in reservoir construction, fishery agencies now face the difficult task of maintaining acceptable levels of angling success in aging reservoirs — a change that will require intensive effort and a much broader knowledge of reservoir fish population dynamics than now exists.

SEATTLE NATIONAL FISHERY RESEARCH CENTER

Role of Virus in Regulating Natural Salmonid Populations. In a cooperative study with the Washington Department of Game, an attempt was made to control mortality due to infectious hematopoietic necrosis (IHN) at a Columbia River production hatchery. All female brood fish were spawned individually and a sample was obtained from each for

virus analysis. The eggs from each female were held separately until results of the virus tests were known; the eggs from virus-positive fish were then destroyed, and those from virus-negative fish combined. Infection rates were 12% in sea-run cutthroat trout, 18% in summer-run steelhead trout, and 23 % in winter-run steelhead trout. Mortality due to IHN at this hatchery was less than 10 % of the total production. Mortalities were 50 to 95% at nearby hatcheries where eggs were not screened by this method.

In a related study done cooperatively with Portland General Electric Co. and the Oregon Department of Fish and Wildlife, all female brood fish at another Columbia River hatchery were examined. None were found to be carriers of IHN virus, but a severe epizootic resulted in an almost total loss of the fry. The source of infection for this outbreak was believed to be waterborne virus originating in known IHN carrier fish in the reservoir above the hatchery.

An effort to control IHN mortality of sockeye salmon in streamside egg incubation boxes was made cooperatively with the Washington Department of Fisheries. Three major experiments were conducted: (1) examining the distribution of virus levels in the adult females used as egg sources for each incubation box, (2) reducing egg and fry densities, and (3) changing spawning techniques to keep eggs from each female separate through fertilization, water-hardening, and disinfection. Severe IHN epizootics occurred in the fry produced in all boxes. The infection rate in this population was 100% for the third consecutive year. However, the virus load in the spawning population was obviously high this year; more than 70% of the individual titers exceeded the midpoint, compared with less than 40% in each of the preceding 2 years. This high level of virus may explain why all control efforts failed.

Contrary to current dogma, male fish may play a role in egg-associated (vertical) transmission of IHN virus. Sperm from steelhead and rainbow trout, kokanee, and chinook salmon were capable of binding from 90 to 99% of the IHN virus present in solution. Virus binding was complete in less than 1 minute, an extremely rapid rate, considering that 1 hour is required for full adsorption of virus to cell cultures. Neither seminal plasma nor ovarian fluid affected the process. At least some of the virus remains viable because it can be eluted by chemical treatment of the sperm. The capacity of sperm to bind virus is fragile, as it can be destroyed by freezing or washing of the sperm. The sperm may bind virus produced by the male itself or virus contributed by the female in the cavity fluid released during expulsion of the eggs. The sperm would then act as a carrier vehicle for the entry of the virus into the egg.

Rapid Detection Methods for Fish Viruses. The lack of a specific high-titered antiserum against IHN virus continues to be the primary obstacle to development of an immunologically based rapid assay. The fluorescent antibody staining of IHN antigens in cell culture was improved by the use of fluorescein isothiocyanate-labeled staphylococcus protein A to replace the second antibody in the indirect test. Less non-specific staining occurred. Tests of several counterstains revealed that enochrome black T yielded the best results. This staining procedure is now being tested to identify viruses after cytopathic effects are seen in cell cultures, to reduce the time required for the neutralization test now being used.

Ovarian or cavity fluid is the sample of choice for detection of IHN virus. It is a complex mixture of at least 25 proteins. Eight to 10 of these proteins differ quantitatively between IHN carrier and non-carrier sockeye salmon; one or more may be suitable for use in an assay that will more quickly separate carrier from non-carrier fish.

Field Testing of Methods for the Control of Fish Diseases. Bacterial kidney disease (BKD) has been a serious problem among hatchery-reared salmonids throughout the United States and foreign countries. Effective control of BKD is impeded by the lack of a rapid method of diagnosis and surveillance. Present methods of detection include isolation of the bacterium *(Renibacterium salmoninarum),* gram-stain, and the fluorescent antibody technique. However, isolation is slow (21 days), and gram-stain and fluorescent antibody technique are arduous when the number of samples is large. In 1981, we completed preliminary work and laboratory testing on the development of an enzyme-linked immunosorbent assay (ELISA) for the rapid detection of BKD. Our efforts during 1982 were directed toward the testing and evaluation of the procedure on large numbers of hatchery samples. Results obtained by ELISA were also compared with those from the fluorescent antibody technique, counterelectrophoresis, and immunodiffusion.

Detection of BKD by ELISA corresponded with detection by the other methods in all cases thus far examined. We were able to detect relatively low concentrations of antigen in BKD-infected salmonids, and ELISA enabled us to test about 200 fish per day. The sensitivity of ELISA is superior to that

of the other procedures tested. Counterelectrophoresis can be used in preference to the more time-consuming and tedious systems of staining (gram and fluorescent antibody technique). Complete success with ELISA depends on solving the problem of reagent stabilization and the production of more powerful antisera.

Dissolved Gas Monitoring System. Both air supersaturation and low dissolved oxygen can be very dangerous to aquatic organisms, and both can occur without warning in hatcheries and laboratories. Continuous monitoring has been relatively costly and time-consuming until a gasometer was recently developed at the Seattle Center. In the operation of this easily constructed device, a semipermeable membrane is used to compare total dissolved gas pressure with the air pressure. A positive pressure is produced when the water is supersaturated with gases (which causes gas bubble disease). A negative pressure is indicative of low dissolved oxygen (which causes hypoxia and suffocation). In cooperation with the Denver Wildlife Research Center, we equipped the gasometer electronically to continuously monitor a water supply. This version of the gasometer not only provides an early warning when dangerous limits are reached, but turns on the appropriate correctional treatment.

Coho Salmon Production in the Columbia River. Among hypotheses examined that could explain the collapse in production of coho salmon in the Columbia River observed in the early 1970's were environmental degradation, predation, loss of wild runs, phenomena related to population density in the ocean, and factors related to the quality of releases.

Through analysis of data on adult sex ratios and return of jacks (early maturing salmon), it was shown that nearly all (92 to 99%) of the mortalities occurred during the first 6 months after release, and that about 74% occurred even before the fish entered salt water.

Multiple regression techniques were used to determine the effects of various hatchery practices on the production of adults. That production was found to be best measured in terms of returns of jacks. Among the hatchery-related factors, pond loading densities (which have increased in hatcheries during the past two decades) proved to be a significant factor negatively affecting the survival of coho salmon to adulthood, although it accounted for only 5% of the variation in returns. Part of the variation may be due to difficulty in measuring the true density.

Histopathology of Salmonids. "Microscopic anatomy of salmonids: An atlas" by W. T. Yasutake, National Fishery Research Center, and **J. H.** Wales, Oregon State University, has been completed and is now in press. The atlas is to include 12 color plates and 50 black-and-white photomicrographs. This project was undertaken in response to numerous inquiries from researchers, biologists, professors, students, and others in related fields, about the availability of a book on the microscopic anatomy of trout and salmon.

The book was prepared primarily as an atlas and supplementary reference. Consequently, the emphasis is on the photomicrographic illustrations, which provide detailed descriptions, and the text consists largely of general comments. The atlas contains an extensive up-to-date bibliography on fish histology and an appendix that includes the fixation and staining procedures used in preparing the materials illustrated in the book.

Decline of Sockeye Salmon in Karluk Lake, Alaska. Preliminary analysis of conditions that could have resulted in a decline of sockeye salmon in Alaska's Karluk River led to a conclusion that the historic "stability" region (stock-recruit analysis) for these fish collapsed and was reestablished at a much lower level. Subsequently, the Alaska Regional Office of FWS concluded that restoration of these sockeye salmon was a matter of high priority and that an attempt should be made to identify the specific mechanism for this collapse, not only because of its significance at Karluk, but also because of its potential significance for sockeye salmon populations associated with other Service lands.

In 1982, the Seattle Center began a project at Karluk to eliminate, as efficiently as possible, the alternative explanations that could account for collapsing stability regions. These explanations included propositions that the collapse resulted from changes in lake productivity or depensatory mortality.

We concluded that the lake productivity possibility could best be addressed by an analysis of sediment core samples. The one core that has been analyzed to date was collected on 12 August 1981, from Thumb Bay in water 40 m deep. It was frozen and returned to the Seattle Center, where it was sliced into 13 samples with an average length of 3 cm. Subsamples were taken from the center of each sample and cleaned for diatoms by oxidation with potassium dichromate and 30% hydrogen peroxide, and mounted for enumeration. Ten or more fields, to a maximum of 25, were counted per subsample in

order to ensure statistically relevant counts. Means and standard deviations were calculated for each type of diatom, and the ratio of araphidineae to centric diatoms (A/C) was calculated. A trophic classification of the lake was determined for the time at which each subsample was laid down. Dominant members of the community were determined by numbers rather than by volume. A total of 86 taxa were identified from the core. The dominant diatom taxa from each subsample were tabulated.

The A/C ratios for the subsamples indicated that the lake has been oligotrophic or mildly mesotrophic over most of the time represented by the core. However, during the period of time represented by two of the subsamples, the lake was extremely eutrophic. Because the core was frozen and thawed an unknown number of times in transit to the laboratory, it was not deemed suitable for nitrogen and phosphorus analysis. Numerous subsamples of the core were examined both with compound and dissecting microscopes for fish remains, but none were found. The core has been transferred to the Institute for Quaternary Research at the University of Washington, for radiocarbon dating.

Depensatory mortality could result from predation or competition. Our first goal was to test the predation hypothesis. Our strategy was to estimate the number of prey (sockeye salmon) consumed per predator at Karluk. Potential predators were collected from May to October 1982 by seining, trapping, and angling. Few of the data have yet been analyzed, but we have virtually eliminated Dolly Varden as an important predator of sockeye salmon fry or fingerlings: Only one specimen collected was found to have eaten a young sockeye salmon. However, Dolly Varden consumed large numbers of salmon eggs during the peak of salmon spawning activity.

Brood Stock Management. A series of models was developed to describe the possible outcomes of genetic manipulation of brood stocks through stock transfer. We concluded that, because of insufficient information and knowledge within the field of genetics, the models must serve primarily to demonstrate the range of possible effects from transferring fish and not to predict the outcome in a particular situation.

Perhaps the most important indication was that the probability for permanent genetic change was much greater for outplanting than for transfers between hatcheries. Continual genetic introgression from the hatchery population to the wild population, combined with associated density-dependent effects, constitutes a powerful force: After 30 generations of outplanting there may be little difference between the wild population and the contributing hatchery population. Consequently, if the same hatchery population is used to supplement 10 genetically distinct wild populations, for instance, it would be expected that there would be little difference among these populations after 30 generations. Hence, to the extent that management agencies are concerned with conserving genetic diversity, they must ensure that large regions to be intensively stocked are divided into areas based on evidence for genetic similarity among the endemic fish populations. The hatchery contributing to each area would develop its fish population from populations endemic to that area. Transfers of fish between areas would be prohibited except perhaps for experimental purposes.

Several recommendations for brood stock management in the Columbia River were made, and a "framework" for decision-making in the use of hatchery-produced salmonids was completed. Recommendations were (1) that each hatchery be designated as either a selective breeding station or a conservation hatchery; (2) that conservation units be established on the basis of electrophoretic data, geographic proximity, and other pertinent information such as life history and disease resistance; (3) that transfers involve few fish and occur infrequently; (4) that brood stocks be developed from wild fish within the conservation unit; and (5) that wild fish (perhaps 10 %) be included in each year's brood stock for hatcheries in conservation units that include wild populations.

Guidelines for Use of Hatchery Fish. A report entitled "Limitations and guidelines for the use of artificially propagated salmonids in management programs" was prepared for the Regional Resource Manager. In the report, we reviewed evidence to show that effects of density regulation, species interactions, gene flow, and ocean productivity cannot be safely ignored in management decisions regarding the use of artificially propagated anadromous salmonids. For instance, when natural recruitment of presmolts is sufficient to use the available food and space, efforts to increase their density merely increases the mortality rate. This effect, combined with the effect of gene flow from hatchery fish ("genetic pollution") can threaten an endemic population's ability to persist. Further, we showed that increasing smolt abundance in one population can reduce other populations in a community, and that ocean productivity for salmonids may be much

less than it is generally perceived to be.

In addition to describing goals in gene resource conservation, and some of the ecological relations that can limit success of management projects in which artificially propagated salmonids are used, a primary purpose of the report was to assist managers and other fishery resource decision-makers by developing preliminary guidelines for evaluating proposals to supplement or enhance salmonid resources. These guidelines were presented in the form of a key that requires the user to progress through a series of paired options until a presumed logical conclusion regarding the proposal is reached.

Biochemical Genetics of Sockeye Salmon. Definition of stocks (populations) and specification of reproductive requirements (escapement) for stability depend on the availability of accurate descriptions of the populations for which management criteria are to be developed and applied. It is sometimes known that more than a single "race" of an anadromous salmonid occurs within a watershed. Each race certainly is a population, but in some situations, several populations are known to exist within a race. Homing behavior and environmental peculiarities that have resulted in reproductive isolation of populations no doubt have also resulted in site-specific adaptations involving reproductive characteristics such as fecundity, age at maturity, and growth. Consequently, all populations cannot be expected to respond to fishing in the same way. Optimum management and use, and gene resource (population) conservation depend first, therefore, on descriptions of the distribution of specific populations and on information that accounts for differences in reproductive potentials.

Our research effort in fish genetics to date has largely been restricted to answering specific questions concerning some sockeye salmon populations that have been raised by the Alaska Department of Fish and Game, and Region 7. Significant genetic differences were found between early and late runs of sockeye salmon in both the Russian and Karluk rivers, and between sockeye salmon from each of these rivers for certain enzymes. The difference in aconitase allele frequencies for fish from the Russian and Karluk rivers was of particular interest because the most common allele in the Russian River fish was lacking in fish from the Karluk River.

Salmon in Kenai River, Alaska. The original objectives of this 3-year study (1979-81), conducted in cooperation with the Alaska Department of Fish and Game, were to delineate and characterize spawning and rearing habitat for permit reviewers, to evaluate the effects of past and present riverine developments (docks, boat ramps, jetties, excavations, . . .) on salmon habitat, to develop new methodologies for research in glacial rivers, and to attempt to provide information useful to fishery managers.

A total of 139 chinook salmon were radio-tagged over 3 years and more than 50 spawning areas were located. In studies of juveniles we used modified Instream Flow methodology. A brief summary of the major findings follows.

(1) The existence of two runs of chinook salmon into the Kenai River was confirmed. Tagging and tracking studies showed that early-run salmon enter the Kenai during May and June and spawn in tributary streams. Late-run salmon enter the stream in July and August and spawn in the Kenai main stem during August and early September.

(2) Early-run fish spawn primarily in two tributaries on Kenai National Wildlife Refuge lands. In the most productive tributary (Killey River) we used an electric weir and mark and recapture methods to estimate an escapement of 8,000 adults. Late-run chinook salmon are more likely to be affected by development structures in the stream because all of the freshwater life history occurs in the main stem.

(3) Several high-use rearing areas were documented. Also, habitat use curves were constructed for three species of juvenile salmon. The components identified included velocity and substrate. It should be possible to determine how the type of development for which a permit application has been made will affect rearing. Catch rates for juveniles along natural banks were compared with those along various developed areas.

(4) Data are now available on diel movements of adults, migration rates, length of time that tagged fish were vulnerable to anglers, sport harvest rates of tagged fish, age and growth of juveniles, and food preferences.

Our successful use of radio-tagging to describe the timing of spawning runs of chinook salmon and their choice of spawning locations in the Kenai River has stimulated interest in the development of similar methods for other species and locations in Alaska.

Atlas of the Distribution of Marine Birds in the Gulf of Alaska and Southern Bering Sea. The impending development of petroleum resources on the continental shelf of Alaska potentially threatens populations of marine birds that are larger and more diverse than in any similar region of the northern hemisphere. In an effort to evaluate this threat,

large-scale studies of populations and biology of marine birds were begun in 1975. Results of censuses conducted in the Gulf of Alaska and Bering Sea are now summarized in an atlas that shows seasonal distributions of all major species. The distributions of individual species differ, but numbers are generally highest near shore, somewhat lower over the continental shelf, high in areas of upwelling at the edge of the shelf, and much lower over deep oceanic regions. Although an estimated 40 million seabirds of 30 species nest in Alaska, dominant species in summer are sooty and short-tailed shearwaters that nest in the southern hemisphere. Other results of these studies have been reported in more than 50 publications.

Fidelity and Reproductive Success in Alaskan Shorebirds. Black turnstones nest primarily along the coastal fringe of the Yukon-Kiskokwim Delta. Densities of nesting birds are highest in salt-grass meadows and coastal lowlands that are susceptible to flooding by spring or storm-driven tides. During a 5-year study, the return rate of individually marked birds averaged 89% for males and 79% for females. Fidelity of birds to territories, which encompassed areas used for courtship, nesting, feeding, and chick-rearing, appeared to serve in part to reunite pairs, which were strictly monogamous. Reproductive success was highest among birds that were faithful to both nests and territories. However, this fidelity of turnstones to mates and territories, which is advantageous under natural conditions, could tend to increase the vulnerability of this species to pollution that may occur with development of offshore petroleum resources.

Migratory Birds

MIGRATORY BIRD AND HABITAT RESEARCH LABORATORY

Illinois Study Confirms Dependence of Neotropical Migrant Birds on Large Forest Tracts. Reduction of total forest area and the fragmentation of native forest into isolated patches have adversely affected populations of many bird species, especially those songbirds that winter in the tropics. Because forest habitat is also disappearing at an alarming rate in Latin America where these birds winter, there is an urgent need to determine the area requirements of those species that depend on forest interior habitats. Current research is designed to determine the magnitude of forest habitat needed to support the nesting species typical of that habitat.

In a contract study in 1979-81, investigators at the University of Illinois used the point-count technique to record bird populations in 29 forest sites in east-central Illinois. They found a strong correlation between area of woodland and number of breeding species of neotropical migrants. In contrast, numbers of species of short-distance migrants were not strongly correlated with forest area. These findings are similar to those reported from the Middle Atlantic States in 1979, indicating that dependence of long-distance forest migrants on large tracts of habitat during the breeding season is not merely a regional phenomenon.

Many of the warblers, vireos, thrushes, gnatcatchers, tanagers, and flycatchers are among the neotropical migrants most dependent on large tracts of forest for nesting. Examples of the smallest tract on which birds were found during the breeding season in east-central Illinois are 600 ha for hooded warbler, 118 ha for American redstart, 65 ha for cerulean warbler, 28 ha for veery and rose-breasted grosbeak, 24 ha for Acadian flycatcher, blue-gray gnatcatcher, northern parula, and ovenbird, and 16 ha for scarlet tanager.

Although these species defend territories of only 1-2 ha, during the breeding season, a block of forest many times that large is needed to attract even small populations of these area-sensitive species. This concept must be taken into account in planning the acquisition and management of natural areas.

Tern Nesting on the Atlantic Coast. Along the heavily disturbed beaches of the coastal Atlantic region, many ground-nesting seabirds have been displaced from beach-dune habitats to alternate habitats, such as salt marsh or dredged-material islands. Common terns, black skimmers, herring and great black-backed gulls, and American oystercatchers

have had to alter their nesting habits because of human activity.

For 3 years, common tern colonies in New Jersey, Maryland, and Virginia were studied to determine if habitat choice influences colony structure and reproductive performance. Information on reproductive success and nest-spacing patterns was collected during weekly visits to natural beach and salt marsh colonies. Reproductive success varied greatly among study colonies within years and within colonies among years. The largest, most successful colonies, however, were in natural beach-dune habitat. Depending on the direction and severity of storms and high tides, nest destruction by flooding was usually (but not always) more severe for marsh colonies. Nest-spacing patterns differed between marsh and beach colonies. Terns in marshes were restricted to building nests on small mats of dead vegetation (eelgrass "wrack"), which provided some flotation when high tide waters encroached. As a consequence, however, nests were placed closer together than in beach habitats.

The results indicate that common terns can adapt readily to marshes for nesting, although long-term nesting success may be lower than in traditional beach habitats. The same appears to be true for gulls. Preliminary results suggest that black skimmers, least terns, or American oystercatchers are more specialized and less adaptable to alternate nesting habitats. For these species, some active management of nesting habitat may be necessary to sustain populations in increasingly disturbed coastal areas.

High Coastal Marsh Systems Important for Migratory Shorebirds. Large numbers of sandpipers and plovers use Atlantic coastal marshes as stopovers and staging areas during migration. The total acreage of these habitats has declined about 16% since 1922. On the coast of New England and the Middle Atlantic States alone, 90% of the high marsh zone, that portion lying above mean high tide level, has been ditched for mosquito control since the turn of the century. The objective of this study was to determine how, and for what purposes, shorebirds make use of high marsh systems.

Two methods were used near Wallops Island, Virginia, to help answer these questions. High marsh ponds frequently visited by shorebirds were observed through full tide cycles, and censuses of all species were conducted at regular intervals. Behavior of individuals was recorded during each census. To determine microhabitat preferences, we established 40 census plots along transects through the high marsh. Birds were censused in all plots twice per day during the spring migration. Habitat structure and composition and water levels were measured in each plot.

Results of the censuses through tide cycles showed that most species exhibit strong population cycles, peaking in the high marsh at high tide when intertidal mudflats are flooded and returning to the flats when the tide recedes. Feeding activity of species like short-billed dowitchers and semipalmated plovers was similarly cyclical, tapering off markedly during the high tide period. Least and semipalmated sandpipers, however, continued to feed actively on dipteran larvae in the high marsh. Many individuals of these species remained here even at low tide levels. These results indicate that the high marsh is an important high tide roosting area for most shorebird species and is also a significant source of food for some of the smaller species.

Casual observation of shorebirds in the high marsh suggests that large, shallow ponds are the favored microhabitat. Results of the habitat transect censuses, however, showed that those species with statistically significant preferences prefer very small openings amid the marsh grasses. Preliminary studies of prey distribution showed no difference between large and small ponds. It is tentatively concluded that shorebirds select high marsh microhabitats that offer feeding opportunities while minimizing the risk of detection by aerial predators.

The significance of these results is twofold. First, because high marsh habitats provide safe roosting sites for many shorebird species and feeding sites for some, increased consideration should be given to preserving natural high marsh systems. Second, the results of habitat studies suggest simple approaches to high marsh management that may enhance shorebird utilization during migration.

Relation Between Environmental Variables and Distribution of Mallards Wintering in the Mississippi Alluvial Valley. Analyses of band recovery data suggest that mallards from specific breeding areas do not always winter in the same areas each year. A recent study addressed the question of whether variation in distribution of mallards wintering in the Mississippi Alluvial Valley (MAV) was associated with three environmental variables: winter temperatures, winter precipitation, and mallard population size. Data for 1950-81 were obtained for December-January temperatures and days below freezing for northern wintering areas outside the MAV, cumulative November-January precipitation for locations in MAV, and continental mallard

numbers from the winter waterfowl survey.

Winter distributions of mallard band recoveries were centered farther south in cold winters than in warm winters. Winter waterfowl survey data indicated major southward shifts in distribution during the two coldest winters in the period of interest, January 1977 and January 1979. Mallard winter distribution also differed between wet and dry winters, and higher proportions of band recoveries (especially for young birds) occurred in MAV during wet winters. In winters of high population size the proportion of young mallards wintering in MAV decreased, suggesting possible competition with adults.

These results indicate that management activities on specific wintering grounds will not necessarily affect the same wintering population each year. Results also support decisions made in recent years to increase wetland preservation efforts in MAV to offset the massive flood-control and drainage efforts that have cleared more than 80% of the bottomland forests and wetlands.

Effects of Permanent Trap Response in Capture Probability on Jolly-Seber Capture-Recapture Model Estimates. The Jolly-Seber capture-recapture model provides a means of estimating mortality rates, reproductive rates, and population size in natural animal populations. The model is widely used and has been applied in migratory bird research. The model incorporates the assumption that every individual in the population has the same probability of being caught within a given trapping period. Permanent trap response refers to a situation in which unmarked and previously marked individuals have different capture probabilities, and thus represents a deviation from this assumption. A "trap-happy" response occurs when marked individuals have a higher capture probability than unmarked individuals, and a "trap-shy" response occurs when marked individuals have a lower capture probability.

We studied the effects of permanent trap response using analytical approximations and computer simulation. A trap-happy response was shown to produce negatively biased estimates of population size whereas a trap-shy response produces positive bias. Relative biases of population size estimates are worse when capture probability is low and when the studied population exhibits substantial turnover (high reproductive and mortality rates). Trap response does not bias survival rate estimates but does affect their precision. Tests for the existence of trap response can be made with certain closed population models.

Breeding Ground Habitat Conditions and Mallard Survival. Recent analyses of mallard banding and band recovery data indicate that mallard survival rates vary from year to year. However, we know little about what environmental factors are associated with this variation. A recent analysis addressed the question of whether mallard survival rates vary in response to habitat conditions on prairie breeding grounds. Annual survival rates of mallards were estimated from banding and band recovery data corresponding to specific prairie breeding areas. May ponds and mallard breeding population size were estimated from the annual May breeding ground surveys. Results of the analyses indicated that mallard survival rates were generally higher during years of good habitat conditions (reflected by high May pond numbers and low mallards-per-pond ratios) than during years of poor conditions (low pond numbers and high ratios). This relation was stronger for males than females. Land management activities directed at improvement of water conditions on prairie breeding grounds may thus benefit survival as well as reproduction of mallards.

Band Reporting Rates of American Black Ducks. It has been known for years that not all of the bands on ducks retrieved by hunters are reported to the Bird Banding Laboratory. A knowledge of the actual reporting rate of leg bands is needed to adjust band recovery rates in order to estimate harvest rates. Additionally, low band recovery rates result in an inefficient return of data from banding operations; low band reporting rates may suggest the need to encourage band reporting among sportsmen.

Standard U.S. Fish and Wildlife Service (FWS) leg bands were applied to 18,008 American black ducks during the preseason banding period and to 25,070 black ducks during the postseason period, 1978-80. Reward bands (a control band on one leg and an iodized green "REWARD $15" band on the other leg) were applied to 2,965 and 5,055 birds during the preseason and postseason periods, respectively. Maximum likelihood methods were used to estimate band reporting rates, harvest rates, and band solicitation rates and to test hypotheses about temporal and geographic variability in these rates.

Mean band reporting rate for black ducks recovered in Canada and in the Atlantic and Mississippi flyways of the United States was 0.43 (± 0.04, 95% confidence interval). A previous reward band study for mallards found significant regional geographic differences in reporting rates, and within geographic

regions, lower reporting rates at sites close to banding stations. We found little evidence of regional geographic differences in reporting rates for black ducks, and no evidence that rates were influenced by distance from banding station. There was also suggestion of temporal variations in reporting rates over the 3 years of this study, indicating that the constant rate of 0.43 should be taken as the best estimate of overall reporting rates for black ducks.

A critical assumption of all reward band methods is that 100% of the reward bands found by hunters are reported. We believe that this assumption is false, and that the actual reporting of reward bands is 75-90%. The effect of violating this assumption is that the reporting rate of standard bands is overestimated by as much as 50%, and that harvest rates are underestimated by the same amount. In future studies this problem could be alleviated by raising the value of the reward or by applying several samples of reward bands having increasing reward payments.

Cooperative Dove Nesting Study Completed. In recent years, some individuals and organizations have opposed Federal regulations permitting September dove hunting because part of the nesting season may coincide with the hunting season. The concern was expressed that hunting mortality of breeding adult doves in September may result in substantial mortality of eggs and nestlings and that the disturbance of hunting might curtail nesting activity. In 1977 the FWS prepared an environmental assessment which examined the currently available information on the impact of hunting on the dove populations. The conclusion was that regulations allowing September hunting have negligible adverse impact on the maintenance of the mourning dove population in the United States. Although that conclusion was based on a large amount of information, there had been no standardized and coordinated field studies of seasonal dove nesting patterns throughout the United States, nor had there been any comparisons of egg or nestling survival in hunted and non-hunted areas in September.

To obtain this additional information, we initiated a nationwide study in 1978 through the cooperation of 23 State wildlife agencies, six State universities, and the FWS. This study estimated the proportion of annual dove nesting activity and production that occurs in September and October, and compared the survival rates of eggs and nestlings in hunted and non-hunted areas during September.

During the 2 years of the study, about 7,000 active nests were located on 106 study areas in 27 States. Estimates were obtained on nest initiation, nest activity, and fledging. Two methods were used to estimate monthly proportions of nest initiation. One was based on backdating from the hatch dates and the other was based on dates on which nests were initially found. The nationwide percentage of the annual total of nests that were initiated in September and October was 1% based on backdating hatch dates and almost 3% based on nests found for the first time.

Nesting activity was estimated by numbers of eggs and nestlings present in weekly counts. Nationally, 4.5% of the annual total of nesting activity occurred in September and October. The fledging that occurred in September and October was about 10% of the total fledging.

In a separate part of the study, survival rates were estimated from paired hunted and non-hunted areas from data on 668 nests. The survival rates were not significantly different. Even if there had been a real difference in survival rates that was too small to be detected, it probably would reduce the mean fledging rate by less than 1%.

In conclusion, only a small proportion of total annual nesting attempts was exposed to hunting. There was no statistically significant difference in survival rates in areas where hunting was permitted compared with areas where it was prohibited. Thus, dove hunting under current regulations has no substantial effect on recruitment of fledglings into the mourning dove population.

Numbers and Sex Ratios of Canvasbacks Monitored by Aerial Photography. An aerial photocensus of canvasbacks was conducted throughout Chesapeake Bay (tidal Maryland and Virginia) and coastal North Carolina to assess numbers of birds and provide valuable sex ratio information. Color photographs of flocks of canvasbacks were taken with a conventional, hand-held 35-mm camera from the window of low-flying aircraft. Flock size and sex ratio characteristics were determined from photographs of 165 flocks of canvasbacks totaling over 95,000 birds. Sex was determined for 68,800 birds, an average of 80% of the canvasbacks in each of 150 flocks. The resultant flyway-wide sex ratio was 2.91 males per female.

Flock size differences were detected in each State. In Maryland, 70 flocks of canvasbacks exhibited a broad range of flock sizes; 63% of flocks contained less than 500 ducks, whereas 10% ranged from 2,000 to a maximum of 5,000 birds. In Virginia, canvasbacks were widely scattered in numerous small flocks (n = 71) in the James, York, and

Rappahannock rivers; 93% of flocks contained less than 500 ducks and no flocks larger than 1,000 birds were recorded. The open sounds of North Carolina harbored the fewest (n = 24), but on the average the largest, flocks of canvasbacks; 25% of flocks contained fewer than 500 ducks, and 29% ranged from 2,000 to a maximum of 3,600 birds.

Sex ratio varied latitudinally in the flyway as well as locally with flock size. Sex ratio (males per female) was highest in Maryland (3.98) and lowest in North Carolina (1.70), revealing that females and young tended to congregate at more southern latitudes and males at the more northern limit of the winter range. We found that over the same range of flock sizes, sex ratios of canvasbacks in Maryland and Virginia were not significantly different.

