

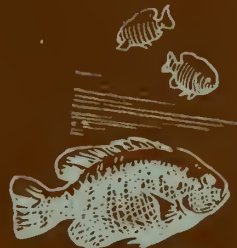
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# Sport Fishery and Wildlife Research 1972



UNITED STATES DEPARTMENT OF THE INTERIOR  
Bureau of Sport Fisheries and Wildlife



**UNITED STATES DEPARTMENT OF THE INTERIOR**

**Bureau of Sport Fisheries and Wildlife**

**Divisions of Sport Fishery and Wildlife Research**

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of this department of natural resources.

The Department works to assure the wisest choice in managing all our resources so that each shall make its full contribution to a better United States now and in the future.

# **SPORT FISHERY AND WILDLIFE RESEARCH 1972**

**Activities in the Divisions of Sport Fishery and  
Wildlife Research of the Bureau of Sport Fisheries  
and Wildlife for the Calendar Year 1972**

Edited by  
Van T. Harris and  
Paul H. Eschmeyer

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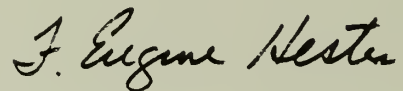
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## FOREWORD

After more than 12 years, the annual reports of the Division of Wildlife Research (*Wildlife Research—Problems Programs Progress*) and of the Division of Fishery Research (*Progress in Sport Fishery Research*) have been discontinued. Documentation of yearly progress in fish and wildlife research, however, will not be interrupted. Beginning with this issue, the highlight reports of both Divisions will be combined in a new annual series.

The combined publication is a logical outgrowth of the planned reorganization of the Bureau to accomplish program management by objectives. In the new organization the previous distinction between Wildlife Research and Fishery Research will be eliminated and the research activities of both Divisions will be guided by one Associate Director for Research who has responsibility for all Bureau research.

The informational needs for conservation and management of our fish and wildlife resources continues to grow each year, indeed, almost daily. The Divisions of Research, as the “biological arm” of the Nation, welcome these new responsibilities. We believe that the new approach to research management will increase the Bureau’s capabilities to produce answers and solve problems, some of which are included in this issue of *Sport Fishery and Wildlife Research, 1972*.



Associate Director—Research

## CONTENTS

	Page
FOREWORD .....	ii
THE DIVISIONS OF SPORT FISHERY AND WILDLIFE RESEARCH .....	1
HIGHLIGHTS OF ACTIVITIES IN 1972 .....	3
Waterfowl and Migratory Birds .....	3
National Reservoir Research Program .....	13
North Central Reservoir Investigations .....	13
South Central Reservoir Investigations .....	17
Southeast Reservoir Investigations .....	21
Great Lakes Fishery Program .....	22
Upland Wildlife .....	32
Classification, Distribution, and Life History .....	42
Endangered Species .....	46
Pesticides and Environmental Pollution .....	52
Fishery Investigations .....	52
Wildlife Investigations .....	61
Fish Population and Wildlife Damage Control .....	68
Fish Population Control .....	68
Wildlife Damage Control .....	72
Diseases and Parasites of Fish and Wildlife .....	79
Fishery Studies .....	80
Wildlife Studies .....	85
Fish Nutrition .....	88
Tunison Laboratory of Fish Nutrition .....	88
Western Fish Nutrition Laboratory .....	91
Fish Culture .....	95
Fish Genetics .....	101
Sierra Nevada Aquatic Research Laboratory .....	103
Cooperative Wildlife Research Units .....	104
PUBLICATIONS .....	105
APPENDIXES	
A. Directory .....	122
B. Location of Fishery and Wildlife Research Activities .....	124



The complex of land and water depicted here is habitat for fish and wildlife, both game and nongame, for which the Bureau of Sport Fisheries and Wildlife has research responsibility. Both the wilderness and the fauna are resources of incalculable value to the American people. (Photo by Lee E. Yeager)

## THE DIVISIONS OF SPORT FISHERY AND WILDLIFE RESEARCH

The Divisions of Sport Fishery and Wildlife Research fulfill the broad authority given the Bureau of Sport Fisheries and Wildlife for research on a wide array of mammal, bird, and fish species—resident and migratory, game and nongame, beneficial and harmful, unthreatened and endangered. Facts about these wildlife species, the environmental factors required for their existence, and the effects of management on them are used by the Bureau and by cooperating Federal, State, and private agencies in wildlife management programs. The purpose of these programs is to safeguard a valuable natural heritage and to provide social, economic, aesthetic, and scientific benefits for the people.

Current programs of the Division of Fishery Research include research on pest control, fish husbandry (fish diseases, genetics, nutrition, and cultural methods), and Great Lakes and Reservoir Ecosystems. The programs are carried out at 12 laboratories and 15 field stations located in 17 States. A program on the effects of stream channelization on fish and wildlife was initiated in 1972.

Current programs of the Division of Wildlife Research include research on waterfowl management; migratory birds other than waterfowl; wildlife ecology on public lands; pesticide-wildlife relationships and environmental pollution; wildlife diseases and parasites; animal damage control; classification, distribution, and life history of birds, mammals, reptiles, and amphibians; endangered wildlife; and the Cooperative Wildlife Research Unit program. This research is carried out at the Division's five major research facilities and their 44 satellite field stations, and at the 20 Cooperative Wildlife Research

Units. These facilities are in 34 States and one Territory. Work funded by the Agency for International Development is also conducted in 3 foreign countries. The Wisconsin Cooperative Wildlife Research Unit was activated in 1972.

In fulfilling the Bureau's research responsibility, the Divisions cooperate with agencies of the Departments of the Interior, Agriculture, Defense, and Health, Education and Welfare; the Atomic Energy Commission; the Agency for International Development; the Environmental Protection Agency; and various State agencies and private organizations. Information produced by research is communicated by talks and lectures, processed reports, and articles in popular and technical publications. This information is available to Federal, State, and local governmental agencies and to private organizations and individuals. Articles published in 1972 are listed.

The planning, coordination, and administration of programs for the Divisions of Fishery and Wildlife Research are centralized in the Divisions' Washington, D.C. offices. Fiscal, personnel, and property management and a variety of supporting services are provided to the research facilities and the Units through the five Regional Offices of the Bureau. By the end of 1972 the Division of Fishery Research had 160 professional and 100 nonprofessional employees. The budget included approximately \$5,500,000 of appropriated funds and \$500,000 of other funds. The Division of Wildlife Research had 230 professional and 126 nonprofessional employees. The budget included approximately \$10,038,000 of appropriated funds and \$1,364,000 of other funds.



The American avocet is a strikingly patterned shorebird that breeds on wetlands throughout the western United States. (Photo by John T. Lokemoen)



# HIGHLIGHTS OF ACTIVITIES IN 1972

## WATERFOWL AND MIGRATORY BIRDS

All migratory birds are protected under international treaties with Canada and Mexico and are, therefore, the responsibility of the Bureau. A treaty with Japan, listing all species of birds common to that country and the United States, was ratified by Japan in 1972 (and by the United States in 1973). These treaties provide protection for 65 species of game birds, including 44 species of waterfowl (ducks, geese, and swans), and 611 species of nongame birds.

The loss of wetlands and nesting habitat, the periodic drought in major breeding grounds, and the demand for sport hunting are important reasons for continuing research on waterfowl to improve existing habitat, develop new habitat, define guidelines for wetland acquisition, evaluate effects of management measures, improve inventory techniques, and increase knowledge of the resource and its utilization. Research on the so-called "webless gamebirds"—rails, doves, woodcock, snipe—has been increased by congressional action and deserves this attention. As a result of increased awareness and aesthetic utilization of nongame birds by many of our people, research has been increased on nongame species.

*Canvasback studies.*—A detailed project was initiated in the summer of 1972 aimed at saving the canvasback and providing information for its restoration at harvestable levels. Although all factors influencing the canvasback will be evaluated, the study will concentrate on Chesapeake Bay where up to 90% of the Atlantic Flyway population and 40% of the continental population formerly wintered.

A study of rooted aquatic vegetation in shoalwater areas of Chesapeake Bay, utilizing quantitative measurements at randomly selected stations, was designed to describe abundance, composition, and distribution of major aquatic vegetation and to provide a baseline for monitoring its trends. An analysis of data from nearly 800 sampling stations in the upper Bay in 1971 showed at least a trace of vegetation on nearly 20% of the Maryland portion of the Bay. In 1972 the study was expanded to cover shoalwaters of the entire Bay and to show changes that may have occurred in the upper Bay.

In June 1972, record rainfall produced by hurricane Agnes caused flooding and excessive turbidity that persisted for weeks. An estimated average of 1 inch of silt was deposited throughout the upper Bay, and aquatic vegetation was nearly obliterated in much of that area and in major tributaries along the Western Shore. Little was left of the famous "celery" beds that once attracted vast numbers of canvasbacks to the Susquehanna Flats. Eelgrass and wigeongrass growing in the more saline waters of the lower Eastern Shore seemed relatively unaffected.

In November and December, 837 canvasbacks were color-marked to determine the mobility of flocks and individual birds on Chesapeake Bay and other estuaries, and to determine if flocks tended to stay together and to remain in the same general area during the entire winter. Subsequent observations of the color-coded birds to date revealed different behavior and distribution patterns for various areas in the Chesapeake Bay region.



By banding canvasbacks (female shown, top), biologists learn more about movements and mortality rates of this declining species. The food habits of the canvasback are ascertained by examining the contents of their gizzards. (Photos by Matthew C. Perry)

*Population ecology of the mallard.*—Mallards are the most abundant duck in North America, representing between 20 and 30% of the breeding duck populations in all surveyed areas except the far north and the eastern portions of the Dakotas. The estimated size of the continental mallard breeding population during 1955–71 has ranged

from a high of 19.1 million in 1958 to a low of 7.9 million in 1965. In recording the following statistics, species of ducks could not definitely be distinguished by aerial survey. However, mallards are a large component of the waterfowl in the areas surveyed, and the statistics for all waterfowl are believed to be representative of the mallard.

A number of significant trends were found in production statistics in the primary waterfowl breeding areas of southern Canada. The average size of broods (all species) in the prairie and parkland areas of Canada was larger in the western breeding areas than in the eastern areas (5.8, 5.7, 5.4, and 5.6 west to east, respectively). A lower rate of loss of broods from Class II (partially feathered) to Class III (fully feathered but flightless) was indicated in the western breeding areas (0.20, 0.45, 0.56, and 0.65 from west to east, respectively). In addition, the average number of duck broods per square mile decreased markedly from west to east in the prairies and parklands of Canada. Although there are problems in measuring these variables, it seems apparent that the eastern breeding areas are less productive than the western breeding areas.

Spacing of breeding birds on the primary breeding grounds in southern Canada was suggested as a key factor in the density-dependent regulation of the population. These spacing mechanisms, in conjunction with habitat conditions, influence some birds to overfly the primary breeding grounds into less favorable habitats to the north and northwest. The production rate of waterfowl in southern Canada appears to be independent of density (*after* emigration has taken place) and dependent upon the number of breeders in the area.

*Winter ecology of maritime black ducks.*—A study was carried out in Nauset Marsh, Cape Cod, Mass., to ascertain the movements of wintering maritime black ducks. The data indicate that these ducks did not fly far in severe weather, but remained in small groups in the vicinity of adequate food. The strongest attachment was to the food rather than to the group. The groups were open, that is, additions and exchanges with other groups were accepted, and aggression was



A female mallard with her brood of young. The mallard is the most abundant species of ducks in North America. (Photo by John T. Lokemoen)

infrequent. The winter groups formed in late November or early December and broke up in February when the ice began to disappear.

Blue mussels, soft-shelled clams, and bent-nosed clams were the most important foods during low tides, and salt marsh snails and beach flies were most important during high tides. Vegetation was unimportant as food to the maritime black ducks during winter.

*Effect of agriculture on duck production.*—The detrimental effect of intensive agriculture on duck production is dramatically illustrated by the results of a 3-year study in east-central North Dakota. Eighty-four percent of the 5-square-mile study area was cultivated croplands which were either seeded to small grains or summer-fallowed. The uncultivated remainder included wetlands and their fringes (12%), heavily grazed pastures (2%), shelterbelts and farmsteads (1%), and idle grasslands (1%).

On an accumulated total of 5,015 acres of cultivated land searched during the three seasons, 38 duck nests (0.8 per 100 acres) were located, only one (3%) of which hatched.



Height and density of upland nesting cover for ducks in North Dakota prairies are estimated by means of a "cover board." (Photo by John T. Lokemoen)

On a total of 368 acres of uncultivated land searched, 42 nests (11.4 per 100 acres) were located of which 7 (17%) hatched. The principal causes of nest destruction on cultivated

land were farming operations which generally coincided with early nesting ducks (especially mallards and pintails), and predation by mammals. Predation was the principal cause on uncultivated lands which, typical of the prairie agricultural region, were in narrow strips, small plots, or heavily grazed pastures. These findings clearly point up the need for leaving some nesting cover if waterfowl production in intensively farmed areas is to be successful.

*Food values of temporary and seasonal wetlands.*—The foods consumed by breeding ducks inhabiting the prairie pothole area of North Dakota are being studied to assess the value of different kinds of wetlands. This information is needed to establish guidelines for the preservation, acquisition, and management of suitable aquatic habitat for different species of waterfowl.

Temporary (Class II) wetlands retain water long enough to develop an inverte-

brate population that is diverse in species structure, abundant, readily available, and utilized in the early spring by breeding and migrant dabbling ducks. Because of their shallow nature wetlands of this class warm early and provide invertebrate food items at a time when the larger and deeper water areas are still frozen.

Temporary wetlands are occupied by a unique invertebrate fauna. The key factor related to survival of these invertebrates in such wetlands is a short life history (e.g., fairy shrimp) or a means of dormancy facilitating survival during short periods of desiccation (e.g., snails). The basic food chain is established when spring runoff inundates dead vegetation from the previous year and creates a hay infusion which supports a myriad of one-celled organisms. This in turn supports a whole spectrum of interacting multicellular organisms, to the benefit of the waterfowl.

Temporary wetlands may dry in early spring, but each time that rains supply additional water these wetlands again provide an abundant invertebrate population. As a result, temporary wetlands serve as a food source for late breeding and renesting ducks. Thus, the high evaporation-precipitation ratio that is typical of the prairies is a key factor associated with the maintenance of this high protein waterfowl food.

Seasonal (Class III) wetlands have an invertebrate fauna similar to that of temporary wetlands early in the spring, but because water is retained for a longer period in the spring and summer, seasonal wetlands can be used by breeding ducks for a longer period and support a more diverse invertebrate fauna not restricted to a short life cycle.

*Some nutritional aspects of pintail reproduction.*—Biochemical analyses of major foods consumed by pintail hens during egg formation indicate that invertebrates are an excellent source of protein, which accounted for 45% of the pintail egg by dry weight (excluding shell). Fairy shrimp, midge larvae, and earthworms, all dominant food items in the diet of laying hens, contained 72, 66, and 60% protein, respectively. Barnyard grass and wheat, which contained 14 and



Apparatus used to obtain quantitative samples of invertebrates from the bottoms of wetlands. Invertebrates are important foods of immature and breeding adult waterfowl. (Photo by James M. Thompson)



Adult male pintail, cached alive by a red fox in a 10-acre pen, displays the typical death-feigning posture with head outstretched and eyes open. This behavior undoubtedly allows some ducks to escape from wild foxes. (Photo by Alan B. Sargent)

18% protein, are the dominant foods of hens after laying is completed. Invertebrate foods tested were excellent sources of the essential amino acids required for egg formation, whereas the plant foods were poor sources, particularly of lysine and methionine. Calcium levels in barnyard grass and wheat were far below needs for reproduction, while snails, another important food item in the pintail diet, were a rich source of this nutrient.

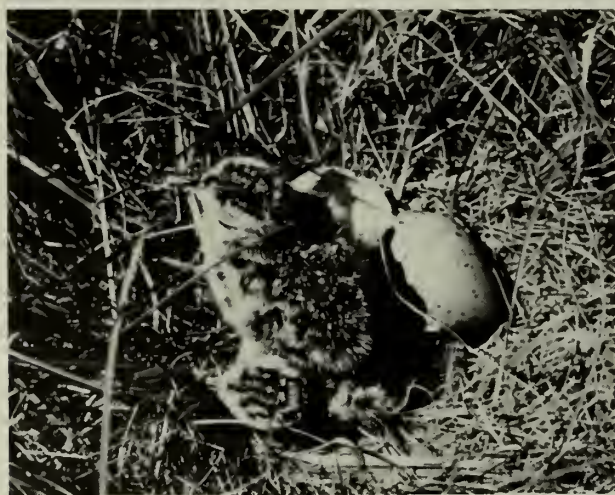
In pen studies, pintail hens fed only wheat during spring and early summer experienced nearly complete reproductive failure; egg production, fertility, and hatchability were significantly lower than among pairs on a control diet containing animal matter. Vitamin B<sub>12</sub>, a nutrient needed for hatchability, is largely lacking in plant foods, and may be a factor contributing to the poor reproductive response among birds on a wheat diet.

Food habits data indicate that, although pintail hens frequently feed on cropland and

tilled wetlands, the bulk of the animal foods is obtained in nontilled temporary and seasonal wetlands. The apparent need for animal foods during reproduction underscores the importance to this species of maintaining nontilled, shallow wetlands.

*Red fox predation on waterfowl.*—To better understand the relationships between foxes, ducks, and other prey, a 10-acre pen with a small impoundment, an elevated observation booth, and a radio-tracking system were constructed in North Dakota. During 1972, four mated pairs of foxes were placed in the pen for periods of about 1 month each, and their responses to systematically placed mallards, nests with eggs, and mallards restrained on nests were observed.

The foxes had distinctive feeding and predatory habits. Predation was a solitary behavior conducted primarily by the males. Interest in nesting hens (restrained on six eggs) diminished with increased availability, and eventually surplus birds were handled



A cable-chain device dragged through the vegetation is effective in locating nests of ducks and other birds in prairie habitats (top). In tests, 88% of known upland plover nests (bottom) were thus located. (Photos by Leo M. Kirsch)

carelessly or not killed. When food was restricted, the foxes killed and ate or neatly cached all birds offered. Interest in the eggs, however, never waned, and 485 of the 504 that were set out were taken. One egg was broken and left by the foxes and the remain-

ing 18 were not discovered. None was eaten at the nests, and few were eaten the night they were discovered. The eggs were taken one at a time and generally were cached 20 to 500 feet away. Caching trips frequently led to the discovery of nearby nests. Recaching of eggs by the same or other foxes was common. Eggs taken and cached during spring were still being uncovered and eaten during fall.

The foxes were reluctant to wade in the small impoundment to retrieve dead ducks placed in shallow water near shore. No foxes were observed swimming. Few of 15 wing-clipped ducks and no wild ducks that used the impoundment were killed, and a pair of wild horned grebes nested and raised a brood. Despite their aversion to water, the foxes hunted during rainstorms, and their activity appeared unaffected by heavy dew.

*Annual physiological changes in mallards.*—Studies of reproductive physiology underway in penned wild and game-farm mallards may provide greater insight into the influence of environmental factors on productivity and may suggest ways of inducing reproduction in birds difficult to breed in captivity.



A flock of giant Canada geese released at Chase Lake National Wildlife Refuge to restore the species to its former breeding range. (Photo by John T. Lokemoen)

Pituitary gonadotropin levels were low in experimental ducks in December (12–25  $\mu\text{g}$ -equivalents per gland); they rose significantly in males by January but remained low in females until March. High gonadotropin levels were achieved by both sexes in March, attaining levels of about 55 and 95  $\mu\text{g}$ -equivalents per gland in wild and game-farm males, respectively, and peaking at about 40  $\mu\text{g}$ -equivalents in both strains of females, even though the game-farm birds did not lay until April and the wild birds until May. Gonadotropin dropped to very low levels by the second day of incubation in both sexes. Changes in gonadotropin levels suggest that the final development of ovaries to the laying stage in wild females is controlled by factors other than the “readiness” of the pituitary. Levels of pituitary gonadotropin remained low in females during the rest of

the year but were temporarily elevated in males, particularly game-farm birds, in July through September.

Bursa weights decreased from January to at least the 20th day of incubation. Between the period of early laying and incubation, body and thyroid weights declined in both sexes. Game-farm males and females and wild males had similar relative thyroid weights, but wild females had much lighter thyroids throughout the year.

*Giant Canada geese released in North Dakota.*—In 1972, 885 giant Canada geese were liberated at four locations in east-central North Dakota. These releases represent the first of a 5-year Federal-State experimental release program to restore nesting birds to many parts of the State. The geese were produced from select breeding flocks at the Sand Lake National Wildlife Refuge and the



The horned lark was estimated to be the most numerous bird species in North Dakota. According to counts on sample areas, about 25.9 million pairs of birds breed in North Dakota. (Photo by Tom Dwyer)

Northern Prairie Research Center. Most of the goslings were hatched in incubators at the Center and raised in brooders for 3 or 4 days before being moved to Sand Lake to be reared to release age (55–62 days).

New approaches are being tested to improve and simplify restoration methods without closing large areas to goose hunting. Three of the releases in 1972 were made at distances 18 to 26 miles from the Slade National Wildlife Refuge where a breeding flock was established from releases made by the Center in 1969. This flock is now fully migratory. Some of the geese released in 1972 joined the Slade flock, taking advantage of the 3½-township protected area and food provided on refuge lands. Apparently all of the released geese left North Dakota by the end of November, and some migrated with the experienced Slade birds. When they reach nesting age, the released geese can be expected to move to the general area of liberation to nest. The releases represent an attempt at “artificial pioneering” from the Slade Refuge which would become a fall “staging” area.

*Waterfowl harvest surveys.*—The Bureau annually conducts two mail surveys to deter-

mine activity of waterfowl hunters and the waterfowl harvest. The Waterfowl Hunter Questionnaire Survey, sent to a representative sample of waterfowl stamp buyers, provides estimates of the average bag of ducks, geese, and coots per waterfowl hunter and the average number of days hunted. These averages are used in conjunction with duck stamp sales figures, obtained from the Postal Service, to estimate total numbers of ducks, geese, and coots bagged and total hunter days. During the 1971–72 hunting season, approximately 69,000 questionnaires were returned by waterfowl hunters.

The Waterfowl Parts Collection Survey allows determination of the species, age, and sex composition of the waterfowl harvest through examination of duck wings and goose tails sent in by a representative sample of waterfowl hunters. During the 1971–72 waterfowl season, approximately 9,000 hunters returned slightly under 79,000 wings and tails.

Duck stamp sales totaled 2,426,058 in the United States. Hunters bagged 14,013,100 ducks, 823,000 coots, and 1,478,800 geese during 16,719,800 hunter days afield. Those persons buying duck stamps for hunting averaged 6.5 days afield and bagged an average of 7.1 ducks and 0.7 geese each. The two most commonly harvested duck species were mallards (36%) and pintails (9%). The ratio of immatures to adults harvested was 1:1 for both mallards and pintails.

*Hunter performance in point-system tests.*—During the 1971–72 hunting season, 13 States again tested a system of waterfowl bag-limit regulations based upon points assigned to various species and sexes of ducks—an alternative to limits based upon fixed numbers of ducks. Point assignments were 10, 20, 90, and 100 varying by duck species and sex. The bag limit was reached when the last duck shot resulted in points equalling or exceeding 100.

Hunters were secretly observed by cooperators and their actions were recorded. Reports on 1,274 hunts were obtained, 939 of which were watched from beginning to end. Observers recorded that hunters usually fired at fewer flights of 90- and 100-point ducks than at flights of 10- and 20-point



ducks. The proportion of ducks killed, relative to those available, also was lowest for 90- and 100-point ducks. Hunters apparently did not discriminate between 10- and 20-point ducks. Ducks assigned 90 or 100 points were left unretrieved at a higher rate than were ducks assigned 10 or 20 points. In about 25% of the hunts, enough ducks were shot to make bag violation a possibility, and bag violations were observed in 4% of the hunts. Most bag violators could not have concealed the violation by reordering their bags. Because of limitations in field observation, it was possible to measure the opportunity to reorder only in terms of extremes. It was estimated that in at least 3% but no more than 16% of the hunts, hunters could have benefited from reordering their bags.

*Status of mourning doves.*—Mourning dove population indices obtained from counts on over 900 randomly selected routes increased in all management units between 1971 and 1972, as follows: 2% in the Eastern Unit, 17% in the Central Unit, and 12% in the Western Unit. None of these changes was statistically significant. A significant increase in the population index was determined for the 17 combined hunting States but no statistical change occurred in the 31 combined non-hunting States.

Long-term population trends were determined from regression analysis of call-count data from 1962-72. This showed a statistically significant downward trend in all management units. Annual mean rates of decline were 1% in the Eastern Unit, 2% in the Central Unit, and 4% in the Western Unit. Significant downward trends generally occurred in those States bordering the Pacific Coast, Mexico, and the Gulf of Mexico, and in several Canadian border and central States. Upward trends were limited to several widely distributed mid-latitude States.

*Status of woodcock.*—The woodcock harvest and the number of participating hunters have increased substantially since 1964; the U.S. harvest in 1970-71 exceeded 1.3 million birds. Information on the current status and population trend of the American woodcock is provided by annual singing-ground surveys over much of the species' breeding range, and by wing-collection surveys in

eastern United States. In 1972, this survey showed that the breeding population index increased 1.6% in the Atlantic Region, 3.7% in the Central Region, and 2.7% rangewide. These indices are based upon 813 comparable, randomly selected survey routes.

The wing-collection survey for the 1971-72 season suggested a decline of 27% in productivity; this followed a substantial increase of 25% the preceding year. Both the daily bag per hunter and the average seasonal bag decreased slightly.

*Urban bird habitat relationships.*—A research program was begun in 1972 to increase our understanding of the factors affecting bird populations in urban environments. The information gained will help urban planners, developers, park managers, and interested citizens to improve the environment near their homes for beneficial wildlife.

Initial emphasis was placed on the development of a survey method that would permit urban bird populations to be related meaningfully to urban habitat conditions. Birds were counted in a series of plots 100 × 100 yards (about 2 acres) along streets. Data were collected in approximately 700 segments primarily in the new city of Columbia, Md., during the summer of 1972. Additional



Mourning dove nest with adult and nestling. The status of the population of this popular gamebird is estimated annually from counts on randomly located census routes. (Photo by C. W. Schwartz)

field-testing was carried out in Chicago, Ill.; Columbus, Ohio; Bowie, Md.; and Raleigh, N.C.

The results indicate that the techniques employed appear satisfactory and indicate striking differences in the number and species composition of birds using various urban situations. In general, the densest breeding bird populations were associated with intense development such as apartments and townhouses. These dense bird populations, however, consisted almost entirely of starlings and house sparrows. Within developments of the same type, striking differences

in bird use were associated with building design and quality. For example, one residential area having high-priced detached homes in an area where original trees have been retained had a much higher starling and house sparrow population than a similar development nearby with a different building design and quality.

Studies were also begun to better understand waterfowl use of urban impoundments, to learn the impact of adjacent development on "natural areas," and to develop wildlife management practices suitable for urban areas.



Pintail drake with miniature radio transmitter. The movements, behavior, and habitat of several species of dabbling ducks are being studied in North Dakota. (Photo by Tom Dwyer)

## NATIONAL RESERVOIR RESEARCH PROGRAM

A long-term fishery research program on large reservoirs was established in 1963 in response to requests from many public and private agencies. Construction of Federal impoundments had created fishery management problems which most State agencies were unable to attack single-handedly. The widely recognized need for intensive ecological research has been met through concentrated field study of three groups of reservoirs that differ greatly in environmental and operational characteristics, plus the analysis of all the information available nationwide on fish standing crops and angler harvests. The effort is yielding results that are broadly applicable, as well as specific findings that are useful to the State agencies charged with managing the particular reservoirs under study.

In 1972, the inland waters of the United States included about 1,350 man-made lakes larger than 500 acres, which totalled 9 million acres at average water levels. This total exceeds the area of natural lakes in the Nation, excluding the Great Lakes and Alaska. In 1970, 28% of all freshwater fishermen fished most often in reservoirs.

By the year 2000, a three-fold increase in reservoir angling has been forecast. Management methods must be improved if this greatly increased angling pressure is to be satisfied. This improvement is the aim of the Bureau, working in concert with State agencies, other Federal agencies, and academic and private institutions.

The National Reservoir Research Program, headquartered in Fayetteville, Ark., was established in 1963 to provide administrative coordination of the field research units and to conduct a nationwide analysis of the effects of reservoir environmental and operational factors on fish production and yield. Correlation and multiple regression statistical techniques have been used to test the effects of 14 environmental factors in relation to standing crop, angler use and harvest, and commercial fishing yields. Basic data have been obtained from published pa-

pers, Federal Aid completion reports, and unpublished information from State and Federal fishery agencies.

More than 40 regression formulas have been derived to predict fish crop and harvest in various types of reservoirs, using one to five independent environmental variables. In 1972, crop and harvest were predicted for 55 planned or existing reservoirs in reports prepared for the Division of River Basin Studies and other agencies. Predictions of sport fish harvest indicate declining harvests as the age of reservoirs increases; the decline is most pronounced in the first 20 years of impoundment. Management agencies are vitally concerned with this general decrease in angler success and are striving to develop methods of restoring harvest rates to those typical of the early post-impoundment years.

### North Central Reservoir Investigations

The six reservoirs of the Missouri River main stem system—Fort Peck Reservoir, Lake Francis Case, Lake Oahe, Lake Sakakawea, Lake Sharpe, and Lewis and Clark Lake—have a total area of 1.1 million acres at normal operating levels. In surface area, they make up the largest integrated reservoir system in the United States. Studies of the fish population and environmental conditions began on four of the reservoirs in 1962. Objectives of the research have been to describe the vital statistics of the fish stocks and associated biota; to determine the relations between changes in the fish population and the water management programs of the U.S. Army Corps of Engineers; and to develop the knowledge required for effective management of the fish populations. The Missouri River main stem system reached normal operating levels in late 1967 and the present fish population is a result of environmental conditions during the filling stage and during the first 5 years of normal operation. The research program is designed to

determine the environmental factors that have reduced fish production since the reservoirs reached operating levels, and to develop corrective measures for use by fish management agencies.

Emphasis in 1972 was on a 2-year inter-agency effort to evaluate the effects of stocking predator sport fishes, primarily striped bass and walleye, in southern reservoirs. Systematic collection of data on physico-chemical characteristics, water level fluctuation, water exchange rate, fish stocking history, standing crop, and angler harvest is being undertaken on 34 reservoirs by 14 fishery agencies. The National Reservoir Research Program is responsible for data collection and computer analysis. The study is under the auspices of the Reservoir Committee of the Southern Division of the American Fisheries Society.

North Central Reservoir Investigations is attacking fishery problems on main stem impoundments stretching along 800 miles of the upper Missouri River. Field bases are at Yankton, Pierre, and Mobridge, S.D. South Central Reservoir Investigations, headquartered in Fayetteville, Ark., began studies in 1963 on Bull Shoals and Beaver Reservoirs on the White River in the Ozarks. The research objective is to compare a relatively new and an older reservoir to identify the principal differences in environmental conditions and fish populations which lead to the rise and decline of sport fishing success following impoundment. Southeast Reservoir Investigations was established in July 1972 at Clemson, S.C., to study the effects on fishery resources of heated water from a thermonuclear generating plant and of diurnal water level fluctuations that result from large-scale pump-back operations.