Monitoring the annual change in sex ratio of the wintering canvasback population can provide valuable information on recruitment success and thus on population status. For example, during the 1981 breeding season, widespread drought on the prairie resulted in poor breeding success for canvasbacks. An abbreviated aerial photo-census completed in January 1982 revealed that the Maryland canvasback sex ratio increased from 3.98 in 1981 to 4.93 in 1982. This increase reflects the lower survival of females (vs. males) among the adult population. During years of good reproduction, large cohorts of young birds tended to lower the sex ratio because of their more balanced sex ratio.

Brood-rearing American Black Duck Females Use Beaver-created Habitats Extensively in Maine. Radio-marked female American black ducks were monitored with broods during 1977-80 in Maine. Eight marked hens moved broods an average of 1.2 km from the nest site to a rearing wetland. Only one hen moved her brood after the initial movement from the nest. The eight broods were observed on 21 wetlands, but 43 (51%) ducklings from these broods were reared on only three ponds. All of the ponds selected by the hens for brood-rearing contained active beaver colonies, and new flowages (<3 years old) received greater brood use than older ones. Broods did not use wetland types in proportion to their availability. Emergent wetlands were used more, and lakes and evergreen scrub-shrub wetlands were used less. The wetland components that attracted brood hens were areas of flooded alder-willow, herbaceous vegetation, and wetlands with large surface water area. Clearly, beaver harvest regulations that promote an expanding beaver population will result in the creation of brood-rearing habitat.

Nesting Effort of Individual Mourning Dove Pairs in Georgia. In 1979 and 1980, mourning dove pairs were radio-tagged at the beginning of the nesting season in Georgia. Attempts were made to recapture and retag these birds every 2 months through the nesting season so that nesting efforts and successes of single pairs could be recorded through the nesting season. In 1979, 11 pairs of mourning doves were radio-tagged through their complete breeding season; in 1980, 14 pairs were radio-tagged.

In 1979 the nesting season began in March and ended in September; only 9.7% of the nests were begun after 31 August. In 1980 the nesting season began in February and ended in September; 4.6% of the nests were begun after 31 August. The length of the breeding season averaged 174 days in 1979 and 180 days in 1980. In 1979 nesting success averaged 48% and an average of six young were produced per breeding pair. In 1980 nesting success averaged 37% and an average of 5.4 young were produced per breeding pair. The number of nesting attempts averaged 6.6 per breeding pair in 1979 and 7.6 per breeding pair in 1980. Most nests were lost during the egg stage, and predation and severe weather were the most common causes of these losses. The length of time between nesting attempts ranged from 4 to 21 days and averaged 9.4 days in 1979 and 1980.

Estimates of Juvenile American Black Duck Survival Rates Affected by Loss of Entire Broods. In Maine, recently completed radiotelemetry studies of juvenile American black duck survival during brood-rearing revealed that failure to consider loss of entire broods inflated the survival rate by nearly 20%. If survival rate is based on the product of the Class III brood size (5.26) divided by the expected number of ducklings at hatching (8.55), the apparent survival rate is 0.6152. However, when a method described by Mayfield which considers daily survival rates and accounts for loss of entire broods is used, the survival is significantly lower, only 0.4244.

As would be expected, younger ducklings had a survival rate about 10% lower than that of older ducklings and nearly 20% of the breeding females lost their entire broods. Therefore, brood production estimates that do not consider loss of entire broods should be used with caution because they overestimate actual recruitment by about 45%.

NATIONAL WILDLIFE HEALTH LABORATORY

National Wildlife Health Laboratory Serves Diversity of User Groups. A total of 422 different submissions for diagnostic assistance were received by the National Wildlife Health Laboratory (NWHL) during fiscal year 1982. These submissions accounted for 2,163 specimens of which 64% were waterfowl, 12% eagles, 16% all other bird species, and the remaining 8% mammals and other specimens.

The origin of these submissions included the National Wildlife Refuge System (23%), U.S. Fish and Wildlife Service (FWS) Special Agents (18%), other Federal agencies (24%), State conservation agencies (23%), and other public and private conservation organizations (12%). Documentation of cause of death for legal purposes was requested by Special Agents in 29 submissions (7%). In addition to the above, more than 1,700 tissue swabs taken from wild waterfowl in the Mississippi and Central flyways were tested for the presence of duck plague virus.

Fish and Wildlife Service research programs at other locations also benefited from NWHL activities during the year. Vitamin A deficiency was diagnosed as a problem in Mexican bobwhite quail being propagated under Endangered Species program activities, and the parasite *Capillaria hepatica* was identified as the cause of liver damage in captive Richardson's ground squirrels. In addition, cooperative efforts with FWS environmental contaminant studies resulted in more than 300 avian carcasses that were evaluated for infectious diseases before submission of tissues for contaminant assays.

The number of non-infectious diseases and chemical intoxications increased in fiscal year 1982. Organophosphate pesticides were identified as the cause of three waterfowl and one songbird die-off. Strychnine was responsible for mortality of yellow-headed blackbirds on a national wildlife refuge (NWR) and for the deaths of pigeons, urban birds, and a peregrine falcon at another location. Improper use of Avitrol was also identified as a cause of songbird mortality.

Lead poisoning from causes other than ingested lead shot was diagnosed during the year. In one instance mine tailings in Idaho were implicated, and in another ingestion of lead-based paint chips was the cause of death of Laysan albatross chicks on Midway Island.

The diagnosis of Tyzzer's disease (caused by *Bacillus piliformes)* in muskrats, tularemia in beaver, avian tuberculosis in a wild whooping crane, and starvation of a Mississippi Sandhill crane due to parasitism of the tongue by *Capillaria* sp. were some of the more interesting cases encountered during the year. An aberrant form of aspergillosis (caused by fungus) was also observed. Deaths occurred in Canada geese as a result of asphyxiation from blockage of the trachea due to fungal growth.

Wildlife Disease Affects Recreational Use of Wildlife Areas. Because tularemia is a bacterial disease of animals transmissible to humans, outbreaks of this disease in wildlife populations have public health significance whenever exposure of human populations is likely. This situation occurred in spring and early summer 1981 and 1982 at the Necedah NWR and adjacent State wildlife areas in central Wisconsin.

Beaver carcasses submitted to the NWHL were infected with tularemia. Field observations indicated substantial mortality in the Refuge's beaver population and on adjacent State wildlife areas. These findings caused local public health authorities to recommend closure of problem areas to the public until the epizootic was over.

Bacteria responsible for tularemia are released into water when infected animals die in the water. Man most often becomes infected by handling infected carcasses and by ingesting contaminated water. Biting insects such as mosquitoes and ticks that have fed on contaminated animals are another important means of transmission.

Fishermen, campers, hikers, and canoeists using the infected impoundments faced risks from the contaminated water and biting insects. Refuge personnel and State biologists faced additional risks associated with carcass removal and were instructed to use gloves and take other protective measures in carrying out this activity.

Tularemia is only one example of diseases of wildlife transmissible to humans. Other common examples include rabies, brucellosis, leptospirosis, and rodent plague. In addition to wildlife losses that occur, failure to adequatley address these types of disease problems can result in substantial loss of recreational opportunities at site-specific locations because of human health considerations.

Disease Investigations in an Urban Wildlife Refuge. Jamaica Bay Wildlife Refuge, part of the Gateway National Recreation Area, lies under the skyline of the World Trade Center, Empire State Building, Brooklyn high-rises, and JFK airport.

Wildlife in metropolitan areas is continually exposed to the by-products of industry and urbanization. National Wildlife Health Laboratory studies at this landfill site adjacent to the National Park Service's Gateway Refuge, Jamaica Bay, New York, disclosed salmonella infections in 28% of moribund and dead gulls, as well as 33% of a small sample of apparently healthy gulls. This bacterial disease is commonly associated with unsanitary conditions. *Photo by C. J. Brand.*

Thousands of birders, naturalists, and others from the surrounding metropolis visit the Refuge to observe the abundant bird life.

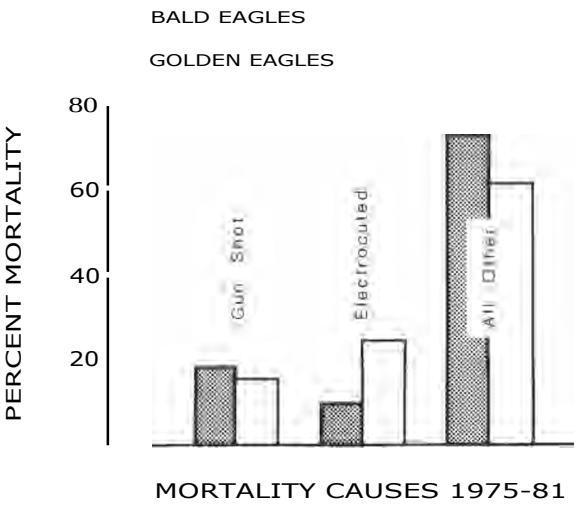
For the past 2 years NWHL was funded by the National Park Service to study avian botulism on the Refuge for the purpose of developing plans for control of this disease. Avian botulism occurred at low levels throughout the summer, but was only one of a variety of diseases found. Aspergillosis, a fungal disease, occurred frequently and was the major cause of bird mortality during late August and September during both years of the study. Other diseases included salmonellosis, renal coccidiosis, and heavy infestations of cestode, nematode, trematode, and pentastome parasites.

Field studies failed to disclose any focal points for botulinum toxin in living and dead invertebrates, algal mats, or sediment samples from shorelines and stagnant pools. In addition, there was no relation between water temperature, pH, dissolved oxygen, conductivity, alkalinity, or turbidity, and the onset of botulism.

Vertebrates dying from any cause can serve as a source of botulinum toxin for fly maggots. Birds consuming these maggots can then die from botulism. Avian botulism at Jamaica Bay may be initiated and perpetuated by this type of maggot cycle. Botulinum toxin was found in maggots associated with carcasses on the Refuge and it is likely that removal of carcasses from Refuge ponds during this study prevented large-scale botulism losses such as those reported in the past.

Bald and Golden Eagle Mortality 1975-81. Since 1975, bald and golden eagles found dead and submitted to FWS Special Agents have been sent to NWHL for necropsy. Following necropsy, appropriate bald eagle tissues (brain, liver, kidney, and carcass remains) were submitted to the Patuxent Wildlife Research Center for chemical analysis. The resulting data were entered into a computerized data storage and retrieval system at NWHL.

In 1975-81, 755 bald eagles and 520 golden eagles were submitted for necropsy. The four major causes of mortality among bald eagles were trauma (exclusive of shooting), 20.3%; shooting, 17.9%; electrocution, 9.4%; and various poisonings, 9.0%. Immature bald eagles were much more frequently shot than adults. For golden eagles, electrocution



Shooting and electrocution were major causes of mortality among the 1,275 bald and golden eagles necropsied at the National Wildlife Health Laboratory from 1975 through 1981. The observed differences between species for both causes were largely due to differing habits. Public education and law enforcement efforts have helped to reduce shooting as a mortality factor, but more such efforts are needed. Cooperation by power companies in modifying existing problem power lines has helped to reduce losses from electrocution.

(23.8%) was the largest cause of mortality, followed by trauma (exclusive of shooting), 22%; shooting, 15.2%; and various poisonings, 4.8%. Infectious diseases, including aspergillosis, pox, and various bacterial infections, accounted for mortality in 8.0% of the bald eagles and 7.0% of the golden eagles.

Computer analyses of these data revealed relations between causes of mortality and geographical locations. Bald eagles from Adak Island, Alaska, were usually electrocuted, whereas those from Kodiak Island and Kodiak Bay, Alaska, were much more likely to have been shot. Lead poisoning was diagnosed most often in bald eagles from the North Central States, a heavily hunted area where dead and crippled waterfowl form a major portion of the eagle food base. In Florida, motor vehicle strikes were a major mortality factor. In addition, these analyses disclosed an absence of bald eagle submissions from the western States of Montana, Idaho, Wyoming, and Nevada, or from Tennessee, Louisiana, and Alabama. Bald eagles are no longer present in Alabama, but are frequently observed in these other States.

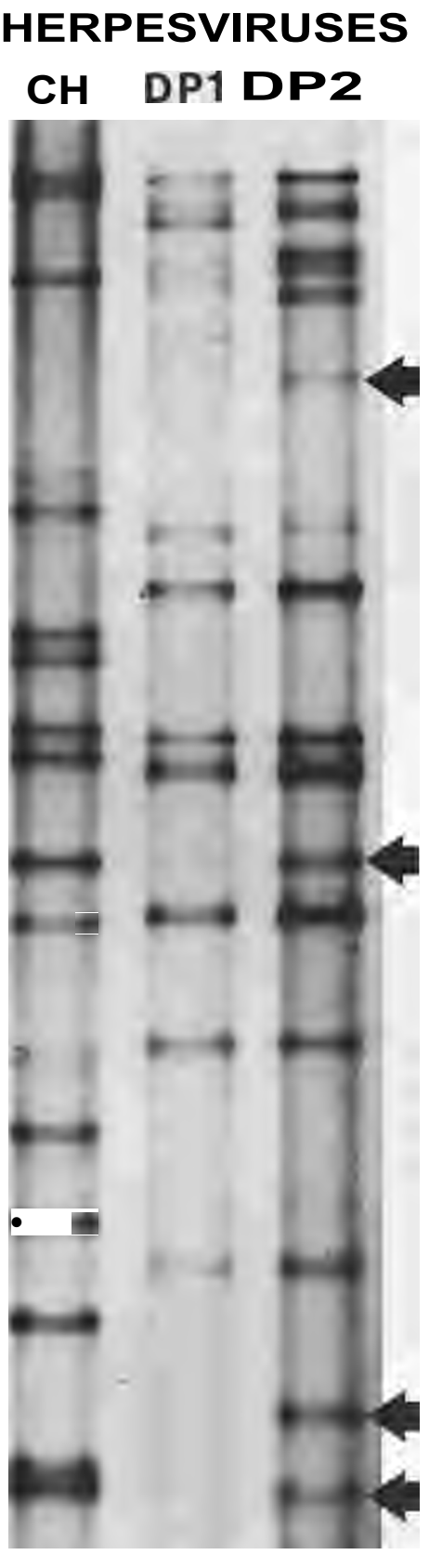
Non-hunting Mortality in Mississippi Valley Canada Geese. The **NWHL** participated in a 5-year study of the Mississippi Valley population of Canada geese to provide a data base on causes and trends of non-hunting mortality and to detect disease outbreaks within the population. Dead geese were systematically collected in major waterfowl areas in southern Illinois and east-central Wisconsin. Necropsy examinations were conducted at NWHL on over 3,300 of these geese from 1976 to 1981.

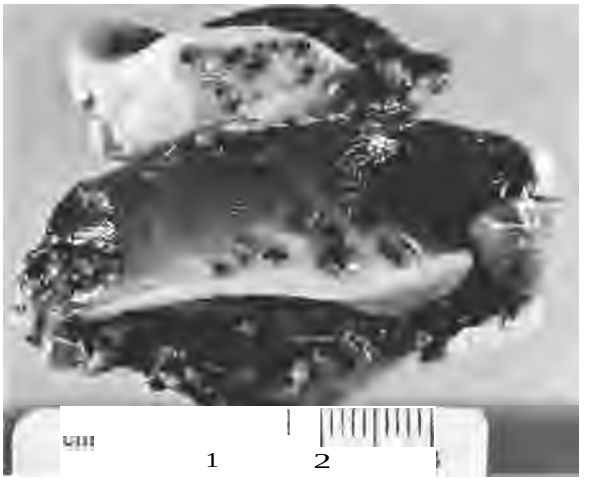
Mortality factors included mycotic (fungal) infections, avian cholera, and lead poisoning, as well as losses indirectly related to gunshot. Also noted was a condition of unknown cause that we have called necrotizing enteritis, of which 57 cases were identified in Mississippi Valley Canada geese during the study. Forty-two of the 50 cases from Wisconsin occurred in 1980, when unusually large numbers of birds remained throughout the winter. That particular winter was characterized by a lack of snow cover enabling geese to readily feed on an abundant supply of waste grains. Thirty-four of the 57 cases of necrotizing enteritis occurred in geese that also had lesions and chemical findings indicative of lead poisoning. The other cases occurred as either single entities or in conjunction with other debilitating factors such as aspergillosis and crippling.

Gross lesions of necrotizing enteritis are immediately recognizable upon opening a carcass. The affected portion of the intestine is distended and discolored purplish-red to black and the lumen is filled with dark material containing a mixture of blood and necrotic tissue. The involved area of the intestinal tract varied; lesions occurred in duodenum, lower small intestine, colon, and in both small and large intestines. Microscopic examination of the necrotic tissue revealed gram-positive bacilli morphologically compatible with *Clostridium* sp. in 47% of the cases examined.

A necrotic enteritis associated with *Clostridium perfringens* has been described in domestic poultry, captive wild birds, and in a die-off of free-flying mallards and shorebirds in Florida. *Clostridium perfringens* is suspected of causing the condition observed in Mississippi Valley geese. The high frequency of occurrence of this condition suggests dependence on some environmental factor. Sixty percent of the cases involved birds with concurrent lead poisoning. Development of necrotizing enteritis in those geese may have been enhanced by the paralytic effect of lead on the digestive system.

Poisoning of Laysan Albatross Chicks by Lead-based Paint. Several hundred 3- to 4-month-old Laysan albatross chicks were found sick or dead on Sand Island, Midway Atoll, in the South Pacific,





Nematode infections of the gizzards of geese are relatively common. However, pathogenic effects are generally limited to the epithelial (surface) lining of this structure. The cross section of this snow goose gizzard shows lesions in the gizzard muscle itself caused by the gizzard worm, *Epomidiostomum crami.* Heavy infections of this worm result in progressive degeneration of the muscle tissue. *Photo by B. Tuggle.*

during spring 1981 and 1982. The affected birds displayed signs of droopy wings, difficulty in raising their heads, weakness, incoordination, and apparent blindness.

A sample of the birds submitted to NWHL for necropsy revealed that the chicks were in good physical condition, but that liver lead levels ranged between 7.1 and 15.1 ppm, wet weight, and blood lead levels were near 9 ppm. These are considered lethal lead levels in waterfowl. A variety of miscellaneous material was present in the stomach including paint chips. The stomach contents from a bird with paint chips were analyzed for elemental lead and contained 63 ppm.

Although lead poisoning from consumption of lead-based paint is common in humans, domestic

Herpesviruses can be separated into groups by serological techniques, but distinguishing between group members such as duck plague is very difficult. This photo of an autoradiograph produced by ^{32}P labeled DNA fragments obtained from three herpesviruses, representing two serological groups, demonstrates that techniques are now available to identify groups of viruses and to separate members of a group. Only a few bands are shared by crane herpesvirus (CH) and either the duck plague vaccine (DPI) or a duck plague isolate (DP2), supporting the serological group differences between the crane virus and duck plague. Although many bands are common to the two duck plague viruses, there are several obvious locations (arrows) where bands specific to DP2 do not occur in DPI. This technique has great promise for tracing the movement of different duck plague isolates in waterfowl populations. *Photo by J. Runningen.*

animals, and wildlife species confined in zoos, lead poisoning resulting from the ingestion of paint has been infrequently reported in free-living wildlife species. The unique combination of the chicks' habit of picking up miscellaneous items and the availability of lead-based paint chips from deteriorating military buildings resulted in the deaths of these birds.

Avian Botulism Defies Stereotypes. Avian botulism is often characterized as a disease that occurs in waterfowl and shorebirds during the hottest periods of the summer in shallow alkaline wetlands of the western United States. However, this disease occurs under a variety of conditions throughout the United States, Canada, Mexico, and other parts of the world.

During fiscal year 1982 NWHL identified type C avian botulism outbreaks at 21 locations in 14 States. Although 10 of these outbreaks occurred in New Mexico, Arizona, California, Montana, and Idaho, the 11 remaining outbreaks occurred east of the Mississippi River in Minnesota, Wisconsin, Illinois, Iowa, Louisiana, Virginia, Florida, Maryland, and the District of Columbia. This clearly demonstrates the broad geographical distribution of this disease within the United States. Although 13 of these outbreaks occurred in June, July, and August, other outbreaks also occurred during cooler weather in November (Wisconsin and Northern California) and April (Idaho and Florida).

The outbreaks that occurred at Agassiz NWR in Minnesota, on Lake Michigan, Horicon NWR in Wisconsin, and Chincoteague NWR in Virginia, and previous outbreaks in major river systems clearly demonstrate that shallow alkaline waters are not a prerequisite for botulism outbreaks.

The essential components for an outbreak of avian botulism are the presence of toxigenic strains *of Clostridium botulinum* (a common soil bacterium), suitable environmental conditions for toxin production, birds, and invertebrates. Toxin production occurs as a by-product of bacterial multiplication under anaerobic conditions at relatively high temperatures in the presence of an appropriate source of protein such as invertebrate or vertebrate carcasses. Toxin is ingested during feeding and the disease cycle perpetuated when dead birds become flyblown and the resulting maggots are eaten by other birds. Since maggots are tolerant of botulinum toxin, they are capable of storing substantial amounts of toxin in their bodies. Botulinum toxin is stable when provided a protective "protein coat" such as invertebrate or vertebrate carcasses, but denatures relatively rapidly when "free" in the water. Cool weather outbreaks of avian botulism probably represent consumption of toxin produced during warmer months, but maintained within the aquatic environment in a protective protein coat.

Electron micrograph of a previously unrecognized herpesvirus isolated from a healthy bald eagle nestling. *Photo by D. Docherty.*

It is evident that avian botulism is a more complex problem than traditional perspectives would suggest. Within the United States, this disease has occurred from border to border, coast to coast, during every season of the year, and has caused the death of large numbers of terrestrial and aquatic birds.

Unknown Herpesvirus Isolated from a Bald Eagle Nestling. In 1980 cloacal swabs were obtained from nine bald eagle nestlings in the San Juan Islands off the State of Washington. A virus isolated from one of these swabs produced a cytopathic effect in duck embryo cells, contained DNA, and had a lipid coat — all properties characteristic of a herpesvirus. Electron microscopy confirmed this assumption by revealing viral particles with herpesvirus morphology.

The virus was reisolated from the original cloacal swab material. Serum neutralization tests indicate that this virus is not related to herpes simplex type I, duck plague virus, or inclusion body disease of falcons. Further comparisons are being made to determine if this virus represents a new entity or one closely related to some other herpesvirus.

Isolation was made from an apparently healthy eagle. Additional work, including species susceptibility studies, are required to assess the degree of risk the virus poses to bald eagles and other avian species.

NORTHERN PRAIRIE WILDLIFE RESEARCH CENTER

Avifaunas of the Great Plains Grasslands. For many years, phytogeographers have used the flora found on sample sites to classify and map vegetation that occurs over large land areas. However, similar attempts by zoogeographers to classify and map faunas have generally been thwarted by lack of sufficient quantitative data. Biogeographical information may be especially valuable to resource managers in that it may allow reasonable predictions of the abundance and species composition of the wildlife resources found on major habitats over large land areas. Thus costs incurred during the assessment of environmental impacts associated with public and private development projects can be reduced.

One large area currently undergoing rapid energy and agricultural development is the northern Great Plains. This area (about 600,000 km^2) includes portions of Montana, Wyoming, Colorado, North and South Dakota, and Nebraska. Because of its vastness and superficial homogeneity, the area has received little attention by zoogeographers. To develop a classification of the breeding bird communities found on the principal habitat types in this region, we divided and mapped the avifaunas of the native grasslands into six broad subregions. Mapping was based on polythetic, divisive indicator species analysis applied to quantitative data obtained from 582 sample plots. Common, ubiquitous species and rare species had little classification value and were eliminated from the data set used to derive the avifaunas. The basis of initial division of the plots probably was nest-site requirements based on morphology of the dominant plant species. Later divisions probably were related to nesting cover requirements based on vegetation height or density, habitat heterogeneity, or possibly the existence of mutually similar distributions or shared areas of greater-than-average abundance for certain groups of species.

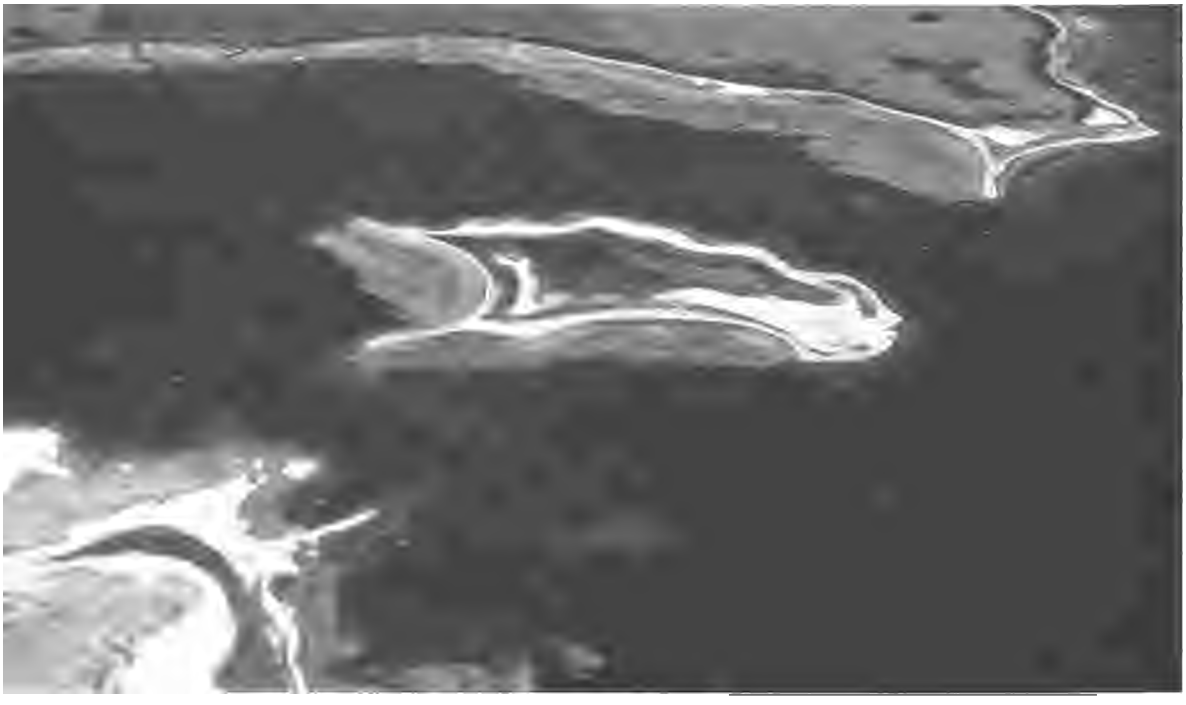
Knowledge of the effects of grazing on habitat use by the breeding bird species was used to interpret the results of the indicator species analysis. Moderate grazing resulted in greater species richness in nearly all subregions, whereas effects of grazing on total bird density were more variable. Effect of grazing on density of several species of birds was similar among subregions; however, effect on several common species probably varied among subregions.

Species with high indicator scores at various decreasing levels included grasshopper sparrow, Baird's sparrow, chestnut-collared longspur, sage thrasher, vesper sparrow, Brewer's sparrow, upland sandpiper, Sprague's pipit, clay-colored sparrow, and McCown's longspur.

Concentrated Nesting of Mallards and Gadwalls on a North Dakota Island. Island nesting is a characteristic feature in the habitat selection of several species of waterfowl. The gadwall and mallard are the principal dabbling duck species for which concentrations of nests have been observed on islands in lakes of the prairies and parklands of North America. Apparently, these two species possess the physiological and behavioral traits that are conducive to formation of nest concentrations and high production in suitable habitat niches. Nesting mallards and gadwalls were studied during 1976-80 on a 4.5-ha island in 385-ha Miller Lake in northwestern North Dakota.

During the 5-year study, 2,561 duck nests were found on island A, located 180 m offshore; 1,500 (59%) were mallard and 861 (34%) were gadwall. In patches of shrub cover, which contained the greatest concentrations of nests, annual densities of mallard nests ranged from 241 to 389/ha and gadwall nests ranged from 139 to 237/ha. Nests of other duck species found on the island included American wigeon (86), blue-winged teal (1); northern shoveler (2); northern pintail (53); redhead (12); canvasback (2); lesser scaup (10); and unknown (34). Over 97% of the nests were placed in four patches of shrub cover composed of western snowberry and Woods rose. The shrub cover totaled about 1 ha and made up about 30% of the island's vegetation.

Average hatching success was 85% for clutches of all species. Abandonment averaged 14% and was the major cause of egg failure. It appeared that behavioral interactions or physiological stresses were the major factors leading to nest abandonment. No mammalian predators occurred on the island during the study and only 15 nests (< 1%) were destroyed, primarily by ring-billed gulls or California gulls. A minimum of 15,960 ducklings, including 9,300 mallards and 5,150 gadwalls, hatched on the 4.5-ha island. Hatchability rates of eggs in successful nests averaged 83% for mallards and 87% for gadwalls. In spite of the close spacing of nests, most individual hens were able to maintain normal nests. Eighty-one percent of the mallard clutches contained 7-13 eggs and 81% of the gadwall clutches contained 8-14 eggs.



Certain islands in lakes within the prairie and parkland region of North America provide highly productive nesting areas for waterfowl. During 1976-80 this 4.5-hectare island in Miller Lake, North Dakota, contained 2,561 duck nests, of which 59% were mallard and 34% were gadwall. *Photo by H. F. Duebbert.*

A complex of 97 natural wetlands occurred within 3 km of the island and, in addition to Miller Lake, provided a total wetland base of 563 ha. Forty wetlands (59 ha in area) were classed as seasonal (Class **III)** and 7 (71 ha) were semipermanent (Class IV). The lake, along with wetlands on the mainland, provided aquatic habitat to furnish the food resources and maintenance area for hens and ducklings associated with the island. Gadwall hens and broods utilized areas of Miller Lake adjacent to freshwater seeps, whereas mallard hens led their broods to freshwater wetlands on the mainland.

This study provided an outstanding example of the potential for high reproduction levels of mallards and gadwalls in small areas of nesting habitat in predator-free environments. Management of existing islands and construction of new islands represent excellent opportunities for development of nesting sites for waterfowl. In planning island construction or cover development on existing islands, the availability of aquatic habitat for nesting hens and brood-rearing, along with potential predator impacts, should be carefully evaluated.

Saline Lakes in North Dakota. Within the prairie pothole region of North America an abundance of shallow wetland basins developed under the influence of glaciation and a semiarid climate. The purpose of this research was to better understand the hydrologic regimes that interact with each wetland basin to control its chemical characteristics and subsequently the plant and invertebrate communities. Saline lakes contain elevated salt levels and usually function as hydrologic sumps in topographic lows associated with glacial outwash or meltwater channels in south-central North Dakota. Of 178 lakes examined, 35, 22, and 10% exceed salinity readings of 5, 10, and 15 mmhos/cm, respectively. Sulfates dominated the anions of the North Dakota saline lakes and sodium, magnesium, and potassium were the dominant cations.

Salt concentrations of saline lakes, and subsequently their biotic characteristics, are dictated by hydrologic regimes that control water balance. Salts transported into hydrologic sumps concentrate in the lake basin as water is evaporated to the atmosphere. Changes in the salt content of saline lakes produce shifts in the species structure of invertebrates and plants that are utilized by ducks. Brine shrimp were consistently found in salt lakes with relatively stable water levels but occurred in

Avocets and other species of shorebirds nest almost exclusively on the mudflats of saline lakes. *Photo by H. F. Duebbert.*

Many species of shorebirds use saline lakes for feeding and resting during migrations through the prairie pothole region. *Photo by H. F. Duebbert.*

seasonally flooded lakes only during wet cycles and in lakes of lower salt content during drawdown when salt concentrations increased to levels suitable for this species. When water levels increased and lowered the salt content, other species of fairy shrimp replaced brine shrimp. Amphipods and snails that dominate fresh prairie lakes do not tolerate high salt concentrations and are restricted to spring seepages on lakes of high salt content.

Waterfowl are attracted to saline lakes where they feed on a variety of salt-tolerant invertebrates, vascular plants, and filamentous algae. Adult birds feed on saline lakes and fly to fresh water that is usually within a reasonable flying distance. There is a paucity of information, however, on the suitability of this type of habitat for ducklings.

Hydrologic characteristics of saline lakes determine whether conditions are suitable for ducklings by controlling salt concentrations and the availability of food and fresh water. Broods observed during a 2-year period occupied lakes that functioned as groundwater discharge areas. Ducklings observed during brood surveys were closely associated with spring seepages or areas receiving intermittent inflow from wetlands of lower salt content.

Seepages not only provided fresh drinking water but also supported stands of tule bulrush and cattail that provided cover for broods. Tule bulrush and cattail do not tolerate high salt concentrations and as the salt levels increased at greater distances from seepage influence, they were replaced by alkali bulrush. In areas where spring seepages were absent, emergent vegetation at the shoreline was also absent. Seepages entering at the shore periphery were consistently lower in salt content than the main pools.

Saline lakes with water supplied only by surface runoff did not support broods even though they contained water during the brood-rearing season and foods that attracted breeding dabbling ducks. The lakes lacked seepage areas with actively flowing water on the shore periphery and were isolated from a source of fresh water. Fresh water appears to be a requirement for initial duckling use because recently hatched ducklings cannot tolerate high salt concentrations unless fresh water is available.

Ducklings first encountering prairie saline water must initially process all of the salts without the benefit of functional salt glands. Once the supraorbital salt glands become fully functional, ducklings can more efficiently process the sodium chloride component. As salt levels increase, however, magnesium and sulfate concentrations may limit duckling use of prairie lakes before total salt content is a factor.

The potential exists for creating brood habitats on saline lakes by management strategies to provide fresh water where it is not currently available. While feeding on saline lakes, ducks have been observed to use fresh water in ponds created in seepage areas for livestock. Resource managers who acquire wetland complexes, manipulate water levels, or assess the quality of wetland components will benefit from research that defines the ecology of saline lakes and tolerances of salts by waterfowl.

Fall Movements and Wintering Affinities of Canvasbacks Staging on the Upper Mississippi River. Canvasbacks traditionally interrupt their fall migration to feed and rest on selected open-water lakes and rivers throughout the upper Midwest and Great Lakes regions. These stopover sites, known as staging areas, are strategically located along major flight corridors. Staging areas where canvasbacks historically gathered in large numbers include Lake Christina and Heron Lake in Minnesota; Lakes Poygan, Koshkonong, Butte des Morts, Winnebago, and Winneconne in Wisconsin, and the Illinois River in Illinois. By 1960, however, use of these staging areas by canvasbacks declined dramatically during fall. At the same time, canvasback use of navigational pools 7, 8, and 19 on the Upper Mississippi River began to increase. Peak numbers increased 22 % annually from 1961 to 1977 on pools 7 and 8. A similar rate of increase was noted on pool 19 until 1970 when peak numbers began to stabilize. Deterioration of former habitats, mainly from siltation, pollution, eutrophication, and rough fish are suspected as causal factors responsible for these changes.

Because of the relocation of these staging areas, a study was conducted during 1973-77 to investigate the distribution of migrating canvasbacks relative to use of traditional wintering habitats. Previous to this study, the affiliation of discrete wintering populations to staging areas on the Upper Mississippi River, and the degree to which these populations are segregated during migration, were unknown. Data on dispersal patterns, population turnover, and winter distributions were obtained by color-marking 1,488 male canvasbacks from 1973 to 1975. Additional data were obtained by banding 3,789 canvasbacks of both sexes from 1973 to 1977 on pools 7 and 8 of the Upper Mississippi River near La Crosse, Wisconsin, and on pool 19 near Keokuk, Iowa.

Information gathered from 1,005 observations of color-marked canvasbacks and recoveries of 258

banded canvasbacks suggests that birds staging on pools 7 and 8 are composed of two distinct wintering populations. One group migrates eastward to staging areas on the eastern Great Lakes and then southward to winter in the Atlantic Flyway, primarily the mid-Atlantic coastal region. A second migrational route extends southward along the Mississippi River to winter in the central and lower Mississippi and eastern Central flyways. Sightings of color-marked birds and band-recovery information suggest that canvasbacks moving south subsequently stage on pool 19 before continuing on to wintering habitats farther south. Observations of individuals marked by different dye colors demonstrated a constant turnover of birds. Therefore, it is difficult to determine the total numbers of canvasbacks using these staging areas. The wintering distribution of birds marked and banded on pool 19 and those migrating south from pools 7 and 8 was similar, which indicates that these birds follow the same migration route and are not discrete populations. Canvasbacks staging on pool 19 did not migrate eastward to the Atlantic Flyway as previously suspected. They also exhibited strong fidelity to specific wintering habitats in the Mississippi and Central flyways in subsequent years. Canvasbacks were widely distributed in small numbers on many rivers, lakes, and reservoirs along the Mississippi Valley, Gulf Coast, and eastern Texas regions of the Mississippi and Central flyways. By comparison, canvasbacks wintering in the Atlantic Flyway tended to concentrate in larger numbers on fewer areas with a long history of use such as Chesapeake Bay, Currituck and Pamlico sounds, and the coastlines of Virginia, Delaware, and New Jersey. Regional variation in canvasback distribution patterns during fall and winter appear to reflect different strategies of exploitation based on resource predictability and availability.

The integration of discrete wintering populations on pools 7 and 8 of the Upper Mississippi River demonstrate the strategic importance of this area as a major staging area. The river habitats facilitate movements of canvasbacks into portions of the Central, Mississippi, and Atlantic flyways. Therefore, food availability and the arrangement of these staging areas are critically important to maintaining migrational integrity between breeding and wintering grounds. Investigators are continuing to study resource availability and energetic relations influencing the migrational strategies of canvasbacks. Knowledge of fall movements and wintering affinities of canvasbacks will aid management efforts to preserve critical habitats and prevent further degradation of unique migration and wintering habitats.

Measurements are taken on tule white-fronted geese during a study to determine their population, distribution, and habitat use on wintering grounds in California. *Photo by D. Gilmer.*

Activities of Tule White-fronted Geese Wintering in California. A 4-year study was conducted to determine population size, distribution, chronology of movement, and habitat use of tule white-fronted geese wintering in California. This subspecies is believed to winter exclusively in the Central Valley of California. Many of these geese had been captured and marked with neck collars or radio transmitters on breeding grounds at Redoubt Bay, Alaska, and on wintering areas. The tule goose is larger and darker and has different behavioral patterns than the Pacific white-fronted goose, which is common in the Pacific Flyway.

Summer Lake Wildlife Management Area (WMA) in south-central Oregon and Lower Klamath National Wildlife Refuge (NWR) in northeastern California are primary fall migration stopover areas. A minor migration stopover area was on private lands near Malheur NWR in southeastern Oregon, an area that is also used by large numbers of Pacific white-fronted geese.

Primary wintering areas were in the Sacramento Valley at Sacramento NWR and Delevan NWR. Peak numbers of tule geese on these refuges were 3,000-4,000 birds. A secondary wintering area at Grizzly Island WMA adjacent to Suisun Bay was used by an additional 1,000-1,500 geese. The total wintering population remained stable the last two years at about 5,000 birds. Production of young in 1981 was considered good at 39 immatures per 100 adults.

The hunting bag limit and season length were again altered for white-fronted geese in 1981-82.

As a result, the number of these geese shot at Sacramento and Delevan NWR's was 564 compared with over 800 birds in the 1978-79 season. These high numbers were in marked contrast to much lower numbers taken in 1979-80(110) and 1980-81 (148) under more restrictive hunting regulations. The proportion of tule geese in the harvest varied between 40 and 70% during these years and exhibited an inverse relationship to the magnitude of the total white-fronted goose harvest.

The distribution, habitat use, and movements of tule white-fronted geese in California during winter have been determined, but a portion of the population (apparently mostly subadults and unsuccessful nesters) uses one or more unknown migration stopover areas. The spring migration route between stopover areas in southern Oregon-northern California and the Alaskan breeding grounds remains unknown.

Hunting Closures Increase Numbers of Aleutian Canada Geese. Closures on hunting of Canada geese on key migration and wintering areas in California have resulted in a dramatic increase in the numbers of the Aleutian Canada goose, an endangered species. Introduction of arctic foxes on principal nesting islands in Alaska had decimated breeding populations, leaving birds only on Buldir Island in the Aleutian chain. Because Aleutian geese are similar in appearance to certain other subspecies of Canada geese and intermingle with them on migration and wintering areas, little was known of their movements after nesting. In 1974 recoveries by hunters of geese banded on Buldir revealed definitely for the first time that birds migrated to and wintered in California. In the spring of 1975 biologists discovered banded birds on the northern coast of California. It was believed that these birds represented nearly the entire population of Aleutian Canada geese on their northward migration staging area.

Starting in the fall of 1975 the State of California closed three areas to hunting of Canada geese to provide protection to the main part of the Aleutian goose population. From spring 1975 to spring 1982 the population of Aleutian Canada geese increased from 790 to 2,600. Corresponding figures in the fall ranged from 1,380 in 1976 to 2,700 in 1981. The average annual increase in the population was calculated at about 18%. Some birds were shot legally in the fall and winter outside the closed areas or seasons, or illegally within the closed areas and seasons. However, the results demonstrated clearly that restrictions of the type instituted were effective ways to reduce hunting mortality. This action has been primarily responsible for a reversal in the downward trend in the population.

Feeding Ecology of Northern Pintails and Mallards in Managed Impoundments. Studies were conducted on the Lower Klamath National Wildlife Refuge during the spring and fall from 1979 to 1981 to obtain information on the feeding ecology of northern pintails and mallards. One hundred sixteen northern pintails and 97 mallards were collected on various types of marshes. This information aids managers in obtaining optimum utilization of managed impoundments. Pintails collected in March had fed mostly on seeds produced the previous year in impoundments that had been drawn down and later reflooded. Mallards were found more commonly in permanent marshes, and specimens collected in those habitats in March had fed primarily on invertebrates. As invertebrates, particularly midges, became more abundant during the spring, both species increased their consumption of them, thereby helping to fill the demand by laying females for a high protein and fat diet. Invertebrate consumption was still substantial in September but dropped later in the fall, particularly by pintails, which fed heavily then on red goosefoot seeds. Abdominal fat reserves and body weights of birds decreased through the spring during the active part of the breeding season. Fat reserves were still low in September, reflecting the subsequent demands of molting and migrating, but increased later in the fall. Birds collected in November and January, when cold weather raised existence metabolism levels, had high to very high abdominal fat reserves. These findings demonstrate the need to manage marsh water levels to provide for a variety of habitats to meet the feeding requirements of ducks whose feeding requirements differ by species, breeding conditions, and time of year.

Bioenergetics of Northern Pintails Wintering in the Central Valley of California. More northern pintails spent the winter months in the Central Valley of California than in any other geographic area of North America. Extensive losses of wetlands since the turn of the century have left only remnants of habitat that must provide food and sanctuary for this large, mobile population of birds. Continuing habitat losses and concern for the welfare of wintering waterfowl in California prompted initiation of studies in 1979 to better understand food and habitat requirements, body condition, and behavior of pintails during winter. Feeding ecology, activity budgets, and energetics formed the core of these

studies. Field work was completed in the spring of 1982.

Foods consumed by pintails from August through March varied among habitat types, individuals, and season. Important seeds included rice, millet, smartweeds, swamp timothy, bermuda grass, and nutgrass. Rice, which dominated pintail diets throughout the period, was obtained from lure crops on national wildlife refuges in August and September and from harvested commercial crops in the surrounding farm fields after September. Invertebrates, such as midge larvae and snails, were most important in early fall and in February and March. Few invertebrates were eaten during midwinter.

When pintails first arrived in the Central Valley in August and September, their body reserve of fat was low, amounting to about 12% of wet body weight. Peak fat load (22-26%) occurred in November or October each year. Reserves declined again in January or December to a range of 14-21%, and then peaked at up to 30% fat before migration in February-March. Females were fatter than males in most months during all 3 years of the study. Body weights followed a similar cyclical pattern of low weights in early fall and mid-winter. Peak weights were attained in late fall and high weights occurred again in spring, just before migration.

Lean pintails, mostly adult males arriving at wintering areas in August and September, require large quantities of high-energy protein foods to facilitate rapid weight gain before the onset of winter and intense courtship activity. Courtship demands high energy because of the great amount of flying time involved and the many months over which the activity occurs. After October, a large proportion of the natural and planted foods on the NWR's has been consumed. At this time the birds depend on rice from private agricultural fields to provide their energy needs through the winter. When the hunting season ends in January, the birds have low body weight and stored fat. This condition coincides with the end of intensive courtship during which time foods can be obtained only at sites at various distances away. In February and March, courtship activity declines and feeding on invertebrates increases. The absence of hunting activity at this time enables the birds to make greater use of available habitats; therefore, body weights and fat stores increase accordingly.

Body weights and carcass fat content of pintails during two winters with above-normal precipitation exceeded those during one dry winter. Annual rainfall in the Central Valley varies widely from year to year and this in turn influences the amount of winter habitat available.

Restoration of a Former Tidal Salt Marsh. Research conducted in northern California revealed that management efforts were successful in achieving partial restoration of a former coastal salt marsh. The marsh, located on Humboldt Bay, was converted in the late 1950's to a log pond by diking to retain upland runoff. In 1969 the pond was drained and abandoned, becoming occupied mostly by upland grasses and forbs. Restoration of this diked area to a tidal marsh was undertaken to compensate for destruction of another tidal marsh in the bay resulting from construction of a marina. The restoration was to be achieved through breaching of the dike, which was accomplished in December 1980. In the 1.5 years following breaching the upland vegetation was killed and replaced rapidly by typical salt-marsh vegetation which had survived in a few poorly drained spots within the diked area. Species showing the greatest increase were California cordgrass, arrowgrass, pickleweed, and saltbush. At the present rate of colonization it is estimated that it may be 5 or more years before restoration to a salt marsh is completed. Because of the 11 years of dewatering, the level of a diked area appears to have subsided about 1 foot. Thus, some of the formerly vegetated areas have become ponds or tidal mud flats.

Conversion of the area has affected the animals studied in various ways. Species adapted to drier areas, such as the northern alligator lizard, common and western terrestrial garter snakes, marsh wren, western meadowlark, American goldfinch, savannah and song sparrows, vagrant shrew, western harvest mouse, and California vole, were reduced in number or eliminated. Other species such as the Pacific tree frog and red-legged frog, which require fresh standing water, were also eliminated. Conversely, species adapted to mud flats or shallow ponded water, such as the great and snowy egrets, greater yellowlegs, least and western sandpipers, and long- and short-billed dowitchers, increased after tidewater was introduced. It is expected that further changes will occur as the salt-marsh vegetation becomes more widespread and dense, and as tidal drainage systems become better developed.

Mammals and Nonmigratory Birds

DENVER WILDLIFE RESEARCH CENTER

Raptor Inventory on Potential Coal Leases in Western North Dakota. A raptor survey covering about 22,274 km^2 of western North Dakota was completed in fiscal year 1982. The objective of this study was to locate and map the nesting sites of golden eagles and other raptors of interest to Federal agencies, including prairie falcons and ferruginous hawks. These data will be used by the Service and the Bureau of Land Management to protect important raptor nesting habitats while planning for future energy development activities. The nesting sites of 124 golden eagles, 64 ferruginous hawks, 23 prairie falcons, and 18 burrowing owls were located, mapped, and photographed. Raptor populations were most abundant and diverse in the Little Missouri Badlands where natural habitats have not been significantly altered by agricultural development.

Distribution and Status of the Endangered Bolson Tortoise. A cooperative study by the Fish and Wildlife Service (FWS), Mexico's Fauna Silvestre, and university personnel has provided important new information on the Bolson tortoise. This species is restricted to the Bolson de Mapimi region of the Chihuahuan Desert in north-central Mexico. It is the largest terrestrial reptile in North America. Despite its size (up to 40 cm long) and conspicuous large burrow, the Bolson tortoise was first described as a distinct species in 1959. Its distribution, population size, and general ecology were poorly known until recently.

Today Bolson tortoises occur in disjunct pockets of suitable habitat where humans have not disturbed them (they are eaten by some people). Roads, rail lines, agricultural fields, villages, and grazed lands now constitute most of the habitat of the tortoise. Few viable populations remain within its former range, an area less than 100 miles wide and 150 miles long.

Field studies show relatively low densities of 11 active burrows on a 25-ha plot in southeastern Chihuahua and only 5 active burrows on the same size plot in western Coahuila. Both sites were selected as areas of favorable habitat with viable tortoise populations. Apparently, Bolson tortoises occur in colonies or in limited areas within the range, mostly below rocky areas and above playas (which sometimes flood). Extensive field surveys and native reports indicate a drastic decline in tortoise numbers in recent years.

Efforts to protect this species include an educational program aimed at ranchers, increased involvement by Fauna Silvestre, and formation of a private council to promote the conservation of the Bolson tortoise.

Kenai National Wildlife Refuge Moose Carrying Capacity Model. The Denver Wildlife Research Center (DWRC) is developing a carrying capacity model for moose on the Kenai National Wildlife Refuge (NWR) in Alaska. Forage biomass, protein, digestibility, and moose energy requirements and expenditures are basic components of the model. Over 300 stands of vegetation on the Kenai NWR have been sampled for forage availability and represent over 20 stages of succession and disturbance in the boreal forest. Quality of important forage plants has been determined in 18 locations that represent a broad variety of succession and disturbance. Tame, trained moose are being used to evaluate energy requirements and expenditure in respiration chambers at the Kenai Moose Research Center. Seasonal protein requirements and energy expenditure have been developed for tame adult moose and have elucidated the partitioning of energy through the moose. Although field aspects of the project were terminated in February 1982, data are being summarized for final development of the model. The model will have wide applicability in Alaska and Canada for evaluating the effects of habitat modification for economic purposes and for moose habitat management.

Evaluation of a Deferred-rotation Grazing System **on Wildlife on the Sheldon National Wildlife Refuge.** The Sheldon NWR encompasses about 575,000 acres of the Great Basin in northwestern Nevada. Cattle grazing is an important economic use on the Refuge and the Sheldon's Renewable Resources Management Plan of 1980 made major changes in the grazing management policy; objectives were to improve wildlife habitat and overall range condition. DWRC began a project in 1981

The Bolson tortoise is the largest land reptile in North America and occurs in the Chihuahuan Desert of Mexico. Cooperative studies with Fauna Silvestre, Mexico's Wildlife Department, have determined the distribution, general ecology, and status of this endangered species. *Photo by R. B. Bury.*

The barefoot gecko *(Anarbylus switaki),* a lizard new to the fauna of the United States, is known from rock habitats in the desert foothills of southern California. *Photo by T. H. Fritts.*

to evaluate the effects of grazing on wildlife and their habitat in the shrubby rolling hills and mahogany rocklands range sites on the Sheldon NWR. A 1,000-acre exclosure was constructed to compare wildlife and their habitat in a nongrazed area with that in a deferred rotation grazing system. Four subprojects are under investigation which compare cattle use with non-use on (1) browse production and utilization; (2) mule deer food habits and forage availability and quality; (3) populations, reproductive levels, and body condition of small mammals; and (4) passerine bird numbers and habitat use. During 1982, browse production and utilization estimates were made on bitterbrush, curlleaf mountain-mahogany, and snowberry at 90 transects in the study area. Tame mule deer were observed in six feeding pens before, during, and after cattle were on the allotment and vegetation in 60 quadrats in each feeding pen was clipped to assess forage availability, plant phenology, and nutritional quality. Over 120,000 deer bites were classified during the 1982 feeding trials; over half of the bites were on bitterbrush. Small mammals were trapped monthly from May through October at 24 traplines; 9 species (523 individuals) were captured with no apparent differences in populations inside and outside the exclosure. Passerine bird censuses were conducted at 241 points and 431 birds were counted; vegetative characteristics around each bird perch site were measured.

The objective of the 4-year grazing research project at the Sheldon NWR is to integrate knowledge about the effects of grazing on a wide variety of wildlife and their food and cover plants so that the Refuge can make adjustments in the grazing system that will effectively benefit target wildlife species.

Response of Willow Communities to Grazing. In western States, cattle graze preferentially in riparian sites due to the availability of water and better forage. The impact of short- and long-term grazing on the dynamics of a high-altitude willow community is being quantified at Arapaho NWR. Historical grazing patterns do not appear to influence the species composition of willows present on these high-altitude sites. Although previous work has shown that grazing alters the physical structuring of individual plants, the floristic structuring of the woody community appears to be influenced more by edaphic factors (possibly soil moisture levels) early in the growing season. Cattle grazing would appear to be compatible with managing the Refuge as a wintering site for native ungulates that show species-specific browse preferences.

Unusual Lizard Found in the United States. A diminutive native gecko, new to U.S. fauna, was discovered in southern California during ecological field work. The lizard, the barefoot gecko, is restricted to rock habitats in the Peninsular Mountain Range and spends most of its life hidden in rock crevices and cavities. Research was conducted to establish the taxonomic relationships of the lizard, to determine its ecological and geographical distribution, and to investigate the lizard's abundance, activity patterns, and faunal associations.

A single specimen of the barefoot gecko was discovered on the Central Baja California Peninsula of Mexico in 1974. Other specimens are now known to inhabit San Diego and Imperial counties in California and an intermediate site in Baja California, Mexico. Barefoot geckos from localities in the United States differed slightly in coloration and size from those from Baja California, but all were considered to be the same species. The gecko is distinguished from other native geckos by unusually small scales on the toes, which aid in locomotion on rock surfaces, and by bold black and white bands on the tail. Barefoot geckos with regenerated tails have spotted tails. The tail may be greatly enlarged with fat during periods of abundant food.

The barefoot gecko was found in a variety of rock habitats in the Upper and Lower Sonoran Life zones at elevations of 300 to 600 m. The lizard was previously overlooked and difficult to locate, in part because of the problem of searching rock habitats. The species may be active throughout the year but spends little time outside the crevices and cavities normally occupied. Consequently, observations are few and knowledge of the barefoot gecko remains limited.

Habitat Requirements and Breeding Success of Charadriiform Birds Nesting at Salt Plains National Wildlife Refuge, Oklahoma. Habitat requirements and breeding ecology of American avocets, least terns, and snowy plovers were studied on the flats of the Salt Plains NWR in northwestern Oklahoma. Direct counts of adult birds revealed 46 pairs of American avocets, 80 pairs of least terns, and 325 pairs of snowy plovers breeding on the salt flats in 1977. Population sizes during 1978 were 53, 135, and 260 pairs, respectively, for the three species. A total of 183 nests of snowy plovers, least terns, and avocets were marked and their progress monitored. Measurements of environmental variables near the nest sites revealed that all three species nested in clumped distributions near streams or

standing bodies of water, independent of woody debris or other discernible structuring of the flats. Food sources utilized by the birds included terrestrial and aquatic insects and small fish inhabiting the streams. All foods eaten by the birds occurred on the salt flats proper; most food species were associated with the freshwater inflow streams. The streams were essential proximate and ultimate components of the nesting habitats of these three species.

The Herpetological Components of Florida Sandhill and Sand Pine Scrub Associations. Investigations of the herpetofauna of the peninsular Florida sandhills and sand pine scrub revealed a diverse complex composed of a minority of xeric-adapted species combined with an array of wide-ranging and aquatic species that can be found in many Florida habitats. The xeric-adapted species required sand for burrowing or sand-swimming. The tortoise *(Gopherus)* digs burrows that serve as shelter for several other species; the wide-ranging generalist species, however, require none of the specialized conditions of the sandhills and scrub. Sand scrub, especially early successional stages, contains 22 species of reptiles and amphibians, which is more than in any other of a wide range of peninsular Florida habitats. Apparently the herpetofauna is responding to the dry, well-drained soil and patches of sand, free from roots, rather than to any aspect of the vegetation. The sand-swimming species (mole skink, Florida crowned snake, and sand skink) depend on periodic disturbance (e.g., fire and clear-cutting) to remove the matted understory and pine canopy. The widespread distribution of these forms attests to the continuous presence, throughout history, of a mix of successional stages in both the sandhills and sand pine scrub.

Estimating Production of Paper Birch and Utilization by Browsers. A 4-year study was conducted to develop methods for estimating production and utilization of paper birch on the Kenai NWR, Alaska. Twenty-four individual birch saplings were tagged in each of 101 stands. Fall estimates were made of annual production and spring estimates were made of utilization of each tagged sapling. Regression equations were developed from clipped-plant measurements and weights and used to estimate production of each tagged sapling. Diameters of browsed twigs on the tagged saplings were measured and regression equations were developed to estimate how much annual growth had been removed from each sapling. Three estimates of utilization were developed for each stand: percentage current annual growth (CAG) weight browsed, percentage CAG twigs browsed, and percentage birch saplings browsed. These were highly correlated. An estimate of percentage CAG weight browsed usually requires clipping studies; however, that value can be estimated reliably with either of the latter two estimators of use. The ability to estimate accurately these variables is important inasmuch as paper birch occurs at high densities relative to other browse species at Kenai and is an important component of the diet of moose.

Evaluation of Rest-Rotation Grazing in the Missouri River Breaks on the Charles M. Russell National Wildlife Refuge, Montana. The vegetative differences between three grazing treatments after 12 years in a 4-year rest-rotation grazing system for cattle in the Missouri River Breaks were analyzed. Treatments were established in two locations in three landforms: benches, breaks, and bottoms. In each location, one treatment was not fenced and allowed free use by cattle and game ungulates; one was fenced only while cattle were on the range; and the third was fenced to exclude all grazing ungulates. After 12 years all vegetation was clipped from 30 randomly located 2- x 5-dm quadrats in each treatment, sorted by species, and oven-dried. Bluebunch wheatgrass and western wheatgrass produced significantly more biomass in protected treatments in three of the six treatment sets, whereas junegrass and blue grama tended to produce significantly less biomass in protected treatments. Yellow sweetclover and scarlet globemallow produced more in protected treatments than in those open to grazing. Most forbs occurred in such small amounts that they were not compared. No significant differences occurred in shrub biomass among treatments. Overall differences in biomass production under the grazing system were not greatly different from that in treatments protected from cattle grazing.

Sea Turtle Distribution Along the Boundary of the Gulf Stream Current off Eastern Florida. Aerial surveys, to 222 km off the east coast of central Florida during August 1980, revealed that marine turtles were distributed in a narrow zone west of the Gulf Stream. Of 255 loggerhead turtles, only 3 were observed east of the western boundary of the Gulf Stream. Radiometric thermometry revealed that the waters occupied by most loggerheads were markedly cooler than the nearby waters of the Gulf Stream. All 18 leatherback turtles were seen west of the Gulf Stream in waters less than 70 m deep. Marine turtles off eastern Florida are confined seasonally to nearshore waters west of the Gulf Stream.

The records of leatherbacks in nearshore waters are in contrast with a deep-water oceanic ecology often hypothesized for this species.

Rodent Occurrence, Habitat Disturbance, and Seed Fall in a Larch-Fir Forest. Small-mammal population changes were measured for 5 years (1970-74) by livetrapping on broadcast burned western larch-Douglas-fir clearcuts and in uncut timber on a north and a south slope in western Montana. Four species made up 96% of the 1,324 animals caught: deer mice, 42%; red-backed voles, 27%; red-tailed chipmunks, 22%; and long-tailed voles, 5%. Deer mice and chipmunks were common on clearcut and timber plots. The red-backed voles were present only under tree canopy and long-tailed voles were found only in absence of tree canopy. A hard burn eliminated most of the organic mantle and all small mammals except deer mice, which existed as the single species for 2 years and as 80-90% of numbers for 5 years after the burn. A light burn that left duff intact was associated with retention of species diversity and a low initial postburn (2 years) mammal population, followed by the largest increases. Numbers of deer mice varied inversely with numbers of red-backed voles in the timber. Deer mice increased sharply on all plots the first fall after a heavy conifer seed crop. These observations suggest that red-backed voles may dominate deer mice, but a heavy seed crop can temporarily enhance competitive standing of deer mice. An open, xeric, pioneering situation (hard burn) was conducive to persistently high deer mouse populations. The most obvious habitat feature associated with an inverse spatial relationship between the two voles was tree canopy. The long-tailed vole may be further discriminated against by drier habitats. Clear-cutting appeared to be the principal determinant of total population size, but burn intensity seemed to influence species composition.

Black-footed Ferret Studies Continued in Wyoming. Since the discovery of a small population of black-footed ferrets in Wyoming by Center biologists, the Wyoming Game and Fish Department, Idaho State University-Biota Research and Consultants, Inc. (ISU-BIOTA), and DWRC have begun cooperative studies to determine the numbers, distribution, and demography of black-footed ferrets in northwestern Wyoming. Snow-tracking studies conducted by ISU-BIOTA from December 1981 to April 1982 revealed that 22 or more ferrets wintered on a white-tailed prairie dog colony of about 2,000 ha. Observations in spring and early summer revealed the presence of eight litters with one to four young. In August and September, one young ferret from each of six litters was trapped and fitted with a radio collar to determine when the young disperse from their natal area and if they survive. Two of these young have been observed intermittently since they were radio-collared. Movements of over 2.5 km have been recorded for each of these animals. Each of three radio-collared young male ferrets slipped out of their collars within a few days of attachment. These collars were recovered from prairie dog burrows at depths of 83, 100, and 238 cm below ground. One of the three radio-collared female ferrets disappeared 2 days after capture and was not observed again. Monitoring of the two remaining individuals will be continued into winter to help determine winter behavior. Snow-tracking studies will also be conducted to determine the number of ferrets wintering on the study sites.

Reproduction in West Indian Manatees. Since **1974** individually recognizable West Indian manatees have been monitored at Crystal River and Blue Spring, two clear-water, spring-fed rivers in northern Florida. The animals aggregate in the rivers during winter to escape low water temperatures. Reproductive histories of several individuals indicate that the reproductive potential of manatees is greater than previously estimated; gestation is about 12 to 14 months. About 50% of the births are twins. Calves are dependent on their mothers for an average of 1.3 years. The average interbirth interval is 2.4 years, and the minimum age at first reproduction is 5 years. Additional information is being gathered on reproduction, as well as other life history traits.