*Status of fish stocks.*—The fish stocks in Lake Oahe, Lake Sharpe, Lake Francis Case, and Lewis and Clark Lake have been monitored since 1964 by the use of gill nets, trap nets, seines, and trawls. Vital statistics on the fish stocks are related to water management programs. The findings are used by State and Federal agencies to improve fishing by modification of water management programs, fish stocking, and habitat improvement. In 1972 the heavy inflow into the

system—about 130% of normal—resulted in high water levels and high water exchange rates in all reservoirs. High water levels are beneficial to fish reproduction when the flooded areas have been vegetated during the previous year; however, water levels were also high during 1971, and thus prevented the development of terrestrial vegetation on the reservoir bottom. High water exchange rates are detrimental to overall fish production in these reservoirs for many reasons.

In Lake Oahe the 1972 catches of sport fish in experimental gear declined in the lower reservoir but remained high in the middle and upper portions. Although abundance and growth rate of the walleye decreased, it remained the most common sport fish species; reproduction was good in 1972 and survival to October appeared to be high. Northern pike, black crappie, and white crappie continued to decline in abundance because of poor reproduction in the past 4 years. Catches of channel catfish increased in the upper and middle sections of the reservoir. Reproduction of species such as northern pike and yellow perch, which require vegetation for egg deposition, was poor. Among commercial species, the abundance of gold-eyes continued to increase but that of bigmouth and smallmouth buffalo declined. The commercial catch of 703,868 pounds in 1972 was dominated by these three species, but poor recruitment after 1965 will reduce the buffalo catch in the future.

In Lake Sharpe, walleye continued to be the most abundant species in gillnet catches but overall abundance decreased 16% from that in previous years. Although 31 species were captured, 4 of these—walleye river carpsucker, channel catfish, and carp—accounted for 77% of the catch. General abundance of young-of-the-year fishes dropped 50% from 1971. The decrease has continued a trend that began in 1968 and is apparently associated with increased water exchange rates during the summer. Emerald shiner and gizzard shad, both important forage species, showed the largest decreases.

In Lake Francis Case, seine catches of young-of-the-year fish in 1972 were only 37% of those in 1971. The greatest decrease was

in yellow perch. Annual abundance of the young-of-the-year of species that spawn near shore, as measured by seine for 1954–71, showed a significant (1% level) positive correlation with high or rising water levels during May and June.

In Lewis and Clark Lake, channel catfish abundance increased significantly in 1972 over that in previous years; sauger and wall-eye abundance was unchanged, and abundance of the remaining species declined. Between 1966 and 1971 the estimated biomass of the major fish species decreased 57%. Reproduction of the major fish species was poor to average in 1972. Paddlefish reproduction, however, was the best recorded to date.

*Zooplankton and benthos.*—Macroscopic zooplankton, which is a primary fish food, is measured in the discharge of three powerhouses every 6 hours by automatic plankton samplers. In Lewis and Clark Lake the 1972 totals were again low and followed the trend that began in 1970 when water exchange rates in the reservoir increased. The sum of monthly means of *Daphnia*, *Cyclops*, and *Diaptomus* ranged from 108 to 187 per liter in 1964–69 and from 45 to 63 in 1970–72. Abundance of *Daphnia* and *Cyclops* decreased sharply, whereas that of *Diaptomus* did not change greatly. Similar relation among water exchange rates, zooplankton abundance, and generic compositions have been documented in Lake Francis Case, Lake Sharpe, and Lake Oahe.

Benthos abundance and production have been related to aging and water management in these reservoirs. Since 1963, 173 species of benthic invertebrates (mostly river species) have been collected from Lewis and Clark Lake and the adjoining Missouri River. Three species constituted 87% of the invertebrates collected over a habitat type that occupies about 68% of the reservoir bottom. Although the diversity is relatively low, the standing crop of 36–79 kg/hectare (wet weight) is much above the 1 kg/hectare recorded for the river before impoundment. Chironomids are numerically the most abundant benthos group. Chironomid abundance increased 1.6-fold from 1965 to 1970.

Nymphs of burrowing mayflies (*Hexagenia*) made up an average of 84% of the

benthic biomass in 1964–71; the estimated annual production (g/m<sup>2</sup>) was 1.7, 2.5, 2.8, 2.3, 2.0, 1.3, 1.3, and 1.2, respectively. The turnover ratios (production/biomass) for 1964–71 ranged from 2.4 to 2.9. The decrease in biomass of *Hexagenia* in 1969–71 was associated with increased discharge rates.

*Effects of reduction in fall drawdown on benthos in Lake Francis Case.*—Water levels in Lake Francis Case were normally drawn down each fall to 403 meters msl (mean sea level), and about 50% of the reservoir bottom was exposed. In 1971 the lower limit of fall drawdown was held at 408 meters msl to facilitate recreational use of the lake, and this drawdown level has been established for the future. Mean chironomid densities (No./m<sup>2</sup>) at depths of 10 m or less were 151 in May 1967 (following the 403 m fall drawdown in 1966), and 2,343 in May 1972 (after the reduced drawdown in 1971); mean *Hexagenia* densities were 2 in 1967 and 41 in 1972. Part of the increase in 1972 may be attributed to increased survival of invertebrates over that portion of the bottom that was exposed in the fall of 1966 but remained inundated in the fall of 1971.

*Lake Oahe limnology.*—The objectives of this work were to describe physical and biological variables during the ice-free seasons of 1966–70 and to determine if rational correlations existed among them. The volume and flow rate of water released through the dam has varied considerably, but generally increased from 1966 to 1970. The annual mean discharge rate increased from about 618 m<sup>3</sup>/sec in 1966 to 836 m<sup>3</sup>/sec in 1970. The temperature regimen is similar to that in large deep temperate lakes with two full circulation periods each year. Thermal stratification occurred only in the lower two thirds of the reservoir and was established by June in most years. It was delayed in years of high discharge. During the filling period (up to 1968) the mean temperature rise from 1 April to the summer maximum varied from 0.16 to 0.20°C/day. After filling the rates ranged from 0.11 to 0.13°C/day. As a result the summer maximum was about 1 month later after fill than during filling. The mean annual reservoir water temperature was about 1°C less

after filling than before. Conductivities ranged from 405 to 1,010  $\mu$  ohms/cm (25°C); the highest readings were associated with high water levels and high tributary inflows.

Phytoplankton standing crops and number of genera were generally lowest in the lower third of the reservoir and highest in the middle third. Zooplankton abundance peaked in 1967 and declined thereafter.

*Primary productivity.*—In 1971–72 the physical and chemical environment was studied in relation to primary productivity along a 434-km stretch of the Missouri River between Gavins Point Dam and the lower end of Oahe Reservoir. Four reservoirs are included. Monthly measurements were made at six stations during the ice-free seasons of 1971 and 1972, of chlorophyll a and b, phytoplankton, zooplankton, light, turbidity, solar radiation, organic matter, and various forms of nitrogen and phosphorous. Although productivities ranged widely, the measurements showed clear gradients from the lowest readings in Oahe to the highest at Gavins Point. Phosphates are directly related and nitrates appear to be inversely related to phytosyn-



A moderate sloping shoreline on Lake Sakakawea with heavy growth of curled dock in the water and native prairie grasses on the shore. When inundated, this type of shore is ideal spawning habitat for northern pike and yellow perch. (Photo by Lowell Stanley)

thetic activity. Light penetration was lowest and turbidity highest in the most productive station.

*Shoreline vegetation along Lakes Sakakawea and Oahe.*—The purpose of this research is to determine the growth of shoreline vegetation with various schedules of water level management and substrates. The abundance and types of flooded vegetation have much bearing on the success of reproduction of many fish species and the abundance of many kinds of fish foods. Studies on shoreline vegetation were conducted in July-September 1971 and May-October 1972 along 50 transects in each reservoir. Shoreline vegetation patterns of the two lakes differed greatly.

At Lake Sakawawea, three shoreline vegetation zones can be identified. Zone 1 is annually inundated, and smartweed is the most common plant; most plants are killed each summer during inundation. Zone II was inundated only in 1969 and is dominated by prairie grasses; reed canary, which tolerates some inundation and may be useful in erosion control, occurred at isolated sites. Zone III has never been inundated and is also dominated by a prairie grass. The annual succession appears to be completely controlled by water levels. Other conditions that limit the growth of shoreline vegetation are



This eroding shoreline on Lake Sakakawea is common to all Missouri River main stem reservoirs. Shoreline vegetation does not develop except where slopes are moderate as shown left of center. Fish spawning and nursery areas are of poor quality and food production for fish is low on eroding shores. Efforts are being made to compensate for these adverse environmental conditions by development of vegetation. (Photo by Lowell Stanley)

wave action, which results in natural armoring of glacial deposits by removal of fine silt, and deposition of sediments on plant beds during the high water period (at one site, a layer 30 cm thick was deposited in 1 year).

In Lake Oahe, zones were not distinct and vegetation on inundated areas was much sparser. In August 1972, it was estimated that 70% of the land exposed by drawdown was completely devoid of vegetation; about 20% had light vegetative cover; 8% moderate, and 2% heavy cover. Curl dock and a prairie grass were the most common forms in the previously inundated areas. Within the major embayments of Lake Oahe, much of the soil is derived from Pierre shale (60–70% clay) and these substrates support little vegetation under the present water level regimen.

### South Central Reservoir Investigations

Reservoirs on the White River of northern Arkansas and southern Missouri are typically deep and clear, with relatively steep shorelines and a gradation of environmental conditions from the headwaters to the dam. Near the dam the reservoirs are typically clear (up to 10 m transparency) and tend to be oligotrophic, with an oxygenated hypolimnion; at the upper end the reservoirs are more eutrophic, with transparencies varying from less than 1 m to 5 m. The middle portions of the reservoirs are transition zones varying each year with changes in inflow and water level fluctuation.

The sport fishery in the reservoirs is primarily for black basses, crappies, and white bass. These species constitute 80% or more of



Beaver Reservoir is the uppermost reservoir on the White River system in northern Arkansas and southern Missouri. The conservation pool level is about 28,200 acres in area and has a storage capacity of about 1,650,000 acre feet. Depth at the dam is over 200 feet. (Photo by Sam Lanham)



A laboratory assistant counts samples of forage fish collected by trawling and sorts them by species. (National Reservoir Research Program photo)

the total number and pounds of fish harvested each year. The threadfin and gizzard shad are the most abundant forage fishes and are very important in the diets of predator species.

Research has been underway since 1963 to understand the successional changes occurring with increasing age in Beaver Reservoir (now 9 years old) and Bull Shoals Reservoir (20 years). Interrelated studies in population dynamics, life histories of fishes, and limnology are providing new insights and techniques for reservoir managers.

*Pelagic fish populations.*—The deep, open waters of reservoirs (pelagic zone) have been inadequately sampled because suitable sampling gear has been lacking. However, mid-water trawls developed by South Central

Reservoir Investigations have made it possible to estimate populations of pelagic fishes. In 1972 comparative tests between trawls for larval and juvenile fish collection demonstrated that a 1-m (0.78 m<sup>2</sup>) townet was much less effective than newly designed 1.88 m<sup>2</sup> or 5.95 m<sup>2</sup> trawls as speed was increased. The relation of catch to towing speed was linear.

The new 1.88 m<sup>2</sup> larval fish trawl was used to sample weekly at 10 stations on Beaver Reservoir from May 4 to June 29, 1972; relative abundance was determined for larval shad, crappie, white bass, brook silverside, sunfishes, log perch, and channel catfish.

The larger midwater trawl was used in late summer for sampling juvenile fish. Larval shad were much more numerous during the spring in 1971 than in 1972, but threadfin shad spawning occurred over a much longer period in 1972. By August the total population of young shad was double that estimated in 1971. The September sample indicated that a large population of small threadfin shad had survived past the period when natural mortality normally greatly reduces the population. Except for threadfin shad, reproduction of the sampled species was generally less successful in 1972 than in 1971.

*Estimates of fish populations in coves.*—Samples are taken in three coves of Beaver and Bull Shoals Reservoirs annually to assess composition, abundance, and fluctuation of fish populations. In Beaver Reservoir, the total standing crop estimate in 1972 exceeded that in 1971 by 90 pounds per acre. This increase was reflected in nearly all species. Young-of-the-year largemouth bass decreased, whereas young-of-the-year spotted bass increased greatly; the numbers of the two species combined were comparable with those in 1971.

The total standing crop estimate in Bull Shoals Reservoir in 1972 was 75 pounds per acre lower than that in 1971. This decrease was reflected in lower numbers of all species concerned except white bass, smallmouth bass, spotted bass, and log perch. The Corps of Engineers raised and held the water level of Bull Shoals Reservoir above the terrestrial vegetation line (652 msl) from May





A small-meshed trawl is being lowered into the water to obtain a sample of eggs and larval fishes. From the data obtained time of spawning is ascertained and the size of the new crop of fish is estimated. (National Reservoir Research Program photo)

through July 1972. The estimated standing crop of the young-of-the-year black basses in mid-August was the highest since 1968—the last previous year with high summer water levels. Apparently the strength of black bass year classes is directly correlated with water levels.

*Black bass population studies.*—Population estimates of the black basses of Beaver and Bull Shoals Reservoirs have been made by mark and recapture methods since 1968. Nearshore population estimates are made each April with electrofishing equipment, to provide an index of spawning potential.

For example, in 1972, sampling in Beaver Reservoir yielded estimates of 74 largemouth bass (28 kg) per kilometer of shoreline in the lower part of the lake and 303 (60 kg) per kilometer in the upper lake. In Bull Shoals Reservoir, these estimates were 30 largemouth bass (15 kg) per kilometer in the lower reservoir and 33 (27 kg) per kilometer in the upper reservoir.

*Food of black basses in Bull Shoals Reservoir.*—Crayfish are conspicuously abundant in Bull Shoals Reservoir. However, the analysis of stomachs of adult black bass collected

over a 1-year period indicates that the fish eat crayfish extensively only during the colder portions of the year and eat principally fish during the warmer portions. Crayfish thus appear to serve primarily as a winter maintenance food.

*Spawning behavior of black basses.*—SCUBA has been used to study several aspects of the spawning behavior and distribution of fish species since 1966 in Beaver and Bull Shoals Reservoirs. Underwater observations of black bass spawning in Bull Shoals Reservoir in 1972 showed that spawning began on April 13, the earliest date since 1967. During the spawning season, 141 spotted bass, 53 largemouth, and 21 smallmouth bass nests were found within five study areas which total nearly 2,900 m of shoreline. The water level in Bull Shoals was below conservation pool level at the beginning of spawning, but rose to a level above conservation pool by June 1. This rise in level was sufficient to flood shoreline vegetation by as much as 1 m and make abundant cover available to the bass fry.

In addition to the observations in standard study areas, the use of brush shelters for



A pair of spotted bass spawning in a nest beside an artificial brush shelter in Bull Shoals Reservoir. Studies indicated that this species was selective for nesting sites having brush cover. (Photo by Lou Vogeley)

spawning by black bass was studied in Bull Shoals Reservoir. Shelters were constructed of brush cut from the banks of the reservoir, weighted with rocks, and placed at a depth of about 2.5 m, at 10-m intervals, within alternate 100-m segments of shoreline in each of the coves. Each cove thus consisted of eight adjacent segments, four with shelters and four without. Divers observed bass nesting activity weekly in all segments, and recorded nests and fry schools for each species in each segment. Forty nests of largemouth bass, 57 of spotted bass, and 69 of smallmouth bass were observed. The results indicated that largemouth and spotted bass were selective for the sheltered habitat, whereas smallmouth bass were not.

In three Beaver Reservoir study areas comprising 900 m of shoreline, divers counted 29 spotted bass nests and 9 largemouth bass nests from April 21 through June 6. This was the first year (ninth year of impoundment) in which nesting spotted bass outnumbered largemouth bass since regular observations began in 1968. Smallmouth bass have not been observed in the study areas.

*Angler harvest estimates.*—The Beaver Reservoir creel census was continued for the

ninth year in cooperation with the Arkansas Game and Fish Commission. During 1972, the estimated average of eight daytime angler-trips per acre resulted in a harvest of 14 fish or 17 pounds per acre. Data gathered on night fishing from May through September yielded an estimate of one angler-trip per acre and a harvest of 0.6 pound per acre.

The Arkansas Game and Fish Commission, the Missouri Department of Conservation, the Corps of Engineers, and South Central Reservoir Investigations cooperated for the second year in an estimate of angler effort and harvest on Bull Shoals Reservoir and 100 miles of the White River below Bull Shoals dam. The night survey ran from May through July in 1971; in 1972 it was extended from May through September.

An estimated 10 angler-days per acre recorded on Bull Shoals Reservoir in 1972 resulted in a harvest of 10 pounds per acre. Fishing pressure equalled that in 1971, but harvest was about 25% lower. In the Bull Shoals tailwater 227,500 angler-days of fishing were estimated for 1972—22,500 angler-days below the 1971 estimate.

*Limnology.*—Physicochemical data collected at six stations on Beaver and Bull

Shoals reservoirs over a 7-year period have been summarized and regressions derived in an attempt to relate standing crops and yield of black basses with fluctuations in the environmental variables.

In Beaver Reservoir, oligochaetes have continued to increase in abundance since sampling began in 1969. The biomass of profundal invertebrates has increased steadily since the study began, particularly in the upper region of the reservoir. In Bull Shoals, oligochaete numbers and biomass were lower than in 1971, previous year, particularly in the upper region of the reservoir. Profundal populations appear to vary by at least one order of magnitude from year to year. Fluctuations appear greatest in the upper region of the reservoir and may reflect responses to variations in inflowing water quality and quantity.

### **Southeast Reservoir Investigations**

The increasing demand for electrical energy and the scarcity of additional suitable sites for hydroelectric projects in the United States have resulted in a need for steam-electric installations. These plants use fossil or nuclear fuel, and many require large amounts of water for cooling. In addition, there has been an increase in pumped-storage projects to meet peak power requirements. Under the Fish and Wildlife Coordination Act, the Bureau must make recommendations for the protection of fish at such projects; however, too few data are available on the effects of cooling effluents and pump-storage operations to provide a basis for sound decisions.

To help correct this deficiency, the Bureau began studies in 1972 of the Keowee-Toxaway Project of Duke Power Company, northwestern South Carolina. When completed in 1974 or 1975, this power complex will use three sources of power: hydraulic power generated at the outlet of Keowee Reservoir; nuclear power generated at a site on Keowee Reservoir (this reservoir will be used as a source of cooling water); and pump-back storage hydraulic power generated between Keowee (the lower reservoir of this system)

and Jocassee (the upper reservoir). In these studies, emphasis is being placed on establishing base line data for comparison with similar data to be collected after nuclear and pump-back operations begin. All research is currently being carried out on Keowee Reservoir; Jocassee Reservoir is not yet filled.

Four indicator fish species were chosen for complete life history studies: largemouth bass, black crappie, yellow perch, and bluegill. Systematic collections of these fishes are to be made in control areas and in the area receiving heated effluents. Spawning and early life history data are being collected by direct observations with SCUBA, or with small-meshed seines and traps, trawls, and plankton samplers. For older fish, data on length, weight, age, stomach contents, and sexual development are obtained from samples taken in gill nets, trap nets, or trawls, or by electrofishing and the use of rotenone. These collection methods are also used to identify changes in composition and abundance of reservoir fish populations. Fishing methods have been standardized, so that results should be comparable between seasons.

Fishes collected in 1972 included carp, black crappie, bluegill, brown bullhead, carp, chain pickerel, flat bullhead, green sunfish,



Electro-fishing boat used to obtain samples of fish. A generator charges the metal probes hanging from the poles at the bow of the boat, and the electrical current passing between them momentarily stuns the fishes nearby. (National Reservoir Research Program photo)



Fishery biologists setting trap net. From the catch of fish, the abundance and species composition in the reservoir can be estimated, and fish can be tagged to ascertain the amount of migration. (National Reservoir Research Program photo)

largemouth bass, quillback, redeye bass, redhorse sp., redbreast sunfish, spotted sucker, warmouth, white catfish, whitefin sucker, and yellow perch. The use of rotenone in August to sample three coves—one each in the upper, middle, and lower reservoir—disclosed that total biomass of fishes was about 75 pounds per acre; carp contributed 51 pounds and largemouth bass about 5 pounds.

## GREAT LAKES FISHERY PROGRAM

The Great Lakes Fishery Laboratory is on the North Campus of the University of Michigan, Ann Arbor. Supporting field units are biological stations at Ashland, Wis., and Sandusky, Ohio; vessel bases at Cheboygan and Saugatuck, Mich.; and four 45- to 65-foot research vessels, the *Cisco*, *Kaho*, *Musky II*, and *Siscowet*. The mission of the Laboratory is to describe and understand Great Lakes ecology and to develop the knowledge required for the conservation and enhancement of the fishery resource.

*Appraisal of lake trout restoration in Lake Superior.*—Although the abundance of lake trout of legal size (17 inches long or longer), as estimated from commercial assessment gillnetting, declined in all U.S. waters of Lake Superior, it was still high in Michigan (roughly 2.5 times the 1929–43 average) and

Water temperature, dissolved oxygen, and conductivity profiles were taken at 13 stations on Keowee Reservoir. Measurements were made at 1-m intervals from the surface to 15 m and at 5-m intervals below this depth. During 1972, there were no notable differences in temperature profiles at any of the 13 locations for any sampling day. The reservoir became stratified in mid-June and a well-defined thermocline was evident by mid-July. Thermal stratification was most pronounced and depth of the thermocline was greatest (extending from 5 to 19m) in August. The surface temperature reached a high of 28° C in early August. In September, the surface water began cooling and by October thermal stratification was disappearing. By January, the reservoir had become mixed and temperatures were homothermous.

Dissolved oxygen profiles taken in the main reservoir were similar to those taken in embayments. As the summer progressed, oxygen concentrations in the deepest water at different stations reached values as low as 0.1 to 2.5 ppm.

Conductivity profiles were taken from the surface to the bottom at 5-m intervals. The readings ranged from 25 to 35 micromhos per cm at 25° C.

Wisconsin (about twice the 1929–43 average), but was less than half the long-term average in Minnesota. In general, the changes in abundance of lake trout appeared to reflect changes in stocking rates in the late 1960's, although high stocking rates in Minnesota have not yet resulted in greatly increased abundance there. Heavy sea lamprey predation, as indicated by the high incidence of lamprey wounds on lake trout in Minnesota waters in 1967–71, may have limited the survival of the stocked fish.

Spawning lake trout (25–32 inches long) were abundant in several areas in both Wisconsin and Michigan during the October spawning run. At Gull Island Shoal, the largest spawning ground in the Apostle Islands region of Wisconsin, abundance of spawners was the highest since 1950 (before the sea

lamprey had become abundant in Lake Superior). The large numbers of native fish of the 1965 and 1966 year-classes in the run caused a sharp reduction in the percentage of hatchery-reared (fin-clipped) fish, from 57 in 1970 and 30 in 1971 to only 19 in 1972. Since the available evidence suggests strongly that lake trout return to their natal reefs to spawn, and since the native spawners of the 1965 and 1966 year-classes on Gull Island Shoal were roughly twice as abundant in 1972 as their parents were in 1964 and 1965, the Gull Island Shoal population should now be self-sustaining.

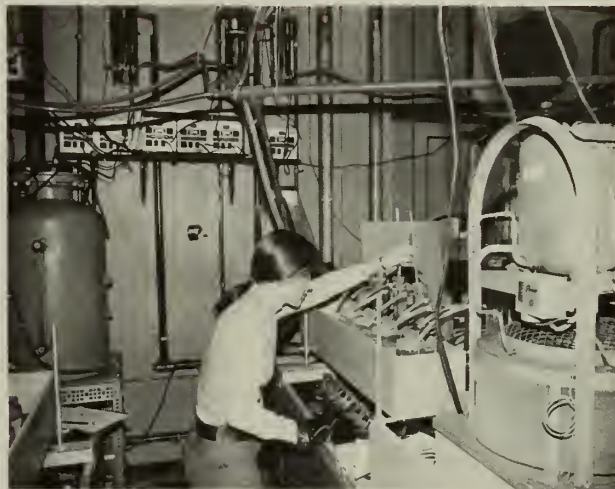
Many hatchery-reared lake trout released along the shore apparently return to spawn near the planting sites, in areas that are probably not suitable for incubation of eggs or survival of fry. This indication was supported by the results of fishing in Wisconsin during spawning runs and in Michigan (inside the harbor at Marquette) during spawning operations, and by numerous reports of lake trout spawning in unusual areas (such as rivers and shallow sand beaches). The 1970-72 returns of spawners surviving from a 1965 plant of hatchery-reared fish on Gull Island Shoal suggest that stocking directly on known spawning grounds can result in the later return of many of the fish to those grounds to spawn. Stocking by boat on suitable spawning grounds rather than from shore should hasten the rehabilitation of self-sustaining stocks in the upper Great Lakes.

Experimental bottom trawling at four index stations in the Apostle Islands region revealed that survival of the 1970 year-class of planted lake trout to age II was poorer than that of 11 of the 12 other year-classes (1958-69) for which data are available. Reductions in the number of fish planted in recent years have not resulted in generally higher survival rates. The combination of lower survival and smaller plants since 1964 has led to sharp reductions in the abundance of 3- to 6-year-old fish.

In Michigan waters, the catch of age-II lake trout per trawl tow was slightly less than half that in 1971, undoubtedly reflecting the 1971 reduction in stocking rate (roughly half that in 1966-70). No native

young-of-the-year lake trout were taken in trawls, but 3 to 33% (average, 12%) of the lake trout taken at nine locations with small-mesh gill nets were native fish, mainly of ages III-VI. Although natural reproduction of lake trout is not capable of sustaining the population, it appears to have been somewhat more successful in recent years than was generally believed.

*Lake trout reproduction in Lake Michigan.*—Widespread spawning of lake trout in Lake Michigan, which took place in 1971 for the first time since the late 1940's, occurred again in 1972. (Native lake trout were exterminated by the sea lamprey in the mid-1950's. Present stocks are from plantings of 1.2 million fish in 1965 and about 2 million each year since then; concurrently, the sea lamprey was brought under control by the treatment of tributary streams with a selective lamprey larvicide.) As in 1971, lake trout spawned along much of Lake Michigan's shoreline over all bottom types and mostly (perhaps exclusively) in water less than 30 feet deep.



Measuring water temperatures in cylinders containing lake trout eggs. The eggs were taken from spawning lake trout captured in Lake Michigan in the fall of 1972 and are being incubated to determine the effect of temperature on hatching and the production of normal fry. This study is part of a program to reestablish self-reproducing stocks of lake trout in lakes Michigan and Huron, where the species was eradicated by the sea lamprey. (Great Lakes Fishery Program photo)

A representative sample of spawning lake trout collected in southeastern Lake Michigan comprised 359 mature males and 91 mature females. More than 90% of the fish had been stocked as yearlings in 1967 or 1968.

No young-of-the-year lake trout were recovered in 1972 during extensive experimental trawling by the *Cisco* and research vessels of other agencies, despite the heavy spawning in 1971. Although the lack of young trout in the trawls does not preclude the possibility of some reproduction (experience in Lake Superior has shown that lake trout are difficult to catch in their first year), it is clear that reproduction was extremely poor in relation to the potential indicated by the amount of spawning in 1971.

The reason for the apparent reproductive failure of lake trout in Lake Michigan is not known. Predation on eggs was not believed to be an important factor, and percentage hatch and survival appeared to be normal among eggs taken from Lake Michigan trout in 1971 and held in a hatchery of the Michigan Department of Natural Resources. It seems likely that a significant factor contributing to the failure was the unsuitability, for egg survival, of spawning sites chosen by most of the planted fish. Eggs deposited on sand bottom in shallow water in 1971 undoubtedly were subjected to severe molar action by ice, and many were probably buried in shifting sand. Eggs deposited in rocky areas should have escaped destruction by these agents, but if so, most if not all apparently failed to survive the adverse effects of other unknown factors.

*Dynamics of Lake Michigan alewife and bloater populations.*—Catch rates for adult alewives in bottom trawls during spring and fall assessment surveys in Lake Michigan averaged lower in 1972 than in 1971. The unweighted mean catch per 10-minute trawl haul at four southern stations—Ludington, Saugatuck, and Benton Harbor, Mich., and Waukegan, Ill.—during the main assessment period in late October and November dropped from 239 alewives in 1971 to 126 in 1972.

Additional evidence of the decline in abundance suggested by the lower catch rate was the improvement in physical condition of



Alewives were far less abundant in Lake Michigan in 1972 than in the years immediately preceding a massive dieoff in 1967. This catch of 6,400 pounds was made in a 15-minute drag with a 52-foot trawl on May 7, 1966. The Chicago skyline is in the background. (Photo by Alfred Larsen)

adult alewives (indicated by the unweighted means of body weights over a standard range of length intervals). The basis for this premise is that physical condition varied inversely with relative abundance during 1965–72. Regression of condition on relative abundance accounted for 73% of the statistical variation in the weight indices of males and 82% of the variation in females during the 8-year study. Selective depletion of zooplankton has been identified as probably being the direct cause for the poor condition of the fish at the crest of the tremendous population upsurge of alewives in 1965–66. It is believed that this poor condition later intensified the mass mortality that reduced the adult population an estimated 70% in early 1967. The condition improved markedly by fall 1967, after only one growing season at the lower population density.

A scattered dieoff of alewives was observed from the R/V *Cisco* during widespread sampling in southern Lake Michigan in May,

June, and July 1972. The mortality appeared to be light to moderate, similar to that in spring and summer 1971. A light mortality in 1972 had been predicted in fall 1971 on the basis of similarities in the physical condition and population density of alewives at the beginning of the 2 years. Dead and decomposing alewives were scarce on the bottom in March and April 1972, indicating that winter mortality was light.

The rate of an exponential decline in abundance of adult bloaters in Lake Michigan during 1960-72 (about 20% per year) was measured by adjusting and combining catch-effort data from several semi-independent surveys with bottom trawls. It is generally believed that this small deepwater cisco reached peak abundance between 1955 and 1961. During this period bloaters filled a void left by the decline or disappearance of the larger cisco species that resulted from selective fishing and sea lamprey predation. The decline of bloaters at a seemingly constant rate in the 1960's and 1970's was accompanied by the great increase in the density of alewives and lakewide mass mortality mentioned above, and the later stabilization of alewife populations at lower but still substantial levels.

A steady increase in mean catches of young-of-the-year bloaters during fall surveys at four index stations in 1967-70 was viewed as a sign that the bloater population might stabilize after the great reduction in interspecific competition that followed the massive alewife dieoff in early 1967. This possibility is now questionable, however, because catch rates for young bloaters decreased in 1971 and 1972. In fact, there is no real evidence anywhere that bloaters and the other deepwater ciscoes can sustain themselves in the presence of large populations of alewives (and possibly smelt). The drastic declines in the cisco stocks of Lakes Ontario and Huron suggest that these species are incompatible with, and are eventually replaced by, the non-native competitors.

*Hatch and survival of fish in western Lake Erie, 1972.*—Evaluation of the hatch and survival of fish in western Lake Erie in 1959-72 has been based on the abundance and distribution of the young-of-the-year, as assessed

during the summer and fall with experimental small-mesh trawls. The indices of abundance formulated are then the basis for determining the status of the forage species and for forecasting the future contributions of particular year-classes to the sport and commercial fisheries.

Hatch and survival for most species was better in 1972 than in 1971, although catches of young-of-the-year were generally more variable than in other recent years. The 1972 year-class of walleyes was the third largest produced in 1959-72 (most year-classes have been weak since the collapse of the walleye fishery in the late 1950's). Because spawning occurred later than in most years and water temperatures during the spring and summer were lower, the growth of young-of-the-year walleyes was retarded. By the end of the year the average length was about 8 inches, as compared with the more usual 9 to 9-1/2 inches in other recent years.

The hatch and survival of yellow perch was poor in 1972, as it was in 1971. Year-class strength has fluctuated considerably in recent years. The last relatively good year-class, which occurred in 1970, was well below the level of the exceptional year-classes produced in 1959, 1962, and 1965.