Mass Manatee Die-off Attributed to Red Tide. Every spring over 150 West Indian manatees disperse down the Caloosahatchee River in southwestern Florida from a winter warmwater refugium created by a power plant effluent. In 1982 from 4 February through 22 April, 41 manatees died in Lee County, Florida, in the lower Caloosahatchee River and San Carlos Bay. Thirty-nine carcasses were recovered, two of which were deaths due to collisions with water vessels. Causes of death for the remaining 37 animals were classified as "natural." Results from clinical observations, gross necropsy, histopathology, and bacteriology suggest that a fast-acting neurotoxin is involved. Other alternatives have been ruled out on the basis of these studies and the results of chemical analysis of tissues from environmental contaminants. An extensive red tide in the area, coincident with an unusual bloom of filter-feeding ascidians, has been impli-

A female manatee with her 2- to 3-month-old twin calves in the Crystal River warmwater refugium. *Photo by J. A. Powell.*

cated as the source of the neurotoxin. The ascidians probably underwent their bloom due to hypersaline conditions in the Caloosahatchee River and offshore areas brought about by unusually dry weather in the area and water-conservation measures. The ascidians were ingested incidentally by manatees feeding in sea grass beds, and in some instances thousands of the invertebrates were discovered in the gastrointestinal tracts of the manatees at necropsy. Mouse bioassay tests on ascidians exposed to red tide in the laboratory showed that they accumulated red tide toxin, so that the manatees probably were exposed through this route. It has been concluded that the die-off was the result of an unusual coincidence of events (dispersal of the manatees from the winter refugium, a red tide outbreak, drought conditions, and a bloom of ascidians) that was unusual and unpredictable.

Manatee Survey in Honduras. In cooperation with the Honduran Department of Natural Resources, aerial surveys and interviews with coastal residents were carried out in 1979 and 1980 to determine the distribution and status of West Indian manatees along the Honduran north coast. During a 13-hour entire-coast survey, 11 manatees were seen (0.8 manatee per survey hour). Most of the animals were sighted in the rivers and a lagoon north of La Ceiba. During six replicated flights in the La Ceiba area, manatees were seen 40 times (13.3 manatees per survey hour). The number of animals seen per flight ranged from 2 to 10 and averaged 6.7. Although natural mortality occurs when manatees are entrapped in small landlocked coastal lagoons, the greatest threat to manatees is from subsistence hunting for their meat. Enforcement of existing protective laws and enlistment of public support is required to preserve the remaining manatees in Honduras.

Polar Bear Movements Monitored Throughout Winter in Alaska. Valuable population information was obtained from 116 individual polar bears that were captured and released along Alaska's Beaufort Seacoast and in adjacent waters.

Twenty-eight radio collars were attached to adult female polar bears in autumn 1981 and spring 1982. For the first time, scientists have been able to follow movements of individual polar bears throughout the winter. Several polar bears have been relocated periodically for an entire year. Preliminary indications suggest that polar bears occupying the Eastern Alaskan Beaufort Sea in autumn hold their positions or drift gradually westward throughout the winter. In early spring most bears appear to move toward Canada, some possibly approaching the mouth of Amundsen Gulf. During late spring and summer they move progressively westward again, some actually entering the Chuckchi Sea.

Also for the first time, two maternity dens of Alaskan polar bears were located while occupied, rather than after abandonment in the spring. One of these was occupied by a female radio-collared in October 1981. Knowing from the radio signal that the female remained in the den all winter, FWS biologists set up a tent camp adjacent to the den. From there, FWS personnel observed the female shortly after her emergence in late March with two newborn cubs. We were also able to document the family's rapid eastward movement into Canada after leaving the denning area.

Walrus Haulout Patterns and Foraging Behavior. During the past decade walrus use of beach areas for hauling out has increased. Before 1982 a few scattered reports were received of walruses once again using the traditional sites on St. Matthew Island and adjacent Hall Island. During summer 1982 a cooperative effort between personnel from the FWS Alaska Region and Research provided additional information of walrus use of these sites. Walruses, predominantly large-bodied males, regularly used beaches on Walrus Cove and Lunda Bay on St. Matthew Island and North Cove on Hall Island for hauling out. Walrus use of beach areas appeared cyclic but the duration of a cycle could not be determined accurately at each area. Nearly 200 walruses were counted on each of the two beaches on St. Matthew Island. The highest of five counts at Hall Island was eight animals.

Walruses were observed foraging in inshore areas 10 to 30 m deep adjacent to St. Matthew Island

haulout sites. Although walruses generally fed as groups of up to 35 animals, individuals were also sighted. The feeding groups dove and surfaced synchronously with the average surface and dive times 1 and 5.5 minutes, respectively.

Movements and Population Growth of Sea Otters in Alaska and California. The sea otter population in Prince William Sound, Alaska, continues to provide insight into changes that occur as a population reoccupies historic range. Early in the 20th century southern Prince William Sound was one of the few sites where a few sea otters survived the final intensive hunting period that began with the purchase of Alaska. This population has increased and has reoccupied the entire Sound. In recent years natural mortality apparently has increased in the southern Sound and nearly half of the carcasses found on the beaches in late spring are of animals born the previous year. In the northeastern Sound where reproducing females are still reoccupying additional areas, natural mortality appears to be very low and too few carcasses are found on the beaches to obtain meaningful age composition. This suggests that the female population in the southern Sound is at carrying capacity but that the female population in the northeastern Sound is not. An important implication of this result is that two contiguous groups of females apparently form discrete populations, one increasing and expanding, the other apparently at carrying capacity. From resightings of marked otters it is clear that males from both areas intermingle in a common "male area." Observations of marked females suggest that they have an annual range of less than about 20 miles and that young females tend to remain near the area where they were raised when they become mature. Data for males show that they move as far as 60 miles seasonally and leave the area where raised late in the first year of life or early in the second year. Scientists from the University of Minnesota and the FWS have marked and released more than 200 sea otters in Prince William Sound since 1976.

Fish and Wildlife Service biologists have marked and released 117 sea otters in the vicinity of Piedras Blancas, California, since 1978. Since that time several thousand resightings of marked individuals have been accumulated. From these data the following patterns of movement have emerged: After weaning, male sea otters generally leave reproductive areas sometime during their first year of life. Males tagged near Piedras Blancas have been resighted throughout the present range from Santa Cruz, about 130 miles north of the Piedras Blancas study area, to near Surf, California, about 90 miles to the south. Adult males move seasonally from territories near Piedras Blancas to wintering areas 40 to 60 miles to the south. This seasonal migration has been repeated for several territorial males for 1-5 years since the study began in 1978.

Resightings of marked females on the other hand indicate that they generally have an annual range of less than 20 miles of coastline. This is true for adults and preliminary indications are that it is also true for subadults. This information strongly supports the information presented here on Alaska sea otters and suggests that sea otters follow the common mammalian patterns of males, tending to disperse more readily and over greater distances than females. The ramifications of this pattern on our understanding of population growth are important. For example, it may be incorrect to think of the California population as a whole when population growth rates are examined. The above information suggests, both from Alaska and California, that female dispersal distances may be less than 20 miles of coastline, and therefore it may be only the 20-mile segments of each end of the population range that are contributing to population growth. Thus, the growth rate of a population like the one in California with a range of 200 miles of contiguous coastline would be much lower than expected.

Activity Patterns in the California Sea Otter. An issue central to future management of sea otters in California is the status of the population. In recent years, a variety of data have been gathered and analyzed to indicate that the population no longer is growing perceptibly in size. In fact, although survey work currently is ongoing, it appears as though the otter population in California has remained roughly static, or perhaps even declined in numbers, over the past 5 years or so. Two hypotheses have been proposed to explain this situation. One is that the population has reached an equilibrium with limiting resources. The other is that some extrinsic source of mortality (such as net entanglement, pollution, and predation) is the causal factor. Resolution of this matter will have a strong bearing on the future management of sea otters in California.

It has been reasoned that time budgets and activity patterns may provide an acceptable indicator of population status. This is based on the results of studies in Alaska and Oregon, which show that populations known to be at or near equilibrium with available resources invest roughly three times more time foraging during a day (Amchitka Island) than do populations known to be well below equilibrium

density (Attu Island and Oregon).

Similar data now are available for California. Observations consisted of scan samples, done at ½-hour intervals, from dawn to dusk. Sufficiently large segments of coastline were selected for study to provide what is believed to be a representative sample of local subpopulations. Viewing stations were chosen within each segment so that contiguous subsegments could be monitored on successive days. Data sets, by using this or closely related techniques, were obtained from a number of times and locations. Some of these are from areas near the center of the existing range and are known to have been occupied by sea otters for decades. Others are areas near the present limits of the range in California, and only recently were reoccupied by otters.

The results of these studies show a consistent pattern among areas and over times. Overall, the percentage of time devoted to foraging is about 20 to 25% of the daily (dawn to dusk) time budget. There are no apparent seasonal effects, nor are there evident trends between long-inhabited and recently inhabited areas.

The Alaskan and Oregon studies established that sea otter populations, known to be near equilibrium density, devote from about 50 to 55% of their time foraging, whereas those below equilibrium density devote between 15 and 20% of their time foraging. These results also are consistent among areas and over time. Together, these data indicate that the sea otter population in central California is not limited by food availability. At present it seems unlikely that the population is at equilibrium density.

Interatoll Movement of Hawaiian Monk Seals. The endangered Hawaiian monk seal population declined by about 50% between 1958 and 1978. This species is distributed throughout the waters around the Leeward Islands, northwest of the Hawaiian Islands. The chain of atolls used by monk seals is about 1,000 nautical miles long and these islands and atolls are separated by distances varying from 50 to 330 nautical miles.

During 1966 through 1972, we tagged 863 monk seals with monel cattle ear tags on the hind flippers. Tagging and resighting were done on an opportunistic basis, primarily during survey and inspection trips to the Hawaiian Islands NWR (Leeward Islands). Usually, tagged seals were not captured or disturbed when resighted; consequently, tag number could frequently not be determined.

We resighted and identified 351 tagged seals a total of 674 times. Only 27 of these were sighted at atolls other than the one where they were tagged. No age- or sex-associated differences were detected in the proportion of seals that had moved. The longest distance moved was from Pearl and Hermes Reef to French Frigate Shoals, about 575 nautical miles. There was no obvious directional movement to the east or west.

Observations of tagged monk seals suggest that they have a high fidelity to their natal beaches but use other beaches intermittently. Therefore, each atoll has a relatively discrete subpopulation and the proportion of seals that moves between atolls varies between subpopulations. This knowledge of monk seal movements and site fidelity is particularly important when developing total population estimates and management plans that will stimulate population recovery for this endangered species.

New Classification of Mexican Deer Mice. Deer mice of the genus *Peromyscus* have long presented difficulties in identification to field workers. Most of the species occurring in the United States are reasonably well defined, but south of the Mexican Border, where distributions are poorly known and large samples of specimens are not often available, species limits are less well known, and many taxonomic problems remain.

As part of a cooperative study with the Mexican Wildlife Service, the mammal fauna of the State of Nayarit is being surveyed. Those groups whose classification is poorly known are being studied intensively and systematic revisions prepared. So far, results of these studies have been published for cottontails, genus *Sylvilagus,* and deer mice, genus *Peromyscus.*

Seven species of *Peromyscus* are now recognized from the State of Nayarit. An eighth, *P. banderanus,* is now considered as belonging to a separate genus, *Osgoodomys,* named for W. H. Osgood, whose 1909 monograph on *Peromyscus* was a classic of its kind. Three of the seven species, *P. simulus, P. madrensis,* and *P. spicilegus,* were formerly considered subspecies of *P. boylii,* a widespread form common in the southwestern United States.

We determined the specific status of these three kinds of mice using a combination of techniques. A series of computer programs aimed at handling large amounts of data permitted detailed multivariate morphometric analyses of cranial and external features. Chromosome slides were prepared in the field for many of the specimens collected. Careful microscopic examination of the preparations provided new data on the karyotypes of these rodents. In addition, extensive field surveys revealed several

localities where various combinations of the species occur together.

Ecological differences among these closely related species were also determined. *Peromyscus simulus* is confined to the coastal-plain region (sea level to 100 m); *Peromyscus madrensis* occupies the Tres Marias Islands; *Peromyscus spicilegus* inhabits intermediate montane zones (100 to 1,600 m) but has been found as high as 2,100 m; and *Peromyscus boylii* occurs at high elevations (1,900 to 2,100 m) in the eastern mountains of Nayarit.

Habitat Destruction Adversely Affects Aquatic Reptiles. During the course of a long-term study to evaluate the suitability and ecological impact of the grass carp as an aquatic weed control agent, population data on several reptile species were gathered. Five permanent transects covering 4,000 m of shoreline with 175 trapping stations were established in five pools on Lake Conway, Orange County, Florida, and populations of all species of amphibians and reptiles were monitored every 2 weeks from 1977 to 1981. Because Lake Conway is a large (743 ha) urban lake with increasing recreational use, the opportunity to assess the impact of expanding use, increased shoreline development, and the resultant habitat loss on select species of reptiles existed.

Nine factors were identified as having detectable changes on the ecology of species in the lake. These causative agents were grouped into four general categories: effects of the grass carp, human disturbance, natural phenomena, and unknown causes. Under the category of human disturbance, we included the effects of shoreline development, destruction or removal of individual reptiles, boat mortality, and investigator influence. A brief description of the impact of upland development on a single semiaquatic species illustrates some of our findings.

The green water snake was common in some habitats on the lake. We estimated a mean density of 0.26 green water snake per meter of shoreline or 116.8 g of snake biomass per meter in good habitat before disruption. This converts to a mean snake density of 130.4 per hectare and an average standing crop of 58.4 kg/ha; these values are the highest reported for any snake species. Most individuals (51.4%) were found in the littoral zone but some individuals occupied shallow, open-water habitat (29.7%) and terrestrial environments (18.9%). Aquatic sightings of green water snakes during nocturnal transects peaked in spring and fall with an apparent lull in June and July and in winter. Aquatic trap data showed peaks during summer in the same habitat, suggesting that the snakes were active in the water from spring to fall. Most terrestrial sightings were confined to the cooler months (89.9% in October through April), whereas most aquatic sightings (64.2%) were from May through September.

The tendency of the green watersnake to move onto shore or bask on emergent vegetation during the cooler months had important implications for their survivorship at different sites on Lake Conway. We found that during spring and fall this species typically was aquatic but often spent the morning and mid-afternoon hours basking on emergent vegetation. During summer, little basking occurred. However, once water temperatures dropped below 16°C in winter, the snakes left the aquatic environment and overwintered in cotton rat burrows on shore. Of 17 individuals observed during winter months, 15 were basking at the entrances of rodent burrows.

Highly significant reductions in green watersnake densities occurred on some sites during the study. Sightings on one area dropped from 98 in the first year to 3 and 2 in the next 2 years. These reductions were caused largely by clearing the adjacent uplands for housing during the winter and spring of 1977-78. We believe that a majority of the population was killed during these site preparations; only 16.7% (n = 17) of our first-year sample was taken after April 1978. This reduction in density occurred even though much of the littoral zone habitat remained intact. We suspect that clearing of the uplands during summer months would have had little direct impact on the snake population. Thus, an understanding of the terrestrial activity of certain semiaquatic reptiles proved crucial to maintenance of those populations in intact aquatic environments and illustrates the temporal susceptibility and dependency of this species on knowledgeable management of adjacent terrestrial habitats. This work was done in cooperation with the U.S. Army Engineer Waterways Experiment Station and the University of South Florida.

Status of Marine Birds of the Southeastern United States. This review is a cooperative effort between the Service and the Bureau of Land Management. The objective of this project is to provide a synthesis and analysis of information about marine birds of the coastal and offshore waters of the southeastern United States that will allow an assessment of the effects that offshore oil development may have on marine bird populations.

We assembled thousands of references and produced three volumes that provide the first basic synthesis for a little studied area. These volumes deal with 102 species of marine birds and, for some species, gather together fundamental information about their biology for the first time. The combined bibliographies that follow each species account provide about 10,000 citations, making these reports one of the largest specialized bibliographies of birds compiled in decades, and, as a result, supplying a unique source of data for planning further research.

Two of the volumes in this series have been completed and published, and the third is in the final stages of production. These reports should be of great value for planning future research on marine bird populations and should provide Federal, State, local, and private agencies a better understanding of the nature of the problems that may arise when exploitation of the coastal zone for human needs conflicts with the needs of marine bird populations dependent on this area for survival. These reports should also be helpful in choosing subjects for further autecological research and, because of the breadth of the coverage of the literature, be a highly useful reference work for administrators, researchers, and the general public.

New Technique for Livetrapping Cormorants and Wading Birds. The basic Bal-chatri trap, originally developed for use with raptors, is a small cage (for holding live bait such as a bird or mouse) covered with slip nooses. When the predator flies in and attempts to grab the bait, its feet catch in the nooses and pull them tightly shut. The cage usually is made of chicken wire or hardware cloth, and the slip nooses of monofilament fishing line. The size and shape of the traps vary according to the size and habits of the birds to be trapped. This year, as part of a project with olivaceous cormorants, we developed a modified form of the trap for use with aquatic species of birds.

Each trap was a 1 x 1 m^2 of 0.635-cm mesh hardware cloth covered with pale blue nooses made of monofilament fishing line and placed at intervals of about 5 cm. Nooses made of 8.2-kg test line were less apt to tangle or accidentally close than those of other strength lines. Loops were 6-8 cm in diameter. The traps were placed under 15-30 cm of water on the mud floor of a pond and anchored at the four corners with spikes 15 cm long. As a cormorant moved at the edge of the pond to sun itself or to manipulate a fish on the bank, its toes caught in the nooses, which closed as the cormorant attempted to pull free. The cormorants gave no alarm calls, and other birds in the area seemed unaware of what was happening. Traps were monitored by an observer in a blind, and captured birds were removed immediately. No birds suffered injury from the trapping. The rate of capture of cormorants was about one bird per 3 hours of trap time. This value probably underestimates the potential capture rate because the times when traps were in use did not necessarily coincide with peak feeding times of the cormorants.

The location of the traps under water did not interfere with the functioning of the nooses, although dense aquatic vegetation might do so. The nooses tended to float in the water, which helped to keep them erect and open. We did not bait our traps directly, but in habitats where fishes occupy clear water, individuals or schools swimming above the traps might attract piscivorous birds. Likewise, shallow cages (e.g., 10-15 cm high) could be made and baited with live fishes and placed under the water. Such traps should be extremely effective for the capture of wading birds in shallow-water areas.

Longevity Records of North American Birds Now Available. Longevity records provide information on a basic aspect of biology for over 400 taxa of North American birds. The purpose of the four papers that comprise this work is to provide basic data that will allow an examination of biological interrelations between length of life and other factors such as body mass, nesting habits, and other elements that may influence the survival of an avian species.

This work has been pursued intermittently over a period of 5 years, has involved the examination of over 1,000,000 records on microfiche at the Bird-Banding Laboratory, and the examination of many thousands of banding schedules and recovery records, and has entailed an exhaustive survey of the North American literature on the longevity of birds. Because the papers resulting from this study list the total numbers that have been banded and recovered in North America, they are uniquely useful in determining which species have been relatively poorly studied with regard to migration, dispersal, and other topics for which individual marking of birds is required.

Cooperative Research Unit Program

The Cooperative Research Unit Program is jointly supported by the U.S. Fish and Wildlife Service, the Wildlife Management Institute, and the State game and fish agency and the land grant university in the State where each Unit is located. Program direction for each Unit is provided by a Coordinating Committee composed of representatives from each cooperating entity. Unit personnel, who are Service employees, are headquartered on the campuses of the cooperating universities where they have full faculty status and access to university resources. In this way, the Units provide a major focal point for State-Federal cooperation on appropriate fish and wildlife issues in 29 States. They also provide special mechanisms for the Service to bring the vast array of expertise and facilities available at 31 major universities to bear on problems where the Service has responsibility but lacks resources to respond.

The objectives of the Cooperative Research Units are to conduct research that is responsive to needs of fish and wildlife resources, provide training and retraining at the graduate level for prospective and practicing professional fish and wildlife biologists, and to participate in technical assistance activities for the benefit of all cooperators. Although training was the primary objective when the Unit Program began in Iowa in 1935, changes in cooperator needs in recent years have dictated a change toward increasing the focus on research. This has resulted in a gradual decrease in students enrolled in the program over the last 5 years, and an increase in use of professional staff.

Research programs have historically focused on applied problems of fairly restricted scope for States or other agencies that have contracted for research. In recent years the cooperators, with special direction from the Service, have broadened the general scope of research in the Units to include complex contemporary issues of regional and national importance. In fiscal year 1982 the Units were involved in an array of research, including impacts of energy development in the Intermountain West, development of waterfowl management strategies for the Central Flyway, reestablishment of runs of American shad and Atlantic salmon in the Northeast, mitigation of impacts of development and changing land-use practices on Pacific salmon stocks, development of information prerequisite to recovery of a wide variety of endangered species, scope and effects of acid precipitation, and many others. While undertaking this type of research, the Units have

	Wildlife Units		Fishery Units		Combined Fish and Wildlife Units	
	M.S.	Ph.D.	M.S.	Ph.D.	M.S.	Ph.D.
Students in program	212	63	244	54	42	17
Minority students	6	4	23	6	3	0
Female students	57	2	45	8	7	1
Degrees granted	56	6	53	11	10	3
Employment						
Fish and Wildlife Service	5	0	5	2	0	1
State agencies	17	1	22	1	5	1
Universities	12	6	9	4	1	1
Other fish and wildlife biology	15	2	7	1	0	0
Other biological sciences	4	0	0	1	0	0
Education continued	13	0	9	0	1	0
Miscellaneous	0	1	0	1	1	0
Unemployed	3	1	1	0	0	0

become directly involved in cooperating with Service research laboratories, often providing capability that the laboratories do not have and adding breadth to individual laboratory research programs.

The Unit Program gives emphasis to training minorities and women in fish and wildlife science. In fiscal year 1982, 174 minorities and women were being trained at the graduate level in the Units, the largest number ever.

Of the 139 graduates in fiscal year 1982, only 5 (4%) are unemployed; 94% are working or continuing their education in fish and wildlife programs.

COOPERATIVE FISHERY RESEARCH UNITS

Alabama. Forage species often are introduced without consideration of possible harm to existing fisheries. One candidate species of wide interest among public agencies is the inland silverside. It is an important forage component in lakes of the southern Mississippi Valley, and was proposed for introduction to reservoirs of the Southeast. However, there were misgivings about its potential to outcompete young game fishes and existing forage species such as the bluegill. A comparative study of the diets of inland silversides, young largemouth bass, and juvenile bluegills was conducted in experimental ponds and plastic pools at Auburn University, as well as on fish from a natural population in Louisiana. An unexpected resemblance was observed in the feeding of largemouth bass and inland silversides: both ate large numbers of bluegill fry. High diet overlaps in **all** three species were also seen in their consumption of several types of zooplankton (notably copepods, cladocerans, and ostracods). Inland silversides were judged unsuitable for introduction in waters of the Southeast because of the potential for competition with young-of-the-year largemouth bass for bluegill fry, as well as for other kinds of food. Inland silversides also have the potential to reduce already established bluegill populations through food competition and predation.

Research on the conservation status of the so-called Cahaba shiner, an undescribed species that resembles the mimic shiner, showed it to be one of the most geographically limited fishes in eastern United States. It has been collected only in a 20-mile reach of the main channel of the upper Cahaba River, a tributary of the Alabama River in central Alabama. The ruggedly mountainous Cahaba headwaters recently were opened to development by the expansion of Greater Birmingham resulting from construction of an interstate highway. The "developing urban" category of land-use tends to imply a very serious pollution potential. Moreover, main-channel species are especially vulnerable to events in headwater areas. Therefore, the Cahaba shiner may be threatened, and perhaps even endangered (if, for example, sewage treatment centralization in the basin can be shown to pose a hazard through eutrophication).

Alaska. The Alaska Department of Fish and Game has a continuing project in which fry of Arctic grayling are stocked from hatcheries into ponds barren of other fish, for a summer of accelerated growth. In fall they are captured and stocked in a large stream fed by groundwater, Delta Clearwater Creek, to support a recreational fishery. We attempted to determine the limits of growth and survival of grayling fry stocked in barren ponds. Experiments conducted on the effects of stocking density (the number of fry stocked per unit of surface area) on growth in the nursery ponds showed no relation between stocking density and growth over the range of densities tested. Growth in the ponds was rapid (about 2 mm per day) during early summer, and slowed in September as pond waters cooled. In fall, the fish were considerably larger than those stocked as fry in Delta Clearwater Creek. The difference was probably due largely to a difference in water temperature; water in Delta Clearwater Creek never rises much above 9°C, but that in the ponds reaches about 20°C. Oversummer survival of the grayling was always less than 20%, and early mortality was identified as the probable cause. Enclosures provided the sac fry with protection from waves, and zooplankton as starter food. Heavy mortality began as the fry completed absorption of their yolk sacs, and continued until more than 90% had died. The enclosures excluded predators, eliminating predation as a significant cause of early mortality. High early mortality has also been noted in Alaskan hatchery-held fry as they complete absorption of the yolk sac and become dependent on prey for nourishment. It is not known whether this mortality is a function of inadequate food (grayling during their first month eat chironomid pupae almost exclusively), stress due to minute currents (wild fry remain in bottom substrates until the yolk sac is lost), or some other factor.

Arizona. Extensive beds of aquatic vascular plants, primarily spiked watermilfoil, in numerous

Many fish of the older year classes of largemouth bass in Alamo Lake, Arizona, choked to death when they tried to feed on tilapia (presumably stressed by low winter temperatures) that were too large for them to swallow. *Photo by B. Wanjala.*

small mountain lakes in Arizona cause pH's to rise to levels that cause stress and mortality in trout. Peak values, during the afternoon, may reach pH 10.9, but usually range from 10.0 to 10.4. These high values occur only in areas that have heavy growths of plants, and usually near the surface. Diel pH's often exceed 10.0 for several days or even weeks at a time. In larger lakes, the high pH's are mostly restricted to heavily vegetated edges; the open waters, although influenced by phytoplankton, have much lower values that are not known to exceed 9.8 during peak periods. These results indicate that pH cycles in mountain lakes should be studied before trout stocking schedules are prepared. Each area requires individual attention because pH cycles vary widely from site to site. Once pH cycles are known, trout can be stocked in specific areas at times when the pH values are below stress or lethal levels (i.e., lower than 9.0).

California. Northern California streams are located largely in forests of redwood and Douglas-fir that are in various stages of timber harvest and management; most of the streams are important producers of salmonids. Restoration of the declining stocks of anadromous fish of the Klamath-Trinity Basin and other north-coast streams is a high-priority objective of the California Department of Fish and Game, and is listed among the Important Resource Problems of the Fish and Wildlife Service. A major portion of the Unit's current program is related to problems of declining salmonid stocks. As part of one of these problems, we completed an evaluation of the use of radio-

The California Fishery Research Unit is evaluating the effects of suction dredge gold mining on fish and fish food organisms in northern California streams. Note the instream excavation remaining after dredging. *Photo by W. L. Somers.*

telemetry to study upriver migration of adult chinook salmon in Klamath River. From July to October 1980, internal radio transmitters were placed in the anterior digestive tracts of 27 adult salmon. Of these, 16 tagged upriver from saltwater influence moved downstream after release, 5 moved upstream from the tagging site, and 6 tagged in the estuary were lost immediately after release and not relocated. The period between tagging and subsequent location upriver ranged from 0 to 14 days. Long-term tracking was successful for three salmon: these fish progressed consistently upstream with only minor delays and made no detectable downstream movements. Migration rates were 4.3, 6.3, and 6.7 km/day. To assess the reliability of these results, we compared the radio-tagged salmon with control salmon tagged only with spaghetti tags. Downstream movements of these control salmon were indicated by tag returns in the estuary. Control salmon that ascended the main stem of Klamath River had significantly higher migration rates and shorter travel times than did salmon that ascended the Trinity River, the Klamath's largest tributary. Migration rates for two radio-tagged salmon that ascended the main stem Klamath River were within the range of 5.6 to 9.6 km/day determined for two groups of control salmon, and the rate for a single radio-tagged salmon that ascended the Trinity River was within the range of 3.2 to 6.5 km/day determined for control salmon. Our success was limited by problems associated with logistics, equipment failures, saltwater interference in the estuary, predation on tagged salmon by harbor seals, and possible mortality due to tagging and handling stress. We recommended the use of ultrasonic telemetry in the estuary, the movement of tagging sites farther upriver to avoid seal predation, the investigation of alternate methods of transmitter attachment, and the use of more than one signal-receiving system and more efficient tracking methods.

Colorado. Successful fishery management is essentially a planned sequence of field operations that create or augment different kinds of angling opportunities in approximate proportion to angler preferences for each kind. Although managers are often constrained by budgets, the state of the art, and ecological rationality, a perhaps equal or more important factor that is seldom addressed is angler preference or demand. In an effort to document the kinds of angling most desired by Colorado anglers, and to provide the demand component for fishery management planning in Colorado, we mailed an attitude questionnaire to more than 8,000 Colorado anglers. The survey included questions pertaining to preferences for kinds of angling experiences, attitudes toward fishing regulations and other management options, the extent of each angler's interest and participation in the sport, and demograhic characteristics of the anglers, such as age, sex, education, occupation, and income. The results indicated that Colorado anglers prefer fishing for "wild" fish but also support programs involving the stocking of catchable-size trout, as well as warmwater fishery management. In general, anglers objected to any basic restrictions on their opportunity to fish; however, regulations pertaining to how they fish were not opposed. Our results provide a basis for allowing angler preferences to guide the fishery management program, rather than managers' guesses or the preferences of special interest groups. This kind of demand-based planning should result in a more satisfied and supportive angling public.

The Pyramid Lake Paiute Indian Tribe and the U.S. Department of the Interior are working toward restoration of the once famous trophy Lahontan cutthroat trout fishery in Pyramid Lake, Nevada. Estimating the potential trout production that Pyramid Lake will support can provide fishery managers with a goal toward which to direct their restoration efforts. Because primary production by algae generates most of the organic matter in lakes — including that which ultimately becomes trout tissue — knowledge of Pyramid Lake's present primary production can serve as an indirect estimate of its potential trout production. The primary production of Pyramid Lake was measured monthly for 4 years. Other potential sources of organic matter (e.g., river inflows, blowing tumbleweed) were also evaluated. To determine how much primary production would be transferred to fish, experiments were conducted in plastic-lined swimming pools in which actual primary production and fish production were measured. Production of tui chubs (the major food of Lahontan cutthroat trout) averaged **1.1%** of primary production. Applying a range of trophic efficiencies from swimming pools to a corresponding range of primary production in Pyramid Lake, and using various assumptions about the transfer of tui chub production to trout production, we estimated the median potential annual production of Lahontan cutthroat trout in Pyramid Lake to be 21 kg/ha.

The study of primary production in Pyramid Lake showed that one salt-tolerant, nitrogen-fixing filamentous alga, *Nodularia spumigena*, was the major single energy source in the Lake. Because fila-

High-volume pump being used to sample larval fishes in standing timber plots in Georgia. The cover provided by such plots may be an important factor in survival of larval fishes. *Photo by R. Petering.*

mentous blue-green algae are often not eaten by zooplankton, we undertook a study to determine if *Nodularia* was important to the food chain of Pyramid Lake as a source of detritus or food for bacteria. Numbers of bacteria were strongly correlated with the abundance of *Nodularia;* however, particulate detritus was not high, even after blooms. The significance of *Nodularia* to Pyramid Lake was thus primarily as a source of new nitrogen, rather than as forage. Because the lake is a nitrogen- rather than a phosphorus-limited system, new nitrogen produced by *Nodularia* is critical for the growth of diatoms and green algae. These algae are in turn eaten by zooplankton, which then become food for fish.

Georgia. Reliable diagnostic characteristics are needed by biologists and fishermen to distinguish hybrid bass from their parent species, the white bass and striped bass. Striped bass and hybrids have been introduced by fishery managers into reservoirs and rivers throughout much of the United States, and popular fisheries have been established in many of the waters. In most States, legal size and creel limits differ for white bass, striped bass, and the hybrids. Since all of these fish superficially resemble one another, fishermen, law-enforcement officers, and biologists have had difficulties with proper identification and compliance with or enforcement of regulations. Techniques for separating the species and the hybrid have been described for one population of fish from Virginia and one from South Carolina, but inasmuch as morphological traits of fish can vary among populations and locations, we determined whether characteristics for Savannah River fish were similar to those from other locations. Diagnostic characters described elsewhere

generally were valid in the Savannah system, but there were minor differences in numbers of fin rays and scale counts. In the Savannah River, simple counts of the number of tooth patches on the base of the tongue and the number of branchiostegal rays accurately identified 240 of 241 fish examined. White bass and striped bass have seven branchiostegal rays, the hybrid eight; striped bass and hybrids have two tooth patches on the base of the tongue, the white bass only one. In previously published work, these traits were much more variable among specimens within each species or hybrid group.

The Fish and Wildlife Service attempted to predict the biological consequences of habitat alterations through a series of species-specific Habitat Suitability Index (HSI) models. The objective of this study was to assess performance of selected species models (green sunfish, warmouth, bluegill, black crappie, largemouth bass, black bullhead, channel catfish, and common carp) by comparing estimated standing crops of fishes and calculated HSI values. Models were tested by using data from six reservoir and six riverine areas. There was little correlation among estimated standing crops and calculated HSI values for areas and models tested. The models posed some obvious problems: (1) difficulties in obtaining or predicting precise information concerning variables used in the models; (2) determination of appropriate weighting or influences of interactions of variables; (3) failure to compensate for the ability of fish to overcome or avoid short-term or restricted adverse physicochemical conditions; (4) failure to recognize the biological interactions of fishes; (5) dependence on relatively simple or easily measured physicochemical variables; (6) failure to recognize the influences of exploitation on sport and commercial species; (7) the assumption that standing crop is a direct reflection of carrying capacity; and (8) the implied assumption that physicochemical factors are the limiting elements for fish populations. Correlation coefficients of standing crops and HSI values ranged from 0.05 to —0.74.

Hawaii. We studied the Puako Coast to attempt to characterize the ecology of this rich coastal reef tract on Hawaii Island, assess its resources, and determine the nature and effects of the small-scale local fishery operating there. Motivated by the increasing pressure of population, land development, and an unregulated fishery concentrated on this small, vulnerable area, we designed the study to produce information that State resource managers can use to determine what regulation may be required on the fishery or other activities to maintain a high natural quality and productivity. Operating from a field station established locally, Unit personnel estimated populations of fishes and resident macroinvertebrates by seasonal visual census, described habitat types, collected fish specimens and analyzed gut contents for trophic information, collected benthic fauna to assess the food base, examined gonads to determine the size at first maturity in relation to sizes of fish in the fishery, and studied the nature and intensity of the fishery through repeated observations and interviews with fishermen. Results indicated a rich and varied fauna that presents considerable potential for recreational and subsistence

A young monk seal on a remote island of the Hawaiian Islands National Wildlife Refuge shows evidence of shark attack. A trophic system study by the Hawaii Cooperative Fishery Research Unit, in cooperation with the Refuge, concerns the feeding relations of sharks with this endangered species and other important components of the nearshore fish community. *Photo courtesy of Hawaiian Islands National Wildlife Refuge.*

Blueline snappers caught in a gill net set under water by Hawaii Cooperative Fishery Research Unit divers are being carried to the surface. Unit researchers are studying the food habits and habitat of this highly successful new species (recently introduced into the coastal waters of Hawaii) to determine its place in the ecology of the community. *Photo by D. K. Oda.*

harvest of a large number of species. For many reef fish species, visual census estimates of local populations were compared with harvest rates based on observations of effort and catch per unit of effort from creel census. These comparisons strongly suggested overharvesting in several local areas. Large quantities of immature fish are taken in the fishery.

The goatfishes are important components of recreational, subsistence, and commercial fisheries throughout tropical, shallow, marine waters of the world. In Hawaii all species have long been part of the fishery, but little is known of the ecology of the stocks in the potential new fishing grounds of the northwestern Hawaiian Islands. Research on the shallow-water fish communities of these grounds included an intensive study of the dominant goatfish species, their diets, and the invertebrate fauna of the sandy substrate available as feeding areas. Fish specimens and sand core samples were collected together at Midway Islands, and the fish gut contents and infauna of the sand communities were identified and quantified. Diets of goatfish in the northwestern Hawaiian Islands were generally similar to those known for goatfish in the main Hawaiian Islands. As a whole, the group of goatfish species showed rather generalized carnivorous habits, eating mostly small crustaceans, polychaete worms, and bivalve and opisthobranch mollusks. One species of goatfish preferentially selected for some polychaete species and against others. Some partitioning of food resources among goatfish species may result from differences in specific feeding locations and different feeding behaviors. Some species appeared to feed more actively at night than during the day. The goatfishes are well adapted to seeking out concealed invertebrate prey species, particularly in sandy substrates. Of the relatively few species in these fish communities that feed consistently in sandy substrates, the goatfish are probably the most numerous and ecologically important large fishes.

Idaho. As part of a study relating the size composition of spawning gravel to the survival of salmonid embryos, we developed a new method for describing the size composition of gravel in spawning redds. For gravel samples from Idaho, Washington, and Wyoming streams, cumulative particle size distributions for material smaller than 25.4 mm consistently plotted as straight lines on log-probability paper. Because of the lognormal distribution of particle sizes in this range, the size composition of material smaller than 25.4 mm was closely approximated by two points on the cumulative particle size distribution. The two particle size classes that best reflected spawning gravel size composition were the percentage of the substrate smaller than 9.5 mm and the percentage smaller than 0.85 mm. Laboratory experiments related these two classes of particle sizes to the survival of salmonid embryos. In these tests, 90 to 93% of the variability in embryo survival was correlated with differences in substrate size composition. Equations were developed to quantify the effect of spawning gravel size composition on survival (to emergence) of chinook salmon and steelhead trout in a wide range of spawning gravel mixtures. Mixtures containing high percentages of fine sediment produced slightly smaller steelhead fry than did gravels containing low percentages of fine sediment. However, the inverse relation between fine sediment and the size of steelhead fry was not significant over the range of experimental gravel mixtures. There was no relation between changes in gravel size composition and the size of emergent chinook salmon. In gravels containing large amounts of fine sediment, steelhead and salmon fry frequently emerged before the yolk sac was completely absorbed.

Iowa. The movement and habitat use of paddlefish were investigated by radiotelemetry in the Upper Mississippi River. Fish in which 49-MHz transmitters had been surgically implanted were released at capture sites in Pool 13. Seven fish were marked in summer 1980, and 10 in spring and summer 1981. Physical characteristics of the habitat at telemetry location sites and proximity to man-made structures were determined. Paddlefish were very mobile, especially during spring, when adults nearing spawning condition moved long distances. Activity was reduced in summer. Some movement between pools, upstream and downstream, through navigation dams was observed. Upstream movement through the dams occurred when gates were fully raised. Habitats in tailwaters and borders of the main channel were frequented most in spring, and backwaters in summer. Areas of reduced current near man-made structures such as wing dams were commonly occupied by paddlefish. Two gravid females were tracked over a gravel shoal that may be a spawning site in the study area. Direct injury of tagged fish resulting from the passage of barge tows was documented.

During summer 1981, vegetated, non-vegetated, and gravel-rock littoral habitat types were sampled with 38 m experimental (graded-mesh) gill nets and fyke nets. Gill nets were fished at dawn, midday, and dusk for about 2 hours, and fyke nets during the day and overnight for about 12 hours. Catch

Radio-tagged shovelnose sturgeon have been followed by researchers at the Iowa Cooperative Fishery Research Unit to determine the summer movement patterns and habitat associations of this commercially important fish. *Photo by G. Marty.*

per unit of effort was used as a measure of relative abundance to determine fish habitat use and preference. Twenty species of fish were captured during the summer sampling. Among eight that were frequently captured, black bullheads, black crappies, and bigmouth buffaloes preferred vegetated habitats; yellow perch, white bass, and white suckers preferred non-vegetated habitats; and walleyes and yellow bass preferred nearshore gravel-rock habitats. Yellow perch and white bass were most active during daylight and black bullheads, walleyes, yellow bass, and white suckers at dusk and at night. Inshore activity of black bullheads and yellow perch declined as the summer progressed, whereas that of white bass and yellow bass was greatest in late summer. Yellow perch and black bullheads dominated the fish community associated with each habitat type. The composition of the fish community inhabiting vegetated areas was generally dissimilar to that of communities in non-vegetated or gravel-rock habitat types. The results of the study are being used to assess the effects of a water-level stabilization project that has been proposed for Clear Lake.

In a study of the levels and trends of organochlorine residues in Red Rock Reservoir and of the relation between organochlorine residues and sediment characteristics, dieldrin and DDT metabolites were the only insecticides found in the sediments. Dieldrin concentrations were higher than those of DDT but lower than those of polychlorinated biphenyls (PCB's). Levels of all organochlorines were substantially lower in sediments than in fish from the reservoir. The Des Moines metropolitan area seems to be the major source of the PCB's; residue concentrations in fish taken from the Des Moines River were much lower upstream from the metropolitan area than downstream. Organochlorine residues in the sediments appeared to be undergoing a slow degradation and to be in equilibrium with residues in the water and in fish. Organochlorine residues in the sediments of Red Rock Reservoir may influence residue concentrations in the water and fishes for a long time, but the levels are not known to cause substantial environmental or human health problems.

Louisiana. Larval black crappies and white crappies were collected weekly from nine areas representing three major habitat types of the lower and upper Atchafalaya River Basin. Otoliths were used for determining and computing daily growth rates; one ring or growth increment was assumed for each day of life after hatching. In general, protolarvae of black crappies grew significantly faster than did those of white crappies. Their growth was fastest in the rivers and lakes and negligible in the bayous and Lower Old River. In contrast, late protolarvae of the white crappie grew fastest in the bayous and Lower Old River. Growth of the white crappie was not significantly related to water quality characteristics, whereas specific conductivity seemingly accounted for some of the variation in growth observed in the black crappie.

Larval development of the pugnose minnow and the taillight shiner was compared to provide information of possible relevance to their phyletic affinities. Protolarvae and early mesolarvae of the pugnose minnow are noticeably longer (about 1 mm) than comparably developed taillight shiners. During these early phases, the pugnose minnow has a subterminal mouth and blunt snout, whereas the taillight shiner has a more terminal mouth and an attenuate snout. Upon attaining the late mesolarval phase (at lengths of about 7.8 mm for the taillight shiner and 8.2 mm for the pugnose minnow), pugnose minnows are characterized by 9 dorsal rays and 14 or 15 postanal myomeres. Discriminant analysis functions derived for the three developmental phases resulted in high classification success. Although it has been postulated that the pugnose minnow and the taillight shiner are somehow related below the subfamily level, observations on their comparative larval development argue against this hypothesis. As larvae, the two forms are at least as distinct as some other cyprinid genera.

Swamp water habitats of the Atchafalaya Basin were dependent on physical phenomena for aeration during most of the year. Lotic waters and headwater lakes functioned as distributaries for most planktonic rotifers during high-water months in the lower Basin; however, a distinctive rotifer fauna

was found during low water in most habitats of the Basin. Cluster analysis yielded similar groupings of stations based on similarities in rotifer communities and water quality, regardless of water stage. Lower Basin habitats yielded samples with nearly twice the number of taxa, but only 0.01 the number of rotifers taken in upper Basin habitats. Variations in suspended solids, total dissolved solids, and organic carbon were most often significantly associated with variations in rotifer numbers in regression models of data from the lower Atchafalaya Basin.

The stomach contents of 716 juvenile croakers taken from April through September 1980 were examined to describe the major components of the diet, compare the diets in two marsh habitats, illustrate changes in diet with growth, and demonstrate the temporal separation of feeding groups. Polychaetes composed the largest portion by volume of the croaker diet, followed by detritus, fish, amphipods, and mysid shrimp. Copepods were most abundant numerically, followed by polychaetes. Juvenile croakers appeared to eat large amounts of freshwater organisms. Most of the differences in the diet between fish from the canals and those from shallow marsh were attributed to particular locations within these areas. Diet changed with growth: small croakers, less than about 40 mm in standard length, were basically planktivorous, but shifted to larger organisms as they grew, and the diet became specialized among fish longer than 80 mm. Statistical analyses defined three major diet groups, associated with particular size groups of fish. Temporal separation did not appear to be an important mechanism for the division of resources among croakers in the marsh; croakers of all sizes fed at the same time of day. Seemingly, the division of food among juvenile croakers in the marsh occurs through diet specialization among fish of different size groups.

Maine. The ecological impacts of intensive logging near streams is little known in Maine, although forestry is the most important industry in the State. A study along the East Branch of the Piscataquis River indicated that the aquatic ecosystem was considerably changed. Although the fish biomass was higher, brook trout were replaced by more adaptable species, such as common shiners and fallfish. The invertebrate species changed as well, probably as a result of increased water temperatures, thus perhaps indirectly affecting the fishes.

A study of the ecological effects of pulpwood log driving and log salvaging showed that some fishes were dependent on submerged logs, and that invertebrates that serve as fish food changed after log salvaging. Salvaging of 1 to 2 million cords of submerged pulpwood logs in the Kennebec River system will indirectly affect the resident fishes.

Extensive pulpwood log drives from 1830 to 1976 left an estimated 1 to 2 million cords submerged in the Kennebec River system, Maine. Preliminary results of a study of the ecological effects of salvage operations suggest that certain invertebrates and fishes depend on the submerged logs for substrate, cover, and food. *Photo courtesy of Maine Department of Inland Fisheries and Wildlife.*

Reproductive sterilization of fishes has potential for increasing production and longevity, and preventing dilution of wild gene pools caused by interbreeding with hatchery fish. Polyploid Atlantic salmon induced by treatment of fertilized eggs with cytochalasin B grew about as fast as controls during hatchery life. They are being tested in two lakes in Maine. Such engineering techniques could become valuable tools in managing exotic species and protecting native or unique species.

High demand for baitfishes for ice fishing has led to high prices (up to $7.50 per dozen for rainbow smelt) and illegal bait importation. The illegal trafficking brings in exotic fish species and diseases, and the State is interested in developing a Maine bait culture industry. The Maine Cooperative Fishery Research Unit, which developed techniques for culture of rainbow smelt in ponds and hatcheries, receives more requests for information on smelt culture than on any other problem.

Massachusetts. As part of the Connecticut River anadromous fish restoration program, the construction of upstream fish passage facilities for American shad, blueback herring, and Atlantic salmon is continuing. Unlike Pacific salmon, Atlantic salmon do not die after spawning but return to the sea.

Inserting a transmitter into an adult American shad, as part of a study of the survival and behavior of anadromous fish that pass through hydroelectric turbines in the Connecticut River. *Photo by B. Kynard.*

Thus, if post-spawning adults suffer high mortality during downstream migration through hydropower facilities, downstream fish passage facilities will also be required. We used radiotelemetry transmitters inserted into Atlantic salmon smolts and adult American shad to determine whether the fish survived passage through a 17-Mw Kaplan turbine at the Holyoke Dam on the Connecticut River. Mortality estimates for shad ranged from 18 to 53%, depending largely on their physical condition before passage through the turbine. The effects of such turbine-inflicted mortality on the sustainment of Connecticut River shad as a resource must now be assessed. The experiments with Atlantic salmon indicated that 13% of the smolts passing through the Kaplan turbine at Holyoke would be killed each spring during their downstream migration to the sea.

If the restoration of American shad to spawning areas above hydroelectric dams is to eventually result in increased returns of adults to the river, many of the young that originate above the dams must survive downstream passage past the dams. The hydroelectric turbines are an obvious source of mortality to migrating juveniles that have no other means of passing through the hydropower facility. Using mark-recapture techniques to evaluate turbine-induced mortality at Holyoke Dam, we developed mortality estimates as high as 85% for both juvenile American shad and blueback herring.

The design of an upstream fish passage facility must have features that take into account the fish's ability to use the facility. During 1980 and 1981, we monitored the movements of radio-tagged adult American shad in the Holyoke Dam tailrace area, in relation to concentration of dissolved gases, water temperature, water velocity, and turbulence. The shad that were successful made repeated trips up the tailrace before being lifted by the fish elevator. However, less than 50% of the radio-tagged fish were lifted over the dam. Water turbulence at the head of the tailrace appeared to be the main factor preventing the upstream movement of shad.

Fish that pass through turbines without suffering immediate mortality may die later due to turbine-related scale loss and eventual osmoregulatory failure. We found that scale loss from Atlantic salmon smolts that had passed through an Ossberger turbine was as great as 28% of the total scaled area of the body; smolts that died within 48 hours after turbine passage showed scale losses approaching that percentage. Laboratory studies on scale loss confirmed the field results.

Each study relating possible fish mortality to passage through a hydropower facility has permitted electric utility owners to further assess their operations in relation to mitigating fish losses. The success of the anadromous fish restoration program in the Connecticut River may depend on such mitigation.

Missouri. The size of fish caught is among the most important variables that influence the quality of fishing. Bluegill populations of high quality should include some fish longer than 20 cm. However, bluegills of this size are lacking in most impoundments in Missouri and the Midwest. Identification of density-dependent and habitat factors associated with bluegill populations that do include large bluegills should be helpful in the development of management plans for the improvement of the quality and harvest of bluegills. Four factors were common to bluegill populations that consistently produced fish 20 cm long and longer: longevity of the fish was 8-10 years; the habitat included aquatic plants of the proper quality and quantity; fish diets were composed largely of Chironomidae; and predation by largemouth bass was evident.

The smallmouth bass is the major predator in the Ozark National Scenic Riverways. It is both eco-

logically important and highly sought after by the angler. If this species is to provide optimum sustained benefits to the public, management decisions must be based on information that accurately describes the structure and dynamics of populations of this fish within an ecosystem. We evaluated the production of smallmouth bass, and related food and feeding and habitat to the condition and growth of the fish. Mortality and growth were similar among populations at all sites. Growth was relatively slow; 6 years were required for bass to reach the legal length of 12 inches. We developed a relative importance index to analyze food habits that combined weights and caloric contents of food items. Adult bass fed almost exclusively on crayfish, which appeared to be abundant. Density differences among sites, although not great, appeared to be related to habitat — especially the abundance of logs for cover.

Annual fall harvest of redhorses by gigging is an important recreational event on the streams of the Ozark National Scenic Riverways. Little information is available for use in the management of these members of the sucker family. We examined the effects of the harvest on the population dynamics of two species—the black redhorse and golden redhorse — in Jacks Fork and Current rivers by estimating their densities, mortalities, age class structure, and movements in four study areas. Population density in downstream reaches was twice that in upstream areas. Growth rates exceeded the State average in both rivers. Giggers were selective for large fish, and overharvest did not appear to be occurring. Short-term reductions in densities of the black redhorse at specific sites are not a problem because this species is highly mobile.

Montana. Streams are often straightened and confined to accommodate road building and agricultural activities. These channel alterations result in a loss of fish habitat and require that stream improvement structures be installed for mitigation of that loss. Effectiveness and durability of three types of structures were evaluated in several Montana streams with gradients of 0.85 to 1.7%. After 8 years, randomly placed boulders were still in place and were more effective than rock jetties in increasing cutthroat trout populations in narrow channelized sections of a stream with a bedrock bottom. Such boulders were ineffective in stream actions without a bedrock bottom because they often became buried within 4 years. Rock jetties placed in this stream improved rainbow trout populations and were largely intact 7 years after installation; brown trout populations showed no response. Log step dams did not improve rainbow trout populations in another stream, although they were functionally intact 16 years after placement. Results of this study show that the effectiveness and duration of habitat improvement structures depend on the species involved and the physical characteristics of the stream.

Bioaccumulation of mercury in fish can result in a potential health hazard to the public when fish are eaten. We examined mercury concentrations in walleyes and white crappies in the Tongue River Reservoir and quantified the dietary accumulation of mercury by these two species. Mercury concentrations increased with increasing fish length, and were similar in walleyes and white crappies of the same age. This similarity appeared to result from similarities in food habits. The percentage of accumulated methylmercury derived from food was estimated to be 41-62% for walleyes and 51–73 % for white crappies; however, the potential error associated with these estimates is large. Analysis of stomach contents showed that young-of-the-year crappies predominated in the diet of walleyes and were also important in the diet of white crappies; however, zooplankton and aquatic insects were also prominent in the diets of crappies. Diet composition of both species varied with fish size and season, and white crappie diets varied with time of day. Annual food consumption rates were estimated to be 1.5 to 2.2% of body weight per day for walleyes and 1.1 to 3.5% for white crappies. Mercury in forage organisms averaged 0.08 μg/g (range, 0.02 to 0.40 μg). Calculated average concentrations of methylmercury in fish diets averaged 0.05 μg/g for walleyes and 0.04 μg for white crappies. Concentrations in only 2 of 163 walleyes and none of 248 white crappies exceeded the current Food and Drug Administration consumption guideline of 1.0 μg/g.

New **York.** The recent resurgence of interest in hydroelectric development, particularly for small-scale or low-head facilities, has prompted an examination of our understanding of the effects of such plants on resident and migratory fish populations. Throughout much of the United States, small-scale hydroelectric plants are being built or restored on streams and rivers that support valuable populations of anadromous fishes or have been the object of fish restoration efforts in the last decade. Many of these plants will be equipped with high-efficiency hydraulic turbines, for which information on fish passage, at least for some species, does not exist. In studies at a small-scale hydropower demonstra-

tion site, the New York Cooperative Fishery Research Unit developed testing methodology and evaluated fish passage through two newly designed impulse-type turbines. Anadromous fish of particular interest on the northeast coast that were tested were Atlantic salmon, striped bass, and American shad. Information was also obtained on rainbow and steelhead trout. Juvenile salmonids all demonstrated a size-dependent mortality relation as they passed through the 650- or 850-kw Ossberger Crossflow turbines. Losses ranged from 15% for fish equal in size to outmigrating Pacific salmon to over 60%70 for fish as large as many Atlantic salmon smolts. Suitable testing methods for American shad and striped bass were not developed, although it appeared that the mortality of these species during passage through hydraulic turbines is higher than that of the salmonids tested. The estimates of mortality developed in this study should provide management agencies with the background information required to make recommendations regarding the use of these particular turbines at hydroelectric sites, as well as to suggest the need for incorporating downstream passage facilities at certain sites. Both State and Federal agencies with responsibility for the fisheries have previously been constrained by a lack of information on this turbine design.

North Carolina. Surf clams and other marine organisms near New Jersey are adversely affected by intermittent periods of low oxygen conditions. We attempted to determine some of the ecological conditions accompanying the success of surf clam populations. Sampling with two dredge types showed a 7-fold increase in density and a 1.4-fold increase in weight of the surf clam population within the 111-km^2 area adjacent to Little Egg Inlet between 1976 and 1977. The increase was due to the exceptionally high survival of the 1976 year class. Hypoxic water conditions occurred from mid-July through mid-September 1976, after the peak abundance of recently settled surf clams. The hypoxia reduced predation of crustaceans, echinoderms, and fish on recently settled clams, and contributed to the unusually successful survival observed. Adult surf clams were most abundant in the shallow inlet delta. The density of adults in 1977 was strongly correlated with the density of adults in 1976, as well as with the density of young of the year and yearlings. A multiple regression model indicated that 70% of the variation in the density of adult surf clams in 1977 was accounted for by the density of adults in 1976, the density of yearlings, and the density of young of the year. Adult surf clams had the highest similarity coefficient with young surf clams in 1976 and with yearlings in 1977.

A comprehensive review of the literature and the current status of the anadromous fishes of southern waters was completed. The review describes the life histories and ranges of these species and discusses their economic and recreational values. All of the major conservation agencies of the southern States contributed their assessments of the major problems affecting the species and the programs they have under way to protect them from further degradation. In addition, groups within the Fish and Wildlife Service and in the States were consulted to determine research and development needs required to promote their population in the major river systems of the South. The 520-page report provides the first compendium of past and current information about these fish, which contributed materially to the early economy of the United States and have the continuing potential of being important in the future.

Ohio. Sublethal effects of contaminants on fishes are often difficult to detect and quantify. Recent work on marine fishes has indicated that contaminants influence development in fishes by causing bilateral asymmetry: certain bilateral structures (e.g., numbers of fin rays and lateral line scales) are not the same on both sides of the fish. If the degree of asymmetry is directly related to levels of contaminants, it could be a valuable tool for detecting and quantifying the degree of contamination in a given environment. We attempted to relate contaminant levels in yellow perch to degree of bilateral asymmetry, and to induce bilateral asymmetry in fathead minnows by exposing adults and eggs to DDT, PCB's, and mercury. Yellow perch from Lake Erie and from four reservoir populations that originated from Lake Erie were analyzed for contaminant levels. Morphometric characters that were counted to determine degree of bilateral asymmetry were pectoral fin rays, gill rakers, and number of scales above, below, and along the lateral line. Although the degree of bilateral asymmetry differed among populations, the differences were not related to contaminant levels. In the laboratory, however, bilateral asymmetry was induced by exposing adults and eggs of the fathead minnow to DDT and PCB's. Clearly, contaminants can induce asymmetry, but in yellow perch, in which natural levels of asymmetry are high, moderate to high exposure rates may be necessary before the effects of contaminants become evident.

Supplemental stocking of new impoundments is

Aquatic plants significantly affect fish communities and fishing success. At the Ohio Cooperative Fishery Research Unit, we are describing and quantifying the relation between plant density and largemouth bass feeding success, using artificial plants in laboratory systems. The results are being tested in controlled field experiments, where natural aquatic plant densities are known. Density of prey and growth of both predator and prey are monitored as experimental responses. *Photos courtesy of Ohio Cooperative Fishery Research Unit.*

Measuring the buccal gape of a striped bass x white bass hybrid, as part of a food study in Oklahoma of this increasingly popular fish. The measurement enables estimation of the maximum size of prey that the fish can swallow. *Photo by G. Gilliland.*

frequently done to insure rapid development of sport fish populations. Such stocking of moderate to large impoundments can be costly. In a 5-year study we documented the development of fish populations and the sport fishery in 482-ha Paint Creek Reservoir, a new impoundment in southern Ohio that was not stocked. Fish populations expanded rapidly and peaked in the third and fourth years after impoundment. Growth rates were exceptionally fast during the first 2 years and then declined. Black basses, crappies, and bluegills were the predominant sport fishes. Catch rates were highest in the third year, and thereafter declined to levels typical of older reservoirs. The fish community had stabilized in 5 years and it was clear that supplemental stocking was not needed to insure successful development of a sport fishery in this reservoir.

Oklahoma. The feeding interactions between striped bass x white bass hybrids and largemouth bass were investigated in Sooner Lake, Oklahoma, by seasonal estimation of relative abundances of predators and prey, and evaluation of the food, food selectivity, and diet overlap of the predators. Both predators preferred gizzard shad and threadfin shad. Sunfishes were eaten in proportion to their abundance in the environment, and inland silversides were generally avoided. Significant diet overlaps were found between various length groups of hybrids and largemouth bass during several seasons, but the frequency and degree of overlap decreased for all but the largest length groups after threadfin shad were introduced.

Channel catfish and blue tilapia appear well suited for use together in small-scale cage fish culture. We attempted to determine whether polyculture in small, shallow ponds could produce marketable-sized channel catfish from small fingerlings in one growing season, to ascertain whether small numbers of blue tilapia would increase net production of caged channel catfish, and to document any differences in mean weight per channel catfish and the percentage of harvestable fish produced in polyculture versus monoculture. We cultured channel catfish and blue tilapia in 1-m cages at three densities: 0 tilapia and 400 channel catfish, 10 tilapia and 390 channel catfish, and 50 tilapia and 350 channel catfish. After 136 days, the mean weight of channel catfish and percent harvestable fish per cage were both significantly higher in cages containing 50 tilapia and 350 channel catfish than in cages containing only 400 channel catfish. Net production, food conversion efficiency, and condition factor did not differ significantly among channel catfish stocked at the different densities.

Oregon. To evaluate habitat use by resident fishes of the lower Columbia River reservoirs, we established biological sampling stations on the basis of the results of a limnological survey conducted during summer. Water current and depth were the only variables that changed significantly throughout John Day Reservoir. The water flowed relatively fast and was shallow in the tailrace, and slower and deeper in the forebay. The reservoir, which does not stratify, was divided into three main zones on the basis of their physical characteristics: the tailrace, transition zone, and the forebay. Habitat types sampled in each area included open shorelines, protected shorelines (coves and back eddies), and backwaters (sloughs and tributaries). Adult, juvenile, and larval fishes were sampled with a variety of gears. The most striking differences were the preponderance of exotic fishes in the slower backwaters and of native fishes in the main channel. Cyprinids and catostomids were more abundant in the tailrace during late summer and early fall, perhaps as a result of lower discharges and higher temperatures. Larval fish distributions suggested that the backwaters and upper main channel are important spawning and rearing areas. Patterns of fish distribution were the same in 1980 and 1981. Nongame fishes, particularly sculpins, were found to be important dietary components of game fishes. We at-

Power plant reservoirs represent a potential new fishery resource in northern climates. Evaluation and testing of these new environments for fish will assist in ensuring their optimum use. Some appear to be well adapted for the rearing and retention of walleye and muskellunge brood stock. Here the gill net being lifted was set to sample fish populations in a power plant cooling reservoir in South Dakota. *Photo by R. L. Applegate.*

tempted various approaches to classifying fish habitats but found that a better relation was obtained when fishes were grouped into functional classes.

The objective of a study of seasonal distribution and habitat selection by the redside shiner in a small Oregon stream was to document habitat selection by this shiner, a small cyprinid that is believed to compete with juvenile salmonids for food and space. We found that redside shiners changed their patterns of habitat use with life stage, size, season, and availability of usable habitat. Water velocity, depth, temperature, and size of substrate particles were important variables accounting for variation in the habitats selected.

We examined stomachs of cormorants from Crane Prairie Reservoir as a first step toward determining the extent to which they prey on salmonid fishes. Tui chubs composed 64% of the diet and trout 3%; 33% of the contents were digested to a stage where identification was difficult or impossible, but bony remains suggested that they were not trout. Our work supported past findings, which indicated that cormorants are not voracious predators of juvenile salmonids.

As part of the Habitat Evaluation Program of the Fish and Wildlife Service, we developed models that enable an assessment of habitat quality for 13 species of Pacific Northwest fishes. Literature information was supplemented with field observations to refine the models. Multivariate analyses suggested that factors influencing the distribution of fishes in streams do not have constant relationships from reach to reach. Habitat availability, presence of other species, and physiological responses to gradients may act in concert to change these relationships.