The reproductive success of other species in 1972 was excellent for rainbow smelt (best on record) and gizzard shad (second-best year), and fair for white bass and freshwater drum. Some of the forage fishes, including the important emerald shiner and spottail shiner, produced unusually poor year-classes in comparison with other recent years.

*Environmental factors affecting walleye reproduction.*—The collapse of the walleye population in western Lake Erie in the late 1950's has been attributed to various factors. Year-class success since 1954 has been extremely erratic.

An analysis of climatological, water temperature, and other data in relation to walleye egg deposition showed no relation between year-class strength and fluctuations in water levels, brood stock size, or intensity of egg predation. Correlations were strong, however, among the densities of eggs deposited on the reefs, young-of-the-year produced, and the average daily rate of temper-



Experimental gill nets being set in Lake Ontario for fish population assessment. (Great Lakes Fishery Laboratory photo)

ature rise during the spawning and incubation periods. In 1960–70, reproductive success was highest in the years when temperature increased steeply during the main incubation period (1962, 1965, and 1970). Rapidly rising temperatures speed up embryonic development and shorten the incubation period, and thus minimize egg exposure to such stresses as smothering by inorganic sedimentation, low oxygen tensions from organic sedimentation, dislodgment from the reefs by waves and currents, and disease.

*Assessment of Lake Ontario fish stocks.*—In conjunction with the 1972 International Field Year for the Great Lakes, the Great Lakes Fishery Laboratory and field units of the New York Department of Environmental Conservation and Ontario Ministry of Natural Resources made a season-long survey of fish stocks in Lake Ontario in 1972. Major

objectives were to improve our knowledge of the composition and distribution of the fish fauna and to develop baseline estimates of the magnitude of the major fish stocks. The work was divided into two phases—a study of offshore stocks (in water 30 feet deep or deeper) and of inshore stocks.

The R/V *Kaho* completed five 15-day assessment cruises of offshore fish populations during the period from May to October. Experimental bottom trawls and gill nets were fished at pre-established stations along a total of seven sampling transects off Port Credit, Hamilton, and Prince Edward Point, Ontario; and Olcott, Rochester, Oswego, and Cape Vincent, N.Y. The *Kaho* made 190 half-mile tows with a 39-foot (headrope) semiballoon bottom trawl at depths of 5 to 80 fathoms and fished almost 107,000 linear feet of 1½- to 6-inch mesh gill nets at depths of 5 to



60 fathoms. Acoustical equipment on the vessel continuously recorded fish concentrations by depth and location.

Offshore fish collections comprised 32 species. American smelt, alewives, and slimy sculpins predominated numerically in catches by trawls (40, 33, and 24%, respectively); and alewives, white perch, and smelt in catches by gill nets (63, 15, and 13%). The once abundant coregonids were very scarce: Only 1 bloater, 2 lake whitefish, and 13 lake herring were taken during the survey.

Inshore collections were made with bottom trawls, graded-mesh gill nets, trap nets, beach seines, and half-meter townets. Of the 56 species positively identified from inshore fish collections, 7 were abundant: alewife, brown bullhead, white perch, rock bass, pumpkinseed, smallmouth bass, and yellow perch.

*Respiratory metabolism and swimming performance of juvenile lake trout.*—The production processes in an ecosystem involve interactions between energy supply, metabolism, and growth. In one study oxygen consumption (a measure of the energy dissipated in all of the metabolic “work” performed) of small (60–260 g) lake trout was determined continuously for 24 hours or longer while the fish were forced to swim at various speeds in a tunnel-type respirometer. Since the oxygen in the respirometer was constantly above 70% saturation, the rate of oxygen consumption by the fish was independent of the ambient oxygen level.

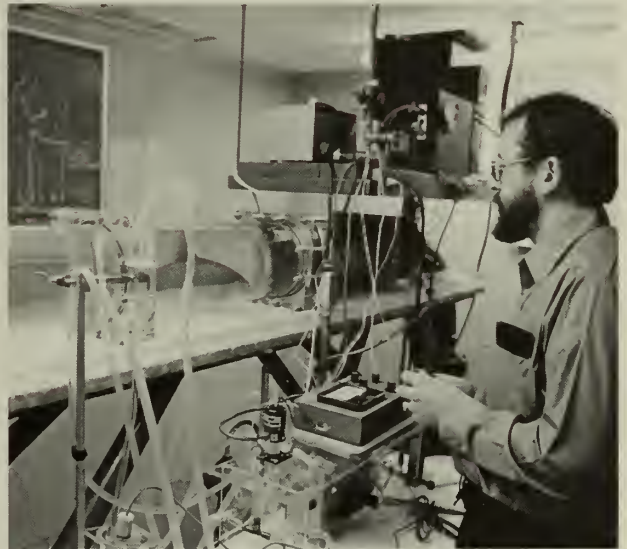
Preliminary analyses of the data indicate that the logarithm of oxygen consumption increases linearly with swimming speed for fish swimming at 10 to 60 cm per second. Oxygen consumption per kilogram of fish per hour ranged from about 50 mg for fish acclimated to 3.5° C and swimming at 0.3 body length per second to about 400 mg for those acclimated to 18° C and swimming at slightly more than two body lengths per second—an increase of “metabolic capacity” of 700%.

Conversion of the data on the amounts of oxygen consumed at various temperatures and swimming speeds into caloric equivalents, and inclusion of caloric information from other studies, will permit construction of an energy budget for individual fish. Such

budgets will in turn provide a partial basis for computer modeling of the lake trout production systems of the Great Lakes.

*Growth of lake trout in the laboratory.*—Studies of the effects of temperature and availability of food on the food intake, growth, and food conversion efficiency of yearling lake trout (average weight, 23–45 g) indicated that growth can be good at temperatures as low as 3 and 5° C for lake trout fed unrestricted amounts of young-of-the-year alewives. Food intake was greatest (as much as 6% of body weight) and growth rate and conversion efficiency were highest at 10 and 12° C. Lake trout fed daily rations equivalent to a specific percentage (1.5, 2.5, or 4.0) of their body weight gained less weight but generally converted food more efficiently than trout fed unrestricted rations.

The rate of growth (percentage of body weight gained per day) of the yearling lake trout was nearly twice that of 2-year-old fish and more than three times that of 6-year-old fish. The rate of food intake (percentage of body weight eaten per day) and conversion efficiency were also highest for yearling fish and lowest for 6-year-old fish.



Measuring the oxygen consumption by lake trout in a tunnel respirometer. Oxygen consumption at various temperatures and swimming speeds are converted to caloric equivalents for use in construction of an energy budget for lake trout. (Great Lakes Fishery Laboratory photo)

*Effect of different constant temperatures on egg survival and embryonic development in lake whitefish.*—Among eggs of Lake Michigan whitefish incubated at six constant temperatures, the length of the incubation period (time to 50% hatch) varied inversely with temperature. Percentage hatch was markedly higher and the percentage of abnormal fry was lower at 4.0, 5.9, and 7.8° C than at 0.5, 2.0, or 10.0° C.

Mortality of eggs was high at all temperatures during the stages of embryonic development preceding the onset of organogenesis. Thereafter mortality was very low, with one exception: Mortality of eggs held at 10° C

rose sharply soon before hatching began and remained high throughout the hatching period.

The temperature requirements for the incubation of lake whitefish eggs were closely similar to those found for lake herring in a 1970 study at the laboratory.

*Effect of sublethal thermal shock on vulnerability of lake whitefish fry to predation.*—Most of the early research on the adverse effects of power-plant cooling systems on fishes has dealt with the possibility that the high temperatures of discharged water would cause mortality. Less work has been done on the indirect or sublethal effects of



Lake whitefish are hatched and reared at the Great Lakes Fishery Laboratory for experimental use. (Great Lakes Fishery Laboratory photo)

heat on fishes, but the available evidence now shows that sublethal exposures to elevated temperatures can indirectly increase mortality by reducing the ability of fish to avoid predators. A laboratory study demonstrated that whitefish fry exposed briefly to high temperature became significantly more vulnerable to predation by yellow perch.

In the tests, groups of fry were removed from their acclimation tank, transferred to a shock temperature tank for 1 minute, and then placed in a test tank at their original acclimation temperature. The test tank contained several perch that had been deprived of food for 48 hours. The shock temperatures for fry acclimated to 10, 15, and 18° C were 25, 28, and 29° C, respectively. These temperatures were about 2° C below those that previous testing had shown would cause 50% mortality of the fry in 1 minute.

Most of the shocked fry retained equilibrium throughout the test and exhibited behavior that was indistinguishable from that of unshocked control fish; nevertheless, perch captured the shocked fry much more readily ( $p < 0.01$ ) than fry that had not been shocked.

A statistically significant ( $p < 0.01$ ) upward trend in catch per effort with temperature suggested that predation on both shocked and unshocked fry is higher in a heated plume than outside it (presumably because of the higher metabolic rate and greater appetite of predators in the warmer water).

*Preferred temperature of lake whitefish.*—It is well known that fish aggregate within a certain "preferred" portion of the available temperature range. Although preferred temperature varies with the state of acclimation of the fish, the temperatures selected are usually within a range that ensures effective functioning of vital body processes.

Temperature selection by two groups of young-of-the-year and one group of yearling lake whitefish was studied by placing fish acclimated to 10, 15, and 20° C in a vertical temperature gradient and observing the selected temperatures 4 hours later. The results indicated an inverse relation between acclimation temperature and the selected temperature; for example, fish acclimated to 10° C chose temperatures averaging 19.4° C



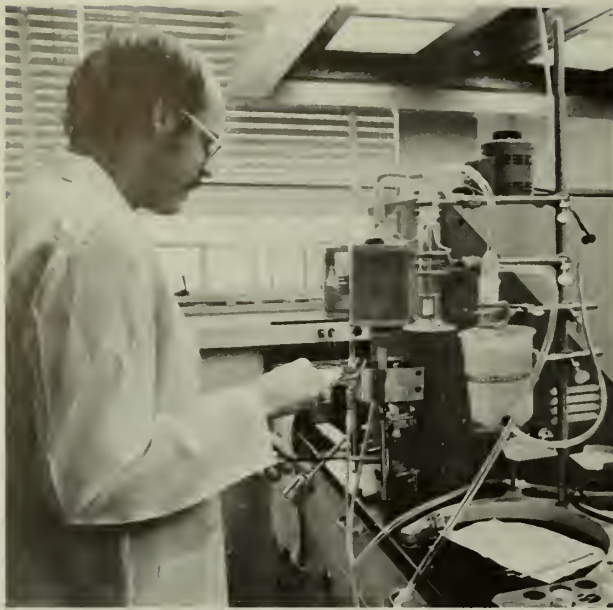
Feeding young lake whitefish in a laboratory experiment to determine the effect of water temperature on growth. Water is maintained at the desired temperature range in large overhead tanks and then adjusted to the desired precise temperature with thermostats and immersion heaters in each fish tank. The experiment is one phase of a broad study of energy flow in food chains of the Great Lakes. (Great Lakes Fishery Laboratory photo)

or higher, whereas those acclimated to 20° C selected temperatures averaging 13.2° C or lower.

The final preferendum is the temperature near which all individuals of an age class eventually collect, regardless of their initial acclimation state. The preferenda in the present experiment were 16.7° C for young-of-the-year whitefish (closely similar to the preferred temperature of 17.0° C reported from field studies for whitefish of the same age) and 15.6° C for yearlings. The lower preferendum of yearling whitefish is in agreement with published literature on coregonines, which indicates that the older fish tend to seek the cooler water.

*Effect of temperature on the accumulation of mercury by fish.*—Thermal pollution has become a matter of increasing concern in the Great Lakes in recent years. Although considerable effort has been expended in studies of the effects of heated effluents on the biota, the effect of increased water temperature on the amounts of pollutants accumulated by fish and other organisms has been ignored.

In an experiment at the Great Lakes Fishery Laboratory, designed to determine the



Analysis of the mercury content of environmental materials by the combustion-amalgamation technique developed at the Great Lakes Fishery Laboratory. A 100-milligram sample of fish tissue is being placed in the radio-frequency induction furnace. The sample is burned and the resulting mercury vapor is measured with a mercury-vapor meter. (Great Lakes Fishery Laboratory photo)

effect of temperature on the amounts of methyl mercury accumulated by fish from water, yearling rainbow trout (initial average weight, 31 g) acclimated to 5, 10, or 15° C were exposed to about 250 parts per trillion methyl mercury for 12 weeks. Concentrations were maintained with infusion pumps that operated continuously. Control fish were held at each of the three temperatures. Five fish from each experimental and control tank were removed for analysis every 2 weeks throughout the experiment.

Concentrations of methyl mercury in fish increased with temperature. Concentration factors (concentration in fish/concentration in water) after 12 weeks exposure at the three temperatures were as follows: 5° C—4,541; 10° C—6,628; and 15° C—8,000.

*Relation of nutrient release to microbial action on biochemical substrates.*—Inorganic and organic biochemical substrates that accumulate in bottom sediments of lakes and rivers generally must be chemically changed by bacteria and other reducer organisms be-

fore they become available as nutrients for phytoplankton. The biochemical and chemical reactions involved result directly from metabolic activities of these organisms or indirectly from changes in such variables as pH, dissolved oxygen concentration, or oxidation-reduction potential. A study was made to evaluate the capability of various biochemical substrates to release nutrients—particularly phosphorus.

Experiments were carried out in reaction vessels fabricated from 2-quart mason jars. Rubber closures were used, with serum-bottle stoppers as sample ports. About 500 g of sediment and 1,500 ml of water were added to each reaction vessel before closure. The systems usually became anaerobic in 1 to 2 weeks.

From 0.5 to 40 g of glucose were injected into different reaction vessels with a needle inserted into the sediment to a depth of 1 to 8 cm. After 3 months, phosphorus levels that initially were 300 ppb (parts per billion) in Lake Michigan sediment systems had increased to 5,300–8,700 ppb; silica levels were 40 ppm and iron 20 ppm. These changes were accompanied by a drop in pH from 8.0 to 5.0 and a rise in conductivity from 300  $\mu$ mho to 4,500  $\mu$ mho. Phosphorus increases in reaction vessels not injected with glucose, or injected with 5 g or less, did not exceed 2,500 ppb.

The loading of a bottom sediment with glucose, an organic constituent of seston, thus produced high concentrations of phosphorus under anaerobic conditions. The amount of nutrient released appeared to be directly related to the amount of glucose added.

The release of phosphorus under anaerobic conditions increased with temperature. At 25° C the phosphorus level was 2.5 times that at 15° C.

*Silica in the Great Lakes in relation to algal dominance.*—Silica is essential for the growth of diatoms, the most abundant algal group in the Great Lakes, but is not a major nutrient for any of the other prolific groups. Consequently, if silica is not present in concentrations high enough to support diatom growth, green or blue-green algae often become dominant. Silica levels are typically

lower in eutrophic lakes, where green and blue-green algae are dominant, than they are in oligotrophic lakes.

Field sampling by the R/V *Kaho* in 1972 provided information on the distribution of silica in the four lower Great Lakes. Hourly water samples were collected while the vessel sailed from southeastern Lake Michigan to Lake Ontario in mid-April and returned in November. Throughout the intervening field season, samples were collected in Lake Ontario at the inshore and offshore ends of five transects used in fish assessment studies.

In April, silica values were highest (2.0 ppm), as expected, in samples from Lake Huron, the most oligotrophic of the waters sampled, and lowest (0.9 ppm) in Lake Erie, the most eutrophic. Silica was particularly high in the Straits of Mackinac (3.2 ppm), possibly because an ice cover was still present. The resulting reduction in light penetration would be expected to limit photosynthesis and, therefore, diatom growth and silica uptake.

In November, the relation between silica concentration and the degree of eutrophication was the same as in April, although the measurements were consistently lower (1.2 ppm in Lake Huron; 0.5 ppm in Lake Erie).

At the fishing transects along the south shore of Lake Ontario, silica was depleted much earlier in nearshore than in offshore waters. Silica became generally limiting (less than 0.5 ppm  $\text{SiO}_2$ ) in June.

*Seasonal abundance of macrozooplankton in west-central Lake Erie in relation to dissolved oxygen depletion.*—Seasonal abundance of crustacean macrozooplankton was measured in the west-central basin of Lake Erie to determine the effect of annual depletion of hypolimnetic dissolved oxygen (DO) on the distribution, composition, and abundance of macrozooplankton.

On the basis of measurements made in July (before depletion) and August (after depletion), the composition, abundance, and vertical distribution of macrozooplankton shifted markedly during hypolimnetic DO depletion. The composition shifted from primarily carnivorous, cyclopoid copepod forms dominated by *Cyclops bicuspidatus* in July to herbivorous forms composed primarily of cla-



Preparing extracts of fish for pesticide analysis. The automated gel permeation system shown in use removes interfering fats and oils from extracts prior to gas chromatographic analysis. Samples are from fish collected in the Great Lakes to determine trends in pesticide residues, and from fish exposed to pesticides in the laboratory to evaluate the uptake and effects of various compounds. (Great Lakes Fishery Laboratory photo)

docerans and naupliar copepods by mid-August.

The maximum abundance of macrozooplankton shifted from the hypolimnion in July to the epilimnion in August. From July to August, total macrozooplankton abundance at thermally stratified offshore stations dropped 50 to 80%. The mechanism of the decline may have included mortality of adults and diapause or aestivation of stage-IV copepodites during, and in response to, anoxia.

*Retention of mercury by fish.*—In an experiment at the Great Lakes Fishery Laboratory, rock bass and yellow perch collected in Lake St. Clair in September 1970 and transferred to hatchery holding ponds in Saline, Mich., were sampled periodically to follow changes in mercury concentration in the fillets. The concentration, which was about 1 ppm at the time of transfer, had declined 50 to 60% by November 1972. However, the weight of the yellow perch had nearly doubled and that of rock bass had trebled during the same period. Thus the estimated total

body burden of mercury did not decline; rather, the residues stored in the edible portion of the contaminated fish were merely diluted by growth of the fish. The form of the mercury in the fish did not change during the holding period; more than 90% was methyl mercury at both the beginning and end of the experiment.

*Mercury in forage fishes in western Lake Erie.*—Mercury contamination in western Lake Erie has resulted in restrictions on commercial fisheries for walleyes and white bass. A study was made by the Great Lakes Fishery Laboratory in 1970–72 to determine the pathways of mercury uptake through various trophic levels, and to establish baseline values that will make possible the detection of changes that follow pollution abatement. Forage species included in the analysis were spottail shiner, emerald shiner, alewife, and gizzard shad.

Mercury residues were 2 to 7 times higher in adults than in young-of-the-year in each species in each area tested. The greatest rate

of increase with age was in spottail shiners; average residues were 0.04 ppm in young-of-the-year, 0.10 ppm in yearlings, and 0.25 ppm in adults. Emerald shiners had much higher absolute values of mercury than other forage species of the same age; average concentrations were 0.11 ppm in young-of-the-year, 0.28 ppm in yearlings, and 0.46 ppm in adults. The level of mercury residues in adult emerald shiners was thus similar to that in climax predators from western Lake Erie.

*Chlorinated hydrocarbons in the Great Lakes.*—Analyses at the Great Lakes Fishery Laboratory showed that concentrations of DDT in the Lake Michigan bloater (a deepwater coregonid) continued a downward trend in 1972 that first became clearly evident in 1971. Average concentrations (ppm) in different years were as follows: 1968, 9.6; 1969, 11.1; 1970, 10.2; 1971, 7.2; and spring 1972, 6.7. The concentration of polychlorinated biphenyls (PCB's) exceeded that of DDT in the bloater in 1972, as it did in Lake Michigan coho salmon and lake trout in 1971.

## UPLAND WILDLIFE

Nonmigratory small game in the United States, both mammals and birds, is hunted largely on State and private lands. Responsibility for its management lies primarily with the State game and fish departments. The Bureau participates in research on small game, and on big game also, on State and private lands through its Cooperative Wildlife Research Unit program which is conducted in cooperation with State agencies.

Research on game and other wildlife on public lands is a responsibility of the Bureau which is carried out largely through the Denver Wildlife Research Center. The Center cooperates with Forest and Range Experiment Stations of the U.S. Forest Service in accomplishing much of this research. Denver's Section of Ecology on Public Lands also carries out basic studies on populations of predacious, colonial-nesting birds.

*Reproduction and hematology of a Utah elk herd.*—Objectives of the first 3 years of a 10-year reproductive study of the Cache elk

herd were to: (1) ascertain pregnancy rates of wild trapped cows and associate these rates with subsequent fall cow:calf ratios, (2) determine the breeding efficiency of yearling male elk, (3) induce twinning in elk, and (4) determine mean values for blood components in elk.

In the winter of 1969–70, 100% of 19 adult elk and 0% of 5 yearling elk were pregnant. These rates were associated with subsequent cow:calf ratios of 100:55 for the pre hunting season and 100:68 for the post hunting season. In 1970–71 pregnancy rates were 83% for 60 adults and 17% for 23 yearlings. These rates resulted in pre hunting season cow:calf ratios of 100:52 and post season ratios of 100:39.

Twelve of 14 cows (86%) bred with yearling bulls became pregnant and 8 of the 12 conceived in October. Fourteen of 15 cows (93%) bred with adult bulls became pregnant and 10 of the pregnant cows conceived in September. The peak in breeding of yearling bulls



Mature elk bulls are scarce in some Utah herds because of selective hunting pressure. Reproduction in an elk herd is the subject of a long-term investigation in Utah. (Colorado Division of Game, Fish and Parks photo)

occurred between 11 and 25 October whereas that of adult bulls occurred between 5 and 20 September.

Inducement of twin births was attempted by synchronized superovulation in two groups of six cows during the September rut in 1970. Apparently, none of the cows conceived during the estrous cycle immediately following the hormonal injections, but nine of them did during the second cycle. All gave birth to single calves.

Mean values for the following were determined in the blood of captive and free-ranging mature elk: total leucocytes, differential leucocytes, erythrocytes, hemoglobin, packed cell volume, blood urea nitrogen, serum glutamic-oxalacetic transaminase, lactic dehydrogenase, alkaline phosphatase, total protein, albumin, globulin fractions, glucose, creatinine, cholesterol, total bilirubin, inorganic phosphorus, and calcium ion. Some statistically significant differences were noted between free-ranging and captive elk, and between sexes, ages, and reproductive status.

*Deer-vehicle collisions on highways.*—Increasing numbers of deer are being killed on highways; in Pennsylvania white-tailed

deer-vehicle collisions have increased 213% from 1960 to 1967 and 5% from 1967 to 1971, stabilizing at about 22,000 annually. To reduce both the hazard and the mortality, information is needed on the ecological factors associated with frequent sites of the collisions. Characteristics of vehicle-deer mortality along 313 miles of Interstate 80 in Pennsylvania were ascertained from 787 reports made by State Game Protectors from August 1970 through January 1972.

Seasonal variation in deer mortality on Pennsylvania Interstate 80 was highly correlated ( $r = .81, P < 0.01$ ) with highway mortality reported for the entire State during the same period. Mortality peaked during November and December, and was high also during the spring. Male and female mortality rates were similar for most months, but during December male mortality declined while female mortality increased. During May and June, male mortality rose abruptly while female mortality remained essentially stable. The drop in male mortality during December may have been due both to the male kill by hunters and to the removal of road-killed males by hunters. The increase in male mortality during May and June was unexpected because bucks are growing antlers and are normally secretive at this time. Yearling males, abandoned by their dams, may have contributed to this increase, but age data were not believed to be accurate enough for use.

Fence location was the most biologically significant factor in deer mortality. High deer mortality occurred where fences were 4 to 5½ feet high and located at the edge of a wooded area or within 25 yards of the nearest wooded area. The lowest deer mortality occurred where the fence was located over 25 yards from the nearest wooded area. Low mortality also occurred where the fence was located within the woods. The effect of vegetation was biologically significant only where fencing was absent. In this situation the mean deer kill per mile was significantly higher where one side of the highway was wooded and the other was open field.

*Human disturbance of Dall sheep in Alaska.*—A 2-year study was made of the number and movements of Dall sheep in the



Dall sheep rams on Kenai National Moose Range. Disturbance of Dall sheep by aircraft was studied in the Brooks Range at the site of the trans-Alaskan pipeline. (Photo by Steven Heizer)

Atigun Canyon of the central Brooks Range. This site lies in the route of the proposed Trans-Alaskan pipeline. Dall sheep used the Canyon to the greatest extent in June and early July; at least 200 sheep were concentrated there in 1970. Two mineral licks, located in the valley, received the most intense use also in June. In April 1971, 113 sheep were found in the Canyon, and an undetermined number of lambs were born on the north side of the valley. In August of both years sheep returned to the north side of the valley in small numbers. No winter observations were made.

The Atigun Canyon is a route much used by small airplanes and helicopters. Several instances of aircraft disturbing sheep were noted during the field work. Usually, helicopters caused more disturbance than airplanes, and sheep were most readily disturbed when congregated at the mineral licks. Aircraft flying low directly over the river or high above the canyon walls caused the least degree of disturbance.

The study makes recommendations for keeping disturbance of the sheep to a minimum during the construction phase of the

pipeline. In particular, on-the-ground activity should be avoided from mid-May through early July and again from mid-August until the end of summer.

*Biology and behavior of the bobcat.*—A bobcat population was studied for 3 years on a 250 square mile study area in southeastern Idaho. Sixty-six bobcats were captured 110 times during the period of study, and 17 of them were fitted with radio transmitter collars. About 35 adult bobcats were present on the study area each year.

Resident bobcats were territorial and this appeared to set an upper limit to the breeding density. Avoidance behavior appeared to space resident bobcats; transient individuals seemed to avoid areas occupied by residents. Avoidance appeared to be greatest between residents of the same sex. Few adult social interactions were recorded.

Rabbits were the most frequent item in the diet of bobcats; they were eaten more frequently than would be expected from their numbers in the area. After the rabbit population declined abruptly in the area, rodent and bird remains increased in bobcat feces. Although mule deer, pronghorn antelope,



and domestic sheep were present on the study area, their remains were not found in the feces or prey remains of bobcats.

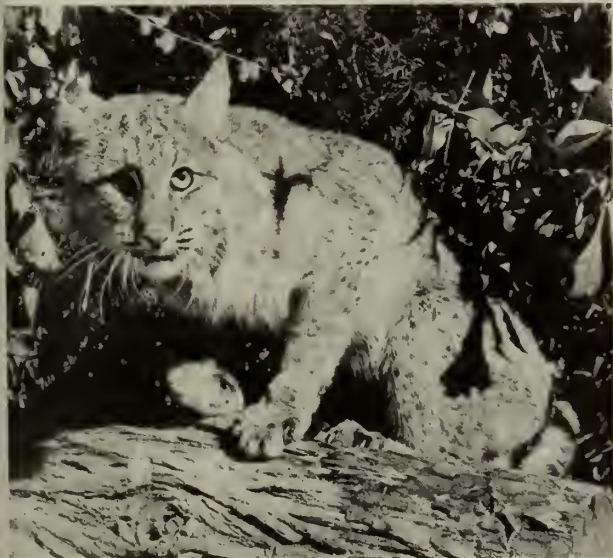
Sixteen bobcat litters averaged 2.8 kittens. Kitten survival was apparently related to rabbit numbers for few survived after the rabbit population collapsed.

Marking by bobcats was accomplished by depositing feces or urine and by producing scrapes. Deposition of feces marked habitually used locations of special significance to the bobcat in its home range. Other bobcats, especially those of the same sex, appeared to avoid these locations. Urine marking may be used to prevent or to facilitate encounters along common routes of travel, and such marking may be signalled by scrapes. The secretion from the bobcat's anal glands differs with sex and age and probably labeled the feces or urine.

*Productivity of river otter in Oregon.*—Little information on year-to-year and long-term changes in otter numbers is available on which to base harvest regulations for optimum management. A study was conducted in western Oregon to describe reproductive biology and harvest. The data were obtained from the carcasses of 254 otters trapped during the seasons of 1970–71 and



A directional antenna and portable radio receiver are used in southeastern Ohio to monitor movements and habitat use of ruffed grouse equipped with radio transmitters. (Photo by Theodore A. Bookhaut)



The bobcat is a predator whose breeding population is limited by territoriality. A widely distributed mammal, it is being studied in Louisiana and Massachusetts as well as in Idaho. (Photo by Arnold O. Haugen)

1971–72. Ages of otters were ascertained from counts of cementum rings in the teeth.

The recruitment rate for maintaining population stability, given the current estimated rate of survival, was calculated as 1.17 female young per mature female 3 or more years of age. The observed recruitment rate, determined from the age structure of the sample population, was 1.14 female young per mature female. This indicates that the population of otters in the areas studied was near stability.

Intrauterine mortality was apparently low; the mean number of corpora lutea, blastocysts, and implanted embryos per pregnant female was 3.00, 2.79, and 2.75, respectively. The smallest number of any of these reproductive stages was 2.0, and the largest was 4.0. Parturition probably begins in early April since small (2 to 13 mm), recently implanted embryos were found in females



The gray squirrel is important as a game animal and as one of the few wildlife species that will tolerate urban conditions. It is a subject of study in eastern Oklahoma, Pennsylvania, and Virginia. (Photo by E. P. Haddon)

taken as early as February 3. It was not possible to ascertain the duration of the parturition period because no females were trapped after February 15.

Information supplied by the trappers revealed that 79% of the otters were caught in traps set for otter, 16% in traps set for beaver, and 3% in traps set for either beaver or otter. The coastal counties produced 67% of the otter harvest, and 66% of the otters were trapped during the first half of the trapping season.

*Population biology of the snowshoe hare.*—The population and reproductive biology of snowshoe hares were studied on four areas in the Rocky Mountains of Colorado from 1969 to 1971. Live-trapping was conducted from mid-April through mid-September; data on reproduction and on age composition of the population were obtained by autopsy of hares collected during the reproductive season and during December.

The average size of the home range of adult hares was 18 to 22 acres. In July and August, juveniles used open habitat to a greater extent than did adults. "Surplus"

juveniles were probably forced by social interactions into the sparsely populated, open habitat. This may have been an important self-regulation mechanism of the population. Population density remained stable for the period of study. The prebreeding density in spruce-fir forests was a minimum of 200 adults per square mile.

The average rate of ovulation (3.43 ova) for adult females producing first litters was significantly lower ( $P < 0.01$ ) than for later litters (5.09 ova). Prenatal mortality ranged from 6.8 to 10.9% of the ova shed. Whole litter resorptions occurred in less than 2% of the females examined. The average size of first litters (3.00 fetuses) was significantly smaller ( $P < 0.01$ ) than that of later litters (4.79 fetuses). Variations in rate of ovulation and litter size among years were not statistically significant. The average annual number of young produced per adult female surviving an entire reproductive season ranged from 7.5 to 9.3 on the study areas.

The annual survival rate for adult hares remained the same in 1969–70 and 1970–71, averaging 0.43 in three study areas in densely forested habitat. Only 15 to 20% of the juveniles born each summer needed to survive until the following breeding season to maintain the population. Juveniles of first litters had a higher survival rate than juveniles of the second litters, and those living in forested habitat had a higher survival rate than those living in open habitat.

*Effects of pinyon-juniper control by fire on small mammals.*—Studies of wildlife populations in relation to management of pinyon-juniper range are being conducted at the Benmore Experimental Range in central Utah. A fire ecology study was begun in 1970, when one area of reseeded crested wheatgrass reinvaded by pinyon-juniper reproduction was partially burned. An additional area was burned in 1971, and a third in 1972. Monitoring of small mammal populations was begun on each area before the burn and has continued afterward.

The low-intensity fire of 1970 had no demonstrable immediate effect on either deer mice or pocket mice; both were at least as abundant in the 2 summers following the burn as they had been before it. The more

complete and intense fire of 1971 had no demonstrable effect on deer mice or pocket mice in 1972, although deer mice appeared to be temporarily set back immediately after the fire. The very complete and intense fire of 1972 cut pocket mouse numbers about in half and eliminated deer mice. However, deer mice reinvaded the complete burn of 1972 within 2 weeks, and within a month their numbers appeared to be comparable with those before the burn.