South Dakota. The National Task Force for Public Fish Hatchery Policy (1974) reported that the inability to rear the tiny fry of fishes like walleyes and yellow perch on artificial diets was a major problem in the national fish-culture program. We conducted studies to determine if invertebrates in municipal sewage lagoons could be used to feed fry. The studies were designed to document the species composition of invertebrates in a local municipal sewage lagoon and the species and sizes of invertebrates selected by the fry. Invertebrates of five genera were fed to walleyes for 51 days after hatch-

ing. The cladoceran *Moina brachiata* was selected for; the copepod *Cyclops vernalis* was initially eaten in the same proportion as available, but later selected for when *M. brachiata* was not available; and the cladocerans *Daphnia magna* plus *D. pulex* (combined) and the rotifer *Asplanchna sieboldi* were selected against. The rotifer *Brachionus* sp. was not eaten. As the walleyes grew, they selected for progressively larger cladocerans but not for progressively larger *C. vernalis.* Walleyes collected during the day (11:00 a.m.) ate significantly more organisms than did those collected at night (11:00 p.m.) initially, but significantly fewer after 15 days of feeding. The same genera of invertebrates that were fed to walleyes were fed to yellow perch for 32 days after hatching. During the first 5 days of feeding, *Brachionus* sp. was selected for by yellow perch collected during the day and *M. brachiata* by perch collected at night. During the rest of the study, *Brachionus* sp. made up most of the food eaten, although it was not selected for. *Moina brachiata* was selected for on days 6-20 by fry collected both during the day and at night. *Cyclops vernalis* was eaten in the same proportion as available by fry collected at 11:00 a.m. during the first 10 days, but was selected for by fry in both day and night collections on days 11-25. *Daphnia magna* plus *D. pulex,* and *A. sieboldi,* were selected against. Mean diameter and length of cladocerans eaten increased from 0.20 and 0.36 mm on day 1 of feeding to 0.34 and 0.57 mm by day 20. The mean size of cladocerans eaten by fry collected at 11:00 a.m. and at 11:00 p.m. did not differ significantly, but significantly more organisms were eaten by fry collected at 11:00 a.m. than by those collected at 11:00 p.m. The studies demonstrated that fry of walleyes and yellow perch can be reared by feeding them invertebrates from municipal sewage lagoons, and that they selected invertebrates that commonly predominate in wastewater stabilization ponds. We concluded that sewage lagoons may provide an abundant and economical source of invertebrates of suitable size to feed to walleyes and yellow perch during their early development.

Tennessee. The immature forms of insects living in streams are primarily important as food for fishes, but they also serve as an indicator of the relative condition of the stream. The number and kind of organisms present often indicate whether a stream is being polluted or has been polluted in the past. We sampled these bottom organisms in more than 100 streams in the coal-production areas of Tennessee, Kentucky, and Alabama so that data would be available for comparison with data that might be collected after mining occurs. In watersheds where mining and other kinds of pollution have already occurred, our data can be used to evaluate reclamation efforts.

In a study similar to that on stream insects, freshwater mussels were studied in the Stones River, Tennessee, to determine the effects of pollution on the aquatic life of streams. This river is being adversely affected by agricultural practices, domestic and industrial wastes, and gravel removal. Since mussels cannot move away from pollution, they are a good indicator of what is occurring in the stream. The number of species of mussels collected in 1980-81 declined 22% from the number collected in 1968, suggesting that conditions have deteriorated over the years. More specific information on the likely sources of pollution was provided to the State and Federal agencies concerned with the problem.

Utah. In recent years considerable information has been collected on the toxicity of fluoride to freshwater fishes. Unfortunately, concentrations that produce adverse effects are still difficult to predict because toxicity is influenced by the chemistry of the water in which the fish live. Standards for fluoride in wastewater often fail to reflect the influence of important environmental factors on toxicity. In the western United States where measurable concentrations of fluoride from natural sources are common in surface waters, water is becoming increasingly valuable. Multiple use of water will soon become imperative in the dry arid parts of the region as the human population expands and energy development continues. Hence, additional information is urgently needed to establish realistic standards for fluoride for other than domestic use. In a study of the acute toxicity of different concentrations of fluoride at different levels of water hardness to rainbow trout, a species common to cooler waters of the West, we demonstrated that the tolerance of trout to fluoride increased markedly with increases in water hardness.

The overall goal of the rough-fish management program at the Bear River Migratory Bird Refuge is to reduce damage to aquatic habitats caused by common carp but still provide optimum forage for fish-eating birds. We conducted a study to determine the movement and behavior of carp in the Refuge so that the most effective control measures could be identified. The efficacy of an experimental control program involving poisoning and screening was evaluated. Biotelemetry, mark-recapture, catch per unit of effort by electrofishing, and

trapping of downstream migrants were used in the evaluation. On-site bioassays were conducted to determine rotenone treatment levels. We analyzed body width of carp to aid in determining screen design, and trapped stream migrants, counted fish killed, and set fyke nets to monitor the effectiveness of the experimental control program. A combination of poisoning and screening was recommended to control carp in units of the Refuge. We concluded that many carp overwinter in canals and deep areas of the Refuge, below potential screening points, rather than in Bear River proper. Other carp enter the Refuge from the River during spring floods. The overwintering fish can be killed in early spring with rotenone. Bar screens placed at intake structures can then be used to prevent reinfestation of Refuge pools. In Unit 1, poisoning followed by screening effectively controlled large carp for 2 years. Numbers of common carp and Utah chubs of a suitable size for forage for fish-eating birds increased substantially after the larger fish were controlled.

Little information is available on the habitat requirements of many species of fish in the Intermountain West, even though proposed energy and water development projects will greatly alter existing aquatic habitat. One segment of a study to acquire information on fish habitat requirements involved determination of temperature preference of mountain whitefish, one of the few species of coldwater game fish that are sustained completely by natural reproduction. Adult mountain whitefish were collected from the Blacksmith Fork River, Utah, before spawning, after spawning, in mid-winter, and in spring. Tests in a thermal gradient where a range of water temperature was available showed that adult fish of the post-spawning and winter groups preferred lower temperatures than did those of the pre-spawning and spring groups. Fish collected just before they spawned preferred water temperatures that would have been lethally high for mountain whitefish embryos. This finding indicated the need for caution in altering water temperature of mountain whitefish habitat in fall.

Virginia. Headwater streams in the southern Appalachians support the major populations of brook trout in the southeastern United States. These streams are relatively infertile, and the amount of trout biomass produced each year appears to be low. However, that amount has not been quantified. We attempted to compute fish production for 1 year in a second-order stream and determine the relative contribution of each species to this annual value. Fish production was evaluated at three sites in Guy's Run, western Virginia, from August 1979 to July 1980. Block nets were set at the upstream and downstream boundaries of each section, and population estimates of each species were obtained at quarterly intervals by electrofishing at each site three consecutive times on each sampling date. Lengths and weights of fish were measured and scales were taken to compute growth rates for each age class. Annual production was computed by the instantaneous growth method, where production per species equals growth rate multiplied by mean biomass for that species. Mean biomass in the stream ranged from 21.4 kg/ha at the upstream site to 47.5 kg/ha downstream. Total annual production by all fish (11 species) was estimated to be 28.4, 31.6, and 39.6 kg/ha at the upper, middle, and lower site, respectively. Brook trout, mottled sculpins, blacknose dace, and bluehead chubs were dominant species and accounted for 87 to 99% of the total fish production. Production by brook trout alone contributed roughly 60% of the total, and half of the trout production was contributed by young of the year.

Five rainbow trout strains (Ennis, Fish Lake, McConaughy, Fish Genetics Lab Standard Winter, and Sand Creek) were stocked into four put-and-take Virginia trout streams as catchable-size fish and evaluated for survival, growth, and movement. Ennis and Fish Genetics Lab Standard Winter strains provided the highest return during the opening weekend of the fishing season and the McConaughy strain the lowest. Returns after opening weekend were high for Sand Creek, Fish Lake, and McConaughy strains. The Sand Creek strain had the highest average percent return for the study and the McConaughy strain the lowest. Mean percent returns for all strains in all streams was 40.5. Survival of fish not creeled was poor, and too few fish remained after 3 weeks of fishing for accurate estimates of growth. Creel analysis suggested that there was downstream movement (11.8% of all fish creeled were captured more than 1 km downstream from the stocking areas), but no upstream movement. Survival and relative growth in an unfished stream were highest for the Fish Genetics Lab Standard Winter strain, due to lower post-stocking mortality; natural mortality rates among strains were similar after strains were established in the stream. Overall survival for all strains was poor, and estimated rates of natural mortality indicated that less than 2% would survive for 1 year, even without fishing. Condition of fish of all strains

deteriorated throughout the study. Both Sand Creek and Fish Genetics Lab Standard Winter strains appeared to be suitable for Virginia's put-and-take fishery; however, no strain evaluated had the characteristics of long-term survival and growth desirable for other types of stocking.

Washington. A perplexing problem facing management agencies attempting to increase coho salmon runs on the Columbia River by planting hatchery-produced fish has been an apparent tendency for survival to decline as output increased. One theoretical explanation that has emerged is that certain trends in hatchery practices may be causing declining quality of smolts in terms of readiness to migrate to sea. Records of hatchery production and facilities at stations where Columbia River coho salmon have been reared over the past 20 years have shown no direct, observable mortalities caused in the rearing ponds by increased rearing densities. However, it is theorized that the increased densities have tended to increase stress, particularly on smaller individuals, making the fish physiologically less capable of successful out-migration. Coho salmon reared in hatcheries under present densities may need to average about 20 mm longer at release time than wild smolts, if they are to be ready for migration; however, about half of the fish now being released into the Columbia River may be smaller than that size. Strong evidence supporting this theory came from an analysis of in-river survival and migration timing of 15 lots of wire-tagged coho salmon stocked at various hatcheries along the Columbia River and recovered at Jones Beach, an experimental out-migrant seining site near tidewater. A regression analysis of adult survival rates as indexed by survival rates of "jacks" (2-year-olds) further implicated increasing rearing density as a major factor contributing to the declining trend in abundance of Columbia River coho salmon.

The lingcod, a key sport species in Washington waters, has been seriously depleted in some areas by overfishing. Artificial propagation may be necessary if previous population levels are to be regained. The biological and technical feasibility of raising lingcod in pens was studied, and captive and wild juvenile lingcod were compared. The effects of varying the frequency of feeding and feed quantities were tested to determine their influence on growth and survival and the frequency of growth inequalities at various feeding levels. Growth rates, growth disparities, body composition, survival, and (to a limited extent) food conversion, were all influenced by feeding regimen. Frequency of feeding alone had little effect. However, fish fed more frequently to satiation often ate more total feed, whereas those fed less frequently ate more per feeding. Growth, measured as either instantaneous rate for individuals or as total weight increase of fish per pen, was linear to food intake. The rate of increase was always proportional to consumption, even at the highest levels of feeding. Regardless of the feeding regimen, social hierarchies developed on the basis of size, several large fish growing rapidly and the rest growing slower or not at all. Growth disparities increased with increases in food quantity or feeding frequency. Cannibalism, which was present in every feeding treatment and accounted for most of the mortalities, was reduced by increased feeding frequency or increased food quantity. Increased feeding may have led to a rise in lipids, a fall in moisture and ash content, and perhaps a slight rise in protein content. Compared with wild fish, fish from intensive feeding regimens were fatter (body lipids were higher), had less ash and water, and about the same amount of crude protein. Overall, growth in captivity, even under the most intensive feeding conditions, did not appear to be better than that in the wild.

Upper Granite Lake, Skagit County, is the only lake in Washington containing Arctic grayling. Grayling were introduced in 1947, and the population has since been maintained by natural reproduction in inlet and outlet streams available for spawning. Cutthroat trout (9-10 inches long) were planted in upper Granite Lake in July 1975. No research has been focused on specific interactions between these fishes, but available evidence suggests that the introduction of trout resulted in a marked decline in the grayling population. Stomach analyses indicated that both trout and grayling more than 6 inches long ate exclusively insects. During the spawning season, male grayling become territorial, and are extremely aggressive. Spawning ground is low-gradient sand-gravel substrate having overhead cover and visual obstructions between territorial males. Females are tolerated within a territory only for the spawning act. Grayling and cutthroat trout do not appear to compete directly for the same spawning sites because they prefer water currents of different velocities in tributary streams. Therefore, they use separate parts of the stream for spawning. The estimated standing stock of fish (11 pounds per acre) is only about one-fifth the estimated carrying capacity of the system. Although cutthroat trout and grayling are potential food competitors, the competitive effects are diluted by

low population densities. The amount of adequate spawning space limits population size. The aggressive territoriality of the male grayling limits the number of spawners that can simultaneously use the spawning grounds. Seasonal flow characteristics of the inlet streams further limit the amount of potential spawning area used. Adding instream cover to provide visual isolation for territorial males and rock and gravel or log dams about 1 foot high to the upper reaches of the inlet stream might increase spawning success severalfold. The current catch-and-release regulation for grayling should be retained indefinitely or until grayling production is increased.

Wisconsin. The effects of the notching of wing dikes (ridges of rock extending perpendicularly from the bank) in the Mississippi River were studied. The dikes were up to 400 m long and 15 m wide, and all were submerged for at least part of the year. Sediment, which is often detrimental to aquatic organisms, is deposited behind wing dikes and in chutes and backwaters below them. The notching of wing dikes may increase flow through the dikes, reducing this sedimentation. Objectives of this before-and-after study were to determine the effects of notching on fish, macroinvertebrates, water velocity, hydrographic relief, sediments, temperature, dissolved oxygen, and transparency in the vicinity of the notches and in a downstream chute. Samples and data were collected at the study site, 8 miles below Bellevue, Iowa, in June, August, and October in 1978 and 1979, and June and August 1980. The dikes were notched in May or June 1979.

Current velocity increased after notching, as expected, but the proportion of sand in the substrate of the chute increased, rather than decreased. No appreciable effects on fish were detected. Benthos populations were reduced by unusually high summer discharge during the prenotching phase. The populations in the main channel recovered after notching, but apparently not as a result of the notching. Benthos populations in the chute did not recover after notching — perhaps as a result of increased sand in the chute after notching. The results suggest that the notching of wing dikes that are submerged during much of the year may have little value.

COOPERATIVE WILDLIFE RESEARCH UNITS

Alabama. Habitat used by the threatened eastern indigo snake and some associated species has been investigated in southern Georgia. Thirty-seven adult indigo snakes were instrumented during the study; their locations provided data on habitat use. All radio-instrumented indigo snakes used sandhills during winter, and 94% of the winter dens were gopher tortoise burrows. They nested, foraged, and denned in tortoise burrows during other seasons and frequented sites prepared for reforestation, especially the windrows of plant debris resulting from clearing operations. Spring-fall habitat included sandhills, creek-bottom thickets, upland pine-hardwood forest, upland mixed hardwood forest, and agricultural fields usually adjacent to sandhills. Gopher tortoises colonized sites where sand depth typically exceeded 1 m and occupied a range of about 4 ha. Thirty other vertebrate species were observed using tortoise burrows. Most of the remaining indigo snake habitat is now in sandhills, which are either planted to slash pine or remain in more natural longleaf pine-scrub oak communities where most of the larger longleaf pine has been removed. In a frequently burned slash pine plantation, herbaceous biomass was 2.3 times as great, tortoise density was 3.1 times as great, and indigo snake use was 2.8 times as great as in an adjacent more natural area where most longleaf pine had been harvested and fire was seldom used. Recommended recovery of such areas includes judicious thinning of scrub oaks and reestablishment of the pine component to produce needle cast for carrying fire. The indigo snake feeds largely on other snakes, small tortoises, small mammals, and amphibians. It appears to be at the top of the insect-amphibian-reptile food chain of the sandhills. In Georgia, this species requires many tortoise burrows over a large home range. Gassing burrows of the gopher tortoise with gasoline fumes to drive out eastern diamondback rattlesnakes has detrimental effects on several of the vertebrate species known to use the burrows as dens. In one experiment, two of three indigo snakes died within 14 days after being gassed in tortoise burrows and brought into captivity after they left the burrows. Two Florida pine snakes were also gassed in tortoise burrows (the Florida pine snake and its close relative the black pine snake frequently use gopher tortoise burrows as dens) and brought into captivity after they emerged; both died within 24 days. In another experiment, three of six free-ranging indigo snakes with radio transmitters were gassed. They showed signs of disorientation and inability to regulate body temperature, and died 12-34 days later. The three snakes that had not been

Indigo snake hatching. Captive propagation of this threatened species is being investigated in Alabama. *Photo by D. W. Speake.*

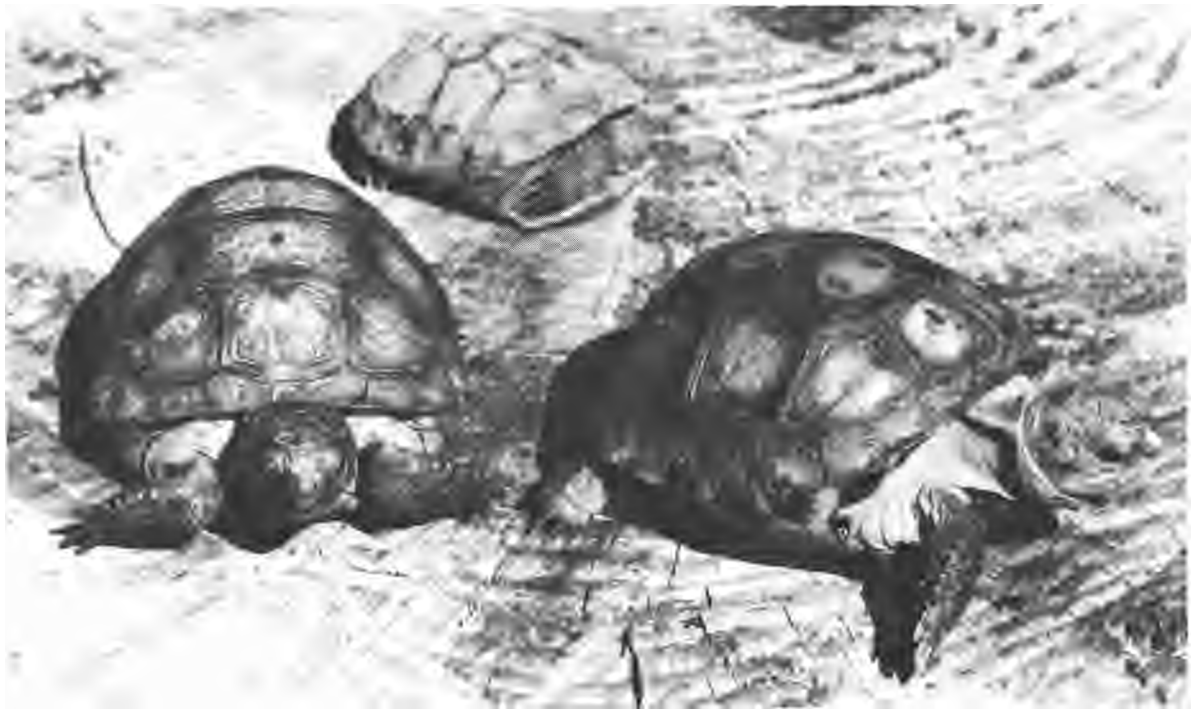
gassed were later recovered in excellent condition. Because most gassing related to rattlesnake hunting is in the winter, it can be lethal to indigo snakes not only through asphyxiation or other direct effects, but also by causing disorientation and inability to regulate body temperature.

Alaska. Lesser sandhill cranes annually migrate from their arctic and subarctic nesting areas to wintering grounds in the southwestern United States. Most populations of sandhill cranes use traditional stopover sites, known as staging areas, along migration routes to rest and feed in preparation for continued migration. The importance of one of these staging areas, the eastern Copper River Delta, to migrating sandhill cranes was assessed from 1979 through 1981. The Copper River Delta is the most extensive area of marshes and tidelands on the northeastern Pacific Coast. Exploration for oil and gas is planned for the Delta, and extensive cutting of old growth forest in the region has been proposed. Use of the eastern Copper River Delta by migrating cranes was determined through watches of 1 hour duration every 2 hours during periods when cranes were moving through the area. The use of foods on the Delta by cranes was determined by examination of gizzard and gullet contents of cranes killed by hunters. Approximately 21,000 sandhill cranes passed through the eastern Copper River Delta during fall migration. Fall migrants arrived in middle to late August and continued to use the Delta through mid-October. Peaks of migration occurred during the second half of September. Spring migration progressed at a more rapid pace and smaller numbers of cranes used the Delta. Cranes fed primarily on arrowgrass, extracting the fleshy bulbs of the plant. Nutritional analysis of bulbs from arrowgrass showed they were rich in carbohydrates and protein, and thus a high-quality food for migrating cranes. These findings confirm the suspected importance of the eastern Copper River Delta to migrating sandhill cranes and provide a basis for protection of this important component of crane habitat during planning for other land-use activities in the area.

Above: Snakes are difficult subjects for radio instrumentation. This indigo snake has just had its radio implanted under the skin. *Photo by D. W. Speake.*

Left: Alabama Unit staff searching for indigo snakes. *Photo by D. W. Speake.*

Below: Gopher tortoises are important to many species as burrow constructors in the southeastern sandhills. *Photo by D. W. Speake.*



Analysis of vegetation on muskox range in the Arctic National Wildlife Refuge is part of an Alaska Cooperative Wildlife Research Unit effort to map muskox habitat as a basis for anticipating expansion of recently reintroduced muskox herds. *Photo by D. R. Klein.*

Eskimo sled dogs were used to assist in live capture and marking of muskoxen in Northeast Greenland in a cooperative study involving biologists of Alaska Cooperative Wildlife Research Unit and Greenland Fisheries Research Institute. The research is aimed at development of guidelines for onshore oil and gas exploration. *Photo by D. R. Klein.*

Muskoxen exterminated by overhunting in Alaska before the turn of the century have now been reintroduced to native ranges. Alaska Cooperative Wildlife Research Unit personnel are investigating habitat selection and use by the expanding muskox herds. *Photo by D. R. Klein.*

Wolves in northwestern Alaska occupied seasonal home ranges coinciding with those of caribou of the Western Arctic Herd and caribou constituted 96% of the large mammals preyed upon. *Photo by D. R. Klein.*

A study team from the Alaska Unit investigated the impacts of gray wolf predation on caribou in and adjacent to the Brooks Mountain Range in northwestern Alaska. Seasonal movements and food habits of two wolf packs were monitored on caribou range. This study was part of a broad investigation of caribou and predator relationships sponsored by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. Wolves were captured with dart guns fired from helicopters and were fitted with collars containing radio transmitters. Movements and hunting behavior of wolves were studied by locating radio-collared wolves and observing them and associated members of the packs. Observations were made from aircraft and by team members with radio receivers on the ground. Carcasses of caribou killed by study wolves were examined to determine sex, age, and general condition of caribou preyed upon by wolves. Scats of wolves were collected at summer homesites of the two packs and examined to determine items eaten. Seasonal movements of caribou were monitored in the vicinity of the study packs. Migrations of the two wolf packs between summer and winter ranges were synchronized with migrations of caribou. Both packs occupied summer home ranges north of the Brooks Range in areas where caribou were common through the summer. During autumn the wolves abandoned their home ranges and appeared to follow bands of caribou south across the Brooks Range to the Noatak River Valley where they spent the winter. During spring the packs moved north to their traditional natal dens a few days before caribou started to arrive on nearby calving grounds. Remains of caribou, moose, and Dall's sheep occurred in 93% of wolf scats examined. Caribou made up about 96% of the ungulates consumed by both packs. One pack fed on 136 caribou from 20 April to 13 October. The annual caribou kill was estimated at 21 to 40 caribou per wolf. This rate would provide roughly 3.2 to 6.1 kg of caribou to each wolf each day. There was no evi-

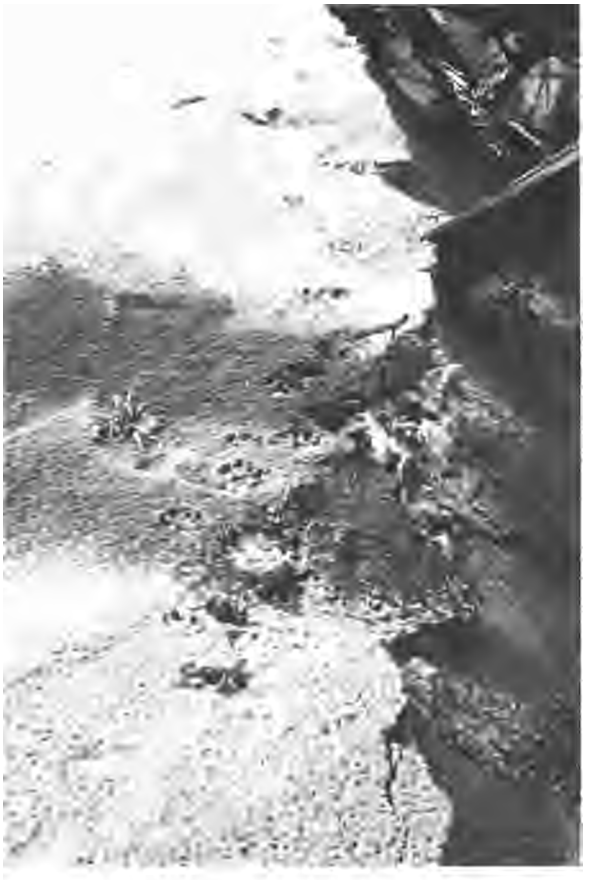
dence of disporportionate predation on caribou calves. This is the first documentation among breeding wolves of synchronization of migration with caribou and results of the study provide a new perspective on management of Federal and State lands in northwestern Alaska.

Moose in Denali National Park were studied during 1976-77 at the request of the Alaska Department of Fish and Game to assess aspects of moose behavior that might influence their sightability during aerial surveys. Interrelationships among diurnal activity, habitat use, and aggregation patterns were considered, and the relationship of season and weather to these aspects of behavior. Diurnal activity patterns changed markedly over short periods of time. Habitat use was strongly related to activity; moose tended to use denser cover when inactive. Aggregation sizes increased from late winter through fall and were larger in open habitats. Moose in aggregations synchronized their activity. No relation was found between aggregation size and weather; changes in activity and habitat use with weather appeared to be related primarily to diurnal weather patterns. Fall is the best time to conduct surveys, but sex-age composition biases will result. Rapid changes in activity patterns over short periods of time make it important to replicate censuses.

Arizona. Populations of black-throated sparrows were studied in a palo-verde-mixed cacti community of the Sonoran Desert during the spring 1980 and 1981 breeding seasons. Territories occurred on similar areas of five 5.8-ha plots in consecutive years. Interspecific relations with other bird or rodent species do not appear to influence territorial establishment. Black-throated sparrows do not select for any single species or plant. There is a positive association between territories and percent coverage of cholla and combined annuals. Comparisons of diversities of annual species from occupied and unoccupied areas show no significant difference. Black-throated sparrows do not appear to focus on any group of annual plant species when establishing territories. Results suggest that black-throated sparrows are not randomly establishing territories across the desert landscape. The absence of stronger distinctions between territories and unoccupied areas are attributed to the insensitivity of measurement (percent coverage data), coupled with large, vaguely defined territories, which may have further masked any differences. Territorial establishment may be dependent on suitable densities of annuals (food), and cholla (nest sites) acting as proximate factors for habitat association.

An evaluation of fencing and nesting island projects to improve waterfowl habitat in the Apache-Sitgreaves National Forest in Arizona was made from 1979 to 1982. Densities and success rates of duck nests on islands were high. These islands probably accounted for much of the increase in the numbers of breeding pairs and ducklings that occurred during the study. At current production levels, ducklings will be produced on the islands at a cost of $2.13 each during the islands' estimated 50-year life span. Densities and success rates of nests on uplands were low, and predation by corvids and coyotes was high. The effects of fencing on the production of ducklings was unclear, but the cost:benefit ratio of the fencing projects will probably be high. As a part of their habitat improvements, the Apache-Sitgreaves Forest personnel created a marsh by using secondarily treated sewage effluent from the city of Show Low. This marsh has been particularly successful — numbers of duck nests found there increased from 3 in 1979 to 378 in 1982. The density (309 per ha) and success (97 %) of nests on the islands at the marsh in 1982 were among the highest that have been reported. The heavy use by waterfowl has probably resulted from the presence of islands with excellent cover and an abundance of aquatic invertebrates as a food source. The success of this project has provided impetus for the construction of similar projects elsewhere in Arizona, but the potential detriments to waterfowl that use wastewater wetlands are poorly understood.

Colorado. To ascertain seasonal movement patterns and important seasonal use by elk in the Upper Gunnison River Valley, we trapped, marked, and released 400 elk, including 87 cow elk instrumented with radio collars, during January-March 1979 and 1980. The elk were tracked primarily by fixed-wing aircraft during May-December 1980 and **1981.** We identified summer and winter range, calving areas, and major movement corridors in three geographic subareas within the study area. Information on movements of elk during the 1980 and 1981 archery, muzzle-loading, and rifle seasons for elk and deer revealed that movements of cow elk during rifle seasons for elk were significantly greater than during the archery and muzzle-loading seasons for deer, and the combined rifle seasons for elk and deer. The Colorado Division of Wildlife and U.S. Forest Service are using the information to make recommendations for adoption of a mining plan and to aid in the development of wildlife recommendations in Gunnison National Forest Master Management Plan.



Sifter, bucket, trowel, and syringe are used to sift sand and construct a scent station for monitoring otter population trends. Otter lure attractant is applied to a tuft of grass. *Photos by J. Clark.*

Georgia. The Convention on International Trade in Endangered Species of Wild Fauna and Flora increased the need for biological data on the river otter. A specific need was for a technique that could be used to monitor population trends. This research evaluated two census techniques: masonite trackboards and sand-substrate scent stations. Environmental pollutant trends as indicated by contaminants found in river otter tissue were also investigated. Trackboards were 0.4 m square, dusted with blue marking chalk, and with a wooden peg inserted upright in a hole in the center of each board. The peg was dipped in an attractant composed of an extract from anal scent glands of the otter. Trackboards were placed at 200-m spacings along stream banks and sandbars and after 2 nights were checked for evidence of otter visitation. Scent stations were 1-m-diameter areas of mud or sifted sand. Otter attractant was placed on a stick or tuft of grass located in the center of each station. Twenty bridge crossings were sampled per study area, and scent stations were placed 100 m above and below each

Survivability of pen-reared cranes released in the wild was tested with 11 greater sandhill cranes reared at Patuxent Wildlife Research Center and liberated at Grays Lake National Wildlife Refuge in Idaho. Only one survived, probably because it achieved a pair-bond with a wild crane. *Photo by R. Drewien.*

Radio-tracking was an invaluable tool in following deer and elk to evaluate range relationships between wild ungulates and cattle under a rest-rotation grazing system in Idaho. *Photo by J. Peek.*

bridge. Trackboard indices were lower and less precise than those of scent stations. The survey was most efficient when two scent stations were utilized per bridge crossing and when stations were checked after 1 night. In Georgia, the survey should be conducted between 15 February and 15 March. The technique is also a useful indicator of mink and raccoon population trends. River otter carcasses were collected from trappers during 1979-81. Muscle, liver, and hair samples were analyzed for cesium-137, DDT and its metabolites, mirex, dieldrin, mercury, and PCB's. Dieldrin, PCB's, and mercury were all higher in the 1979-81 sample than in the 1976-77 sample. Cesium-137 and DDT were lower than in 1976-77.

Idaho. Rest-rotation livestock grazing systems have been in use in the West for a number of years on rangelands utilized in common by livestock and wild ungulates. Rest-rotation grazing systems are designed primarily to benefit livestock. We examined the range relations among mule deer, elk, and cattle in a rest-rotation system on steep, mountainous terrain dominated by sagebrush-grass communities and found that the presence of cattle tended to move deer and elk off the lower, more lush pastures onto higher, steeper, and less-productive slopes. Dietary overlap was low between mule deer and cattle (15%), moderate between mule deer and elk (29%), and highest between elk and cattle (50%). At existing densities of cattle and wild ungulates, vegetation data collected over a 4-year period revealed no drastic change in range condition. Concurrent cattle grazing activities caused redistribution of deer and elk, but the rest-rotation grazing

system was apparently not detrimental to their welfare at existing animal numbers.

The whooping crane recovery plan calls for attempts to start new wild migratory populations of whooping cranes as insurance against catastrophe occurring to the one small existing wild population. One way of starting a new wild crane population is by foster-parenting by transfer of eggs. A second possible approach is by releasing captive-reared cranes into an existing wild migratory crane population with the hope that the captive-reared cranes will adapt and reach breeding age. We conducted such a study using greater sandhill cranes as surrogates for the whooping crane. In June 1980, 11 captive parent-reared greater sandhill cranes of various ages were transported from Patuxent Wildlife Research Center in Maryland to Grays Lake National Wildlife Refuge in Idaho and released into a wild flock. All released cranes were equipped with color markers and were radio-instrumented. Seven of the 11 cranes survived the summer and migrated in the fall. After 2 years of monitoring crane areas up and down the migration route (in conjunction with other studies), only one of the seven captive-reared cranes was known to survive— a 1-year-old female which apparently pair-bonded to a wild male shortly after being released. The other six cranes have not been observed since they migrated from Grays Lake in October 1980, and are presumed dead. This research substantially advances our knowledge of expected behavior from releases of captive-reared cranes and leads the way to a future study which will attempt to avoid some of the problems encountered in the first experiment.

Iowa. Small mammals, studied on reclaimed strip-mine land in Wyoming, used only a negligible proportion of the above ground net primary production. The estimated daily food consumption of the deer mouse population—which averaged 13.5 animals per ha and made up 85% of the small mammal population captured — was about 43 g per ha per day. Green vegetative material made up 33 % of the food, which represented only 0.1% of the total net primary production. Deer mice preferred a native legume, sainfoin, and an annual weed, fireweed summercypress. Relatively large proportions of the net primary production of these two species were eaten. Above ground net primary production of sainfoin was greater on grazed than on ungrazed plots on 2-year-old reclaimed areas, but grazing had no effect on established areas. Plant species composition was not affected by the activities of small mammals.

The use and selection by the marbled godwit of wetland and upland habitat were studied in east-central North Dakota. Godwits frequently used sites with short, sparse to moderate vegetation and open water or bare soil along wetland shorelines. Prebreeding, breeding, and nonbreeding summer-resident godwits seemed to prefer ephemeral, alkali, and temporary ponds but frequently also used semipermanent wetlands. Territorial godwits selected areas with more wetland and more wetland classes than were found on equal-sized randomly sampled areas. The area of godwit territories averaged 0.9 km^2. Postbreeding godwits primarily used feedlots and alkali wetlands. Godwits preferred native or introduced grass pastures and avoided intensively tilled land. At upland sites, prebreeding, breeding, and nonbreeding godwits most frequently used shortgrass (< 15 cm) areas. Postbreeding godwits and broods preferred slightly taller vegetation (15-60 cm). Marbled godwits are adapted to exploit open habitats in the northern prairie that were historically maintained by fire and by the grazing and trampling actions of native ungulates. Management should incorporate the preservation of wetland complexes, including less permanent pond types and alkali wetlands, and the use of fire, mowing, and especially grazing to re-create the characteristics of the pristine northern prairie to which godwits are adapted.

Gray partridge movements, frequency of use of different habitats, and nesting were studied from 1975 to 1977 in north-central Iowa, a region of intensive row-crop agriculture. Use of habitat for nine birds monitored by radiotelemetry, habitat use was compared with habitat availability over four seasonal periods. Strip cover was used at higher-than-expected frequencies in all periods. Partridge occupied the periphery of fields frequently, but the central portion of fields less often. Young partridge broods occupied soybeans at a high frequency and corn at a relatively low frequency; however, the use of corn increased after the young were 5 weeks old. Hay and strip cover and the edges of fields were used relatively often through 2 weeks of age. Activity ranges for six mated birds that were monitored over 4 or more months ranged from 0.84 to 3.66 km^2. Ranges of paired partridge were relatively restricted during prenesting and nesting, but increased in late summer. Birds occupying habitat with a relatively high variety of cover types tended to have the smaller overall activity ranges. In contrast to pheasants, partridges made little use of drainage ditchbank, railroad right-of-way, or grass

Banding a barred owl nestling requires proper equipment, climbers, and a safety rope. This dead elm in southern Iowa, a victim of Dutch elm disease, provided a nesting cavity for barred owls. *Photo by G. K. Gremaud.*

This white-tailed deer fawn in southern Iowa was too young to run faster than researchers of a fawn-searching crew. The radio collar expands as the fawn grows, and gives the location of the fawn as it matures. Because the radio is equipped with a mortality sensor, researchers know by the radio signal if the fawn has been killed by a flood, agricultural machinery, or by predators. *Photo by T. Haindfield.*

waterway cover for nesting; 83% of the partridge nests were found in roadside and fenceline cover. Protection of roadside nesting cover from disturbance should benefit partridge populations in northern Iowa.

The passerine birds of a sagebrush-dominated community in southeastern Idaho were studied in 1980 and 1981. The bird community comprised primarily sage sparrows and Brewer's sparrows that arrived on the study site in early March and late April, respectively. Most male sage sparrows present in 1980 returned in 1981. Sage sparrow territories were continuous and averaged 0.75 ha, whereas Brewer's sparrow territories were not contiguous and averaged 0.51 ha. About 90% of the male sparrows acquired mates. Sage sparrows nested from late April to late July, and Brewer's sparrows from late May to early July. Nesting success was very high for both species (70-90%) in 1980, but substantially lower (40-60%) in 1981. Brewer's sparrows nested in areas with relatively high, dense sagebrush and low herbaceous plant coverage; sage sparrows preferred areas with relatively clumped sagebrush distributions. Both species strongly preferred large, living shrubs as nesting substrates. Sage sparrows placed their nests deeper within shrubs than Brewer's sparrows and avoided placing nests on the southwest side of shrubs. Brewer's sparrows placed their nests irrespective of compass orientation. Vertical vegetation profiles at nest sites of the two species differed; vegetation at sage sparrow nest sites was more dense. Selection of an area for nesting may have been most strongly influenced by foraging strategies, whereas selection of a nesting substrate and nest placement within it may have been influenced primarily by microclimatic factors.

Louisiana. Lead poisoning has plagued our continental waterfowl population since before the turn of the century, but few studies have attempted to estimate the numbers of birds that die after ingesting lead shot. To provide information on mortality from lead poisoning in Louisiana, we collected incapacitated and dead waterfowl on Catahoula Lake and Lacassine National Wildlife Refuge (NWR) during the 1980-81 waterfowl hunting season and analyzed them by postmortem and chemical analyses for lead toxicosis. We found ingested lead pellets in 74.4% of pintails and 68.0% of mallards from Catahoula Lake, and 76.0% of snow geese and 70.6% of white-fronted geese from Lacassine NWR. Lead pellet ingestion was highest in pintails and mallards collected on Catahoula Lake before the hunting season, indicating that waterfowl pick up lead deposited during previous hunting seasons. The number of lead pellets ingested at Lacassine NWR remained almost constant throughout the study in snow geese and white-fronted geese. Of the entire sample of 1,110 ducks and geese, 74.8% had toxic levels of lead. Lead levels ranged to 449.7 ppm dry weight (levels less than 20.0 ppm indicate lead toxicosis). Most of the pintails (82.2%), mallards (80.0%), snow geese (77.0%), white-fronted geese (68.6%), and canvasbacks (52.4%) collected suffered from toxic lead levels. The results of this study show the intense lead poisoning problem on some areas in Louisiana and highlight the need for a suitable alternative in the type of shot used in hunting waterfowl. The Unit conducted a shooting test to evaluate effectiveness in the field of two shot shell loads, No. 4 steel and No. 6 lead, on Lacassine NWR. We compared the loads using data from 8,023 No. 6 lead shot shells and 8,615 No. 4 steel shot shells shot at ducks during the 1980-81 and 1981-82 waterfowl seasons. Of 802 ducks, 366 were crippled with lead shot and 436 with steel shot. Hunters bagged 1,242 ducks with lead shot and 986 with steel. Results of the study showed that No. 6 lead was a more effective load than No. 4 steel because the lead test load hit significantly more ducks per shot fired and crippled significantly fewer ducks that were hit. The lead and steel loads tested did not show relative performance differences at different ranges; however, the proportion of ducks hit per shot was nearly twice as high for both loads at close ranges as for shots taken at distances greater than 35 yards. Also, the proportion of ducks crippled per hit was significantly greater for both loads at the longer distances. The bag consisted of mallards (24%), gadwall (16%), teal (21%), and six other species of less than 10% each. The species composition of the bag was not significantly different between the test loads.

To learn more about the reproductive biology of colonial nesting birds we studied three mixed-species estuarine heronries in Barataria Bay, Jefferson and Plaquemines parishes, Louisiana, during the 1977 and 1978 breeding seasons. We collected information on nesting great egrets, snowy egrets, little blue herons, Louisiana herons, black-crowned night herons, white ibis, glossy ibis, and white-faced ibis. Analyses of 13 egg measurements (including volume, length, widths at various points, and radii of curvature) from 32 eggs each of snowy egrets, tricolored herons, and little blue herons indicated that the eggs were too similar in size and shape to be individually distinguishable to species using these

Tagging of moose in Maine during the summer will enable their ready identification and aid biologists studying the use of ponds by moose. *Photo by R. Dyke.*

Bobcats in eastern Maine are radio-collared and monitored as part of an effort to determine how prey densities and vegetative characteristics influence their numbers. *Photo by D. Harrison.*

variables. We recorded the condition of the eggs and young at 929 nests during the 1977 season and calculated daily survival rates for each of the five stages that make up the nesting cycle: nest-building, egg-laying, incubation, hatching, and nestling. Great egrets had the highest overall probability that an egg would produce a fledgling (78.45%); white ibis had the lowest (10.07%). Little blue herons had the largest average clutch size (3.50) and white ibis had the smallest (1.97). Several characteristics — including nest height, height of vegetation supporting the nest, and nearest neighbor species—were recorded at 722 nests in a heronry to determine if nest sites could be differentiated among the species. Certain species tended to prefer particular sites for their nests within the heronry. The means of almost all variables analyzed were significantly different among species; however, no model could be developed that could reliably determine the species that produced any particular nest.

Maine. During the past 30 years, coyotes have increased dramatically in Maine. Before 1950, virtually none were observed in the State. Their recent appearance and rapid increase have caused some alarm among sportsmen and agricultural interests. The virtual lack of information regarding these animals in New England, and Maine in particular, led to the initiation of this study. Habitat and home range dynamics were investigated. Among seven radio-collared animals, two breeding pairs showed home ranges averaging 50 ± 4 km^2 over a 12-month period. Pair bonds were maintained throughout the year. Marked changes occurred in home range size and in use patterns during the four biological seasons associated with the annual reproductive cycle: pair-bonding and breeding, gestation, nursing and pup-raising, and independence. Home range sizes generally increased from pair-bonding through independence. The range of one other group of three coyotes (one adult and two juveniles) averaged 11 ± 2 km^2 from the latter part of pup-raising season until the juveniles dispersed in late January. Core areas of intensive use (50% of all relocations) inhabited from season to season were similar in diversity of vegetative cover to that of the total ranges. Radio relocations were recorded in forested cover, primarily softwoods, year-round. Blueberry barrens were frequented when fruits were ripe during late summer. Highest levels of coyote activity were recorded in the early morning (4:00-8:00 a.m.) and late afternoon and evening hours (4:00 p.m.-midnight). Snowshoe hares were a staple food source throughout the year. In winter and spring remains of white-tailed deer were commonly identified in scats. Blueberries were utilized heavily in late summer and early fall. In summer and fall remains of mice and voles became increasingly evident.

The Atlantic population of black ducks has been declining since the late 1950's. During the same period the breeding population in Maine has experienced a similar decline. Several reasons have been proposed to account for the decline, including excessive harvest and a stressful environment in winter. This study was initiated to assess the effects of temperature, wind chill, and the availability of ice-free foraging habitat on black duck body condition and behavior during three winters (January-March), 1979-81, in mid-coastal Maine. Fe-

male body condition depended on temperature, wind chill, and foraging habitat availability. Juvenile females were more adversely affected than adult females. Juvenile and adult males were affected less by weather than were adult females. These results suggest that the timing of extreme cold and ice formation influences the sex and age composition and relative condition of black duck flocks. Tide height was the most important factor affecting feeding and resting behavior. Time-activity and energy budgets were thus calculated for a 12.4-hour tide cycle. Nocturnal activity occurred regularly as an adaptation to tidal regimes. Temperature effects modified behavior within the tide cycle and resting was the predominant behavior for all temperatures. During extreme cold and extensive ice cover, black ducks rested more and curtailed activity, including feeding. Birds, however, continued flight activity during adverse weather; as ice covered foraging areas, ducks were forced to fly in search of an increasingly patchy food resource. Energy costs associated with activity decreased with decreasing temperature, but total daily energy requirements increased, a reflection of increased costs of thermoregulation. Daily energy requirements for female black ducks ranged from 150 kcal per bird per day at 5°C to 240 kcal per bird per day at — 20°C. We conclude that weather severity in winter is an important factor affecting the behavior and physical condition of northern-wintering black ducks and probably contributes to reduced survival. Possible management procedures include identification and preservation of critical wintering habitat, reduction of disturbance factors such as hunting and shellfishing, and the viability of artificial feeding programs in winter. Together with other ongoing projects, this study has provided significant data currently being used in the management of black ducks in Maine.

Massachusetts. Beaver habitat classification has progressed from early qualitative descriptions to the quantitative studies of more recent years. This study represents a refinement in the application of statistical analyses to beaver habitat classification. We investigated factors affecting the suitability of beaver colony sites at 55 stream sites in central Massachusetts and used discriminant and principal components regression analyses to relate variables quantifying food availability and water reliability to site longevity and selection. Variables significant in the preliminary analysis were included in the model development phase of the study. We then applied the two statistical techniques to data obtained at 36 1-km stream sections to develop models that predict the maximum density of active beaver colonies. Percentage of hardwood vegetation, watershed size, and stream width had significant positive effects on number of active colonies, whereas stream gradient and relative soil drainage had significant negative effects. Three land capability classes for beaver, characterized by 0, 1, or 2 or more active colonies per stream kilometer, were distinguished. We made an independent test of each model using data from 20 additional stream sections. The discriminant and principal components regression models can be used with 80 and 75% reliability, respectively, to predict the capability class of 1-km stream sections. The models were 95 and 90% successful in predicting presence or absence of beaver.

This 4-week-old black bear cub and its two littermates are being returned to the den after being weighed and sexed. Denning bears in a Massachusetts study are tranquilized in the winter den to acquire data on condition and reproduction, and to change radio collars each year. *Photo by W. E. Dodge.*

Activity and movement data collected from 25 radio-tagged black bears in western Massachusetts indicated that mast crop failures during 1981 caused bears to search for other food sources, resulting in increased crop damage, particularly to field corn.

Thirteen collared bears fed in cornfields at least once in September-October 1981. Extreme movements of the bears were also much greater than the previous fall, indicating wider searches for food. We recorded several 40- to 100-km trips by males and females. A third consequence of poor mast conditions was that all bears denned by the second week of November as compared with late December the previous year. One sow with three yearling cubs denned in the open, 5 denned under windfall trees, and 12 under brush piles in logged-over sites. Heavy snow cover (50-200 cm) produced a deeper state of torpor than in the previous winter that had relatively light snow cover (less than 30 cm). Seven of nine bears observed in dens in 1980-81 denned within 0.5 km of the same den sites used in 1981-82.

Resident populations of non-migratory Canada geese in New England and mid-Atlantic States continue to cause nuisance complaints despite 30 years of capture and transplant operations. Because 95% of these birds are in urban and suburban areas where hunting is prohibited either by regulation or housing density, an alternative control method is needed as a long-term solution. To assess effectiveness of alternative control measures, we are evaluating transplant band recoveries from 1965 to present and also the effects of experimental vasectomy of males of treated pairs. We evaluated the New York and Connecticut nuisance goose transplant program by analyzing band recoveries obtained from Patuxent National Bird Banding Laboratory from 1965 to 1980 for all geese relocated in the following States: Georgia, Maine, New Hampshire, Rhode Island, and West Virginia. The largest percentage of recoveries was from hunting mortality (66%) in the States into which geese were transported. Many geese traveled a long distance from their relocation sites, indicating that they probably joined a mate or migratory flock. Percentages of transferred birds that returned to original capture sites were Georgia 2.2, Maine 1.5, New Hampshire 0, Rhode Island 1.3, and West Virginia 1.9.

Missouri. From November 1978 to June 1981 we conducted a radiotelemetry study of bobcat ecology on a 650-km^2 area in the southern Missouri Ozark Plateau. Concurrently, analysis of historical information, harvest data, and a Missouri Conservation Department agent survey showed that present bobcat range is substantially smaller than during the 1800's, but has not changed significantly since the 1930's. The largest populations are in the contiguous south-central counties. Annual home ranges of adult males were from 29.8 to 107.5 km^2 (average 60.4), whereas those of adult females were from 6.2 to 31.0 km^2 (average 16.1). Juveniles made long dispersal movements, up to 75.2 km straight-line distance; most dispersal occurred during late winter through mid-summer. Telemetric relocations and snow-tracking data indicated that bobcats in Missouri preferred early forest successional stages including regeneration patches, brushy fields, glades, and river and stream bottoms. Rock outcroppings on glades and river bluffs were important daytime retreat sites. Female bobcats had exclusive home ranges, whereas males used larger, overlapping home ranges in a fluid system, separated temporally.

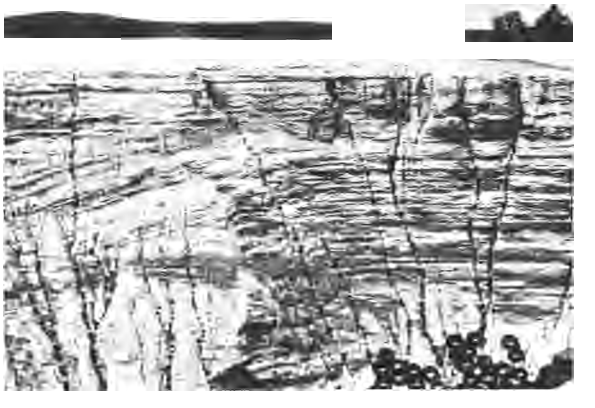
We used three types of questionnaires to determine effectiveness of patrol methods, characteristics of closed-season deer violations, and to establish a sociological profile of closed-season whitetailed deer violations. Information received from public cooperators resulted in apprehension of almost 60% of deer violators that were arrested and convicted during the 2-year study. Deer violations occurred year-round, but most often from early September through February (75% of total violations), on Fridays (19%), Saturdays (20%), and Sundays (14%), and most poaching occurred from 5:00 p.m. to midnight. Ages of violators ranged from 15 to 65 years, and averaged 28 years. Nearly 80% of violators were classified as blue-collar workers. Violators had an unemployment rate of 30%. About 20% of the violators had a felony arrest record, and 48% had been convicted of misdemeanor traffic violations in Missouri; however, only 10% had been convicted previously of game law violations. Forty percent had been drinking alcohol when arrested. Meat (51%) and recreation (33%) were principal reasons given by violators for poaching deer out of season. Deer violators in Missouri apparently represent a distinct subculture, as indicated by the large number of young violators, those drinking alcohol before being apprehended, and the rather large segment with criminal records.

We investigated movement and habitat use patterns of the gray fox in an area of extensive oak-hickory forest in the Missouri Ozarks and located seven radio-marked foxes 2,584 times between May 1980 and August 1981. Composite home range sizes ranged from 334 to 1,329 ha and were correlated ($r_s = 0.62$, $P < 0.05$) to the number of months the foxes were radio-tracked. Nightly ranges averaged 79 ± 51 ha, or 26.8 ± 16.2% of their respective monthly home ranges. The home ranges of neighboring foxes overlapped considerably, but foxes

Neck-banded Canada goose at site of nest flooded by rising waters of a new impoundment. A Missouri study is designed to assess effects of flooding on a resident Canada goose flock. *Photo by D. Brakhage.*

tended to be solitary. Gray foxes were active 87% of the time at night, but only 54% of the time during the day. Diurnal movements were shorter and more localized than nocturnal movements for all seasons sampled, but this difference was most extreme in winter. Foxes used mature oak-hickory forest most frequently and young oak-hickory forest more during the day than at night. The variation in habitat use patterns among individuals suggested that gray foxes are habitat generalists and would probably not be severely impacted by minor land-use changes as long as substantial amounts of woodland are reserved.

Because little information is available on the feeding ecology of blue-winged teal, we studied their food habits and habitat preference during the fall migratory period. We conducted field work on Fountain Grove Wildlife Management Area (WMA) during August-September 1977 and 1978. Gizzards of blue-winged teal collected at Fountain Grove WMA contained 95% plant foods, primarily seeds of emergent moist-soil plants. Esophageal samples collected at Fountain Grove contained 84%



Washout from a pile of lead-mine tailings drains into an Ozark river. Wildlife is monitored for lead burdens in a Missouri study. Bank swallows nest in holes in washout wall. *Photo by R. Atkinson.*

plant foods by volume, and seeds of wild millet accounted for about 83% of total volumes consumed. Culicid larvae and pupae were the dominant animal food. Blue-winged teal gizzards collected at Schell-Osage WMA and Duck Creek WMA con-

tained about 85 and 68% plant foods, respectively. A comparison of vegetation transects from random sites and feeding sites at Fountain Grove WMA described factors important in feeding site selection: shallow water, emergent communities of moist-soil plants, and patchy environments created by habitat manipulations such as mowing and disking. Information gained from this study should be helpful to Missouri waterfowl managers in designing management practices for blue-winged teal, a species that migrates earlier in the fall than other waterfowl.

During May-August 1979-81 we conducted a habitat ecology study of the painted bunting in southern Missouri and northern Arkansas, on the northern edge of the painted bunting breeding range. We described quantitative habitat and investigated comparative ecologies of the painted bunting and its congener, the indigo bunting, to determine if potential competition was limiting the painted bunting's range. Painted buntings exhibited great variation in both territory size (0.64-6.66 ha) and in vegetative features that comprised their habitat. Isolated males had larger territories than birds with adjoining territories. In general, painted buntings occupied old-field-woodland edge sites, but variation within these habitat types was pronounced. Lack of suitable habitat was therefore judged not to be associated with range limitation and the overall low population in the region. Painted and indigo buntings occupied identical habitat and had overlapping territories. Only one instance of agonistic behavior was observed. Limited examination of bill morphology and foraging behavior revealed no significant differences in the two species. There was no evidence of direct interspecific competition; however, we could not definitely conclude that indigo buntings did not have a range-limiting effect on painted buntings.

Both Breeding Bird Surveys (14 years) and Christmas Bird Counts (40 years) revealed continuous and alarming declines in eastern bluebirds in Missouri concomitant with those in eastern United States. We monitored nesting by bluebirds in newly placed boxes and old boxes for two breeding seasons and observed 101 clutches with a mean size of 4.8. Raccoons and black rat snakes were principal predators and house wrens were nest competitors. Unusually high temperatures in July and August inhibited third clutch production and thus productivity. Bluebirds preferred light-colored, thick-walled wooden nest boxes with air vents, placed on east or north sides of poles or under shade trees in open areas at least 400 m from buildings or feedlots. Nestlings (390) were banded but no recoveries obtained; nationwide about 0.1% have been recovered away from the nest site. Analysis of droppings and regurgitated pellets in winter roost boxes showed birds primarily ate wild fruits (20 species), spiders, and ground beetles (Carabidae). Nest boxes may be deathtraps to roosting birds in severe winters and should be closed in fall. A good roost box should be 7 inches square (inside measurement), lined with Styrofoam, have no air vents, and be painted black to absorb solar heat.

Montana. Field investigations on the ecology and populations of river otters in southwestern Montana were conducted from January 1980 through December 1981. Otter presence was detected by examining riverbanks for tracks and latrines, and relative otter populations were determined by scat density. Otters showed strong fidelity to established latrines. Latrine sites were generally in grassy openings on well-vegetated banks and averaged about 15 m^2. Scat deposition at latrines peaked from late April through mid-May. Habitat characteristics that benefit otters include high flow volume, densely vegetated and undercut banks, and the presence of numerous sloughs and side channels that serve as brood-rearing habitat. Low flow volume and turbid water apparently reduced otter use on the Ruby and Beaverhead rivers. Fish occurred in 99% of the 260 scats examined. Suckers were the most important prey item, followed by mountain whitefish. Mottled sculpins were an important sustaining food for otters, as were crayfish, except in winter. Otters took the most available prey, as determined by prey abundance and accessibility. Analysis of harvest distribution and the results of a statewide trapper questionnaire indicated densest otter populations in northwestern and southwestern Montana. Populations in these areas were seen as stable or increasing. Populations are sparse in west-central and central Montana, and otters are generally absent from eastern Montana.

Winter ecology studies of mallards in the Columbia Basin were conducted in November-February 1978-79 and 1979-80. Radio-instrumented mallards remained in contact an average of 17 days, with southward movements predominating. Corn comprised more than 95% of the diet of both sexes after mid-November. Ungrazed stubble fields were preferred feeding sites except when snow cover forced birds to rely on cattle to expose waste grain. Mean distance to field-feeding sites was 7.9 km in 1978-79 and 8.6 km in 1979-80, respectively. Corn supplies

Woodpeckers increased in Montana burns in response to abundant bark- and wood-boring beetle larvae. Three years after the fire, woodpeckers declined and other cavity-nesting birds increased. *Photo by R. McClelland.*

Black-tailed prairie dogs on the Charles M. Russell National Wildlife Refuge, Montana, occupy sites associated with livestock watering areas and homestead sites. By midsummer herbage utilization by prairie dogs was 29%; use by cattle and prairie dogs for the same period was 90%. *Photo by C. Knowles.*

A Montana study indicated that perpetuation of forest mosaics with old-growth components would favor marten populations. *Photo by J. Craighead.*

were adequate to meet the 1979-80 mallard population requirement of 3,285 metric tons. Diurnal mallard populations on concentration areas were highest 1-4 hours after sunrise. Estimates of sex composition were 57.7–58.9 % drakes in 1978-79 and 54.4-56.7% in 1979-80. January body weights of both sexes averaged 10-14% lower than December values. Mid-winter mallard populations in the Columbia Basin were highest when water conditions in the Prairie Parklands were relatively poor, apparently a result of mallards overflying the drought-stricken prairies to breed in the northern Pacific region. Winter weather and its effects on food availability and migration rates also appeared to influence wintering population size.

The ecology and management of black bears were studied from June 1975 through June 1980 on two dissimilar study areas in north-central Maine. The Spectacle Pond study area had no development, human population, or agricultural lands; it also had less exploitation, less access, severer climate, and poorer soils than Stacyville. Bears on the Spectacle Pond area had a more dense population, larger home ranges, lower average litter sizes, an older age for first breeding, less annual mortality attributable to hunting, lower weights for nearly all sex and age classes, longer denning periods, and older average and median ages for females compared with bears on the Stacyville area. Bears on both study areas preferred to use early seral stages adjacent to mature and intermediate forests. Reverting logging roads, raspberry areas, mature hardwood, and, in some instances, agricultural lands were important feeding areas. Important food items were grasses, legumes, and herbs in the spring; various berries and grasses in the summer; and hard mast, non-woody plants, and soft mast in the fall. Hunting regulations should protect adult females in exploited areas. Forest practices harmful to bears included increasing the amounts of permanent logging roads, reducing early seral growth, clear-cutting hardwood, eliminating migration corridors, and establishing large cuts.

New **York.** Birds are among the most visible and adversely affected faunal groups when one considers the impacts of oil pollution on marine environments. Concern has traditionally focused on assessing massive mortalities following major tanker spills. However, relatively little is known about the more subtle effects of petroleum on seabirds. The need for such data is accentuated in view of the widespread distribution of oil at sea and the recent realization that most of this pollution arises from chronic and low-level inputs. Great black-backed and herring gulls were studied in coordinated field and laboratory experiments to assess avian reproductive success and population dynamics in relation to oil contamination. Findings showed that extremely low levels (10 μL) of oil applied to eggs early in incubation severely reduced hatching success. As embryos developed, they became more resistant to oiling. Young hatching from oiled eggs grew and survived normally. Similarly, chicks exposed to oil after hatching were fairly tolerant to small quantities placed on their food or applied externally. However, as was found with eggs, critical periods exist when young may be more susceptible. Current efforts are being directed toward applying these findings to other species and establishing guidelines for petroleum exploration, development, and transportation that will minimize adverse impacts on birds and other biological resources.

Purple loosestrife is a perennial plant that was introduced to the United States from Europe in the mid-1800's. Like many introduced species, once established it expanded its range and now occurs over most of the Northeast and major portions of the Midwest. The plant is associated mainly with wetland environments where it effectively out-competes native wetland plant species. This is generally to the detriment of the wetland system, resulting in a reduction in associated plant and animal diversity. Research was undertaken to help solve the purple loosestrife problem by gathering basic life history and ecological information on this plant and developing strategies for its control. Our findings showed the plant to be extremely prolific and tolerant of a wide range of environmental conditions. Seedling densities as high as 20,000 plants per square meter were observed, and although many of these died during the summer, virtually all those surviving to the end of the growing season resumed growth the following spring. Marshes dominated by purple loosestrife have proved difficult to control and further work is being pursued in this area.

Ohio. Captive mourning doves (24 pairs) were fed diets containing 0, 10, or 40 ppm of the polychlorinated biphenyl Aroclor 1254 and had either a 0 or 10% food restriction imposed on them to examine the effects on courtship behavior. There were no significant interactive effects between PCB's and food restriction. Ten and 40 ppm PCB's significantly reduced courtship intensity and prolonged the courtship phase. In the 10-ppm PCB group, pairs exhibited a differential ability to persist in reproduction under the influence of PCB's. Four

The influence of marsh management practices on nontarget species such as the yellow rail, a species highly sought by birding enthusiasts, is under study at Seney National Wildlife Refuge. *Photo by T. A. Bookhout.*

of eight pairs failed to nest; the other four pairs nested but were less active and the courtship period was longer than that of the control birds. The delay in courtship caused a significant 8-day delay in egg-laying. Pairs fed 40 ppm PCB's did not respond normally to the presence of a mate. They spent the entire 30-day trial period in courtship, and only two of eight pairs formed pair bonds. The 10% food restriction caused a significant delay in pair bond formation. It also reduced the quality of nests built and, because of delayed pair bond formation, delayed egg-laying. This study has shown that some of the reductions in reproductive output occur because of alterations in behavior early in the reproductive cycle, possibly because of contaminant effects on the endocrine system.

Habitat requirements, movements, and breeding biology of radio-instrumented yellow rails were studied at Seney National Wildlife Refuge, 27 April to 4 September 1980. All yellow rails were found in open bog-sedge meadow dominated by the tall, mat-forming slender sedge. This sedge made up 90% of the total stem density which was estimated to be 1,400 stems per square meter. Willow bushes were interspersed throughout the study area and represented the advance of the next seral stage. Seasonally fluctuating water levels and periodic fires were considered to be important to habitat suitability for yellow rails. The principal study area had the highest concentration of singing male yellow rails, one singing male per 5 ha. Four breeding pairs, one immature, and one breeding male were fitted with radio transmitters during the 1980 field season. A total of 1,274 locations were plotted.