*Raptor electrocution losses studied.*—Evidence accumulated from various sources show that raptors, particularly golden eagles, are electrocuted each year on the vast network of power distribution lines that criss-cross the Nation. The problem is most serious in the intermountain region of western United States where the largest golden eagle populations are found, and particularly in areas where the lines cross relatively flat, open terrain having an abundant food supply and a minimum of natural perch sites.

A cooperative program designed to reduce electrocution losses has been developed between Federal and State land-use and conservation agencies, national conservation agencies, and Federal and private sectors of the electric power industries. Existing "problem" lines are being modified to prevent further losses, and specifications for future powerline construction will include safeguards against accidental bird electrocutions.

*Prairie falcon populations in western Montana.*—The population status of prairie falcons was studied during 1970 and 1971 in three multicounty study areas, two (A and B) east of the Continental Divide and one (C) west of the Divide. The mean number of eggs per clutch for 20 clutches from all areas was 4.3. The mean number of hatchlings per eyrie (nest) for 27 eyries from all areas was 2.4. These averages are equal to or greater than averages obtained in several other States and Provinces. They suggest that prairie falcons are maintaining a stable population in western Montana.

Nesting success, as determined by one or more fledged young, was 62% for 58 nesting territories in all three areas. The success was 35% in area A, 73% in area B, and 88%



Populations of prairie falcons (young, top; adult and young at nesting site, bottom) have received attention because some species of birds of prey have been declining in numbers. Studies suggest that, at present, populations are stable in western Montana. (Photos by John J. Craighead)

in area C. In area A (east of the Divide) an average of only 0.9 young per area were at the eyries during the study. This rate may be below that necessary to maintain a stable population in that area.

Alfalfa is the major agricultural crop treated with chlorinated hydrocarbon insecticides in all study areas. According to agricultural records, twice as much cropland was

treated with this insecticide in Area A than in Area B; treatment in Area C was negligible. Total residues of organochlorine compounds averaged 2.15 ppm in eggs from all study areas. Although sample sizes were small, average total residue levels were highest in eggs from Area A and lowest in eggs from Area C. Levels of DDE were low (1.58 ppm) in all areas. The thickness of shells of eggs from all three study areas averaged 0.306 mm, which is about 16% thinner than 0.336 mm which represents the thickness of eggshells before the use of pesticides, particularly DDT, became common in 1947. Eggshells from Area A, however, were 27% thinner than the pre-1947 average. Also, eggshells were thinner from unsuccessful than from successful eyries—0.272 mm v. 0.318 mm.

The correlation coefficient between eggshell thickness and total organochlorine residues was  $-0.786$ . Considering what has been reported in the literature, this highly significant negative correlation suggests that

chlorinated hydrocarbons probably caused the thin eggshells found regionally in Montana east of the Divide. However, on the study areas as a whole, the data suggest that prairie falcons are not suffering biologically significant reproductive failure as a result of eggshell thinning.

*Behavior of a sage grouse lek.*—The major objectives of this study were to describe quantitatively the behavior of the lek (an aggregation for mating), particularly the social organization, and to ascertain the mechanism of mate selection by the hens. Data were collected on individually marked cocks at Ford's Creek in central Montana during the breeding seasons of 1969, 1970, and 1971. Analysis of the observations on locations and flights of the cocks demonstrated that social organization was consistent with the classic concept of sexual territoriality. Older cocks occupied relatively stable areas during morning and evening leks and from year-to-year. Fighting excluded other cocks from a



Cock sage grouse displaying to hens. At the lek (mating aggregation) studied, hens seemed to select the most active males for mating. (Photo by Paul D. Dalke)

resident's territory, and neighboring cocks tested one another many times a day throughout the lek. Some fights were vigorously waged; in a few instances, cocks were forced to leave their territories by aggressive neighbors. Thus, ownership of a territory was not, by itself, a guarantee that the resident would never lose a fight. Apparently, only cocks in excellent physical condition could maintain a territory on or near active mating centers. No stable dominance relationships emerged from these fights, and evidence for dominance hierarchies was not found among cocks.

Relatively few cocks performed most of the copulations. Most copulations occurred before 1 hour after sunrise during the first 3 weeks in April. A few occurred at the evening lek. Apparently, yearling cocks never copulated.

Two major hypotheses were considered as the mechanism of mate selection by hens: hens were attracted to geographic sites on the arena and mated with the cocks on the sites, and hens were attracted to and mated with individual males whose behavior differed from that of other males. On the basis of the data the site hypothesis was rejected in favor of behavioral differences hypothesis. In 1971, the researcher successfully predicted which cocks would become breeders on the basis of the over-all activity rank before copulation began, thus supporting the behavioral differences hypothesis.

At least in the Ford's Creek lek, hens select the most active males as mates. This mechanism seems to ensure that only genetically superior and physiologically strong, healthy males breed. The territorial system of cocks, in which males on active mating centers must fight to maintain their territory, further limits breeding to males in excellent physical condition. These males contribute most of the male genetic material to sage grouse populations, clearly an adaptive system.

*Aerial photography measures upland habitat changes.*—Wildlife biologists have not developed satisfactory methods of measuring rates of forest regeneration on formerly cultivated lands. Neither have they devised a classification scheme for the early stages of



The wild turkey (gobbler, top; nest, bottom) has responded well to reintroduction and management in many areas of its original range. Intensive research on the wild turkey is being conducted in Alabama; studies are being made also in Louisiana, Massachusetts, Missouri, Pennsylvania, and Virginia. (Photo by Henry S. Mosby, top; A. M. Pearson, bottom)

forest regeneration which are of great importance to wildlife. This information would be useful in analyzing habitats and in planning wildlife management programs.

A study recently completed in New York examined the use of time-lapse aerial photography in measuring upland wildlife habitat changes. A system of ground cover classification was developed and procedures described to convert this information to both



Studies of the American bison, or buffalo, at Wind Cave National Park, South Dakota, will provide life history information for a popular, interpretive bulletin for visitors at parks and refuges with bison. (Photo by Paul F. Springer)

cover maps and computer data. These procedures were then applied to the entire land area of Tompkins County, N.Y. (314,240 acres), where about 75% of the land has been retired from agricultural use since 1900.

Each 1/100th square kilometer (about 2.5 acres) in the county was classified as predominantly one of six vegetative cover classes from 1968 aerial photographs. Ten percent random sampling of 1938 and 1954 aerial photographs provided comparative data from which rates of forest regeneration were developed for the 30-year period. These data were further examined for correlation to six ranges of soil pH, six soil drainage classes, and three physiographic positions (hill, through-valley, and plain).

During the 30-year period studied, cultivated land decreased about 10%, while acreage in full forest cover increased 6%. The extent of the intermediate four vegetative cover classes varied considerably,

through time, with a net loss of 15% in acreage having less than 50% crown cover, and a net increase of 17% in acreage having more than 50% crown cover. The rate of change of crown cover density was remarkably constant, increasing about 1% each 3 years. North and south slopes reverted to old-field succession much sooner than other slopes; similarly, reversion occurred on hills sooner than in valleys. However, once retirement occurred, the rate of old-field succession and forest regeneration was considerably faster in valleys than on plain or hill sites.

These findings indicate that the techniques developed in this study are useful for determining long-term trends in vegetative cover conditions over large areas. Computer storage and retrieval of data obtained from interpretation of time-lapse aerial photography is new in the field of wildlife science. The method may also be useful in studying the

effects of site factors on rates of plant succession and corresponding changes in wildlife habitat.

*Predevelopment study of Twelve-Mile Creek watershed.*—The need for small watershed development (Public Law 566) in Iowa may involve an estimated 473 projects covering about 55% of the State's acreage. Therefore, an appraisal of the effect of watershed development on wildlife abundance and diversity will be important in coordinating future watershed projects. The study of Twelve-Mile Creek watershed in south-central Iowa, conducted from April 1970 to March 1972, has provided basic information for comparison with a similar study to be made after completion of watershed improvement.

In the northern one-third of the watershed, present land use is supporting an acceptable population of pheasants, but low populations of bobwhites and white-tailed deer. Habitat, in the form of 47.0% cropland, 1.5% woodland, and 0.2 miles of grainfield-woody edge per square mile, is believed to be the main factor determining these population levels. In the southern two-thirds of the watershed, 1.1 miles of grain field-woody edge per square mile, 19.0% woodland, and 35.0% of cultivated land are maintaining acceptable numbers of bobwhites and deer, but low numbers of pheasants. Seventy percent of the "wildlife ponds" sampled on the watershed were located in pastures isolated from food and cover. Grassy and herbaceous cover in 23 of 43 pond exclosures were rated only fair or poor for potential wildlife use.

The proposed improvements of the project will have their greatest effect on the southern portion of the watershed. Structural improvements, resulting in loss of timber and shrub habitat, decreased cropping of uplands, and more intensive agricultural use of bottomlands, will affect deer and bobwhite

abundance negatively. Awareness of the watershed—wildlife relationship can be developed in four key areas: (1) coordination in watershed planning, (2) responsibility of local, State, and Federal sponsors and agencies, (3) integration of wildlife resource planning with small watershed project planning, and (4) the role of significant mitigation in project development and enhancement.

*Budget allocation system for wildlife management.*—At the Virginia Cooperative Wildlife Research Unit, a joint study was conducted between the Division of Federal Aid and the Unit to develop, test, and make functional a computer system to aid State fish and game administrators in choosing the best combination of projects for funding. The system minimizes the volume and type of information required for reviewing project alternatives and maximizes the use of existing data, employee experience, and insights in evaluating the effectiveness of the management projects. Linear programming procedures were used to define the best budget allocation for two alternative objectives: (1) to minimize costs required to meet management objectives, and (2) to maximize the benefits of management given a fixed budget.

The processes in the system include the use of the Churchman Ackoff technique for determining the relative values of the various products; the use of the Weibull distribution to describe production curves, cost, production, use, and supply estimates; and the use of the Mathematical Program System for the IBM 360 series of computers to solve the linear programming problems and perform the subsequent sensitivity analyses.

Based on the results of a case study in one district of West Virginia the system was found to be functional and useful.

## CLASSIFICATION, DISTRIBUTION, AND LIFE HISTORY

A basic need in wildlife research, management, and protection programs is the identification of distinctive populations of animals being studied, and a knowledge of their geographical and ecological distribution. These studies are carried out mostly at the Bird and Mammal Laboratories, housed in the Natural History Building of the U.S. National Museum. The museum collection is essential for taxonomic investigations, and the Laboratory staff maintains and curates the largest collection of specimens of North American birds and mammals in the world. In addition to these activities, Laboratory biologists supervise the Bat Banding Program in the United States and maintain its records. The staff is involved in compilation of the Department of the Interior's lists of endangered species and in listings of birds and mammals imported into the United States. Staff members are called on routinely to identify bird and mammal specimens, including fragments of bones and feathers; to act as consultants; and to provide expert testimony in court cases involving identification of birds and mammals. Manuals for the identification of some groups of foreign endangered animals were prepared in 1972 for use by agents at ports of entry. Also in 1972, the activities of the Laboratories were broadened by the addition of a Herpetology Section.

*Polar bear studies.*—Continuing the international cooperative mark and recovery program, biologists of the polar bear project captured 60 bears on the sea ice adjacent to Cape Lisburne, Alaska, in March and April. Sernylan, injected with a syringe gun from a helicopter, immobilized the bears for handling and marking.

Recoveries of marked animals now indicate that there are at least six somewhat geographically isolated groups of bears in the main Polar Basin. These are in addition to separate populations which occur further south in the Hudson Bay region of Canada. Off the Alaska coast, 518 animals have been marked since 1967 by the Alaska Department of Fish and Game and the Bureau of Sport Fisheries and Wildlife. Sixty-three ani-

mals recovered 1 to 5 years after tagging indicate that there is relatively little interchange between the population of bears west of Alaska and the one north of Alaska.

Knowledge of the distribution and status of different polar bear populations is particularly significant at this time because of new or proposed national hunting regulations, a proposed international agreement for polar bear conservation and management, and increasing interest in Arctic oil exploration and extraction.

*Effects of AEC activities on marine mammals.*—The possible effects of the Amchitka underground nuclear test on the large population of sea otters in the surrounding waters elicited concerned responses from conservation groups, government agencies, and private individuals as well as the U.S. Atomic Energy Commission. The primary objective of this study was to determine the effects of the underground nuclear test on sea otter numbers. The investigation was carried out from October 1970 to November 1972. A complete sea otter count of 1,215 animals was made in June 1971 along a 10-mile strip of the Bering Sea coastline adjacent to the test site. Another count over part of the area, when extrapolated, accounted for 940 animals.

During the period between the test on 6 November and 28 November 1971, 18 dead and one moribund sea otters were recovered at Amchitka. Thirteen of the recovered sea otters were autopsied; eight were killed by pressure effects in water, two died from rock falls, and three were fatally injured when the land upon which they were resting was violently elevated 15 feet. There was no evidence to indicate that otters had been injured by recent storms. It must be assumed that these casualties were only a fraction of those killed by the detonation. Adverse winds and tides, and the inherent difficulties in making beach surveys along the rocky coasts made complete recovery of dead or injured animals impossible.

Sea otter counts in November 1971, following the test showed a 90% decrease in numbers of animals in the count area, although



the counts were made under poor visibility conditions. Counts made in March and June 1972, under conditions comparable to those of June 1971, along the identical 10-mile strip of Bering Sea coast recorded 450 to 500 animals. These figures indicate 50 to 60% fewer, or about half as many sea otters in this 10-mile area in June 1972, than in June 1971. It is believed that this decrease can be attributed to the Cannikin test. However, since it was limited to only a portion of the entire island, it is not thought to be a hazard to the population as a whole.

*Biology of sea otters in Prince William Sound.*—Much is known regarding the general biology of sea otters in Alaska, but almost all of this knowledge is derived from studies in the Aleutian Islands. A study was begun in 1971 to obtain information on the

distribution, feeding habits, and general behavior of sea otters in the Prince William Sound area. Field work was carried out from May through September on Montague and Green Islands. Otters were found to be associated with certain features of the habitat such as kelp beds, lagoons, favored feeding areas, and sheltered areas. No otters were seen hauled out on land. No areas were used exclusively by males or females.

On Montague Strait otters fed primarily on bivalve mollusks, shrimps and crabs, and starfish. The most important species in each of these groups were *Saxidomus giganteus*, *Telmessus cheiragonus*, and *Evasterias troschelii*, respectively. Feeding effort by the otters was distributed as follows: 81.0% on mollusks, 7.0% on shrimps and crabs, and 0.8% on starfish. Clams were dug from the



From near extinction in 1911, sea otter populations have been restored by protection and management to an estimated 30,000 individuals. The greatest populations are now in the Aleutian Islands; smaller numbers inhabit the Pacific shores of Siberian USSR, Alaska, and California. (Photo by Karl W. Kenyon)



A nest with eggs (top) and a nestling (bottom) of the herring gull. Behavior studies of this species and the great black-backed gull were carried out in Massachusetts. (Photos by Robert L. Downing)

bottom and opened with the aid of stones. Sea urchins and fishes appeared to be of minor importance as food.

Two otters in Montague Strait exhibited territoriality by territorial defense, fighting, and border patrolling. A female with a large pup joined one of these males and completed the breeding sequence with him. The male devoted only 8.5% of this time to feeding during one day as compared to 52.0% for a breeding male reported in the literature.

*Walrus survey.*—Between 7 and 16 April 1972 a Grumman turbo conversion aircraft

was used to survey marine mammals along 4,280 nautical miles over the Bering Sea ice from Bering Strait to the Alaska Peninsula and from Alaskan to Siberian coastal waters. During the survey period the ice remained at its maximum extent in the Bering Sea. Eight species of marine mammals were observed and counts and estimated numbers in a 1-mile wide survey track were as follows: sea otter, 8; walrus, 9,300; largha seal, 79; ringed seal, 29; ribbon seal, 6; bearded seal, 221; bowhead whale, 1; and beluga whale, 33. Walrus were abundant north and south of the west end of St. Lawrence Island, and in the central part of Bristol Bay. No marine mammals were found in the Nunivak or St. Matthew areas or on the ice north and east of these areas to the east end of St. Lawrence Island. Available information indicated that no walrus were in the Chukchi Sea at the time of our surveys.

Estimates based on the field data indicate that the Pacific walrus may number about 136,000 animals. Statistical treatment of these data indicates that there could be as few as 93,000 or as many as 178,000 walrus.

*Bat banding.*—The Bureau has administered a bat-banding program since 1932. Recent studies, made possible by the program, have indicated that populations of 22 species of bats in the United States have declined alarmingly in the last few years. One of the major reasons for these declines is the disturbance of bats in roosts, including the activities of banders. The Bird and Mammal Laboratories initiated a three-part Bureau program to aid in the conservation of bats consisting of the following: Place a 5-year moratorium on issuing bat bands to new banders or for new banding projects; evaluate the bat-banding program, reviewing records for the recovery of pertinent biological data and determining the feasibility of automated techniques for the program if it is to continue; take appropriate steps to effect an international treaty for the protection of North American bats. This program was announced at the Third North American Bat Research Conference in November, and the moratorium became effective immediately.

*International treaties protect more birds.*—The addition of nineteen families of birds to

those protected by the treaty between the United States and Mexico, and the adoption of a treaty between the U.S. and Japan greatly increased the number of bird species protected by Federal law.

*Salamander range extended.*—A woodland salamander, *Plethodon nettingi*, includes three isolated races which are restricted to montane habitats in eastern West Virginia and extreme western Virginia. The least common race, *P. n. hubrichti*, has been known from only five localities along 4½ miles of the Blue Ridge Parkway in the Appalachian Mountains. Field work by Bureau biologists has established four new localities and has extended the known range of the race 4 miles to the north. These relict populations will not be threatened with ex-

inction in the foreseeable future if the habitat, which is on Federal lands, is managed to maintain natural landscapes.

*Behavior study of gulls.*—An interest in the rapid ecological succession of larids along the New England coast prompted an examination of certain social aspects of parental care of two sympatric nesting gulls: the herring gull and the great black-backed gull. Field work was carried out on Nantucket Island, Mass.

Thirty nests of each species were divided into three statistical treatment classes yielding a total of six groups of species and treatments. In one treatment class 10 three-egg clutches from each species were exchanged between species. In a second treatment class the same number of clutches and eggs were



Newly marked young California brown pelicans on Isla San Lorenza Norte, Gulf of California. Marking birds provides data on their movements after fledging. (Photo by Daniel W. Anderson)

exchanged between individuals of the same species. The third treatment class served as a control group in which eggs were not exchanged.

No significant differences were found between treatments or species that affected hatching success or chick survival until fledging. The incubation time of some foster parents was altered by as much as 16 days due to the egg exchanges. But this had no apparent effect on egg or chick survival. The relationship that developed between a foster parent and an egg or chick that was placed in its nest was as strong as that existing between a biological parent and its own egg or chick.

*Movements of California brown pelicans.*—Nearly 5,000 young California brown pelicans were banded from 1970 through 1972 to provide basic information on the effect of pesticides on pelican numbers. Approximately 400 recoveries and sightings of these birds have revealed certain patterns of movement.

## ENDANGERED SPECIES

Passage by the Congress of the Endangered Species Conservation Act of 1969 and its amendments has registered the concern of U. S. citizens about fish and wildlife that are threatened with extinction. This concern has increased as people have become aware of the adverse environmental effects brought about by their use of this earth. The Bureau's responsibility for preserving endangered species is assigned to the Office of Endangered Species, which funds research by the Division of Wildlife Research. To ascertain the basic needs of wildlife species in danger of extinction and to develop techniques to aid these species, a research program is conducted in both field and laboratory by biologists of the Patuxent Wildlife Research Center. Field studies of the occurrence, habits, and requirements of critically threatened species are underway at field stations in five States and one Territory. Studies of the biology and methods of propagation of certain endangered birds and mammals are being conducted at the Patuxent Center.

Following fledging, young pelicans and some adults disperse in many directions from the breeding colonies. Large buildups (associated with food abundance) occur in certain areas, including the California Coast. Aerial censuses of coastal and island habitats have shown that the "local" population off California is about 1,500 adults, but numbers swell to between 15,000 and 30,000 from August to October, depending on the year and circumstances before dispersal. Sightings of marked birds and band recoveries indicate that the added birds off California come from Mexican colonies. Even larger buildups of pelicans occur in the estuaries along the west coast of mainland Mexico, but large numbers of pelicans also remain in local breeding areas after breeding.

The occurrence of a few pelicans in the Southwest Desert of California and Arizona is believed to result from the inexperience of post-fledging juveniles and southern storms that move north through the Gulf region from August through October.

Some investigations of endangered species are carried out at the Cooperative Wildlife Research Units.

*Endangered birds in Hawaii.*—Possible new breeding populations of Hawaiian dark-rumped petrels and Newell's Manx shearwaters were located in 1972. Clued by an unidentified partial specimen of seabird recovered by U.S. Geological Survey personnel, night-calling petrels and shearwaters were discovered on the island of Hawaii late in September. If breeding evidence is substantiated in 1973, reports for both species dating back to the late nineteenth century will be confirmed for the first time.

From 1967 to 1970 the population of Laysan ducks on Laysan Island in the Hawaiian Island National Wildlife Refuge progressively declined from 239 to 50 birds. Counts around the lagoon in the evening which have proved to be the best method of estimating the population in September 1971 revealed 149 Laysan ducks. The latest count in September 1972 revealed 162 Laysan ducks.

More young birds were observed in September 1972 than in previous years. It is believed that higher water levels on the interior lagoon at Laysan Island contributed to better survival of the young.

Hawaiian crow breeding surveys were expanded for the fourth consecutive year. Uncounted miles of habitat were covered in North Kona, South Kona, and Kau Districts, looking and listening for this species. A total of 23 individuals, mostly in groups of two or three, were located over a total habitat range of 40 miles. The maximum number found in any previous year was 20 in 1970.

Status and distribution surveys of endangered birds of Kauai were started in 1968 and the first observations of the Kauai oo were made in May 1971. During a return trip to the same site in early June 1972 six Kauai oos were observed at one time and the second known nest was discovered. Artificial nest boxes, which had been erected in the area in April 1972 to supplement tree cavities, were not used during the summer. On June 7, 1972, in the same area where the oos were seen and studied, a Kauai nukupuu was observed. This was the first observation of the nukupuu since 1965 and one of the few sightings during this century. The Kauai akialoa is the only endangered species for Kauai that has not yet been observed during recent surveys.

*Endangered birds in Puerto Rico.*—Primarily because of loss of habitat, the number of species threatened with extinction in Puerto Rico is increasing. Two distinctive raptors, the Puerto Rican sharp-shinned hawk and the Puerto Rican broadwinged hawk, are limited to high altitude forests, and the small acreage of such habitat restricts their populations to no more than dozens of individuals. Small populations are exceedingly vulnerable to natural catastrophes such as the occasional hurricanes which strike Puerto Rico. Though populations of these species, like those of the newly discovered Elfin Woods warbler and Puerto Rican whip-poor-will may be presently stable, their small size places them in a precarious position.

Other species threatened by habitat loss are the Puerto Rican shorteared owl and the yellow shouldered blackbird. The blackbird is

closely tied to mangrove habitat, and the development of coastal areas for industry and recreation continues to reduce the acreage of mangroves. Pollution from rapid industrialization is widespread and seriously threatens the integrity of certain ecosystems important to the survival of endangered species. A critical case is Guanica Forest, major refuge of the Puerto Rican whip-poor-will, which is bathed in malodorous vapors from local industries.

The status of the Puerto Rican parrot in the Luquillo Forest remains critical although an all-forest count in late October revealed more birds than was anticipated. A minimum of 16 to 18 individuals were seen in widely scattered regions of the forest, including several areas outside the previously known parrot range. This count approaches the count of 24 birds in the 1968 all-forest census, though it falls far short of the 200 birds known in the 1950's and early 1960's. Since 12 birds was the maximum counted in 1971, the 1972 count raises hopes that the decline of the species in recent years has been less rapid than previously thought.

*Aleutian Canada goose.*—Based on information obtained from field investigations and from numerous interviews with workers on Amchitka Island, it is probably safe to conclude that few, if any, of the 75 captive-reared birds released in 1971 are still present. Observations made this year on Buldir Island indicate that there has been no substantial change in the Aleutian Canada goose population since 1963 when the estimated population ranged from 200 to 300 birds. Nineteen of 22 goslings captured on Buldir have been reared to increase the captive breeding flock at Patuxent Wildlife Research Center.

*Florida everglade kite.*—Starting in 1969 and continuing to the present, eight Florida everglade kite censuses have been completed. Numbers of kites counted ranged from 44 to 120, with a mean of 82. The last three censuses, showing a downward trend from the high in 1970, tallied 82, 72, and 44. This downward trend apparently is related to the severe drought in southern Florida in the spring of 1971, during which no nesting was observed. Only one of five nests found in



A research biologist studies endangered wildlife from the top of an observation platform above the rain forest canopy in Puerto Rico. Observation of birds inhabiting the tree tops is greatly facilitated by the structure. (Photo by Helen Snyder)

1972 was known to be successful; this one was on the headwaters of the St. Johns River, where nesting of the species has not been observed in many years. Under conditions existing in southern Florida today, more areas scattered through southern Florida must be managed specifically for the everglade kite.

*Masked bobwhite quail.*—The masked bobwhite study area in Sonora, Mexico, has been subjected to extreme drought the past 2 years and very little new vegetation was produced. The calling season for the masked bobwhites was much reduced; no males were heard to call after August 2, when calling is usually most intense. Thus, reproduction during both 1971 and 1972 probably has been poor. Masked bobwhite populations are probably at their lowest level since 1967. Overgrazing in this last remaining masked bobwhite habitat may be severely reducing the remaining populations.

During spring and summer 1972, 571 propagated masked bobwhites were released in southern Arizona and 240 in Sonora after 1 to 3 months of acclimatization in captivity in Tucson. In addition, 59 birds were shipped to Mexico City for the use of the Mexican Dirección General de la Fauna Silvestre.

Follow-up studies continue to show heavy losses of released masked bobwhites soon after liberation. Nearly 25 cases of mammalian predation were detected soon after releases at one area. In spite of the losses, evidence of reproduction has been found. Two young males and their parents were trapped and banded at the Rancho Seco release area in November 1971. Back-dating by primary-molt progression indicated that the young birds had hatched between September 17 and 25, the peak hatching period for Sonoran birds. In addition, two unbanded males were observed calling at Rancho Seco during the breeding season (July and August) in 1972.

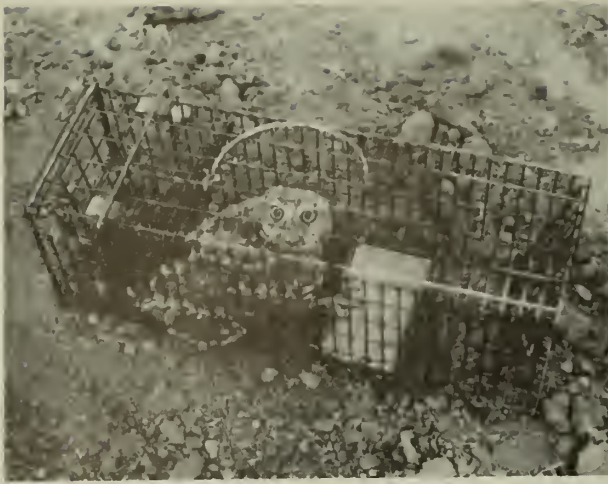
Investigations at other release sites in Arizona and Mexico during 1972 indicate that little if any survival of liberated birds has occurred. The long drought in both areas probably has been detrimental to both survival and reproduction.



Apple snail laying eggs on plant stem. The endangered Florida everglade kite depends on this large mollusc for food. (Photo by M. C. Perry)

*Yuma clapper rail.*—Clapper rails which inhabit areas along the Colorado River and the west coast of mainland Mexico, have been separated into three races by early investigators. Recently, the validity of this nomenclature was questioned because of the small sample sizes used in the determinations. To reconsider the taxonomic status of these populations, 42 clapper rails were collected in 1970 and 1971 at specific sites distributed evenly throughout the area concerned. In 1972, the specimens were closely examined at the National Museum by museum and field biologists. The three similar but distinct races were confirmed by differences in plumage and wing configuration characteristics. The Yuma clapper rail is therefore a distinct entity which must be treated separately from other races.

*Western burrowing owl.*—Additional information is needed to determine the population status of the western burrowing owl. A contribution to the habitat needs and the life history of the species is provided by a study in the panhandle of Oklahoma. Adult owls were censused in 44 prairie dog towns, 10 to 100 acres in size, and in 54 randomly selected square-mile sections lacking dog towns. During the summer of 1970, 359 adult owls (one per 4.8 acres) were present in dog towns, and 184 owls (one per 5,683 acres) were present in



A western burrowing owl in a live trap. The population of this species is declining in western Oklahoma because of loss of nesting sites which are provided by the burrows of mammals, especially the prairie dog. (Photo by Ken Butts)

areas without dog towns. Sixty-six percent of the owls lived in active prairie dog towns although this habitat constituted only 0.16% of the study areas. Approximately six owls wintered in dog towns and most of them nested on the area during the following spring.

Intraspecific territoriality was exhibited by burrowing owls during the reproductive season (mid-March through July). Territories centered around nests, and territorial behavior was not apparent among foraging owls. Calling by males was apparently the most important means of establishing and maintaining territories.

Young owls occupied home ranges having radii up to 1.5 miles. The late spring and early summer home ranges of adults may have been slightly smaller. Owls traveled their greatest distances at night.

Analysis of 790 pellets and 137 prey items at burrows suggested considerable seasonal variability in the food of the owls. Based on percentage volume and frequency of occurrence, small mammals were an important winter food (77.5% by volume), but were of minor importance (3.7% by volume) in summer. Arthropod remains composed 96.3% of the volume of owl pellets during summer, but only 14.8% during winter.

Nine dog towns, and the 9 square miles surrounding each, were chosen for intensive habitat analysis to determine why burrowing owl populations were not distributed more evenly among all dog towns. Differences in hunting pressure, approximate year of last prairie dog poisoning, density of prairie dogs, and distance to the nearest neighboring dog town were not obviously correlated with population levels. However, dog town areas with high owl populations contained significantly more cropland, less grassland, and more miles of road than did areas with low populations. Prey populations were larger in habitat surrounding dog towns containing high owl populations. Vertebrate prey populations may have been a limiting factor for owl populations in early spring before arthropod numbers began building up.

From 1967 to 1970 the number of active dog towns in the study area decreased 18.2% and dog town acreage decreased 8.2%. Complete eradication of a dog town tended to eliminate or to reduce burrowing owl populations.

*Raptors—a reproductive puzzle.*—Decline in populations of several raptors in the wild have been attributed to reproductive failures and to poisons in the environment. Captive propagation, one of several hopes for preservation of the endangered birds, has proved difficult for several species. The arctic peregrine has been a most notable example and the South American snail kite has now proved nearly as difficult. Captive South American snail kites at the Patuxent Wildlife Research Center did not produce eggs for several years. In 1971 two eggs were laid but failed to hatch. Through the use of light and handling, five pairs produced 23 eggs in 1972. Twenty of the eggs were fertile and 14 chicks hatched. For the first few days the chicks thrived but suddenly they grew ill and died. In all cases death occurred before the fifth day of life. In spite of extensive study the cause of these deaths remains a mystery. Two pairs of Richardson's pigeon hawks also produced 25 eggs this year but none of the 15 fertile eggs hatched.

*Hawaiian bird bibliography.*—Now, more than 800 sources of information on Hawaii's



birds have been catalogued, annotated, and compiled in "Hawaiian Bird Bibliography Exclusive of The Elepaio." Completion of this reasonably comprehensive bibliography of past and current literature fulfills a basic research objective.

*Black-footed ferret.*—During 1972 eight black-footed ferrets were located on five prairie dog towns in southwestern South Dakota. The ferret sightings were in the general location where ferrets have been most frequently observed since 1964. During September a young female ferret was live-trapped, held in quarantine for 19 days during which time it received a series of killed vaccine shots to protect it against distemper, and

transferred to Patuxent Wildlife Research Center.

*Utah prairie dog.*—Since 1920, the Utah prairie dog has been eliminated from approximately 90% of its former range according to a conservative estimate. In 1968, the Bureau of Sport Fisheries and Wildlife reported that the species inhabited 3,000 acres in 5 counties and estimated the total population to be 8,000 individuals. Only 3 counties now have significant populations, which total about 5,000. Further, approximately 63% of this population occurs on private lands where the general feeling by landowners is that the species is a nuisance and should be eliminated.



Nest of a Mississippi sandhill crane (arrow) in Jackson County, Miss. The small resident population of sandhill cranes in southern Mississippi was described as a new race by a Bureau scientist. (Photo by James Stephenson)

## PESTICIDES AND ENVIRONMENTAL POLLUTION

The Bureau's responsibility for conservation of wild species requires increasing vigilance to detect and prevent serious damage to wild populations as a result of exposure to problem pesticides and other environmental pollutants. The research role is to measure and predict the toxicologic impact of these pollutants on management of fish and wildlife resources. Also, the Bureau must know in advance the safety of forest insect sprays, terrestrial and aquatic herbicides, bird repellents, mosquito larvicides, or other chemicals used in management of renewable natural resources. The ecological problems are so complex that new research strategies must be developed to bring special disciplines to bear pointedly on these problems.

Research results in 1972 demonstrated the value of the team research concept. Experimentation showed how to interpret the significance of residues in the field in terms of lethal levels, persistence, reproduction, and behavior. New physiological approaches enhanced understanding of the prevalence and causes of eggshell thinning in birds, and mechanisms of teratogenesis in fish. Completion of aquatic flow-through systems enabled biologists and chemists to link life-stage sensitivities of fish and invertebrates to chemical exposures and residues. Computer-assisted instrumentation and new sample cleanup procedures greatly facilitated differentiation of complex pesticide and industrial pollutant residues in fish. The findings suggest changing pesticide use patterns, as well as the presence of less well known pollutants. Toxicological studies were initiated on nonpesticidal chemicals such as heavy metals, polychlorinated biphenyls, phthalate plasticizers, and turbidity control agents. Some of these materials were tested in combination with persistent pesticides to explore the difficult problem of interactions. Research on the effects of environmental pollution on the welfare of declining or endangered species continued as a major objective. Greater national interest in alternative pest control methods sparked investigations of selected methods for their impact on fish and wildlife. The distribution and persistence of

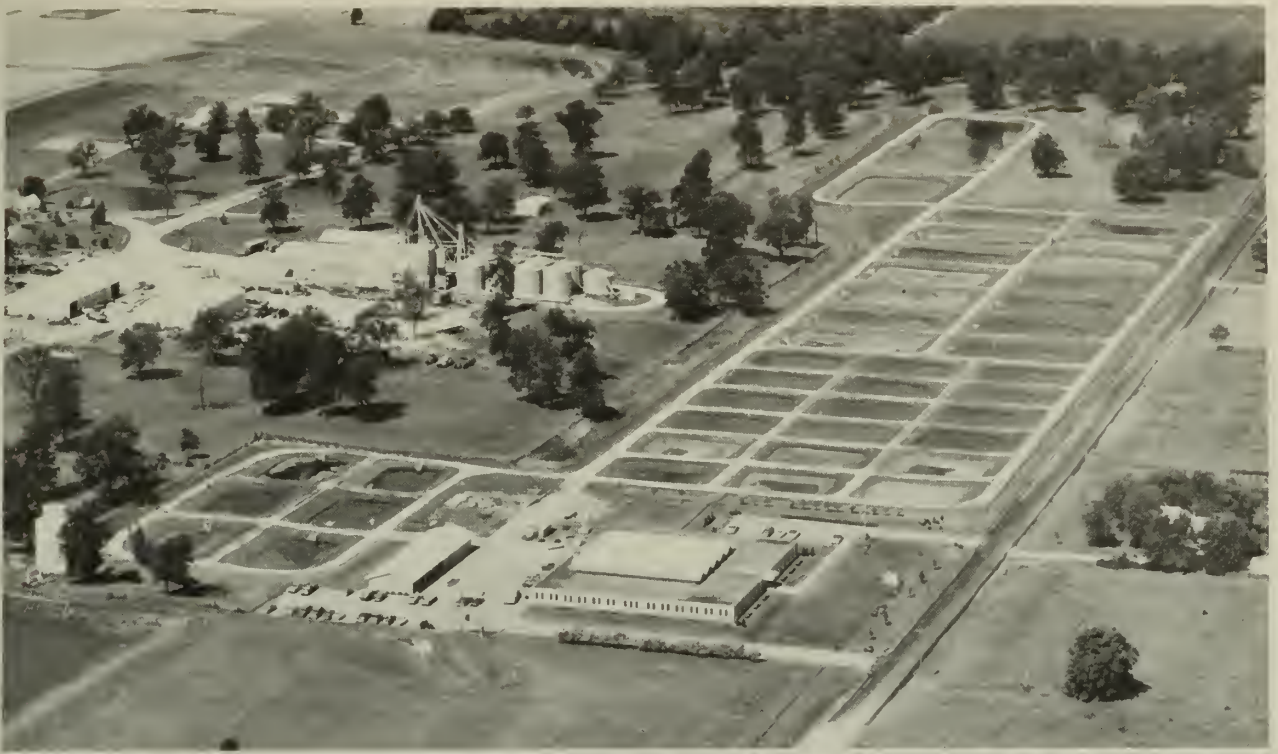
chemicals in U.S. fish and wildlife, and in several species of Arctic birds were evaluated in a series of studies.

### Fishery Investigations

*Biocontrol agent for mosquito larvae potentially safe for fish and crustacea.*—Preparasitic stages of the nematode, *Reeismermis nielsenii*, are under investigation by the Biological Control Laboratory, U.S. Department of Agriculture, Columbia, Mo., for control of mosquito larvae. Inasmuch as the infective stage of the nematode is applied to water, the Fish-Pesticide Research Laboratory initiated a cooperative study with USDA to determine whether this stage infects fish or crustacea. When rainbow trout swim-up fry were exposed for 18 days to infective larvae at concentrations up to 1,500 times those proposed for mosquito control, microscopic examination of the fish showed no parasitic invasion of the buccal cavity, gills, gut, skin, eyes, or any other tissue. When scuds and daphnids were exposed for 8 days, no evidence of parasitic penetration was found, even though nematode larvae were still viable at the end of the test. Investigations by USDA indicate that nematode larvae infect midges but survive for only a short period.

*Screening of mosquito larvicides.*—Fifteen mosquito larvicides proposed for use at Jackson Hole and other parts of Wyoming were tested for their toxicity to cutthroat trout and lake trout. The tests showed that Flit-MLO® was the least toxic; consequently it was used in the Jackson area during the summer of 1972.

*Turbidity control agents have adverse effect on fish.*—The toxicity of two turbidity control formulations—Purifloc® C-31 and Petroset® RB Geotechnic Emulsion—was assessed at the request of the Bureau of Reclamation. Purifloc® C-31 is used to flocculate suspended solids in new reservoirs before the initial discharge of water downstream. The material is applied at rates of 5 to 20 mg/l, depending on turbidity. Data from the Bureau of Reclamation indicated that the flocc-



The Fish-Pesticide Research Laboratory, Columbia, Mo.

culent-silt complex is not acutely toxic to fish, but that excess flocculent is toxic. Static toxicity tests by the Fish-Pesticide Research Laboratory gave  $LC_{50}$  (the concentration that kills 50% of the animals treated) values of 0.45 mg/l for rainbow trout and 1.5 mg/l for bluegills. Thus, application rates must be calculated carefully in relation to turbidity to prevent the application of excess flocculent.

Petroset® RB Geotechnic Emulsion is a plastomeric binder-stabilizer used to bind rock in highway and railroad beds. The chemical was being tested for binding small, flow-through rock dams used to settle suspended solids. Rock samples treated with the binder were placed at the head ends of small, recirculating, artificial streams containing 0.3- and 2.7-g rainbow trout. The amount of binder used to coat the rocks was calculated to give a theoretical concentration of 0.6 mg/l, but the actual exposure was limited to the undetermined amounts of chemicals that leached from the rock surface. The tests continued for 14 days at 12° C. Mortalities began

after 2 days among the 0.3-g fish and after 7 days among 2.7-g fish, and reached 50% after 6 and 10 days, respectively. Toxic effects—including severe exophthalmia and loss of tactile responsiveness—became increasingly apparent before death.

*Toxicity of forest sprays.*—A number of new or registered pesticides were proposed during the year as substitutes for DDT in controlling gypsy moth, spruce budworm, and other insect pests of National Forests. In cooperation with the National Forest Service, the Fish-Pesticide Research Laboratory tested the toxicity of pyrethrum extract, synthetic pyrethrins, Zectran®, Sevin®, trichlorfon (Dylox®), Phosvel®, and other insecticides against several coldwater and coolwater species. A synthetic pyrethrin, RU-11679, was extremely toxic, and values for the  $LC_{50}$  and  $LC_{10}$ , or for static and flow-through tests, were almost the same. The time-dependent  $LC_{10}$ 's (T—I  $LC_{10}$ ) for coho salmon and channel catfish at 12°C were 0.024 and 0.18  $\mu\text{g/l}$ , respectively. However, this compound was far less toxic at 22°C, and the

rate of deactivation at pH 6.5 was twice that at pH 9.5. The toxicities of pyrethrum extract and most synthetic pyrethrins were affected by temperature or water quality; however, the toxicities of *d-trans*-allethrin and *s-bio*allethrin were essentially unchanged by these variables.

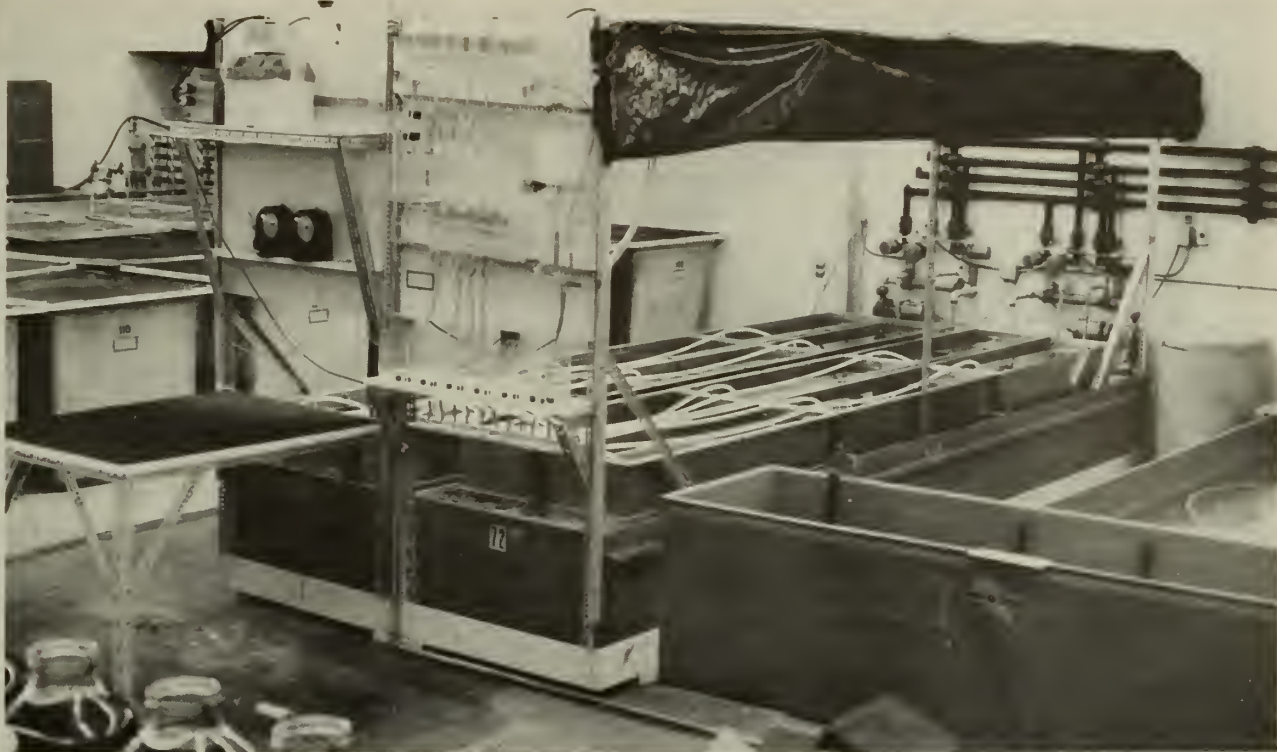
Trichlorfon (Dylox®) is a proposed forest insect spray that is also being tested for control of fish ectoparasites. Pond studies initiated 2 years ago to provide registration data for its use in parasite control are nearly complete. No residues were detected in the water 1 day after application; analyses of residues in fish have not been completed. Species diversity of invertebrates had returned to normal within 2 weeks after trichlorfon was applied.

*Registration research on TFM.*—The registration of TFM (3-trifluoro-methyl-4-nitrophenol), a lampricide used extensively since 1958 for control of sea lamprey ammocoetes in tributaries of the Great Lakes, was cancelled in 1970. Since cancellation, interim extensions have been granted to permit collection of the information necessary for re-registration. The uptake, dissipation, and effects of TFM on reproduction in invertebrates were investigated in 1972.

Static toxicity tests indicated that field grade TFM (35.7%) is not acutely toxic to scuds and crayfish; 24-hr LC<sub>50</sub>'s were greater than 50 mg/l for both species. However, continuous exposure did produce toxic effects, and 30-day flow-through tests produced LC<sub>50</sub>'s of 14 mg/l and 20 mg/l for scuds and crayfish, respectively. Accumulation of <sup>14</sup>C-TFM was minimal in scuds, crayfish, daphnids, and mayfly nymphs. Residue levels reached a plateau within 7 days for all organisms, at values ranging from 2 to 50 times the exposure concentration. Within 14 days of withdrawal from TFM, residues in scuds decreased 98%, which represents a half-life of 3.5 days. Exposure of daphnids to TFM over three generations in concentrations up to 10 mg/l did not significantly impair reproduction. However, exposure at a concentration of 18 mg/l induced production of ephippial (sexual) eggs and inhibited asexual reproduction.

*Simazine effective in pond management.*—A 2-year study of the herbicide simazine and its biological impact on pond ecosystems was initiated in 1970 to provide data pertinent to registration of simazine for controlling rooted vegetation in ponds. Single applications of 0.3 to 3.0 mg/l controlled a variety of rooted aquatic plants and had no adverse effect on production of bluegills. However, as expected, other plants and animals in the ponds were altered significantly. Phytoplankton production was stimulated in ponds receiving 1.0 and 3.0 mg/l and Eurasian watermilfoil invaded the pond treated at 0.3 mg/l. In general, burrowing or free-swimming invertebrates replaced the crawling-clinging types associated with vascular plants. Simazine was relatively persistent in the ponds, but residues were not biomagnified. Residue analyses indicated that only 80% of the first year's application would be required during the second year to effect equivalent weed control. Largemouth bass introduced into the ponds in the second year consumed 2 to 3 times more bluegills in ponds with little or no vegetative cover than in ponds with considerable plant cover. Bass in ponds with vegetative cover were the more susceptible to angling.

*Xylene causes off-flavor in rainbow trout.*—Xylene is used extensively in western irrigation canals to control rooted vegetation that impedes water flow. At times, water containing as much as 10 mg/l of xylene may be released from canals or irrigated fields back into receiving streams. Although xylene is exempt from tolerance and a level of 10 mg/l is below the 96-hr LC<sub>50</sub>, little is known of its sublethal effect on fish or fish food organisms. Yearling rainbow trout were exposed to single and continuous applications of xylene in two earth-bottom artificial streams maintained by the Bureau of Reclamation at Berthoud, Colo. The single applications were 3.6 and 5.3 mg/l for 2 hours and continuous exposures were 0.1, 0.3, and 1.0 mg/l for 56 days. Continuous exposure to 1.0 mg/l caused a significant off-flavor taste, as did short exposures to higher concentrations. However, taste impairment appeared to last only 3 to 4 days after the fish were moved



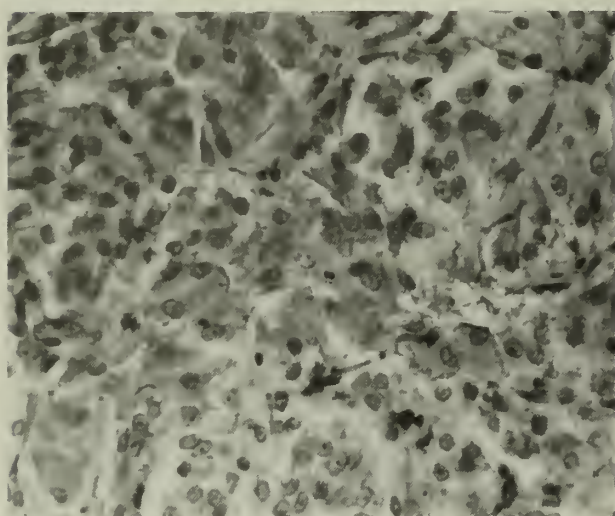
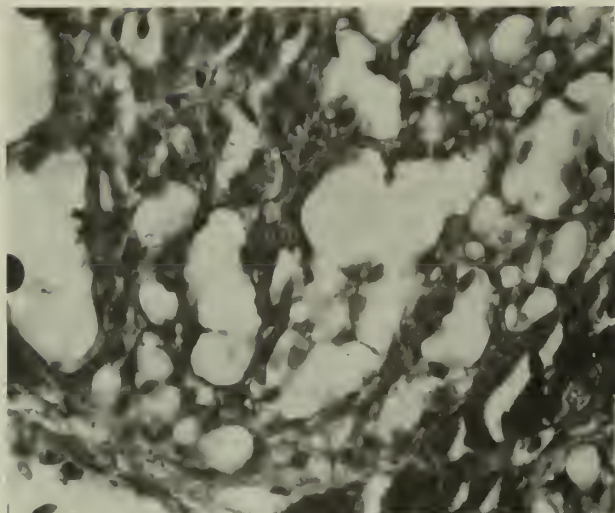
Flow-through diluter used for continuous, chronic exposure of brook trout to toxaphene. Exposures of yearling brook trout begin 6 months before spawning and continue for an additional 3 months with their offspring. Temperature and light are controlled to meet life cycle requirements. (Fish-Pesticide Research Laboratory photo)

into untreated water. Various pathologic conditions were noted in treated fish from time to time, but the incidence did not appear to be significantly different from that in the controls. Invertebrate colonization of Dendy plate samplers in the streams was reduced approximately 50% by the 56-day treatment at 1.0 mg/l, but the other treatments had little or no effect on colonization.

*Laboratory food chain developed to test potential biomagnification of trace organic chemicals.*—A “simple” aquatic food chain was developed with fish as the top consumer to act as a model for estimation of the potential for biomagnification of trace organic pollutants. The food chain model is uncomplicated, easily reproduced, economical, and ecologically analogous to natural conditions. It has three trophic levels and simulates warmwater or coldwater aquatic systems: at temperatures of 16° C or higher, the levels are microorganisms (bacteria or algae), filter

feeders (*Daphnia magna*), and bluegills; at temperatures below 16° C they are detritus (leaves), scavengers (scuds), and rainbow trout. Residue accumulation of an aquatic chemical by direct uptake from water (gills, respiratory structures, body surface) or from natural food, and chemical changes in the residue by abiotic or biotic systems, are generated from the model food chain. That is, quantitative and qualitative information is obtained.

Soil and water bacteria accumulated *p,p'*-DDT directly from water. Uptake of the <sup>14</sup>C-labeled organochlorine insecticides by *Aerobacter aerogenes* (gram-negative type) and *Bacillus subtilis* (gram-positive type) was rapid; 80–90% of the 24-hour residue was reached within 30 minutes. Total cellular residue varied linearly with concentrations of DDT in water, from 0.5 µg/l to 5.0 µg/l. The residue magnification factors from water were 1,400- to 4,300-fold, independent of the insecticide concentration in water. In



Lesions in islets of Langerhans tissue (top) of channel catfish fed 0.64 to 20 milligrams of toxaphene per kilogram of dry diet. The lesions were present after 40 days and they increased in frequency after 143 days. Normal tissue (bottom) lacks the lesions. (Fish-Pesticide Research Laboratory photo)

reporting microorganism biomagnification of test chemicals, *p,p'*-DDT is used as unity.

*Daphnia magna* rapidly accumulated  $^{14}\text{C}$ -labeled hexachlorobenzene (HCB) from water. When daphnids were exposed to  $^{14}\text{C}$ -HCB in a flow-through diluter, residues reached a plateau within 24 hours. Levels of  $^{14}\text{C}$ -HCB residue in *D. magna* were 900 times higher (wet weight) than the water concentrations. The half-life of HCB in *D. magna* after the animals were returned to HCB-free water

was less than 44 hours. The biomagnification factor for HCB from water to *Daphnia* was equal to that of *p,p'*-DDT.

The potential biomagnification of several xenobiotics from water to bluegills via the *Daphnia* route was also investigated. The fish were fed daphnids containing known concentrations of the test chemicals at a rate of 5–10% of fish weight per day, for 31 days. Methoxychlor, HCB, and di-2-ethylhexyl phthalate (DEHP) had biomagnification indices of 0.02, 0.98, and 0.04, respectively (DDT=unity). That is, in comparison with DDT, methoxychlor had one-fiftieth, HCB nearly equal, and DEHP one-twenty-fifth the propensity for passage through the water-daphnid-fish food chain link. The index is based on the relative amounts of the chemical accumulated in the top consumer of the model.

*Toxaphene affects growth and reproduction of fish.*—According to the manufacturer, 30 to 40 million pounds of toxaphene are used annually in the United States; over half is applied to cotton crops. It is a chemically complex compound, and the inadequacy of methods for its analysis at low levels probably accounts for the few reports of toxaphene in monitoring surveys. However, improved techniques for sample preparation have made it possible to detect toxaphene more readily, and it is now being detected more frequently in fish. It can be detected in water concentrations as low as  $0.025\ \mu\text{g/l}$  by extracting it quantitatively on polyurethane foam.

Two investigations—one with yearling brook trout and the other with mature channel catfish—were begun to determine the sublethal effects of toxaphene in fish. The study with brook trout (in collaboration with the Environmental Protection Agency) is designed to estimate impact of continuous exposures at  $0.03$  to  $0.35\ \mu\text{g/l}$  (30 to 350 parts per trillion) of toxaphene on growth and reproduction in a flow-through system. Growth rate of brook trout during the 6-month exposure was depressed 21% and 43% by concentrations of  $0.22$  and  $0.35\ \mu\text{g/l}$ , respectively. In addition, all of the trout exposed to  $0.35\ \mu\text{g/l}$  died during spawning activity. At lower concentrations, egg production and viability

were inversely correlated with concentration. To date, the lowest concentration causing an effect appears to approximate 0.03 to 0.06  $\mu\text{g/l}$  (30 to 60 parts per trillion).

Parallel chemical analyses show that toxaphene consists of more than 40 chlorinated components, that it is concentrated by adult brook trout at levels about 20,000 times the concentration in water, and that some toxaphene components are more persistent in fish than others.

In channel catfish exposed for 40 days to toxaphene in dietary concentrations of 0.64 to 20  $\mu\text{g/g}$  of food, the livers exhibited degenerative and necrotic changes.

*Pesticides in paddlefish.*—A proposed impoundment on the Osage River, Mo., threatens spawning grounds of the paddlefish, but the Missouri Conservation Department hopes to maintain the species through artificial spawning and propagation. However, nearly all sac fry artificially spawned thus far have died during the final stages of yolk absorption. Symptoms of the dying fry suggested contamination by organochlorine pesticides. Analyses of sac fry produced in 1970 revealed average whole body residues of 0.12  $\mu\text{g/g}$  (4.8  $\mu\text{g/g}$ ; fat basis) of dieldrin. In 1971, muscle of adult paddlefish contained an average of 1.2  $\mu\text{g/g}$  of dieldrin and 1.1  $\mu\text{g/g}$  of chlordane, whereas eggs contained 0.18 and 0.22  $\mu\text{g/g}$ , respectively. Fry mortalities were correlated statistically with chlordane residues in the eggs. Organochlorine pesticide concentrations in muscle were much lower in 1972 than in the previous year, but residues of dieldrin in eggs increased more than twofold and chlordane residues remained about the same. Poor hatching success in 1972 (less than 8%) prevented correlation of fry mortality with residues. At this point, organochlorine pesticides appear to be one of the main factors contributing to mortality of paddlefish fry.

*Mirex affects growth and reproduction of channel catfish.*—Mirex was incorporated into diets of channel catfish at concentrations of 0.06, 0.2, 0.6, or 2.0  $\mu\text{g/g}$  for more than 1 year. Growth of treated groups was reduced by an average of 14%. In late spring, the mature fish were moved into outdoor ponds for spawning. Whole body residues of



Adult paddlefish from the Osage River, Mo., held for spawning in pond at the Fish-Pesticide Research Laboratory, Columbia, Mo. (Fish-Pesticide Research Laboratory photo)

mirex in adults were equal to, or slightly less than, the dietary concentrations, and egg residues were 21 to 37% of those found in adults. In groups fed 0.2 or 0.6  $\mu\text{g/g}$ , only 18–19% of the eggs hatched and only 42–45% of the fry survived, as compared with 47 and 78%, respectively, in control fish. (Catfish fed mirex at 0.06 and 2.0  $\mu\text{g/g}$  did not spawn.)

*Polychlorinated biphenyls, phthalate esters, and fish.*—Residues of polychlorinated biphenyls (PCB's) and phthalates have been found in fish collected from various parts of the United States—particularly from industrialized areas. Although both groups of compounds have a number of uses, PCB's are used mostly in heat transfer systems, transformer oils, and electrical components, and phthalates primarily as plasticizers of polyvinylchloride. These chemicals interfere in analyses of pesticides, and are common contaminants in silicic acid, which is generally used to separate PCB-pesticide mixtures. Consequently preliminary cleanup of silicic acid with 40% acetonitrile in dichloromethane is required. The perchlorination method of total PCB analysis was modified to give recovery yields of 85 to 100%. In this

simplified analysis, antimony pentachloride is used to convert the various PCB isomers into one compound, decachlorobiphenyl.

Several biological studies on PCB's and phthalates were initiated in 1972: (1) Different groups of immature coho salmon were fed diets containing PCB (Aroclor® 1254), DDT, dieldrin, or chlordane; reproductive success of the different groups will be compared when they spawn in the fall of 1973. (2) Aroclor® 1254 was incorporated in diets of mature cutthroat trout to determine its effect on reproductive success. (3) When Aroclor® 1254 or 1248 was injected into fertilized eggs of coho salmon with dimethylsulphoxide as a carrier, it was more toxic than dieldrin, chlordane, or DDT. (4) The di-*n*-butyl (DBP) and di-(2-ethylhexyl) (DEHP) esters of phthalic acid were incorporated in pond hydrosols and incubated 1 to 30 days; about 50% of DBP was degraded aerobically and anaerobically into at least 3 unknown and relatively more polar compounds within 7 days, and nearly all of the compound was degraded in 30 days. (5) Fathead minnows accumulated DEHP to plateau concentrations that were 160 to 1,130 times the concentration in water; when the fish were moved to fresh water, 50% of DEHP was eliminated in 12.3 days and half-life was independent of residue concentration. (6) Biochemical studies of DBP and DEHP in channel catfish livers suggest that a mixed-function oxidase and a microsomal esterase act upon these esters. A major residue from this enzymatic action may be the monoester. Since one active enzyme is an esterase, it seems likely that organophosphate insecticides could interact with the enzyme to inhibit degradation of the plasticizers.

*Organochlorine pesticides may be linked to vitamin deficiency.*—Earlier research showed that chronic exposures of rainbow trout to dietary dieldrin at concentrations of 0.36 to 10.8  $\mu\text{g/g}$  altered amino acid metabolism and reduced the fish's ability to detoxify metabolic ammonia. Dieldrin also inhibited the liver microsomal enzyme phenylalanine hydroxylase, which elevated concentrations of phenylketo acids in the urine. Cooperative studies with the University of Missouri and

the Primate Laboratory, EPA, Perrine, Fla., showed that dieldrin had a similar effect on rats and monkeys. The biological implications of this chronic condition in fish are unclear, but the electroencephalograms of dieldrin-treated monkeys suggest extreme neurological disorder.

Research in 1972 was directed toward the secondary or competitive aspects of detoxication because microsomal hydroxylases require vitamin C as a cofactor and are associated with steroid, collagen, and possibly thyroid metabolism. Brook trout sac fry were exposed in a flow-through system to toxaphene concentrations of 0.03 to 0.35  $\mu\text{g/l}$  (30 to 350 parts per trillion) for 30 days. After 15 and 30 days of exposure, the whole-body concentrations of vitamin C and collagen of trout in all but the lowest toxaphene concentration had decreased significantly. We hypothesize that the detoxication of toxaphene depleted the vitamin C and that not enough of the vitamin remained for collagen synthesis or perhaps even for steroid metabolism. Such an alteration in collagen synthesis during the fish's early life stage could be highly detrimental to later normal growth and morphogenesis as the collagen matrix calcifies. Our earlier investigations showing suppression of serum cortisol in adult trout by dieldrin and chlordane, and the *in vitro* alterations in spectral properties of cytochrome P-450 by dieldrin, chlordane, and DEHP appear to support this general hypothesis. Thus, the pattern of these results is beginning to suggest that at least some xenobiotics may cause a variety of interrelated biochemical and physiological disturbances in fish that could adversely affect their ability to survive other environmental stresses.

*Substitutes for PCB's and phthalate esters.*—Three triaryl phosphate esters—Houghto-Safe® 1120, Pydraul® 50E, and Pydraul® 115E—have a broad range of acute toxicity. The  $\text{LC}_{50}$ 's for these compounds ranged from more than 100,000  $\mu\text{g/l}$  for Pydraul® 115E to 380  $\mu\text{g/l}$  for Pydraul® 50E (15-day flow-through test). Sublethal levels of Pydraul 50E® caused severe toxication and persistent immobilization. Three chlorinated paraffins—Paroil 160, 1032, and 1048—were



lethal at concentrations greater than 100,000  $\mu\text{g/l}$  in 96-hour static tests. The toxicity estimates for two highly chlorinated esters, dibutyl chlorendate and dimethyl chlorendate, were similar to those of the triaryl phosphates. However, the toxicity of the chlorendates in 25-day tests gave  $\text{LC}_{50}$ 's of 7.6 and 185  $\mu\text{g/l}$ , respectively. In general, the substitutes are not highly toxic to fish in static tests, but neither are PCB's nor phthalate esters. However, longer exposures to concentrations within their solubility limits causes death and sublethal intoxication. Therefore, these compounds must be tested in chronic, flow-through experiments to further assess their possible subtle biological impact.