Knowledge of high energy yield and consumption of specific plant seeds can be used by marsh managers to provide optimum habitat quality for fall migrating ducks. A known quantity of seeds is being force-fed to a mallard to measure metabolized energy. *Photo by T. A. Bookhout.*

Males were territorial, but the boundaries of the areas of movement of males overlapped during the period singing was heard. Areas averaged 8.3 ha, which was larger than the 1.9 ha used by the only male that carried a transmitter after singing ceased 14 August. The positions of male territories did not vary relative to each other throughout the monitoring period. Females moved within the male territory containing their nest. Females used a larger area before incubation and after hatching (about 1.2 ha) than during incubation (about 0.3 ha). Seven nests, including one re-nest, were found during the study. The average clutch size of nests with completed clutches (n = 4) was eight (range seven to nine). Incubation was estimated to require 17 to 18 days. Hatching was synchronous. One brood nest to which the young were moved shortly after hatching was 15 m away from the egg nest. The only female that was monitored for more than 8 days after hatching of her eggs remained within the area of movement of her presumed mate. Evidence was found for two possible instances of serial polygyny. The immature rail remained near the presumed nest site and moved within an area of 3.3 ha. The primary management activity for yellow rails should be maintenance of the breeding habitat. Present management practices at the Refuge, primarily for waterfowl, have no apparent deleterious effect on habitat used by breeding yellow rails.

Investigation of the decline in eastern cottontail populations on the Delaware Reservoir Wildlife Area, evidenced by a decrease in both hunting and trapping success, showed that a combination of weather and flooding accounted for 59% of the variation in kill per gun hour between 1951 and 1980. Mean minimum temperature for the coldest month of each winter, summer precipitation, and flooding were significantly correlated with kill per gun hour and appeared to be the most important weather factors examined. However, no correlations were noted between changes in the percentage of births by month and low temperatures or flooding during the peak production months of March and April, nor were correlations between the percentage of juveniles in the harvested population and various weather and flooding factors significant. Overall sex ratios from hunting and trapping records did not differ significantly from 50:50, but the percentage of juveniles in the harvest was low (76.7%) compared with other studies and appeared to decline between 1961 and 1980. Predation was the most common cause of death for radio-tagged cottontails between March 1981 and February 1982, and accounted for 58.3% of all known mortalities. Hunting took 18.7% of the monitored cottontails during the 1981-82 season, and accounted for 25% of the annual mortality. Annual adult survival, including hunting mortality, was 0.32.

Oklahoma. There is little information on the density, distribution, and habitat requirements of wood ducks in Oklahoma, a State on the western fringe of North America's interior wood duck population. Furthermore, the implementation of vast water-retention projects has destroyed or altered thousands of hectares of bottomland habitat. River float-counts were conducted on a statewide basis to correlate riverine characteristics with wood duck densities and productivity. Float-counts were also used on an impoundment in southeastern Oklahoma to determine the impact of reservoir construction on breeding densities of wood ducks. Over 130 river float-counts on a stratified sample of 17 rivers revealed the greatest densities and production on rivers in the northeastern region and the lowest densities on rivers in the extreme West. Wood ducks selected log jams and flooded shrub-scrub habitats but avoided open areas. Log jams were also positively correlated with breeding densities, but presence of marsh or swamp habitat around rivers was negatively correlated with densities. Duckling survival on Oklahoma rivers was calculated at 19%. Wood duck densities on impounded rivers equaled densities on unaltered streams; in summer impounded rivers may provide the greatest proportion of wood duck habitat. Wood ducks were concentrated in the secluded cover of impounded rivers. Limited cover and deep water may be responsible for limiting distribution in some impounded river systems.

Oregon. Ruby Marsh is within the boundaries of Ruby Lake National Wildlife Refuge, Nevada, and supports large breeding populations of canvasbacks and redheads as well as a naturalized population of largemouth bass and a stocked population of rainbow trout and brown trout. No forage fish are available as prey, which forces largemouth bass and trout to feed exclusively on invertebrates, an important food resource for breeding canvasbacks and redheads. The feeding ecology of fish and ducks was investigated in 1980 and 1981. Young-of-the-year largemouth bass fed on zooplankton and early instar insects, whereas juvenile and adult largemouth bass fed primarily on nymphs of dragonflies, damselflies, and mayflies. Small rainbow trout and brown trout fed on midge larvae, odonate nymphs, and other invertebrates; large rainbow trout fed pri-

A participant in an extension program sponsored by the Oklahoma Cooperative Wildlife Research Unit demonstrates the use of dogs in quail hunting. *Photo by T. Bidwell.*

marily on snails. Before nesting in spring, canvasbacks fed extensively on tubers of sago pondweed, but once they started laying eggs they switched to a diet of invertebrates. That diet persisted for the remainder of the summer. Predominant foods were snails and nymphs of caddisflies and dragonflies. Redheads fed extensively on muskgrass throughout the summer; however, animal matter—mostly snails, dragonfly nymphs, midge larvae, and bass eggs — made up 50% of their diet during the egg-laying period and 75% during the incubation period. Young redhead ducklings fed nearly equally on vegetation and invertebrates, but older ducklings fed almost exclusively on muskgrass. Young canvasbacks of all ages fed extensively on invertebrates. Snails were the most important food, making up one-third to one-half of the diet of canvasback ducklings.

The dietary overlap between redheads of all reproductive stages and largemouth bass and rainbow trout did not exceed 30%. However, that between certain life stages of canvasbacks and the fish

Biologists from the Oregon Cooperative Wildlife Research Unit study marine communities off the Channel Islands of southern California to determine suitability of these areas for translocation of sea otters. *Photo by K. Miles.*

To help evaluate level ditch habitat in the production of aquatic invertebrates, a biological technician collected samples with a benthic core sampler in eastern South Dakota. Photo by M. R. Broschart.

Quadrat sampling in a large fen wetland in western South Dakota aids in classifying aquatic plants. This information is being used in a botanical survey of wetlands in the Northern Great Plains. Photo by G. E. Larson.

was higher: it was 50% between incubating females and ducklings and rainbow trout, and approached 50% between incubating females and largemouth bass. This study documented the partitioning of the food resource between fish and ducks and clearly indicated the reliance of both on invertebrate food. This information provides refuge management additional biological basis for managing the multiple resources of the marsh.

In the Pacific Northwest, silvicultural practices dictate that old-growth forests be harvested and replaced with younger, faster-growing, managed forests. To determine if such practices influence the avifauna in forest systems in northeastern Oregon, we examined populations of breeding birds and structure and composition of vegetation in managed and old-growth mixed-coniferous forests. Managed forests were about 85 years of age and old-growth stands over 200 years old; both were dominated by Douglas-fir and ponderosa pine trees. Components of vegetation that distinguished old-growth forests from managed forests included large trees (51 + cm dbh) and snags (31 + cm dbh), small understory grand fir trees (2.5-10 cm dbh), and tree height diversity. Each of these components could be associated either directly or indirectly with differences in bird populations between managed and old-growth forests. Bird species diversity and vertical and horizontal structural diversity of vegetation were greater in old-growth forests than in managed forests. These results supported the contention that bird species diversity is correlated with vegetation "patchiness." However, the usefulness of correlations between avian diversity and vegetation structure for management purposes is questioned. Managed forests supported a higher total density of breeding birds than old-growth forests because of the abundance of several species that appeared to prefer structurally open habitats. If remaining old-growth forests are eliminated from areas under intensive management for timber in northeastern Oregon, some species of birds will increase in density, some will decrease, and a few may be extirpated from the area under management. Maintenance of key habitat components for those birds that would otherwise decline in density challenges forest and wildlife managers as the remaining old-growth forests are cut.

South Dakota. Prairie wetlands in eastern South Dakota are of great value to wildlife. They are important to waterfowl and other migratory aquatic birds and furnish winter cover and reproduction areas for most resident game and non-game wildlife species. Our current studies include estimates of recreational benefits of wetlands; small mammal, waterfowl, and shorebird use of natural and modified wetlands; and aquatic invertebrate production in prairie marshes. Recently completed studies examined the aquatic plant communities and invertebrates in a South Dakota prairie marsh at weekly intervals throughout the duck brood-rearing season. More than 1,100 samples of aquatic plants and associated invertebrates were collected. Linear regression revealed a 4:100 ratio of animal to plant biomass. Strong associations were found between common hornwort and Gastropoda, and between corn-

mon duckweed and most zooplankton groups. In the star duckweed invertebrate community, amphipods and gastropods were the dominant macroinvertebrates. Cladocerans were the dominant microinvertebrates. Density and biomass of specific invertebrates varied throughout the summer. Crude protein values of the community samples ranged from 7.6 to 18.5%. Highest protein values were recorded during the early part of the season. The investigations provided valuable information on the quality of food available to duck broods.

Water retention of intact prairie marshes (i.e., not artificially drained) provide groundwater recharge and flood control benefits. However, before these benefits can be quantified, the water retention capabilities of wetland basins must be determined. In fall 1981 maximum storage volumes of 15 small wetland basins (<1.58 ha) in a portion of eastern South Dakota were measured. The logs of these volumes were plotted against the logs of their surface area and an excellent regression equation was attained, demonstrating that storage volume can be predicted by surface area. This technique has potential for determining the amount of water that can be held in storage in wetlands in a given watershed by measuring only surface area of the basins. However, the method needs to be tested in different types of land formations.

We also measured the volume of water retained in 213 small wetlands (all natural basins having ponds less than 3.0 ha) on 726 ha of public lands in eastern South Dakota during April 1982. The basins measured were not filled to capacity but held about 20 ha-m (158.7 acre-feet) of 1982 spring runoff. These types of wetlands store considerable amounts of water over a large geographical area. Loss of this storage capacity through drainage has the potential to increase flooding at lower elevations of the watershed.

Utah. A circular variable filter spectrometer was used to measure electromagnetic energy for several species of birds and their primary habitat types. Energy in the ultraviolet, visible, and near infrared portions of the spectrum was measured and analyzed to determine wavelength bands that allowed discrimination between a bird species and its background. Wavelengths were found in the near infrared (0.744 and 0.981 μm) that were then used as a unique spectral "signature." A mathematical algorithm was derived allowing classification of each species of bird vs. its background. This information may be useful in a remote sensing system to census bird populations.

Circular variable filter spectrometer is used to measure spectral reflectance of a sandhill crane. Photo by J. Payne.

Virginia. Land Between the Lakes (LBL) is a 170,000-acre peninsula in western Kentucky and Tennessee that the Tennessee Valley Authority is developing to provide an optimum opportunity for outdoor recreation and education needs of an urbanizing society. Two important resources are white-tailed deer and fallow deer populations. About 13,500 bow hunters annually hunt the LBL woods, and over 35,000 gun hunters annually apply for a computer selection of 12,000 to 15,000 hunting permits. All hunts combined result in an annual deer harvest of about 2,500 animals. Managers need a good description of the people who hunt in LBL, their hunting patterns, and opinions on important facets of deer management. Three methods have been used to obtain better information on the LBL deer hunter: (1) personal contact with the sportsman at LBL or during local sportsmen's meetings, (2) special regional public meetings, and (3) mailed

Tularemia-infected cottontails are bled to check for bacteria and antibodies in the blood. *Photo courtesy of Virginia Cooperative Wildlife Research Unit.*

White-tailed deer are a valuable resource to both bow and deer hunters on Land Between the Lakes management area. *Photo by J. J. Scanlon.*

questionnaires. Questionnaires were mailed to 1,250 bow hunters and 1,200 gun hunters: 96% of the bow hunters and 87% of the gun hunters completed and returned the questionnaires. Most hunters (97%) were male, with at least a high school education (87%). The average age of both bow and gun hunters was 31 years. The hunters averaged 9 years of deer hunting experience, 3 of which included LBL deer hunts. Bow hunters traveled an average distance of 90 miles, and gun hunters 85 miles, to hunt at LBL. Twenty-six percent of the hunters returned home for overnight lodging, 25% camped along LBL roadways, 35% used LBL campgrounds, and the remaining 15% used other forms of lodging. Bow hunters spent an average of $93.40 within a 25-mile radius of LBL, whereas gun hunters averaged $68.71. Thus, LBL deer hunting contributed over $1.5 million in income to the local economy. Bow hunters typically spent 4 days deer hunting in LBL; 36% spent 4 to 6 hours per day hunting. Only 16% of the hunters hunted alone; 51 % hunted with one other person, and the remaining 33% hunted with two or more people. Most bow hunters walked ¼ to ½ mile (35%) or ½ to ¾ mile (21%) from their vehicles to their hunting sites. For the 8% of the bow hunters who harvested a deer in LBL, the average shot distance was 23 yards. Gun hunters spent an average of 1.6 days deer hunting in LBL; most (43%) spent 7 to 9 hours per day hunting. Only 17% of the gun hunters hunted alone, 44% hunted with one other person, and the remaining 39% hunted with two or more hunters. Most gun hunters (29%) hiked ¼ to ½ mile to their hunting site, 22% hiked ½ to ¾ mile, and 13%, over 1 mile. For the 23% of the hunters who harvested a deer with a gun, the average shot distance was 63 yards. When asked to select the single item that was most important to the hunter's total hunting satisfaction, "being close to nature" was selected most often by bow hunters (19%); "harvesting a deer" was most often selected by gun hunters (23%).

Information on the status and population trend of the bobcat in Virginia is needed to assess the impact of harvest and to formulate management plans. Age and reproductive data from 67 bobcat carcasses and 15 lower jaws were collected during the 1979-80 and 1980-81 trapping seasons. Sex and age information on 16 bobcats taken in 1977-78 and 25 taken in 1978-79 were provided by the Virginia Commission of Game and Inland Fisheries. The mean age from the pooled sample was 2.83 ± 0.24 (SE) years. Juveniles made up 25% of the pooled sample, and the maximum age was 12 years. The sex ratio of the pooled sample was about 1:1. The mean litter size, by counts of placental scars, was 2.27 ± 0.18 (SE). Scent-station survey data and

bobcat harvest records were directly correlated only in the Piedmont region where sharp upswings in both harvest and track counts were noted. Bobcat harvest records for the last 8 years were not correlated with bobcat pelt prices. License sales were not correlated with bobcat harvest. Bobcat harvest was inversely related to precipitation.

The response to a mail survey of sportsmen, game wardens, taxidermists, and fur buyers was 37.7%. Most sportsmen (56%) believed bobcats were increasing, 20% considered them stable, and 24%, decreasing. Game wardens believed bobcats were either increasing (27.9%) or stable (61.8%). The survey revealed that most bobcats killed in Virginia are taken fortuitously by sportsmen seeking other species, and that 13-16% of the annual harvest is taken to taxidermists to be prepared as trophies. Game wardens surveyed believed bobcats were present in 72 counties or cities and absent from eight counties. This survey, coupled with pelt tag records, indicates that bobcats are distributed almost statewide, except for the "Eastern Shore" and are more widely distributed than indicated by a previous study in 1952. Models based on population characteristics and harvest data predicted an increasing population with an adult survivorship of 73%, juvenile survivorship of 36%, and a finite rate of increase of 1.14 (a 14% annual increase). The results suggest that the annual harvest is about 25% of the population and that trapping pressure is relatively low.

In an area of low eastern cottontail abundance, raccoons and other carnivores exhibited agglutinating antibody titers to tularemia antigen. Very little research has been conducted on the effects of tularemia infection on wild carnivores and although usually considered resistant to infection by tularemia, the possibility of a bacteremia in resistant species has not been examined. Resistant species could produce for a limited period a bacteremia that could serve as a source of infection for vectors of the disease. To add to the knowledge of the ecology of tularemia, we conducted experiments examining the possibility of a bacteremia in carnivores and studied the effects of infection on susceptible species. We performed a series of experimental tests using the LVS and Schu S4 strains of *Francisella tularensis* on raccoons, cottontails, white-footed mice, and CD-Sprague-Dawley rats. Raccoons were resistant to high doses of both strains. One raccoon infected with Schu S4 produced a detectable bacteremia of at least 5 days' duration. Doses of 10^6 organisms injected intraperitoneally killed eastern cottontail rabbits in 48 hours, and a dose of 10^2 caused death in 4 to 5 days. High doses (10^{-10}) of LVS had no effect. Rats (CD-Sprague-Dawley) also were susceptible to Schu S4; seven of eight infected with 10^6 organisms died within 48 hours. Rats infected with a dose of 10^2 died between 5 and 21 days after inoculation.

Wisconsin. The ruffed grouse is one of Wisconsin's most valuable game species. Previous studies

Molting adult and flightless young Canada geese were driven into nets so that they could be fitted with leg bands and plastic neck collars. These geese, which are part of the Eastern Prairie Population and which breed on the Hudson Bay lowlands of Manitoba, are marked with orange neck collars engraved with unique alphanumeric codes. *Photo by S. DeStefano.*

on harvest rates in Wisconsin, Michigan, Minnesota, and Alberta have indicated light hunting pressure, but these studies were on large tracts of relatively inaccessible land with short hunting seasons and consequent light hunting pressure. Many of the public hunting lands in central Wisconsin today are accessible to a large and increasing number of upland bird hunters, and ruffed grouse hunting regulations have undergone considerable liberalization in the past four decades.

In 1978 the Wisconsin Cooperative Wildlife Research Unit initiated a study to measure modern-day harvest rates on a large and heavily hunted public area in northeastern Wisconsin. The 6,466-ha Navarino Wildlife Management Area in Shawano and Waupaca counties is readily accessible to over 0.5 million people who live within a 50-mile radius. From 1978 to 1981, over 800 ruffed grouse were captured in lily-pad traps and fitted with aluminum leg bands inscribed with a return address. To encourage returns, the bands carried a $5 or $10 reward, but we detected no difference ($P < 0.05$) in return rate based on reward value. Recovery rates of banded grouse shot by hunters during 1978-81 were 18%, 31%, 31%, and 20%, respectively. These percentages represent minimum harvest rates because of mortality before hunting seasons, crippling loss of banded grouse, and failure of hunters to return recovered bands. Overall, 25% of the grouse were bagged in December, indicating that hunting pressure can be heavy in late grouse seasons. These relatively high harvest rates and the apparent heavy hunting pressure in late season warrant closer examination of the ruffed grouse harvest in Wisconsin.

Adult purple gallinule in *Nuphar* beds. Purple gallinules feed exclusively in the *Nuphar* beds, and the birds' presence or absence in Florida's wetlands is related to the structure provided by *Nuphar* or similar plants. *Photo by R. Mulholland.*

COOPERATIVE FISHERY AND WILDLIFE RESEARCH UNITS

Florida. From May 1981 through April 1982 we analyzed gizzard contents of common moorhens and purple gallinules, common residents of regional deepwater marshes and wetlands, on a north-central Florida lake. Although both species were opportunistic feeders, there was no significant overlap in their diets, except in April, when insects were consumed in large quantities. Common moorhens ate 93% plant and 7% animal food (by volume), and purple gallinules ate 71% plant and 29% animal food. Common moorhens ate primarily leaves and stems of hydrilla, seeds of smartweed, and snails; purple gallinules preferred seeds of yellow cowlily and smartweed and various aquatic beetles. Purple gallinules fed in dense vegetation and preferred cowlily mats as habitat, whereas common moorhens fed in more open areas and nested in dense vegetation. Due to differences in microhabitat use and food habits, competition between the two species was insignificant. Public and private groups interested in biological function and value of wetlands may find this study useful in the face of increasing pressures to alter wetlands for other uses.

The Fish and Wildlife Service is required by Convention on International Trade in Endangered Species of Wild Flora and Fauna treaty obligations to provide evidence that harvesting and exporting river otters is not detrimental to the species. Thus, the Service must now be furnished with harvest or population data from the 26 States where otters are still abundant. To develop better means by which State conservation agencies may regulate a sustained yield of river otters, we compared two indices of otter abundance. Scent stations having a synthetic fermented egg lure of known composition were tested with captive and wild otters and used to survey two rivers in northern Florida for relative frequency of otter visits. On one river, fresh otter scats and scent mounds were recorded along the scent station transects. Captive otters exhibited a sexual dif-

ference in response to scent; males were more responsive than females. Response to scent by captive males and occurrence of sign in the field were seasonal; highest frequency was in winter and greatest concordance in February, coinciding with most independent evaluations of when otters breed. However, otter visits to scent stations in the field were most frequent in the first quarter of deployment, not in winter, and both captive and field tests showed declining interest in scent over short time periods. These results show that sex, season, and habituation are sources of variation limiting the utility of the scent station method. Further work on this method should focus on the winter season and anal gland lure, but the small number and high variance of scent station visits and the large field effort required will limit the utility of this method. In contrast, sign surveys yielded much higher counts and lower variance per unit effort; this method is recommended for further testing.

Mississippi. Walleye populations in Alabama and the Mississippi Gulf drainage may have resulted from undocumented stockings, recent planned stockings, or historical disjunct river basin connections to the Tennessee River system. If walleyes have been native to the Gulf Coast drainages for thousands of years, physiological and genetic differences could have occurred to produce a "southern strain." Polyacrylamide gel disc electrophoresis was used to determine blood protein differences between walleyes in the Tombigbee River drainage in Mississippi and walleyes from Iowa, Pennsylvania, and New York. Results suggested that walleyes of the Tombigbee River system can be distinguished from those collected at the other geographical locations. Walleye growth rates were slower in the Tombigbee River system than in the Tennessee Valley and Mississippi River systems. We believe that spring flooding is one of the major factors limiting the year-class strength of walleyes in the Tombigbee River system.

The bottomland hardwood forests of the Mississippi Delta are believed to have once been important wintering grounds of the central woodcock population. Continued clearing of this forest type over the next few decades will significantly reduce the remaining acreage available to wintering birds. There is little or no information on the effects of continued clearing along the middle and lower river floodplain on overwintering woodcock. In a study of the use of various age classes of hardwood forest and adjacent agricultural lands by wintering woodcock, we used trained bird dogs to search along transects within selected stands of five categories of bottomland hardwood in the northern and southern portions of the Mississippi Delta, from November through March. As judged by flush counts, woodcock were significantly more abundant in regeneration areas composed of sapling or early successional brush and in mature stands than in pole stands, cottonwood plantations, or narrow strips of hardwoods. Significantly more birds were flushed along stand edges than in the interior of stands. Dry weather during November and December restricted woodcock use to areas with high soil moisture or with sandy or loamy soils. No woodcock were flushed during a 6-day period when the ground was frozen, but birds were flushed when the soil thawed the next week. This study showed that stands in early succession as well as open stands of mature bottomland hardwoods were preferred diurnal cover. Management considerations should include production of young second-growth hardwoods and should emphasize opening mature stands to develop understory. The retention of narrow strips of cover along streams and field borders should also be encouraged.

Pennsylvania. Responses of eastern cottontails to habitat changes resulting from disposal of wastewater on land is to be investigated by monitoring population levels, habitat selection, and health profiles of the animals. A data base concerning health profiles of cottontails before introduction of wastewater has been completed. The results of this research indicated that body weight, kidney fat, and thyroxine levels were higher in adult females than in adult males. Significant differences in health profiles were noted among cottontails in different years. For example, greater heart weights and white blood cell counts and lower kidney fat were recorded in 1978 than in 1976, indicating that the animals were in poorer condition in 1978. This difference may have been related to weather conditions and food. Temperatures were lower and snow cover was heavier in 1978 than in 1976 and 1977. Relatively high levels of globulin were associated with, and perhaps reflected in, antibody response to heavy parasite infestation.

Many northeastern States are blessed with an abundance of small, clean streams with high recreational potential, situated on public mountain land. Growth of trout in these streams is often too poor to support an appropriate level of public fishery use. Although acidity from precipitation is implicated, another cause of the poor growth may be a mineral nutrient deficiency. Brook trout were collected from four streams of progressively higher mineral content

Trends in the population levels of cottontails are being monitored in central Pennsylvania to help assess the impact of land application of wastewater (sewage effluent) on the local fauna. This cottontail is being tattooed before being released near one of the wastewater pipelines. *Photo by S. A. Williams.*

Blood samples taken from the ear of a cottontail are part of a long-term study to describe and monitor the health profile of cottontail populations in man-altered environments in Pennsylvania. *Photo by R. L. Dressler.*

The response of cottontail rabbit populations to habitat change resulting from wastewater application is being monitored in central Pennsylvania. Measurements of individual rabbits will add to a data base needed to monitor the health and population of rabbits associated with the wastewater pipeline system. *Photo by S. A. Williams.*

in spring and fall. Total ash weight of the fish was determined, and the concentrations of calcium, magnesium, and zinc were measured in the stream water, and in the whole body, bone, skin, muscle, and viscera of fish. Fish from the low alkalinity streams grew more slowly than fish from the higher alkalinity streams; they also had higher whole body zinc levels, even though there were no differences among streams in the total amount of ambient zinc. Previous work has shown that low pH and low dissolved minerals increase the likelihood of uptake and accumulation of zinc by fish. There is little evidence that excess zinc has a direct effect on growth, but there may be indirect or synergistic effects from the low pH and low ambient calcium levels. Low pH by itself did not limit growth, since there was no significant correlation between growth rate and pH. Calcium concentrations did not increase with age in fish from the lowest mineral stream, as they did in fish from the higher mineral streams. Concentrations of all minerals — not just calcium or

magnesium — were lower in fish from streams of low alkalinity, and the minerals occurred in the same proportions to one another. Further investigation is needed to determine whether the lower mineralization in such fish is a cause of slow growth rates or a consequence of them.

The effects of salvage clearcut logging and associated land and stream disturbances on resident trout populations were investigated in the Appalachian hardwood forest of north-central Pennsylvania. Changes in stream populations of wild brook trout and brown trout in three study segments draining a 190-acre clearcut area were evaluated and compared with the characteristics of a resident trout community in a control segment draining an undisturbed basin. Data were collected in the spring before logging, and again in the spring after logging. Observations included comparisons of population estimates, age structure, biomass, and condition factors of resident brook trout, and stream temperatures during and after clear-cutting. After the salvage clearcut, numbers of young-of-the-year trout declined markedly in the stream segments draining the cut areas. The number of yearling trout was significantly lower in the upper two logged segments than in the control segment. The mean condition factor of fish of at least two age groups in these same study sections appeared to decrease slightly after logging. An unlogged buffer zone maintained on both sides of the permanent stream channel within the clearcut basin apparently prevented stream temperatures from reaching levels lethal to trout. Two specific actions could have substantially reduced the erosion that eventually led to stream sedimentation: (1) more careful planning of the placement, construction, and maintenance of main haul roads, landing sites, and skid trails to avoid spring seeps and excessive grades and reduce the total area of soil disturbance; and (2) changing the harvesting season from spring to winter, when the ground is frozen.

Wyoming. For the past two years, Unit biologists have been studying golden eagle nesting habitats in the Powder River Basin of Wyoming. Conflicts have occurred between golden eagle nesting and activities involving surface mining for coal and explorations for oil and gas. The golden eagle is currently protected under the Eagle Protection Act of 1940, but the U.S. Fish and Wildlife Service is now in the process of developing regulations that would permit the removal of eagle nests that interfere with mining operations, if proper mitigation techniques can be shown. One technique that is being used in an attempt to mitigate golden eagle-mining conflicts is to entice the nesting pair to nest off the coal lease on an artificial nesting structure. This study was designed to identify suitable locations for these artificial structures. We examined nests in cottonwood and ponderosa pine trees, on buttes and knobs (ground nests), and on artificial platforms (i.e., windmills). Data were collected on the overall or gross environmental features associated with the nest and on features immediately around the nest sites. Analysis of the data revealed several significant differences between the types of nest sites and between the nest sites and the surrounding habitats. Nests in cottonwood trees were closer to water and were at lower elevations above sea level than were nests in ponderosa pine trees or on the ground. Ground nests were at higher elevations than were nests in pine trees. Shrub cover and density were greater at ponderosa pine nest sites and shrubs were taller at cottonwood tree nest sites than in the surrounding areas. Both nest types were at lower elevations than the surrounding areas. The data aid in the identification of sites likely to be selected for nest location by golden eagles, and may enable wildlife managers to place artificial nesting platforms in locations that most closely resemble natural nest sites.

Consultants, agency planners, and field biologists now have a statewide vegetation map to help predict environmental consequences of land disturbances in Wyoming. Prepared by personnel of the Unit at the University of Wyoming, the map is a comprehensive classification system of hundreds of vegetation types. Map users can identify vegetation and land types anywhere in Wyoming. They can determine alpine, cropland, grassland, shrubland, and several other features. Infrared imagery taken by a LANDSAT satellite was used to identify vegetation types such as deciduous and coniferous forests. A zoom transfer scope placed the images on a Wyoming map at a scale of 500,000:1. Smaller maps of this type have been developed for specific areas, but none of this magnitude have been developed in Wyoming. The map is beneficial in land management planning and environmental impact assessment, and several agencies such as the Game and Fish Department are finding it to be a useful management tool. One current project involves assessing the impact that a proposed pipeline corridor will have on wildlife. Vegetation types that will be encountered on the pipeline route can be determined, and adjustments can be made if certain wildlife species might be adversely affected by construction ac-

Banding a 7-week-old eagle chick in Powder River Basin, Wyoming. *Photo by S. Anderson.*

tivity. An environmental consulting firm is using the map to predict the extent to which certain cropland areas are susceptible to grasshopper infestations. The effects of mining and other activity can be monitored by updating the map in future years and comparing it with the present map.

The use of thermal effluents may be advantageous in fish culture by enabling fish to be kept at their optimum temperature for growth or by enabling warmwater species to be reared in temperate regions where they would not otherwise thrive. Little work has been done on the potential of thermal aquaculture in the Rocky Mountain Region. Six coal-fired steam electric generating stations in Wyoming and Colorado were evaluated to determine the feasibility of thermal aquaculture at these sites. The plants were evaluated relative to the physical and chemical characteristics of their effluents. Results indicated that plants with once-through or pond-cooling systems discharged effluents with water chemistry adaptable to thermal aquaculture, but problems with gas supersaturation and chlorine would require management. Water quality of cooling waters from zero-discharge cooling systems was unsatisfactory for fish culture. Water volume was also a limiting factor. Only one station discharged enough water (298 cfs) to develop a commercial facility; at all other sites, 4 cfs or less of cooling water was available for aquaculture operations. We concluded that a commercial facility would not now be profitable; a government-operated aquaculture facility to produce fish for management purposes appears to be the most feasible use of thermal effluents.

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Species Index

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Pine marten occur throughout forested regions of Alaska. They are an important source of revenue and recreation to trappers. The life strategy of pine marten is being investigated to gain a better understanding of how they cope with extremely low temperatures and limited food *availability. Photo by S. Buskirk.*

Investigations of daily activity patterns of moose in Denali National Park; Alaska, show that moose are more active in open habitat than where dense cover is available, thus leading to increased bias in aerial surveys. Fall was the best time of year for carrying out aerial surveys. *Photo by D. R. Klein.*

Electrofishing is the most commonly used technique for fish population estimates in streams. In this small Virginia trout stream, one technician maneuvers the electrodes (powered by a back-pack generator) while two others collect stunned fish with dip nets. A fourth (not shown) transfers the fish to a live-box for temporary retention until they are fin-clipped or tagged and released. When the operation is later repeated in the same section of stream, the relation between the number of marked and unmarked fish caught is the basis for the population estimate. *Photo by G. B. Pardue.*