*Residue analyses suggest changing insecticide use patterns.*—Confirmatory whole-body analyses of fish collected from the same selected sites during the 1969, 1970, and 1971 National Pesticide Monitoring Program suggest that use of chlordane and toxaphene is increasing in the southern states. Technical chlordane contains several isomers, among which the *trans*-isomer and nonachlors are relatively less persistent than the others in fish. Therefore, when fish have not been exposed recently to chlordane, or are only exposed to ( $\mu\text{g/l}$ ) concentrations, GC analyses show a higher proportion of the more persistent *cis*-isomer than of other isomers. Fish collected from three 1971 sampling sites contained average chlordane residues of 0.8 to 8.0  $\mu\text{g/g}$  and isomer compositions were much closer to technical chlordane than they were in the 1969 and 1970 collections from the same sites. Toxaphene residues of 0.5 to 48  $\mu\text{g/g}$  were detected in fish from eight 1971 sites, whereas residues (9 and 34  $\mu\text{g/g}$ ) were found at only two of these sites in 1970. DDT residues also remained relatively high in fish from three selected southern stations: 11 $\mu\text{g/g}$  in fish from the Rio Grande River, Tex.; 26  $\mu\text{g/g}$  in fish from the Yazoo River, Miss.; 6  $\mu\text{g/g}$  in fish from the Tombigbee River, Ala. Residues of PCB's in fish from the Ohio and Hudson rivers remained relatively high at 50 to 150  $\mu\text{g/g}$ . Over 90% of the samples from mature striped bass collected by the Maryland Department of Conservation and We-

laka (Fla.) National Fish Hatchery contained PCB residues in excess of 5  $\mu\text{g/g}$ . Ova from these fish contained PCB residues of 2.6 to 47  $\mu\text{g/g}$ .

*Computer assists chemical analyses.*—The installation of a PDP-12 LDP laboratory computer (CDM) at the Fish-Pesticide Research Laboratory has increased analytical capabilities by automatic data reduction of gas chromatographic-mass spectrometric (GC-MS) and gas chromatographic spectra. The "GC-MC-COM" system facilitated the identification of phthalate esters and hexachlorobenzene as environmental contaminants in fish. Specific detection of various compounds is possible when the computer is used to search sequential GC-MS scans for characteristic ion fragments in the chemical spectra. Metabolism of phthalate esters to the monoester was confirmed in this manner.

Implementation of a computer-automated, GC integration system is expected to save several man years of analytical time and facilitate quantitation of residues in complex environmental samples.

*2,4-D metabolites sought in fish.*—The Bureau of Reclamation was granted a 0.1 mg/l tolerance for 2,4-D dimethylamine (DMA) salt in irrigation waters. The tolerance was granted by EPA following studies by the Bureau of Reclamation, Agricultural Research Service, and the Fish-Pesticide Research Laboratory on residues in fish and various crops. However, this tolerance does not cover use of 2,4-D DMA in fisheries, where higher herbicide residues may result from application rates of 1 to 2 mg/l. In earlier cooperative studies with the Corps of Engineers, it was found that 2,4-D residues in fish exposed to the higher rates declined rapidly, but that some unidentified metabolites were formed. Analyses have shown that these metabolites consist of a phenol, its glucuronide conjugate, and an unidentified, volatile, nonpolar compound. Current research on 2,4-D DMA is directed toward GC-MS confirmation of the metabolites and development of routine GLC methods for their analysis.



Biologists band birds where they find them. These nestling ospreys were banded atop a saguaro cactus in Sonora Mexico. (Photo by Kirke A. King)

## Wildlife Investigations

### *Dieldrin enhances DDE storage by quail.*—

Long-term studies in which DDE and dieldrin were fed to coturnix quail both separately and in combination showed that the presence of dieldrin substantially increased the accumulation of DDE in the tissues. Since DDE has been shown to have an effect on the thickness of eggshells, there is a possibility that dieldrin residues could cause an increase in the biological activity of DDE simply by promoting the build-up and retention of DDE in the body.

*Mirex levels in brain and body fat of grackles.*—An experiment with grackles fed mirex gave an excellent demonstration of how important the amount of fat in the body is in controlling the level of pesticide in the brain. When birds were taken off dosage, and were given all the clean food they would eat, their whole-body residues dropped gradually; half was gone only after 28 weeks. Residues in brain, however, first dropped sharply, leveled, then rose to double between weeks 12 and 20 on clean food. Residues in brain rose when birds thinned and they fell when birds fattened. This proved so true that the graph line for mirex in brain (on wet weight basis) was an almost perfect mirror image of the line for percentage of fat in body. The explanation is that the amount of fat in brain holds nearly constant while body fat fluctuates widely, often for unknown reasons. The less body fat there is, the more concentrated the chemical becomes in all remaining fat, including that in the brain. If the concentration in brain becomes high enough, the animal dies. This idea is not new, but the mirex study has given the most diagrammatic example of it we have seen. The demonstration highlights the fallacy of depending upon lipid-based residues because the same things would be true of any other persistent, fat-soluble pesticide.

*Plasma enzymes measure exposure to pollutants.*—A series of experimental studies have uncovered a new and promising technique for appraisal of pollutants in wild birds, without the necessity of sacrificing the birds for chemical residue analysis.

This method measures the leakage of tissue enzymes into the plasma, a leakage that is enhanced by organ damage. Studies with captive coturnix quail showed that abnormal levels of plasma enzymes were directly related to both the dietary dosage and the tissue storage of the several chemicals that were tested. In addition, the pattern of changes was unique to the chemicals that were fed, indicating the possibility of identifying both the kind and amount of chemical exposure. Chemicals studied thus far include DDE, malathion, Arocolor® 1254, and mercuric chloride.

*Acetylcholinesterase activity—an index to pesticide effects.*—Continuing studies to determine the value of changes in brain acetylcholinesterase (AChE) as an indicator of birds' exposure to organophosphate and carbamate insecticides in field situations revealed considerable differences in the effects of these two classes of compounds. Carbamates were very fast acting; intoxication and accompanying AChE inhibition occurred within minutes after exposure, and symptomatic recovery and inhibition reversal occurred within a few hours. Organophosphates, on the other hand, were much slower in these actions. Terminal inhibition levels were also considerably different between these two types of compounds.

Toxic effects seemed to be cumulative over the 30-day period for organophosphates, particularly fenitrothion. Carbamates, on the other hand, did not show a pronounced cumulative toxicity or AChE inhibition. In fact, remission of clinical signs usually occurred overnight for each of the 30-day dosages. Based on data from these and previous studies, birds that die exhibit the highest percentage of inhibition, and lower levels of inhibition in survivors are related to the degree of intoxication. This makes it theoretically possible to determine degree of exposure by AChE levels.

The utilization of this technique in field monitoring is dependent on the availability of fresh material, the development of prior data on the effects of a particular compound on a particular species, and the normal AChE level in the bird species affected. Without



Laboratory measurement of cholinesterase levels in brain tissue is used to diagnose wildlife exposure to organophosphate insecticides. (Photo by James E. Peterson)

prior data, terminal inhibition levels can be used only to suggest that a particular bird died from an insecticidal spray application in the field.

*Behavioral effects of pesticides on coturnix chicks.*—Avoidance behavior (e.g., rapidly moving away from strange moving objects) appears very early in gallinaceous chicks and is almost certainly essential to their survival in the wild.

Coturnix quail chicks, when fed sublethal amounts of certain chemicals, responded less to a frightening stimulus than did controls. Seven-day-old chicks were given chemicals in their diet for 8 days and untreated food for 6 more days. Avoidance behavior was measured daily. Group avoidance response was significantly suppressed by chlordane, dieldrin, endrin, Ceresan M® (a mercurial fungicide), and Aroclor® 1254 (a PCB). DDE had no apparent effect. The behavior of the endrin-treated birds returned to normal after 2 days of untreated feed. Response of the dieldrin- and chlordane-treated birds improved somewhat during the 6 days of untreated food, but response of birds treated with Ceresan M® or Aroclor® 1254 showed no improvement during that period.

*Dietary DDE reduces courtship behavior in doves.*—Many species of birds that have accumulated large amounts of p,p'-DDE residues show impaired reproductive ability. One factor possibly involved is aberrant reproductive behavior, which has been observed in

wild brown pelicans and peregrine falcons. To determine whether DDE adversely affected the courtship part of reproductive behavior, ring doves were fed DDE-contaminated diets, and mated pairs were placed together at intervals for observation.

Compared with pretreatment courtship behavior, birds on 10 ppm of DDE showed no change in behavior at 30 days after the beginning of treatment, but at 60 days they displayed an average of 53% fewer bow coos and 55% less time in courtship activities. Pairs on a 50-ppm diet displayed 46% fewer bow coos and 30% less time in courtship at 30 days, and 84% fewer bow coos and 67% less time in courtship activities at 60 days. Controls at the same periods generally displayed increases in courtship behavior.

Aberrations in courtship behavior, of the type observed in these ring doves fed low levels of DDE, could cause drastic alterations in the reproductive performance of wild birds. Since successful reproduction depends to a large degree upon initial courtship behavior, alteration in this behavior could possibly account for some of the population declines documented in many avian species.

*DDE and embryo development reduce eggshell strength.*—Strength of shells of eggs laid by mallard ducks fed DDE was measured by a mechanical device at various stages of incubation and compared with controls at the same periods. Results paralleled measurements of shell thickness and cracking. Shells of eggs laid by ducks fed DDE were weaker than those of controls at all stages. Strength declined in both groups as incubation and development of the young progressed.

*Lethal pesticidal synergism unlikely among birds.*—Wild animals are frequently exposed to more than one pesticide. Application of more than one chemical to field and forest is common practice, and rivers in the United States are known to carry as many as five pesticides simultaneously.

The possibility that one chemical might enhance the toxicity of another was tested in a series of experiments at the Patuxent Wildlife Research Center using chicks of coturnix quail and ring-necked pheasants. Eighteen chemicals were tested in 13 pairs. The paired



Behavior of ring doves maintained on pesticide contaminated diets is recorded on video tape for detailed analysis. (Photo by Max A. Haegele)

chemicals were: aldrin + chlordane, Aroclor<sup>®</sup> 1254 + DDE, chlordane + endrin, DDT + dieldrin, malathion + Co-Ral<sup>®</sup>, malathion + EPN, malathion + parathion, malathion + trichlorfon, phosphamidon + fenitrothion, Guthion<sup>®</sup> + trichlorfon, Aroclor<sup>®</sup> 1262 + malathion, DDE + Ceresan M<sup>®</sup>, and dieldrin + diazinon.

Malathion + EPN and malathion + trichlorfon were moderately synergistic in tests with both species, whereas joint toxicities of the other chemicals were considered additive. Of 11 of the same pairs of chemicals tested by others against mammals or insects, 8 were reportedly synergistic to rats, mice, dogs, or two species of insects. Apparently the two species of birds are not as susceptible to synergism as are mammals or insects. Malathion + EPN was 50 times as toxic to dogs and 10 times as toxic to male rats as expected, whereas this mixture was only 3 times as toxic as expected to coturnix quail and ring-necked pheasants. The results of this study suggest that pesticides are not likely to prove lethally synergistic to birds, insofar as one can judge from two species, and that when synergism does occur it will not be especially severe. The likelihood of a factor of synergism greater than three in birds does not appear to be great.

*C-12 trichlorfon less hazardous to birds than trichlorfon.*—The chemical addition of a 12-carbon molecular chain to the molecule of trichlorfon, an organophosphorous insecti-

cide, has apparently reduced the hazard of this compound to nontarget avian species. The new C-12 trichlorfon, like the parent compound, is a candidate insecticide for control of forest insects. In laboratory tests, trichlorfon was more toxic than C-12 trichlorfon by factors of 15 for mallard drakes, 17 for ring-necked pheasant cocks, 8 for bobwhite quail cocks, and 2 for California quail hens. Such laboratory findings offer encouragement in the search for safer insecticides.

*Relative toxicity to birds of several mercury fungicides.*—PMA, a phenyl mercury fungicide, is much less toxic to ring-necked pheasants, on the basis of metallic mercury content, than either ethyl or methyl mercury compounds. The acute oral LD<sub>50</sub> (the dose that kills 50% of the animals treated) of PMA to ring-necked pheasants is 169 mg/kg, which is equivalent to 101 mg/kg metallic mercury. The acute oral LD<sub>50</sub> of the methyl mercury fungicides, Panogen<sup>®</sup> and Ceresan L<sup>®</sup>, is equivalent to 23.8 mg/kg and 26.8 mg/kg metallic mercury, respectively, while the acute oral LD<sub>50</sub> of Ceresan M<sup>®</sup>, an ethyl mercury fungicide, is equivalent to 11.5 mg/kg metallic mercury. The 30-day empirical minimum lethal dosage of PMA is greater than 18.0 mg/kg/day in ring-necked pheasants, which means that the test birds survived a total of 540 mg/kg PMA, equivalent to 321 mg/kg metallic mercury. In similar tests, mallards have died from a total dose of an ethyl mercury fungicide equivalent to only 22.5 mg/kg of metallic mercury. These studies indicate that not only is PMA less acutely toxic, on the basis of active mercury, than ethyl or methyl fungicides, but it also appears to have less cumulative action.

*New techniques for arsenic and selenium measurement.*—To support wildlife research and environmental pollution monitoring, two similar methods, one for selenium and the other for arsenic, have been developed. Tissue samples are Schoniger combusted, and the resulting products are then chemically reduced, forming arsine and hydrogen selenide gas. These gases are then swept into an atomic absorption instrument and measured. Both methods are more sensitive, more specific, and simpler to use than previous techniques, and require less sample material. To



Breeding pairs of the California brown pelican (right) have declined about 18% from 1969 through 1972 on islands off the California coast. Heermann's gulls (left) are common associates of the pelicans in nearly all parts of the latter's range. (Photo by Daniel W. Anderson)

date, several hundred samples have been analyzed by the two techniques, and results are quite favorable when compared with those from reference standards and those obtained by classical procedures.

*Woodcock eggshell thickness normal.*—Woodcock eggshells were measured in museums to ascertain whether eggshells were thinner in 1971 than before 1946, the year considered to mark the beginning of widespread use of modern pesticides. Eggs or empty shells were collected from 10 States in 1971 and their shell thickness was compared with that of eggs in museums collected from 16 States during 1859–1939. The measurements showed no statistically significant difference in shell thickness between the two groups of eggs. Shell thickness of eggs containing well-developed chicks (development recorded on museum labels) were thinner than those from undeveloped eggs, but this was true for eggs collected in 1971 and those in the museum series.

*Status of California brown pelicans.*—Census data from various sources have provided

information on the status of brown pelicans along the Pacific Coast. Birds breeding in the Gulf of California are still present in large numbers. Current estimates indicate that this population exceeds some 30,000 pairs, but the trend is not known. Data from 1971 and 1972 suggested declining populations along the west coast of Baja California, particularly in the north. The most acute population problems exist off the coast of California.

Census data indicate that the number of breeding pairs off California declined about 18% from 1969 through 1972. The maximum productivity between 1969 and 1971 was 7 young in 540 nests. Despite a decline in the numbers of breeding pairs in 1972 (249), productivity in the Gulf of California has been more satisfactory, varying between 1.0 to 2.0 young per nest attempt during 1970–72.

Residues of p,p'-DDE have been related to thin-shelled eggs and reduced productivity. The situation in the Gulf of California provided a unique opportunity to test this hypothesis, since there are two "contaminant"

populations—birds with “low” residues and normal eggshells and birds with “high” residues and thin eggshells. Seventy-four eggs collected in 1971 and 1972 revealed a highly significant ( $P < 0.001$ ) negative rank correlation between eggshell thickness and residues of DDE, although thin-shelled eggs composed less than 10% of the total egg population. Where thin-shelled eggs were laid, significant reductions in clutch size occurred. In further support of the hypothesis that residues of DDE were responsible for the reproductive problems off California, there was a fourfold decrease in egg residues associated with the improved reproductive success in 1972. Ten eggs found in California colonies (Anacapa and Santa Cruz Islands) in 1972 averaged 281 ppm (lipid-basis), versus 1100–1200 ppm in 1969–71.

*Recurrence of goose mortality in Texas.*—In 1972, geese again died in rice-growing areas of Texas after early planting of rice fields with seed treated with aldrin and Ceresan L®. Sick geese were first observed in a study area on the Garwood Prairie after seeded rice fields were flooded by a heavy rain on March 20. Fifty-two sick or dead geese (43 snows, 7 blues, 2 white-fronts) were found between March 22 and April 25. Average dieldrin residues in brains of 22 snow geese collected in the study area were: 5 sick (7.4 ppm) and 5 dead (20.9 ppm) collected in and near rice fields planted with aldrin-treated seed; 6 shot (0.83 ppm); in and near treated fields; and 6 shot (0.1 ppm) near untreated fields. Mercury residues in breast muscle of sick and dead geese averaged 0.3 ppm. Seventy-five percent of snow geese found sick or dead and 50% of those shot were males. Weights of sick and dead geese and geese shot in and near aldrin-treated fields were generally lower than weights of geese shot near untreated fields. Since all geese do not migrate northward until late April, mortality of these species has probably occurred in other years when rice was not planted early.

*Bald eagles breed in captivity.*—Bald eagles successfully incubated and hatched two young at Patuxent in March 1972, only to have the hatchlings succumb in an ice storm. The third eaglet died unhatched in the egg

that same night. The male of the pair was an Alaskan nestling in 1965 and thus bred successfully in his sixth year, the first year his head was completely white. The female was taken in Alabama in 1965, when she still was in immature plumage, but her exact age is not known. This same pair laid and incubated two eggs in 1971, but neither egg hatched.

A second pair laid one egg in 1971 and two eggs in 1972 but failed to complete incubation.

*Heron colony established at Patuxent.*—Concentrating on black-crowned night herons, which are subject to shell-thinning and regional population declines, Patuxent biologists began an experimental colony of herons in the spring of 1972. Established for studies



Bald eagles successfully incubated and hatched two young at the Patuxent Wildlife Research Center in 1972. (Photo by John Maestrelli)



A colony of black-crowned night herons (top) was established in 1972 for studies of the effects of pollutants on behavior and reproduction. Four young were hatched and reared from one nest (bottom). (Photos by H. M. Oklendorf)

of the effects of pollutants on behavior and reproduction, the colony was off to a good start when a pair of adult black crowns from the Dallas Zoo hatched and successfully reared four young.

The colony was augmented during the summer by 30 young-of-the-year from breeding colonies on the Maryland-Virginia Eastern Shore. Smaller numbers of chicks of other species, including little blue herons, cattle egrets, common egrets, and Louisiana

herons were taken to evaluate their suitability for captive rearing.

Herons are top-level consumers in aquatic food chains and are widespread in a variety of habitats in the United States, making them exceptionally suitable indicators of pollution in estuarine and fresh-water ecosystems.

*Baseline measurements of pollution in Arctic birds.*—The opportunity to augment studies of Arctic pollution was provided when the Bureau was invited to participate in ecological research studies promoted by the Oceanographic Unit of the U.S. Coast Guard. Starting in 1970, a research vessel, the USCGC *Glacier*, began a series of cruises to the Beaufort Sea to conduct cooperative baseline assessments of the biological, chemical, geological, and physical variables of the marine ecosystem in areas immediately adjacent to the North Slope oil field. Baseline measurements will be needed to properly assess the impact of increasing pollution.

Two cruises have been completed, one in 1970 and the other in 1971. Animals collected on each of these cruises have been analyzed for chemical residues. In 1970, 9 species of birds, predominantly marine forms, totaling 57 individuals were made available for residue analysis. In 1971, 6 species of marine birds totaling 23 specimens, and 2 mammalian species were acquired for analysis. Samples of fat and skeletal muscle were analyzed for polychlorinated biphenyls, organochlorine pesticides, and certain of their metabolites. Samples of kidney were analyzed for total mercury content. All of the animals collected in both years contained relatively small, but detectable amounts of DDT, DDD, DDE, dieldrin, PCB's, and mercury; species differences in residue content also were apparent.

*Mirex in woodcock wings.*—Woodcock wings submitted by hunters in the 1970-71 hunting season were analyzed for organochlorine residues on an exploratory basis. Only adult wings were analyzed. Mirex occurred in all samples, and levels were higher in southern than in northern States. The survey was repeated in 1971-72, this time including both young-of-the-year and adults. Although all samples of adults again contained Mirex, the



chemical was not detected in young birds in the north that had not yet migrated south. The pattern is reminiscent of the early use of heptachlor for fire ant control when heptachlor epoxide first appeared in northern adults but not in the young.

*Residues monitored in ducks.*—Nationwide monitoring in 1970 of pesticides and pollutants in wings of mallards or black ducks revealed no decrease in DDE residues from 1965–66 to late 1969. Wings were analyzed in pools of 25 for residues of organochlorine pesticides; in 1970 for the first time, polychlorinated biphenyls (PCB's) and mercury were analyzed. PCB residues were similar in magnitude to those of DDE; they were highest in birds taken in the northern Atlantic States and generally lowest in the Central States. With the exception of one pool each from New York, Wisconsin, and Nevada, mercury levels were below 0.5 ppm (net weight). Residue analyses of individual wings from California, New York, and New Jersey revealed residue levels of DDE as high as 40 ppm, compared to pool averages of about 2 ppm.

*Pesticides in aquatic and marine ecosystems.*—In the Upper Lake States, 9 out of 13 species of fish-eating birds in 1969–70 had sustained statistically significant decreases in eggshell thickness since 1946. Maximum changes in a thickness index occurred in great blue herons (–25%), red-breasted mergansers (–23%), common mergansers (–15%), and double-crested cormorants (–15%). Great blue heron eggs taken in Louisiana generally displayed a smaller post-1946 change than herons in the Middle West. On a lipid basis, mean PCB- and DDE-residue levels exceeded 100 ppm in 7 out of 13 species in the Lake States and in 1 of 7 species in Louisiana; the average DDE:PCB ratios in the two regions were 1.25:1 and 3.9:1, respectively. These ratios contrast with some around 0.3:1 previously reported for oceanic birds in the Bay of Fundy and with ratios of roughly 5:1 and 10:1 reported by others for the Pacific Coast.

Dieldrin tended to be higher in Louisiana but reached 10.1 and 9.4 ppm (lipid basis) in great blue and black-crowned night herons in Wisconsin. BHC averaged 3.07 and 0.39



The reddish egret is one of the aquatic species whose relationship to pesticides is being studied in the Gulf Coast. (Photo by Kirke A. King)

(lipid basis) in the Lake States and Louisiana, respectively. Of eggs examined for mercury, 29% had levels greater than 0.5 ppm and 9% had levels greater than 1.0 ppm on a wet-weight basis. A relationship between shell-thinning and DDE content of eggs was apparent for most species, and for herons DDE was the only compound so correlated. For two species, however, dieldrin also appeared to be related to thinning, even though DDE was present in much higher amounts.

Partial correlations carried out on a somewhat questionable family basis showed that PCB was also correlated with shell thinning in mergansers, while mercury was positively correlated with thickness index in grebes and negatively correlated in mergansers.



The coturnix or Old World Quail is a desirable laboratory animal for investigating the effects of pesticides on birds because of its prolific reproduction and rapid rate of maturity. (Photo by Luther Goldman)

*Pesticides in grassland ecosystems.*—Millions of acres of rangeland are sprayed annually for grasshopper control, and the pesticide problem has been steadily increasing in recent years. Insecticides can effectively eliminate grasshopper infestations and reduce damage to range vegetation, but the

## FISH POPULATION AND WILDLIFE DAMAGE CONTROL

Research to find methods for alleviating damage by vertebrates to stored foods, crops, forage, and forests is centered at the Denver and Patuxent Wildlife Research Centers, but a few studies are conducted also at the Cooperative Wildlife Research Centers. Work on fish population control is conducted at the Fish Control Laboratories at La Crosse, Wis., Hammond Bay, Mich., and Warm Spring, Ga. Methods for controlling animals and their damage are sought through the use of chemicals, habitat manipulation, mechanical barriers, repellents, and frightening devices. These methods must be selective for the target species and must be nonhazardous to man, his domestic animals, and the environment. In devising these methods, special ef-

long-term effects of chemical control on animal life and ecological relationships have not been studied.

In June 1972, two experimental areas on the Pawnee National Grassland in Colorado were aerially sprayed with toxaphene and malathion, two insecticides commonly used on rangelands. Intensive research is underway on the sprayed areas and an untreated area in cooperation with the International Biological Program, Grassland Biome. Data are collected on all major components of the short-grass ecosystem: birds, mammals, arthropods, plant productivity and species composition, and decomposer activity. Other data include food habits of resident birds and small mammals and insecticide residues in animals and the environment.

Results of the first year of study indicated that toxaphene application had a greater immediate effect than the malathion application. Populations of the major bird species, horned larks and McCown's longspurs, were significantly reduced through emigration, nesting failures, and mortality from poisoning. Small mammals probably also died from toxaphene poisoning. No animals marked before spraying were recaptured in postspray trapping, but 20 to 45% of the marked animals were recaptured on the malathion and untreated areas.

forts are made to find points of vulnerability in the offending species by studying its physiological processes, feeding habits, reproductive behavior, and daily and seasonal movements.

### Fish Population Control

*Biological control of sea lampreys.*—More than 300 adult sea lampreys were captured during spawning migration, injected with potential sterilants, and released in an artificial stream in the laboratory. Most of the injected animals died without attempting to spawn. Some spawned naturally or were spawned artificially, but most offspring died

at early embryonic stages or hatched with gross body malformations. Uninjected controls spawned and produced normal offspring.

Because large numbers of lamprey larvae are required for research in control and in stream-side bioassays to determine efficacious concentrations of lampricides, efforts have been devoted for several years to the artificial culture of larvae. Considerable progress has been made in defining procedures for spawning, hatching, and rearing sea lampreys, but more research is needed on rates of feeding and on optimal rearing temperatures.

*Chemical registration research on lampricides.*—The sea lamprey continues to pose a severe threat to the trout, salmon, and other fishery stocks in the Great Lakes. Control of the highly destructive lamprey is achieved and maintained by application of the lampricides 3-trifluoromethyl-4-nitrophenol (TFM), Bayluscide®, or 98% TFM and 2% Bayluscide® to kill larval lampreys in tributary streams. Each year, dozens of tributaries of lakes Superior, Michigan, Huron, or Ontario are treated with lampricides. According to law, however, the lampricides must be re-registered by the Environmental Protection Agency, and the Agency requires new data on the efficacy and safety of the pesticides. The Great Lakes Fishery Commission has contracted with the Bureau of Sport Fisheries and Wildlife to develop the new data on the lampricides.

The efficacy of TFM, the principal lampricide in use against sea lamprey larvae, was tested in the laboratory in waters of four hardnesses, pH 6.5, 7.5, 8.5, and 9.0, and temperatures of 7, 12, 17, and 22° C. Toxicity of the lampricide is reduced at the higher pH's, and in hard water when the pH is alkaline. Temperature has little influence on efficacy. Free-swimming larvae are more susceptible to the lampricide than are larvae burrowed in sand. The tests also indicated that prolarvae are more resistant than older and larger larvae to TFM, requiring about 50% more of the lampricide to produce mortality in the same time period.

In standard bioassays of TFM against nontarget animals, four salmonids and six spe-



Small rainbow trout under feeding attack by a 14.7-inch sea lamprey in a laboratory aquarium. (Fish Control Laboratories photo)

cies of warmwater fish were more resistant than sea lamprey larvae. In turn, certain aquatic invertebrates were more resistant than nontarget fish to the lampricide.

The uptake of TFM by fish is related closely to the pH and total hardness of the water. Rainbow trout exposed to TFM in very soft water contained 10 times the concentration found in fish that were exposed similarly in very hard water. In vivo studies disclosed that glucuronidation is the major pathway by which TFM is detoxified in fish, and the glucuronide is the major urinary metabolite of the lampricide. After intraperitoneal injection of TFM into a rainbow trout, free and conjugated TFM were detected in the urine for 7 hours, but none thereafter. At 72 hours post-injection, the gallbladder bile was analyzed for TFM. The analyses of the urine and bile accounted for 90% of the injected TFM.

A gas chromatographic method was developed for measurement of TFM residues in fish, other nontarget organisms, water, and soil. Samples of organisms, water, and soil were collected during a TFM treatment of a lamprey-infested river in Michigan. During the treatment, snails contained 15.3  $\mu\text{g/g}$  TFM, the highest concentration of the residue in animals; the water contained 7.7 mg/l; and soil contained 0.62  $\mu\text{g/g}$ . Ninety-six hours after the treatment, snails contained 0.37  $\mu\text{g/g}$ , the water contained no detectable quantity, and the soil contained 0.01  $\mu\text{g/g}$ . The



A sea lamprey and its victim, a rainbow trout. The trout died as a result of the feeding wound which penetrated the body cavity and severed the gut. (Fish Control Laboratories photo)

results confirmed laboratory observations that TFM residues disappear rapidly from animal tissues, water, and soil.

A review of literature on TFM as a lamprey larvicide was compiled and published as a necessary step in the reregistration process.

Bayluscide® (2-aminoethanol salt of 2',5-dichloro-4'-nitrosalicylanilide), which is primarily a molluscicide, also is used alone or in combination with TFM to kill sea lamprey larvae. The registration-oriented studies initiated during the year included bioassays of Bayluscide® against five phyla of aquatic invertebrates and fish. Although the lampricide is toxic to invertebrates, its careful application in lamprey control should create no hazard to most invertebrate communities. Carp perished within 1 to 3 hours during

exposure to Bayluscide; the compound is slightly less toxic in high pH than in low pH water.

A mixture of 98% TFM with 2% Bayluscide® kills lamprey larvae at about one-half the cost of TFM alone. Thus, the mixture is important to sea lamprey control, and efforts are in progress to reregister the mixture as a lampricide. Among the nontarget invertebrates exposed to the mixture of TFM and Bayluscide®, turbellarians, tubificids, snails, and daphnids were more sensitive to the lampricide than were crayfish, water boatmen, dragonflies, snipeflies, and dobsonflies. Careful use of the lampricide should pose no great hazard to the invertebrate communities.

A bottom-release formulation of antimycin, an antibiotic, was subjected to tests against

sea lamprey larvae in raceways and in a stream. The formulation is coated on sand grains, and the toxicant is released only after the sand has sunk to the bottom. Some improvements in the formulation are necessary, but the experiments indicated that antimycin will remain close to the bottom and kill larval lamprey in the substrate while fish in the upper strata of water escape exposure to the toxicant. The formulation, if perfected, would be useful for lamprey control in deep waters, such as river mouths and off deltas, where TFM is relatively ineffective. In answer to a question on the toxicity of antimycin to freshwater clams, specimens of *Corbicula* sp. and *Elipitio* sp. were given 96-hour exposures to concentrations up to 10  $\mu\text{g/l}$ . During a 30-day post-exposure period, no *Corbicula* died and only one of the 50 *Elipitio* perished. Thus, a fish-killing concentration of the antibiotic has little or no toxicity to these two species of freshwater clams.

*Toxicants for white amur.*—The exotic white amur (grass carp) has been publicized as a control for aquatic plants, but little effort has been devoted to control of the amur if it should become necessary. Field trials in ponds showed that antimycin, rotenone, and Thanite® (a candidate fish-collecting aid) are effective in killing the amur at concentrations usually applied to control other fish species.



Testing a walleye for loss of reflex after it has been subjected to benzocaine. (Fish Control Laboratories photo)

*Therapeutants.*—Formalin, malachite green, and a mixture of formalin-malachite green are commonly used to treat parasitic diseases of fish. None of the chemicals is registered for fishery use, but a start has been made to obtain the experimental data required for registration. Each of the compounds was subjected to standard toxicity tests against warmwater fishes in waters of different qualities and temperatures. The results showed that toxicity of formalin or malachite green to fish is influenced little by variations in water hardness, pH, or temperature. A critical literature review on formalin was prepared for submission to FDA to test a new regulation on clearance known as "Not New Drug Monograph."

*Fish anesthetic.*—Benzocaine, a structural analog of MS-222, was tested for efficacy as a fish anesthetic. For salmonids, about 50 mg/l of benzocaine were needed to produce total loss of equilibrium within 2 minutes, as compared with about 100 mg/l of MS-222. During artificial spawning of northern pike and walleye at hatcheries, however, benzocaine held no significant advantage over MS-222.



Adding a stock solution of the fish toxicant, antimycin, to static bioassay jars containing Asiatic clams. (Fish Control Laboratories photo)

## Wildlife Damage Control

*Increases in New England gull population slow down.*—A census of 305 gull colonies between Cape May, N.J., and Eastport, Maine, in early June 1972 suggested that abundance of herring gulls had increased by about 10% in the last 7 years while that of the great black-backed gull remained about the same. The 1972 census was made to ascertain if abundance was increasing as fast as indicated by earlier studies. If so, the population should have increased by about 50% instead of the observed 10%. The census was based on visual estimates made from low-flying fixed-wing aircraft by the same two observers who made similar censuses in 1964 and 1965, when estimates were considered accurate within 20% to 30%.

Breeding censuses between 1920 and 1945 indicated that herring gull abundance in New England was doubling every 12 to 15 years, a rate of increase that appeared to continue during 1961–65. Meanwhile, the population of great black-backed gulls doubled eight times in 13 years during the 1930's and 1940's, and every 4 years between 1953 and 1965. The rapid increase in New England gulls and the growth of major concentrations near urban areas in southern New England had led to increasing incidence of gull-aircraft collisions at metropolitan airports in the late 1950's and 1960's.

Counts of plumage types among gulls in the greater Boston area were made during the fall of 1972, repeating similar counts made in 1962–63. Significantly fewer birds in first-year plumage and in intermediate-plumage types were counted in 1972 than in the earlier years.

These data suggest that reproductive success and/or post-fledging survival has been reduced during the last few seasons. The observed current slow-down in population growth of the New England gulls probably results from a number of influences, among them exhaustion of available breeding islands, improvement in solid-waste disposal, and decline of the commercial fishing industry in New England.

*Bird-aircraft strike hazard studied in South Carolina.*—During the winter of 1970–

71, some 33 bird-aircraft strikes occurred at the Charleston Air Force Base in South Carolina, chiefly due to gulls. Populations and movements of gulls and other species which might be a threat to aircraft were studied from June 1971 to June 1972 in a 500-square-mile section of coastal South Carolina centered at Charleston. This study was made under Bureau contract with The Citadel (formerly The Military College of South Carolina), and was funded by the Air Force. Gull populations and movements in the study area were monitored by aerial censuses, radar, and ground observations at gull-concentration sites in the study area; many observations also were made on bird activities at the Charleston AFB.

Laughing, ring-billed, and herring gulls were the most abundant species; laughing gulls were primarily summer residents, reaching populations of 2,200, whereas ring-billed and herring gulls were present mainly from October to April, each with populations of over 2,500. Band recoveries showed that most herring gulls came from the Northeast while ring-billed gulls migrated from the Great Lakes area. Analysis of Christmas-count data showed that both species have increased in numbers since 1957 in the Charleston area.

Laughing gulls were distributed along the coast, and fed mainly on refuse from shrimp trawlers. In contrast, ring-billed and herring gulls fed mainly at eight dumps and landfills, both along the coast and inland. The gulls moved daily between coastal roosting sites on sandbars and islands and inland feeding areas, using river systems as main flight routes. Gulls used loafing sites that had little vegetation and were near feeding or roosting areas.

In all, 14 bird-aircraft strikes occurred during the 1-year study, compared with the 33 reported the previous winter. The decrease was due primarily to the removal of dumps near the base; as a result, only scattered transient gulls were observed around the aerodrome. The main winter bird hazard was ring-billed gulls, which were involved in at least six of the strikes. Ring-billed gulls were especially prone to appear at the base during rainy, windy weather during October-March.

The other bird-aircraft strikes were caused by blackbirds, pigeons, and cattle egrets, mostly during April, August, and September.

The principal recommendations made by the investigator to reduce the bird-aircraft strike hazard were: (1) locate all Charleston solid-waste disposal sites in zones where gulls and other birds attracted to such sites would not cause hazard to aviation; and (2) maintain regular daylight patrol of the aerodrome by a team of base personnel trained in the use of bird-harassment techniques to drive hazardous bird species from the airfield.

*Blackbird and starling recoveries from Ohio roosts.*—A knowledge of the breeding areas of depredating blackbirds and starlings in fall, winter, and spring roosts is helpful in controlling their damage to crops. Contributing to this knowledge was a recent analysis of 219 band recoveries from red-winged blackbirds, grackles, brown-headed cowbirds, and starlings taken in March and April in central Ohio. The bands were retrieved at roosts near Columbus, Granville,



Micrometeorological studies are made in blackbird-starling roosts, which may contain millions of birds, to determine how weather can affect the success of roost treatments for control. Temperature and humidity were almost the same inside and outside the roost, but wind velocity was much reduced inside. (Photo by William J. Francis)



Biologist paring kernels from an unripe ear of corn to simulate blackbird damage. At maturity these ears will be compared with undamaged ears to determine if compensatory growth occurs in bird-damaged ears. (Photo by Allen R. Stickley, Jr.)

and Mansfield following experimental treatments with wetting agents to reduce blackbird populations. The majority (70%) of the 219 band recoveries were from birds of local origin (within 100 miles of the recovery sites). The data thus indicate that a large proportion of the blackbirds in these Ohio spring roosts probably were birds that contribute to the summer-fall corn-depredation problem in Ohio.

*Feasibility of chemosterilants for male redwings.*—Male red-winged blackbirds, breeding in isolated cattail marshes near Denver, Colo., were vasectomized to ascertain the possible effect of male chemosterilants on the productivity of populations identified with major agricultural damage. When 100, 50, 30, and 0% of the males in a given marsh were vasectomized, clutches of eggs



Activities of blackbirds are monitored by clipping a 164-MHz radio transmitter to the tail of each bird. The amount of time red-winged blackbirds fed in areas other than ripening crops would astonish growers experiencing damage. (Photo by Olin E. Bray)

laid within the territories of the vasectomized males were 12, 33, 44, and 100% fertile, respectively. In another study, six males scattered throughout two marshes were vasectomized; 69% of the clutches laid on their territories were fertile. These results show that male chemosterilants could be used to reduce problem populations of redwings, but a higher percentage of males must be affected than previously believed when promiscuity was reported to be only an occasional occurrence.

*Evaluation of bird-scaring devices.*—Test procedures were developed in Ohio to assess the efficacy of using scare devices to protect cornfields from attack by red-winged blackbirds. The study demonstrated that results will be unreliable in tests that either compare damage in protected cornfields with that in unprotected fields at different locations or that compare damage in one cornfield during protected and unprotected periods. The unreliability arises from varying

growing conditions in the former and from varying bird pressures in the latter. A study design that embodied both location and time comparisons, however, yielded reliable results; significant corn protection occurred when a gas-operated exploder was used, and also with an amplified playback of a red-winged blackbird alarm cry. The findings of this study will allow more accurate evaluation of crop protection measures, and will hasten the day when farmers will be able to judge more accurately the effectiveness of bird-scaring techniques.

*4-Aminopyridine for blackbirds in field corn.*—4-Aminopyridine, a chemical frightening agent, was registered by the Environmental Protection Agency in April 1972 for use in protecting ripening cornfields from blackbird damage. The chemical is applied to cracked corn baits at 3%, then diluted with 99 parts untreated corn and broadcast at the rate of 1 pound of the diluted bait per acre. A residue tolerance of 0.1 ppm in grain and fodder was granted. Application of this crop protectant must be made under the supervision of government agencies trained in bird control. The product, Avitrol® FC Corn Chops—99, was used in about a dozen corn-growing states in 1972 with generally good success. This new weapon for corn farmers was obtained after 7 years of intensive field and laboratory efforts, chiefly by the Bureau and the manufacturers of the chemical.

*Bird damage to cherries, rice, sunflowers, and corn.*—Bird damage surveys in randomly selected fields in the major corn- and sunflower-producing States and in randomly selected trees in the major tart cherry-producing State provided data for estimating the magnitude of losses in these crops. In addition, rice fields were surveyed for damage in a 72-section area surrounding California's largest late-summer roost of blackbirds in Colusa County. The surveys on cherries and sunflowers were the first ever to be conducted and yielded information showing a surprisingly high rate of damage and dollar loss for these two crops. Birds consumed 1 of 6 tart cherries grown in Michigan, resulting in a computed loss of \$2.8 million in that State alone. Birds, chiefly blackbirds, damaged 1 of every 10 sunflower heads checked





Injecting cattle near Trinidad, Bolivia, with an anticoagulant for vampire bat control. At this ranch in 1972, 200 of 1,400 cattle, 9 of 70 horses, 18 of 20 pigs, and 25 of 70 goats died of rabies transmitted by vampire bats. (Photo by G. Clay Mitchell)

in 489 fields in North Dakota and Minnesota. Dollar loss has not yet been computed for the sunflower crop. In contrast to these heavy losses, blackbirds consumed only about 1 of 600 pounds of rice grown in Colusa County, Calif., and damaged only 1 of 900 bushels of corn grown in the 19 leading corn-producing States in the United States. Because of the very large acreage planted, however, the loss in corn amounted to 6,850,000 bushels, about the same as estimated the previous year in 24 major corn-producing States.

*Safety of livestock systemic method of vampire bat control.*—Intraruminal injection of cattle with 1 mg/kg of the anticoagulant,

diphenadione, has proved a highly effective method of controlling vampire bats. Laboratory tests on residue levels in cattle strongly suggest that the method will also be safe for humans that consume meat and milk from treated animals.

In initial tests, single oral doses of up to 5 mg/kg in cattle produced no observable signs of intoxication beyond a moderate increase in the clotting time of plasma prothrombin; the clotting time of whole blood was essentially unaffected. Chemical analysis showed that these levels of diphenadione in the blood of the dosed animals returned to undetectable levels after 144 hours. Lactating cows



Scent station prepared for coyote tracks. Lines of these stations were located in 17 western States to obtain indices of predator abundance. (Photo by Samuel B. Linhart)

dosed at levels up to 2.75 mg/kg showed no detectable residues, and calves nursing these cows showed no changes in either prothrombin or whole blood clotting times.

Residue levels of diphenadione in tissues of cattle given a single dose of 1 mg/kg were determined analytically in blood, liver, heart, kidney, brain, muscle, and fat samples from animals slaughtered 30, 60, and 90 days post-treatment. Detectable levels of diphenadione were found in the kidney (about 0.08 ppm) and liver (about 0.15 ppm) of all animals. The quantities did not change over the three time intervals, suggesting protein binding in the two organs. The liver (the main site of action) of these animals was further tested in a bioassay with adult laboratory rats. The rats were fed 19.2 g/kg of liver a day for 14 days, which is equivalent to 3 pounds a day for a 154-pound man, and were then observed an additional 14 days. None of the rats died; in fact, all three groups showed average weight gains of up to 47 g.

Diphenadione is administered to humans in therapeutic doses that may exceed 0.5 mg/kg a day. This means that a 154-pound man would have to eat nearly 500 pounds of liver from a treated cow to obtain the equivalent of a single therapeutical dose. These evaluations suggest that diphenadione presents no residue hazards and would be appropriate for large-scale application in Latin America.

*Predator survey in Western United States.*—A predator survey in the 17 Western States was initiated in September 1972 to obtain indices of relative predator abundance. The study was undertaken in cooperation with the Division of Wildlife Services, assisted by the Division of Refuges and by interested State and university cooperators. Altogether, 328 scent station lines were run during the latter part of September and early October. Each survey line consisted of 50 scent stations, located 0.3 mile apart, placed along 15-mile routes. Scent stations consisted of 3-foot circles of sifted earth or sand in the center of which was placed a capsule containing an attractant. Survey lines were run for 5 consecutive days, and animal visits to stations (based on tracks) were recorded. Indices of relative abundance derived from the data will be used to indicate the current population status and distribution of coyotes, foxes, and other predators; to determine year-to-year changes in relative densities; and to establish relationships between predator abundance and control efforts, predation, and livestock husbandry practices.

*Tranquilizer tabs on steel traps reduce foot damage.*—Earlier tests indicated that tranquilizers fashioned into small tabs and attached to the jaws of steel traps effectively calmed the trapped animals and reduced foot injury. Recent evaluations confirm the earlier results. Up to 78% of the coyotes captured in steel traps with the tabs attached had no injury or only minor cuts, whereas less than 10% would fall into these categories under normal trapping procedures. Only about 12% of the coyotes caught in traps with tabs were severely cut, and broken bones were infrequent. In a recent tagging operation, only 2 of 72 coyotes caught in the tab-equipped traps suffered broken bones. Without the tabs, more than 80% of the coyotes receive severe cuts and 25% acquire broken legs.

A search is currently under way for an inexpensive tranquilizer that can be obtained in bulk powder form so that the technique can be used in routine operations.

*Multiple-use transmitter.*—Technological advances in low voltage, integrated circuits

have made possible the development of 164-megahertz wildlife transmitters with programmable logic circuits. The design provides a basic pulsing transmitter for normal location monitoring, but simple circuit changes provide additional capabilities: monitoring of the animal's temperature, movements, or death (through either cessation of movement or a drop in body temperature), and a delayed turn-on device that allows the transmitter to remain "off" for up to about 8 months after instrumentation. The transmitter package, as designed for use on coyotes, has a weight of about 9 ounces, a volume of 4 cubic inches, a predicted life of 2 years, and a range of 50 miles (by aircraft).

*Porcupine tastes tested.*—In spite of the well-known craving of wild porcupines for salt, laboratory experimentation to evaluate the taste sensitivity of porcupines to sweet, sour, salty, and bitter stimuli showed that porcupines preferred water to any concentration of salt solution tested. They rejected sour and bitter aqueous solutions, as do several other animal species. Of several sweet compounds tested, the porcupines were indifferent to all but sucrose, which they preferred to water. These findings resulted from research conducted in cooperation with the Monell Chemical Senses Center, University of Pennsylvania, an institute devoted to re-



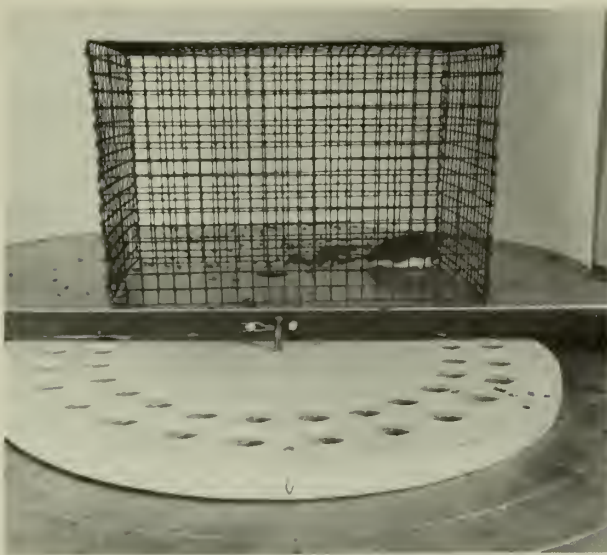
Porcupines have become more common in the Pacific Northwest since 1950. Studies on the significance and long-term effects of their damage indicate that the damage is of little consequence at present. (Photo by James Evans)

search on chemical sensory physiology. Such information is of value in devising methods to control species that cause economic damage.

*Black-tailed prairie dog control.*—Diethylstilbestrol (DES) appears to have promise for suppressing reproduction on prairie dog towns. In the studies in southwestern South Dakota, the entire areas of two prairie dog towns received DES-treated oats whereas only half of the areas of two other towns were treated. Weights of females from towns treated with DES were not different ( $P > 0.05$ ) than those from control towns. However 9 of 31 (29%) females from DES-treated towns were pregnant compared to 27 of 32 females (84%) from control towns ( $P < 0.01$ ). Counts of live embryos ( $P < 0.01$ ) and of total embryos ( $P < 0.05$ ) were greater on untreated towns. There were fewer young per adults ( $P < 0.05$ ) on treated parts than on untreated parts of the two divided towns; the number of young were not statistically different in fully treated and control towns.



Black-tailed prairie dog. Because prairie dogs live in "towns" and compete with cattle for forage, ranchers request that their populations be controlled. (Photo by G. Keith LaVoie)



Deer mice cause seed loss in reforestation programs. Here, a mouse is being trained to feed in a preference-testing carousel; later its response to candidate seed protectants will be ascertained. (Photo by Gerald D. Lindsey)

*Black-tailed prairie dogs—management with zinc phosphide grain baits.*—Recent studies in Montana and Colorado indicate that the rodenticide zinc phosphide is a likely candidate with which to test the role of lethal agents as management tools. In field tests with 2.0% zinc phosphide-treated steam-rolled oats and oat groat baits, overcoated with a 1.5% corn oil adhesive, prairie dog activity was reduced 85 to 97% following prebait (baiting first without the toxicant) and 40 to 75% without prebait. These tests also indicated that the usual application rate, about 1 tablespoon of bait per burrow, is unnecessarily high. A rate one-fourth this amount gave equally good results and should reduce primary hazards associated with high bait exposure rates. Extensive surveys in the vicinity of all treated colonies failed to disclose any primary or secondary hazards to the numerous avian and mammalian species exposed to the treatment. In laboratory tests secondary hazards did not appear in domestic mink which were fed phosphide-killed prairie dogs for 30 days.

*Conifer seed protection studies.*—Because of potential environmental hazards of certain toxicants Bureau biologists are search-

ing for other methods for protecting conifer seeds from small rodents and shrews. Two methods, seeding on snow and a repellent seed formulation using mestranol, were evaluated on a western Washington forest clear-cut in 1972. Placing untreated Douglas-fir seed on a 4-foot snowpack to keep it above the zone of small mammal activity did not provide protection. Apparently, these animals had adequate time between snow melt and seed germination to find and consume the seed.

Mestranol, applied to Douglas-fir seed at 2% (wet weight), increased seed survival from an average of 1,300 germinants per acre for untreated seed to 4,160 for treated seed. Mestranol has evolved as the only nontoxic repellent potentially capable of replacing endrin for coniferous seed protection. In laboratory bioassays, consumption of Douglas-fir seed by deer mice was reduced 62% by treatment with 2% mestranol, about the same as the standard 0.5% endrin seed treatment. Apparently, deer mice are repelled by mestranol because of a learned taste aversion that is retained 4 weeks or longer. More extensive field studies with mestranol-treated Douglas-fir seeds are currently being conducted in Washington, Oregon, and California to verify efficacy.

*Avian hazards associated with rat control.*—Studies to measure nontarget hazards of rat control with zinc phosphide in Hawaiian sugarcane indicated that birds consumed bait but were not killed. In cage tests, lace-necked doves, offered or force-fed zinc phosphide-treated bait, regurgitated before lethal amounts of phosphine were absorbed.

Avian hazards were also assessed during an operational baiting in 6- and 18-month-old cane. Baiting had no effect on population indices of birds as determined by road surveys, numbers of marked and unmarked birds captured in mist nets, dropping counts, and call counts. Five pheasants and four golden plovers, instrumental with miniature radio transmitters and monitored four times daily, were not affected by baiting. Dropping counts and telemetry data suggested that bird activity was concentrated on the open roads within younger cane fields and in drainage systems. Six of 24 birds collected

after baiting were positive for a tracer added to the bait, but no dead birds were found during 50 man-hours of searching in the cane and adjacent forest and pasture lands.

Although no acute hazards were observed during the study, warnings on the registration label are justified with the knowledge that a minimum of five species of birds accepted the bait. Label restrictions prohibiting baiting on open roads and near open water reduce the chance of birds encountering the bait and should be adhered to, especially in the ranges of the endangered Koloa duck and common gallinule.

*Possible replacement for Warfarin.*—For many years, public health and agricultural workers have been searching for chemicals that are of value in Norway rat control but are nontoxic to man, domestic animals, and nontarget wildlife. Warfarin has been in the forefront as a rat toxicant, but after the detection of Warfarin-resistant Norway rats in Great Britain, and more recently in the United States, the search for new chemicals to replace it has taken on a greater emphasis.

In routine laboratory screening, Bureau biologists have found a new chemical, U.K. 786[5-(*N*-piperidino)-10, 11-dihydro-5H-dibenzo (a,d.)-cycloheptene], that may be an



Studies of the pocket gopher indicate that it is capable of exerting a pressure as great as 24,000 pounds per square inch with its incisor teeth. (Photo by G. Keith LaVoie)

excellent species-specific toxicant for Norway rats. In laboratory tests with five species of birds and eight of mammals (including other species of rats), only Norway rats were highly susceptible to its lethal effects.

## DISEASES AND PARASITES OF FISH AND WILDLIFE

The study of diseases and parasites in fish and wildlife is an important Bureau responsibility. Disease organisms aid in regulating numbers of animals; in epizootics they cause obvious mortality; and some find harborage in certain species of wildlife which then become a source of infection for man and his domestic animals.

Most of the Bureau's research on disease and parasites in wildlife pertains to migratory game birds, particularly waterfowl. Researchers at the Bear River Station (in Utah) of the Northern Prairie Wildlife Research Center concentrate on studies of botulism and parasites in waterfowl. Studies at the Patuxent Wildlife Research Center emphasize malaria-like infections of waterfowl and various diseases of mourning doves; dis-

ease specialists also regularly examine animals to determine the cause of illness or death. Other studies of disease and parasites are carried out at the Cooperative Wildlife Research Units. Some of the Bureau's research on diseases of birds and mammals is conducted by contract with the Southeastern Cooperative Disease Study at the University of Georgia.

The Bureau's research on fish parasites and diseases is conducted for the most part in three laboratories: the Eastern Fish Disease Laboratory, Leetown, W.Va., the Western Fish Disease Laboratory, Seattle, Wash., and the Fish Farming Experimental Station, Stuttgart, Ark. Both the Eastern and Western laboratories study coldwater fish, while the laboratory at Stuttgart is

concerned with warmwater species which are important in the fish farming industry; that is, the catfishes, especially the channel catfish, and baitfish for sport fishing. All three laboratories have capabilities in equipment and personnel to conduct research on infectious parasites, bacteria, and viruses.

Presently, plans are well underway to construct a National Fish and Wildlife Health Center as an addition to present facilities at Leetown. This new \$3.5 million laboratory will encompass both fish and wildlife disease and health research. Existing facilities will be used by the Bureau's In-Service-Training Schools for fish cultural and fish health training.

### Fishery Studies

*Bacterial gill disease.*—A 1972 survey showed bacterial gill disease to be the greatest problem of juvenile salmonids. Population density and environmental stress factors predispose fish to the infection. In continuing research, total and myxobacterial counts were determined in cultured samples of gill tissue from yearling brook trout with severe bacterial gill disease. These counts were compared with those obtained last year from stressed and nonstressed trout. Surprisingly, total counts were higher in stressed and nonstressed trout ( $10 \times 10^6/g$ ) than in those with gill disease ( $3.0 \times 10^6/g$ ), but myxobacterial counts were slightly higher in diseased tissue ( $0.3 \times 10^6/g$ ) than in the nondiseased ( $0.1 \times 10^6/g$ ). The results suggest that many of the observed myxobacteria in diseased gill tissue are either not viable or will not grow on the test media.

*Furunculosis.*—*Aeromonas salmonicida* causes furunculosis, a widespread and often serious disease of salmonids. Apparently, healthy carrier fish are the source of infection but the bacterium cannot be cultured from carriers, and reliable detection methods are needed. New findings have shown that injection of corticosteroids such as Kenalog-40® followed by a temperature rise of 8°C will evoke clinical furunculosis and permit culture and identification of the bacterium.

*Aeromonas salmonicida antigen analysis.*—The lipopolysaccharide of *Aeromonas salmonicida* has been identified as an active endotoxin linked with the virulence and pathogenicity of furunculosis. Polystyrene latex particles tagged with the endotoxin functioned as visible particles for agglutination tests. This technique is being used in basic studies leading toward the development of an effective vaccine against furunculosis.

*Corynebacterial kidney disease (KD).*—This disease is prevalent and chronic, but nevertheless serious in salmonids. Effective chemotherapy is not yet available. The most effective control measures are detection, diagnosis, and prevention.

Rabbit antisera have been prepared to implement diagnosis and detection. Microtiter agglutinin tests with eight cultures showed cross-reactions among all isolates, thus indicating serological homogeneity. The sera now provide a serological method of diagnosis.

Work on methods of detection of KD carriers has led to the discovery of differences in the lactic dehydrogenase (LDH) isozymes of exposed and nonexposed trout. The significance is not yet clear since the LDH isozymes of trout injected with the kidney disease bacterium were not the same as for exposed trout. In addition, immunodiffusion, immunoelectrophoresis, and agglutination are being used to detect KD bacterial antigens or antibody.

To date, results have shown agglutinin titers of 1:8–1:25 in trout exposed to KD and 1:2–1:8 in specific-pathogen-free trout. Titers were generally higher in brood fish than in yearlings and higher in brook trout than in rainbow trout. Corynebacterial antigens were not found in liver, spleen, or kidneys from exposed trout but were found in sera of naturally or artificially infected trout.

In the continuing search for an efficacious and acceptable agent to control kidney disease, fingerling chinook salmon were fed an iodide-deficient basal diet to which enough sodium iodide had been added to give 0.1, 1.1, 5.1, and 10.2  $\mu g$  of iodide per g of dry diet. After 8 months on this diet, all groups were fed salmon viscera naturally infected with



Injecting a rainbow trout with Hagerman redmouth bacterin to produce antibodies against the virulent bacteria. (Fish Disease Program photo)

the kidney disease bacterium, to determine if high iodide levels increase resistance to infection. Although the higher iodide levels offered protection in the early stages of the disease, this protection was lost as the disease progressed.

*Oral immunization against Hagerman redmouth disease (HRM).*—A chloroform-killed bacterin was highly effective against HRM in rainbow trout. Inoculation was more effective than feeding; also low temperatures were less inhibiting to the buildup of protection than was previously suspected. Trout weighing less than 2 g can develop immunity when fed or inoculated with the bacterin.

*Infectious pancreatic necrosis (IPN).*—This is the most widespread viral disease of salmonids, and some strains produce significant mortality. Inasmuch as previous research has shown that there are multiple serotypes of the virus, a polyvalent antiserum is required for effective diagnosis.

A provisional polyvalent anti-IPN serum incorporating five antigenic strains of virus was tested and found to neutralize 40 of 42 different isolants. Antisera prepared against the two nonreacting strains showed them to be serologically distinct.

*Infectious hematopoietic necrosis (IHN) in rainbow trout.*—A group of yearling rainbow trout that survived an IHN epizootic were brought to the Western Fish Disease Laboratory and held for 9 months, until maturity, in a virus-free water supply. Twenty-nine fish were spawned and the sex products tested for IHN virus. Virus was isolated from 31% of the fish, demonstrating that rainbow trout can become carriers through maturity and can shed virus during spawning. Although it has been shown experimentally that fish are susceptible to IHN at temperatures as high as 60° F, IHN epizootics have occurred only at water temperatures of 52° F or below. In 1972, however, IHN virus was isolated from natural outbreaks of disease at 58° F.

In studies of the serology of IHN, viral neutralization tests proved to be more effective than complement fixation, passive hemagglutination, or immunodiffusion in diagnosing the disease.

The pathophysiology of IHN was studied in 300 rainbow trout injected intraperitoneally with a suspension of IHN virus; controls received the suspending medium only. Hemoglobin, hematocrit, corpuscular count, blood smear, kidney imprint, and serum samples were collected for 9 consecutive days. The mean hemoglobin, hematocrit, corpuscular count, serum, bicarbonate, and serum glucose levels were significantly lower than those of the controls by the 5th day after injection. Serum chloride, calcium, inorganic phosphorus, ascorbic acid, cortisol, blood urea nitrogen, and total protein levels were not significantly altered after 9 days. In a second experiment in which only moribund fish were compared with controls, the results were similar with a few exceptions. Serum chlorides were significantly depressed, while serum glucose was no different from that in the controls. Serum pH was significantly higher than that in the controls, and the osmolality was lower. The infected fish had a normocytic anemia with a serum electrolyte



External symptoms of gas bubble disease, caused by air-supersaturated water, in a juvenile chinook salmon. (Fish Disease Program photo)

imbalance. The fish apparently die due to an inability to osmoregulate.

Peripheral blood smears and kidney imprints of IHN infected fish consistently show specific hematopathological changes. We believe these changes can be used as a rapid in-the-field presumptive test for IHN.

An antiserum against IHN is being developed. The first application was concerned with an outbreak in West Virginia. The work showed that the disease has been spread across the United States by shipment of contaminated eggs.

*Whirling disease.*—*Myxosoma cerebralis*, cause of salmonid whirling disease, is an exotic sporozoan pathogen that has been established in North America. The disease causes significant mortality and by destruction of cartilage creates crippling deformities among survivors. There is no effective chemotherapy, and control is possible only by elimination of the parasite from water supplies and holding facilities. Detection of asymptomatic carriers is critically important to rational implementation of control.

Work in 1972 showed that water-borne infectivity of *M. cerebralis* was destroyed by a

combination of filtration and ultraviolet irradiation at a dosage of  $35,000\mu\text{W}$  per second per  $\text{cm}^2$ . Lower dosage experiments are in progress.

*M. cerebralis* infectivity has persisted for at least 4- $\frac{1}{2}$  years under simulated pond conditions. Disinfection and eradication procedures are necessary to cope with that problem. Air drying of contaminated mud for 19 months destroyed infectivity, but disinfection of wet infective mud with up to 1,200 ppm chlorine ( $\text{CaOCl}_2$ ) did not. Previous work has shown that calcium oxide on simulated pond bottoms is effective. The use of calcium hypochlorite, quicklime, and ultraviolet irradiation successfully disinfected the Lahontan National Fish Hatchery.

Transmission and related biological studies have not yet shown the infective stage of the organism nor its portal of entry into the host fish. The work has shown that invertebrate vectors and tomites are probably not involved. New findings indicate that there is a dose relationship between infectivity and the incidence and severity of disease.

Differentiation of dead and viable spores is needed for basic studies. Thus far, spores can be uniformly stained with methylene blue only after they have been held at  $70^\circ\text{C}$  for 10 minutes or treated with concentrated  $\text{CaCN}_2$  or  $\text{NaCl}$ .

Immunological studies hold promise for the most sensitive detection of *M. cerebralis*. An effective serological approach will be valuable in carrier detection and possibly in learning the nature of the infective stage and how it is transmitted.

Spores of *M. cerebralis* have been released and concentrated by the use of pepsin-tryptic digestion and centrifugation through dextrose. Over 89% recovery has been achieved in a processing time of about 8 hours with a 1,000- to 9,000-fold concentration.

Trypsinization with acid flocculation and ether extraction similarly yielded clean spores with a concentration of 11,000-fold during a processing time of 20 to 24 hours.

Histologic examination has been used to determine the pathogenesis of whirling disease and to search for the infective stage of the organism. Thus far, an infective stage



has not been found but intramuscularly injected spores were phagocytized. Host response consisted of an early capillary ingrowth, mononuclear infiltration, and appearance of polymorphonuclear leucocytes at the injection site. At 2 weeks post-injection, spores were neither digested nor morphologically altered within phagocytes.

*Immune response of channel catfish.*—Channel catfish were inoculated with channel catfish virus (CCV), *Chondrococcus columnaris*, or *Ichthyophthirius multifiliis*, held at 28° C, and bled at intervals to study kinetics of the response.

Primary response to the virus reached a peak at 4 weeks with 98% plaque neutralization at a dilution of 1:1,000. The titer began to decline at 9 weeks. After multiple primary injections, the peak titer (1:1,024) against *C. columnaris* was reached at 4 weeks. The maximum primary response to *I. multifiliis* was obtained 6 weeks post-injection with 50% tomite immobilization at a dilution of 1:640. A secondary injection at 8 weeks gave a twofold increase in titer.

Heat serum of CCV antiserum at 56° C for 30 minutes resulted in an average loss of

32% of the neutralizing activity at a 1:100 dilution and a 39% average loss at 1:1,000.

*Open-jaw syndrome.*—An unusual condition of spring chinook salmon fingerlings was encountered at a National Hatchery. The lower jaw was locked in an open position. The gaping condition was labelled open-jaw syndrome and resulted from a dislocation of the articulating joint of the lower jaw—apparently a genetic defect.

*Fish tissue culture.*—Cultures of fish cells constitute the principal working tool of the virologist. The Eastern Fish Disease Laboratory established the first continuously cultivable fish cells 13 years ago and has maintained them ever since in pure condition. Methods of management of such cultures have been developed and procedures have been published.

Portions of lamprey heart have been maintained in culture, and rhythmic beating has continued for 4-1/2 years. In addition to their basic value (as tissue culture of a primitive fish), a line of lamprey cells offers a system in which IPN virus might be attenuated for use in a vaccine.

*Normal clinical chemistry of juvenile rainbow trout.*—Baseline ranges for blood chemistries must be known if modern diagnostic techniques now used in human and veterinary medicine are to be applied to fish diseases. The following nonparametric estimates of normal ranges were determined for juvenile rainbow trout held at 10° C in 4-foot circular tanks under a natural photoperiod and fed the Oregon moist pellet:

Blood component	Clinical value
Bicarbonate	7 - 14 meg/1
Bilirubin (total)	0.5 - 1.5 mg/100 ml
Calcium	4 - 5.5 meg/1
Hemoglobin	6 - 8 g/100 ml
Hematocrit	27 - 44%
Magnesium	1.2 - 3.3 meg/1
Osmolality	300 - 341 mOsm

*Physiology of salmonids in intensive culture.*—High pond loading factors, rates, and population densities are necessary in modern fish culture but crowding stress can predispose the fish to disease outbreaks.

By using abnormalities in carbohydrate metabolism as an index of stress, it was shown that the space factor as well as the



Normal chinook salmon (two at top) and chinook salmon affected with open jaw syndrome (two at bottom). (Fish Disease Program photo)



Catching a rainbow trout for a study of hooking stress. The effects of hooking on hatchery-raised individuals is compared with that of wild fish. (Fish Disease Program photo)

carrying capacity of the water (pond loading factors and dissolved oxygen) is important in holding juvenile coho salmon. Acclimation to the stress of reduced space can require up to 3 weeks.

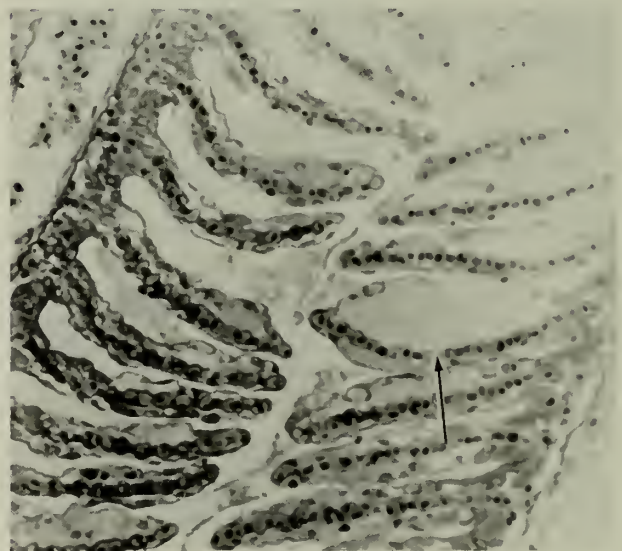
*Comparison of the stress of catch-and-release fishing in hatchery vs. wild rainbow trout.*—In a joint project with the Cooperative Fishery Unit at the University of Washington, the Western Fish Disease Laboratory compared hatchery and wild rainbow trout in terms of their ability to recover from hooking stress in catch-and-release fishing. In hatchery stocks, a relatively severe hyperglycemia occurred which seemed to be directly correlated with fighting behavior. After release, blood sugar levels sometimes remained abnormal for a day or more even though the fish appeared (visually) to be normal.

*Therapeutics.*—A field test was coordinated by the Western Fish Disease Laboratory with nine biologists throughout the United States to determine the toxicity of two organic iodine compounds, Betadine and Wes-codyne, to salmonid eggs. No significant difference in egg toxicity was recorded between

the two disinfectants at concentrations up to 200 ppm when the solution was buffered with sodium bicarbonate. Toxicity did not differ among species of fish eggs (chinook and coho salmon and rainbow, brook, and brown trout) or between development stages (green or eyed) of the eggs. In general, egg losses in comparison with losses in control lots were equal to or significantly lower at 100 ppm iodine and were equal to or significantly higher at 200 ppm iodine. The data for Betadine will be submitted to the FDA for clearance.

*Stress of formalin treatments in juvenile spring chinook salmon and steelhead trout.*—Histological changes in the gills caused by standard formalin treatments were correlated with abnormalities in blood chemistry reported last year. Both the pathological changes and ionoregulatory dysfunction were more severe in steelhead than in spring chinook salmon. A 24-hour recovery period is recommended following formalin treatments before either species is subjected to pond cleaning, hauling, or other stresses.

*The use of salt to reduce the stress of  $\text{CuSO}_4$  treatments.*—Copper sulfate can be very useful in controlling fungus and bacterial gill disease infections in hatchery fish, but it has



Section of steelhead trout gill tissue showing formalin toxicity. Note lamellar edema (arrow). (Fish Disease Program photo)



Examination of cell cultures for cytopathogenic effect following inoculation with fish tissue suspected of harboring IHN virus. (Fish Disease Program photo)

a very low safety margin in soft water. A cooperative laboratory and field project of the Western Fish Disease Laboratory and the California Department of Fish and Game has shown that 0.2–0.4% NaCl can substantially “detoxify”  $\text{CuSO}_4$  (i.e., reduce mortalities), and thus make it suitable for use at soft-water hatcheries.

*Nitrogen gas studies.*—An excess of nitrogen gas in the water can cause a situation in fish that may be likened to the bends in humans. With the construction of power dams on the Columbia River the condition has become critical. Scientists at the Western Fish Disease Laboratory have shown that gas bubble disease is related to the temperature of the water, the total gas pressure of the water, the stage of development of the fish, and the species of fish.

## Wildlife Studies

*Susceptibility of ducks to recently discovered botulinum toxin.*—Recently, Japanese and American investigators reported that the toxigenicity of some strains of *Clostridium botulinum* is dependent on the presence of bacteriophages in the bacterial cells. In some cases, “curing” the cells of their bacteriophages apparently resulted in a complete loss of toxigenicity. American investigators found that a toxic component, desig-

nated C2, continued to be produced at low levels by some “cured” type C strains. Unlike the predominant toxic component (C1), C2 increased in potency as much as 100 times after treatment with the enzyme trypsin.

Studies of the possible practical significance of C2 toxin as a pathogenic agent for wild aquatic birds have been carried out at the Bear River Station in Utah. Although any effects of this toxin would usually be masked by those of the much more abundant C1 toxin, type C strains may sometimes lose their ability to produce the predominant toxin under field conditions, as they do in the laboratory. The newly recognized agent is of low toxicity for mallard ducks by the oral route, but is considerably more toxic by the intraperitoneal and intravenous routes than C1. Conceivably, toxic doses might be absorbed through small breaks in the intestinal mucosa.

In its toxicological effects on ducks, C2 is quite different from C1. It has no observable neurotoxic action in the mallard as does C1, but species that are susceptible to C2 poisoning die in vigorous convulsions. Massive pulmonary congestion is characteristic of these victims, a finding of interest to public health personnel because pulmonary edema is sometimes a complication of botulism in man.

*New strain of botulinum toxic for ducks.*—In 1970 a group of Argentine workers isolated a previously unknown type of *Clostridium botulinum* (type G), from the soil. Since cases of type G intoxication in man or lower animals are not known, the Bear River Station experimentally induced the disease in ducks to provide diagnostic information. On the basis of tests with mice, type G toxin is less toxic to mallards than type C. Leg weakness and an inability to coordinate voluntary muscular movements were observed in affected birds. Marked trembling, not common in type C botulism, occurred in all cases. The nictitating membranes were immobile or sluggish, and the eyes contained the discharge commonly seen in the type C disease. Tests indicate that the standard serum toxicity test in mice will apparently be an appropriate diagnostic procedure when the specific antitoxin is available.



Methods of collecting black fly eggs, larvae, and pupae. The Ekman dredge obtains samples from the bottom of a stream (left). Larvae and pupae attach to gauze spread and weighted on the bottom of a stream (top). The immature stages of the black fly can be collected also by hand from submerged vegetation (bottom). (Photos by I. Barry Tarshis)

*Cestode and acanthocephalan parasites of waterfowl.*—Studies at the Bear River Station on the occurrence and severity of parasite infections in waterfowl are providing information that is useful in appraising the significance of parasitism to the welfare of the birds. Examination of 53 diving ducks

including redheads, canvasbacks, lesser scaup, and a ring-necked duck for cestodes (tapeworms) have revealed 21 named species and 24 unclassified morphological groups of parasites. In 13 scaup the numbers of cestodes ranged from 0 to 18,900. Cestodes of waterfowl examined so far can be separated

into five host specific groups: geese, diving ducks, dabbling ducks, general species, and others with unknown host specificity. Nine cestodes are judged host specific for ducks, but none of these was found in the four species examined, suggesting a narrower host specificity for some.

Examinations of other waterfowl collected at the Red Rock National Wildlife Refuge in Montana indicate heavy infections of acanthocephalans (thorny-headed worms), the intermediate hosts of which are amphipods. The five recorded species were present in 87% of the collections, compared with only 38% in waterfowl taken elsewhere. Two trumpeter swans contained an estimated 10,000 and 7,000 worms, respectively, while the mean for all waterfowl was 780. The most severe infection in any duck taken elsewhere was 43 worms.

*Malaria in diving ducks.*—Canvasbacks, redheads, and scaup have latent malaria infections when they reach their wintering area along the Atlantic coast. The immature birds were also infected, indicating that infections were acquired on the breeding grounds. Studies in the Minnedosa, Manitoba, area revealed no infected ducklings for 2 consecutive years. Since this area is believed to contribute a substantial number of birds to the Chesapeake Bay wintering flock, it must be assumed that the infected birds are coming from elsewhere.

*Continuing studies on Leucocytozoon.*—Of 837 goose eggs counted in nests at the Seney National Wildlife Refuge in Michigan, 300 eggs were lost through failure of the geese to incubate them or were destroyed by predators. Of the remaining 537 eggs, 425 hatched, but 325 goslings died from *Leucocytozoon*. Fifteen dead goslings picked up on the Refuge had enlarged spleens and showed heavy infections with *Leucocytozoon* in tissues and blood. Blood smears taken from 35 live goslings also showed heavy infections with *Leucocytozoon*. Less than 100 goslings reached flight stage this year, a 76% gosling loss. There seems little doubt now that gosling epizootics due to *Leucocytozoon* occur in 4-year cyclic periods. Previous high losses were 87% for 1960, 84% for 1964, and 71% for 1968.

Blood smears taken from 223 wild Canada goose gosling, yearling, and adult birds showed that 158 birds were infected with *Leucocytozoon*, *Haemoproteus*, and microfilaria. Sixty-five geese were negative for blood parasites. Blood smears taken from 37 immature and mature black ducks, mallards, wood ducks, pintails, and blue-winged teal showed that 33 of the ducks were infected with *Leucocytozoon* and *Haemoproteus*. Four of the ducks were negative for blood parasites.

Continuing studies on the identification of various species of black flies collected on and near the Seney Refuge show that more than 85 species have been found to date belonging to the genera *Cnephia*, *Prosimulium*, *Simulium*, and *Twinnia*. However, only one species, *Simulium innocens*, was found to be the principal vector of *Leucocytozoon* in Canada geese, since it was the only one present at the time goslings were becoming infected and/or dying from *Leucocytozoon*.

*Yeast infections of pigeons.*—Twelve species of yeast have been isolated and identified from the upper digestive tract of feral pigeons. These include the genera *Candida*, *Torulopsis*, *Saccharomyces*, *Geotrichum*, and *Kloeckera*. *Candida albicans* and *S. telluris* are the most commonly encountered species while *C. krusei* and *Geotrichum* are found somewhat less frequently. A 16-month survey of feral pigeons shows *C. albicans* to be continuously present, but most common in late summer. *Saccharomyces telluris* is also present at all times but most common in the spring. The remaining 10 species occur at irregular times and in no particular sequence. A total of nine North American columbid species have been examined for yeast and all have been found to be carriers. The feral pigeon, mourning dove, and white-crowned pigeon are the most heavily infected of those examined.

*Salmonellosis in birds.*—Salmonellosis caused by *Salmonella typhimurium* was diagnosed as the cause of a die-off of 116 evening grosbeaks at Elkins, W. Va. The bacteria were isolated from the livers of infected birds. *Salmonella typhimurium* was also isolated from a pine siskin collected at a

backyard bird-feeding station near Baltimore, Md., where daily losses of goldfinches and house sparrows had been observed for more than 1 month.

Salmonellosis was diagnosed as a cause of heron mortalities among a captive flock of

herons at the Patuxent Center. Thirty-six of the forty-one birds that died were autopsied and thirteen were found to be infected. Infected birds showed enlarged livers, with focal necrosis and hemorrhage, and caseonecrotic changes in the intestinal tract.

## FISH NUTRITION

### Tunison Laboratory of Fish Nutrition

*Effects of temperature and water chemistry on mineral metabolism in Atlantic salmon.*—A new recirculating, biologically filtered freshwater facility was used in a study to investigate (with a  $^{45}\text{Ca}$  tracer) the effects of certain environmental alterations and cultural procedures that stress captive fish. The tracer measured mineral ion uptake and regulation in small (2 g) Atlantic salmon. Temperatures were changed from the usual  $11^\circ\text{C}$  of the running water troughs to 6, 16, or  $21^\circ\text{C}$ ; and major mineral cations (Na, K, Mg, and Ca) were doubled. Each group of fish was conditioned for 3 days to a closed system (at  $11^\circ\text{C}$  and normal water chemistry); the fish were then netted and transferred into other closed systems where water temperature or chemistry, or both, could gradually be changed during an additional 1-day period. The fish were maintained in the altered environments for 0, 4, or 8 days before transfer to similar, nonfiltered environments containing 2 liters of  $^{45}\text{Ca}$ -labeled water. After 1 to 4 days, the gills, viscera, bones, and skin of the fish were analyzed for radiotracer uptake.

The Atlantic salmon, like other salmonids previously studied, used divalent calcium cations as a significant source of mineral nutrition; they absorbed and retained up to 2% of their total tissue calcium from the water in 4 days. Generally, they needed the full 8-day period to acclimate to the stress of handling alone before they used calcium efficiently. In contrast, they acclimated promptly to a doubled concentration of major cations, and acclimated within 4 days to  $5^\circ\text{C}$  changes of water temperature. The salmon failed to survive for more than 10 days at  $21^\circ\text{C}$

C, even though the deposition of calcium in the structural tissues was extensive at this high temperature.

Atlantic salmon with the shortest acclimation time showed an extensive retention of labeled calcium in their gills during their first day in enriched water, with correspondingly less absorbed calcium distributed to their skin. This regulatory adjustment did not continue significantly beyond 2 days. Distribution of labeled calcium to both skin and skeleton was reduced by the transfer to cold ( $6^\circ\text{C}$ ) water; this reduction also, however, was not evident after 2 days. The enriched waters doubled the amounts of labeled calcium deposited in skin and bones; at the two higher temperatures (16 and  $21^\circ\text{C}$ ), the calcium absorption was doubled and tripled, respectively. On the average, 18% of the calcium uptake went to the skeleton and 36% to the skin.

Stress on the salmon from netting into each environment appeared to have a deleterious effect of reducing the structural contribution of water calcium to young fish, especially when the netting was done in conjunction with changes in water chemistry or temperature.

*Effect of certain physical factors on hatchery salmonids.*—In an experiment designed to measure the effect of water current and level of feeding on the growth, food conversion, and swimming stamina of brook trout, three treatments were employed: One group of fish was reared in directed water currents and fed ad libitum; a second group was reared in tanks without directed water currents and also fed ad libitum; a third group was reared in directed water currents and fed the same percent of body weight per day

as that accepted by the group-two fish (reared in tanks with no directed water currents).

After 10 weeks, stamina tests showed that the fish of group one (reared in a water current and fed ad libitum) had the greatest swimming stamina and that fish of group two (reared in tanks with no directed current) had the least. The third treatment group (reared in a directed water current but not fed to satiation) had intermediate swimming stamina. The third group also had the lowest food conversion rates. Fish fed to satiation in tanks with no directed current weighed the least and those fed to satiation in tanks with directed water currents weighed the most after 10 weeks. The results suggest that forcing brook trout to swim in a moderate current of about 0.5 foot per second is a desirable rearing procedure.

*Effect of dietary protein on growth, survival, and chemistry of brown trout.*—Inasmuch as research has shown that manipulation of the ratio of total energy to protein and ratio of energy as protein to nonprotein sources can alter the growth and body chemistry of salmonids, the effects of eight semi-purified diets on brown trout were tested. The diets contained 20 to 80 g of concentrated eviscerated herring protein, 3 to 12 g of raw linseed oil, 2 to 27 g of glucose, and predetermined amounts of minerals, vitamins, and nutritionally inert ingredients per 100 g of dry diet. They were fed, after incorporation with water (1:1) to duplicate tanks of juvenile brown trout (starting weight, 5.2 g) at 8.3° C for 18 weeks. Some of the results follow.

Increasing the protein level in isocaloric diets (158 Cal/100 g of wet diet) from the usual 18% to 36%, with a concomitant rise in percent of protein energy from 22.2 to 44.4%, produced a 136% increase in total body weight gain and a mean final increase of 75% in body weight and 19% in length. A further increase of diet protein to 72% (88.6% protein energy) produced only 33% more body weight gain, and further increases of 25% in mean body weight and 11% in length.

The food and energy utilization efficiencies were each 45% greater and protein utilization was 10% less in the 36% protein diet

than in the 18% diet. Food and energy utilization efficiencies in the 72% protein diet were each 12% greater than those of the 36% protein diet, and protein utilization was 75% less efficient in the 72% protein than in the 36% protein diet.

Fish fed the intermediate (35%) protein level contained 31 and 41% more whole carcass and visceral fat, respectively, than those fed the lower protein diet. However, the fish fed the highest protein diet had 46 and 29% less carcass and visceral fat, respectively, than those fed the intermediate protein diet.

The increase of protein to 36% resulted in a significant increase in swimming stamina, but the second increment (to 72%) did not further enhance swimming endurance.

In a second bloc of three nonisocaloric diets, simultaneous increases of energy from 71 to 140 Cal/100 g of wet diet, and of protein (dry basis) from 18% to 36% (thus maintaining 1:1 protein:nonprotein energy ratio) produced a 381% increase in total weight gain, a 153% increase in body weight, and a 31% increase in body length. However, a further simultaneous increase in total energy to 229 Cal/100 g and protein to 42.5% (50% of the energy still derived from protein) resulted in no further body weight gain, although the fish increased slightly in length. The high energy content apparently suppressed food intake (as evidenced by an efficient food conversion as well as a reduced consumption of food).

The first simultaneous increments of energy and protein produced a 64% increase in food conversion, a 29% increase in energy, and a 28% increase in protein utilization. The second increment, however, resulted in reduced efficiency of protein and energy utilization.

The fish fed at the intermediate energy and protein level deposited three times as much visceral fat and 70% more body fat than those fed the low energy and protein diet. The second increment of energy and protein produced no further increase in visceral fat deposition but caused a 47% further increase in whole carcass fat.

The trout fed at the intermediate energy and protein level showed greater swimming

stamina than those in either the low energy-low protein or the high energy-high protein groups, which were similar.

*Effect of dietary pepsin on growth and body chemistry.*—In a study of the effect of supplemental dietary pepsin on the growth and chemistry of fingerling brook trout, fish averaging 3.2 g were held at a constant temperature of 8.3° C for 20 weeks and fed a casein based diet containing 50% water, 30% protein, 9% carbohydrate (glucose), and 3% corn oil; total kilocalories per pound of dry diet were 1,153 as measured by bomb calorimetry. Duplicate lots were fed either the control diet or the control diet plus 0.25 pepsin (150,000 units) at each of two feeding levels: 0.75% and 1.5% (dry matter) of body weight per day.

At either feeding level the addition of the pepsin to the diet had a negative effect on growth, percent gain, and protein efficiency ratio of the trout. At the higher feeding level, conversion was not affected. The overall growth depressing effect of the supplemental pepsin was much more pronounced at the lower feeding level. In the following summary of the results, conversion rate shows grams of food required to produce a gram of gain and protein efficiency ratio shows grams of gain produced by 1 g of protein.

Statistic	Feeding rate (% of body weight)			
	0.75%		1.5%	
	Control diet	Diet with pepsin	Control diet	Diet with pepsin
Final average weight (grams) -----	8.6	5.0	12.6	11.0
Total gain (%) -----	167	61	294	251
Conversion rate -----	2.0	4.3	3.0	3.2
Protein efficiency ratio	1.66	0.78	1.10	1.05

*Energy expenditure in lake trout eggs and fry.*—In a study of the energetics of developing lake trout eggs and larvae, the changes in dry weight and energy of the developing lake trout egg and of the partitioned alevin and yolk sac were followed from fertilization through absorption of the yolk sac.

Duplicate samples of 300 eggs each were collected immediately after fertilization and

at 1, 2, 4, 6, and 8 weeks (hatching) after fertilization. Duplicate samples of 300 sac fry each were collected at 1, 2, 3, and 4 weeks after hatching. Duplicate samples of fry with completely absorbed yolk sacs were collected 5 weeks after hatching.

After the yolk sacs were separated from each alevin, the tissues of the developing eggs, the yolk sacs, and the alevins were homogenized and dry matter determined by drying to constant weight in a vacuum oven. Duplicate energy determinations (kilocalories/gram of dry matter) were subsequently made on all samples by combustion in an oxygen bomb calorimeter.

The dry weight changes showed that after a transitory fall and rise during the first 2 weeks of incubation, a gradual decline occurred from a maximum dry weight of 34.7 mg to 30.7 mg per egg near hatching.

The mean combined dry weight of the sac and alevins continued to decline gradually from 27.7 mg per alevin at 1 week post hatch to 23.0 mg at 4 weeks post hatch, and 12.0 mg at complete absorption of the yolk sac.

The mean dry weight of the sacless alevins increased from 6.2 mg at 2 weeks post hatch to 9.3 mg at 4 weeks after hatching. Simultaneously, the mean weight of the severed yolk sacs steadily fell from 18.7 mg at 2 weeks post hatch to 13.2 mg at 4 weeks.

The gross energy per egg, except for a transitory increase at 1 week after fertilization, gradually declined from 0.27 Cal after 2 weeks of incubation to 0.18 at hatching. The total energy for the sample of 300 eggs or fry, except for the first 2 weeks of incubation, gradually declined from 59.1 Cal at 2 weeks incubation to 38.8 Cal at 4 weeks after hatch.

The mean energy for each alevin steadily increased from 0.032 Cal at 2 weeks after hatch to 0.051 Cal 4 weeks later, and to 0.054 for the fry after complete yolk sac absorption. At the same time, the energy per severed yolk sac declined from 0.11 Cal at 2 weeks post hatch to 0.016 Cal at 4 weeks.

These gross yolk sac energy values, which include retained metabolic waste products, show that the yolk sac energy reserves may be critically depleted prior to complete yolk sac absorption. This depletion would indicate a need for an available food source and the

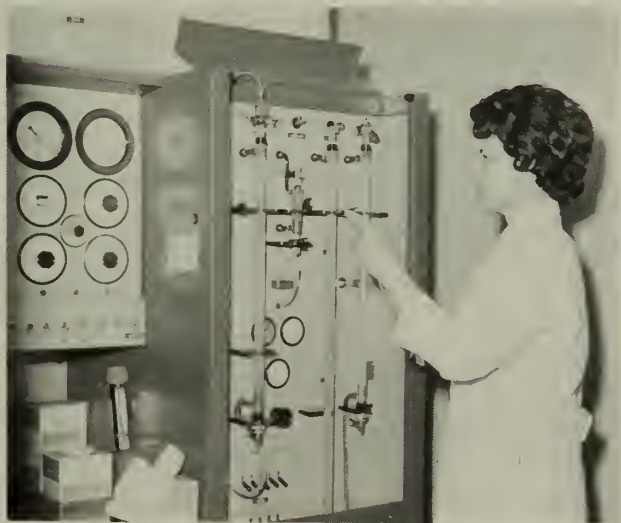


initiation of feeding before the "button up" stage is reached.

### Western Fish Nutrition Laboratory

*Alternate sources of protein for salmon diets.*—As fish meal, a major component of today's diets for production fish hatcheries, becomes more difficult to obtain, a search for other sources of protein becomes essential. Inasmuch as research in Japan has shown that half of the dietary protein requirement for trout can be furnished from yeast protein preparations, the Western Fish Nutrition Laboratory determined the amino acid content in two different lots of yeast protein prepared at the British Petroleum Plant at Grangemouth, England, from yeast grown on petroleum alkane fractions. Replicate analyses showed that this crude extract preparation contained reasonable amounts of most indispensable amino acids, but low levels of methionine and cystine. Tests indicated that most of these amino acids would be available to young growing fish.

The thermophilic alga, *Cyanidium caldarium*, which has a well balanced amino acid pattern in the protein fraction, seemed a good potential source of protein for fish diets.



Analyzer used for identification of amino acids in feeds and body tissues of fishes. (Western Fish Nutrition Laboratory photo)

However, young chinook salmon fed from the time of hatch to 1 year with this alga as a sole source of carbohydrate and the main source of protein grew poorly; they gained only 27% as much weight as controls.

*Absorption of dietary amino acids is being tested in trout.*—Amino acid patterns are being determined in diets that are force-fed to large rainbow trout confined in metabolism chambers, and in the excreted feces. The objective is to determine if the limiting indispensable amino acids in the feed are completely or only partly absorbed. If some loss occurs it will be possible to determine coefficients which can be incorporated into feed-amino acid formulation equations to ensure the presence of sufficient amounts for balanced growth.

*Availability and utilization of diet ingredients.*—Fifteen dietary ingredients have been tested for digestibility and metabolizable energy by feeding them to individual fish isolated in metabolism chambers. The list comprises meals, prepared from corn gluten, soybean, cottonseed, wheat gluten, poultry by-products, whitefish, pea, Peruvian fish, salmon, and meat; and delactosed whey, brewer's yeast, torula yeast, and Canadian herring. Diets which included some of these ingredients have been used in fish feeding experiments. One of the most promising ingredients is soybean meal. At 8 weeks on test, fish receiving a diet containing 80% soybean meal made from soybeans which had been roasted at 205° C for 5 minutes were growing at about 80% of the rate of fish fed a commercial trout feed. Diets made from soybeans roasted at lower temperatures produced less growth. Herring meal supplement improved diets in which soybeans roasted at low temperatures were used, but not those prepared from beans roasted at 205° C.

*Protein requirements of salmonids in saline waters.*—Rainbow trout required diets containing more than 40% protein for maximum growth in 10 parts per thousand salinity (6-g fish tripled their weight in 10 weeks). Rainbow trout held in 20 ppt salinity grew equally well only when fed diets containing 45% protein. The requirement for higher dietary protein with increased salinity is probably related to an increase in stress. Coho



Surgical inspection of internal organs of a fish. Fish are anesthetized prior to surgery and incisions are closed by suture, permitting recovery. (Western Fish Nutrition Laboratory photo)

salmon showed similar protein requirements in water of these salinities.

Diet efficiency (defined as weight gain per gram of dry diet) increased as the percentage of protein in the diet increased, until an optimum protein level was obtained. For rainbow trout in 10 ppt salinity the highest efficiency ratio was 0.86 g gain per 1 g of dry diet. The diet efficiency for fish held in 20 ppt was more erratic but nevertheless good with the higher protein diets. Coho salmon showed similar trends; that is, diet efficiencies were poor when protein content was low, and much better when protein content was high.

*Seventeen trace minerals assayed in fish.*—The Western Fish Nutrition Laboratory completed a 12-week National Science Foundation-supported, cooperative student-originated, research study with Reed College on trace minerals in young trout and salmon. Fish were held for 12 weeks in different water systems and were fed test diets with and without added mineral components. Weekly water samples and representative samples of fish were selected and tissues were prepared for analysis. All samples were analyzed at Reed College utilizing the nuclear reactor

facilities and neutron activation and analysis equipment there. A final report has been submitted to the National Science Foundation and provides a base line for 17 micronutrient elements present in young growing trout and salmon. Cadmium in the water and in the food was tested for rate of absorption and for toxicity.

*Hepatoma carbohydrate metabolism investigated.*—Tumor-bearing livers from rainbow trout given aflatoxin in the diet for 20 months and normal livers were prepared for examination of carbohydrate metabolizing enzymes in a cooperative study with the Fels Research Institute, Philadelphia. Tissue preparations were made at the Hagerman Field Station of the Western Fish Nutrition Laboratory from material detected during surgical internal inspection of the experimental fish. The incidence of hepatoma was



Fish livers with massive tumors induced by aflatoxin, a mold toxin found in some seed products used for fish feed. (Western Fish Nutrition Laboratory photo)

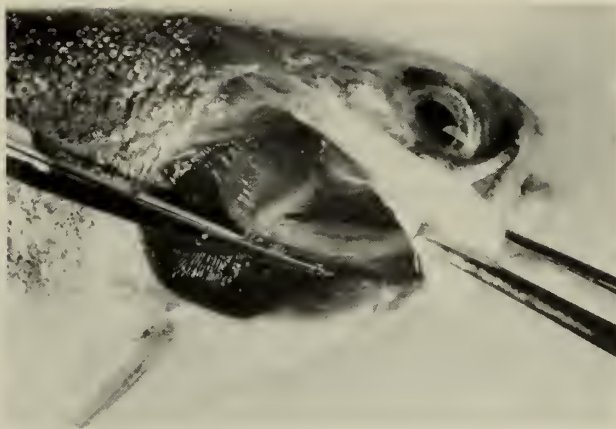
about 35%, which compared favorably with previous work.

*Histidine transamination in trout liver.*—Experiments are underway to examine some of the biochemical reactions involved in protein metabolism in rainbow trout. Reactions being studied involve the transfer of amino groups of amino acids to imidazolepyruvic acid by enzymes called transaminases. The product, histidine, has been shown to be readily acted upon by the enzyme histidase, resulting in the liberation of ammonia. Such a system may be instrumental in the production of ammonia, which is excreted as a waste product of metabolism.

*Methionine requirements for coho salmon.*—Tests indicated that about 0.50% methionine is required in the diet in the presence of 1% cystine, to ensure normal growth of coho salmon.

*Gill ATPase activity and parr-smolt transformation.*—Sodium, potassium-stimulated ATPase activity (NaK-ATPase) in gill microsomes has been used during the past year as an index of smoltification in salmon and steelhead trout. In an effort to determine the maximum temperature which would permit smoltification in summer-run steelhead, groups of these fish were reared at 6, 10, 11.3, 12.7, 14 and 15° C. Enzyme activity was not elevated (elevation is an indication of smoltification) in fish held at 12.7, 14, and 15° C, but was elevated in fish held at 6, 10, and 11.3° C. However, enzyme activity returned to a presmolt level 4 to 6 weeks earlier in fish held at 10 and 11.3° C than in steelhead held at 6° C. This information suggests that temperature in the range of 12 to 13° C and above inhibits parr-smolt transformation in summer-run steelhead. Simultaneous studies on salt-water adaptability of fish from these groups showed survival in 36 ppt "Instant Ocean" salts to be greater for steelhead held at 6, 10 and 11.3° C than for those held at higher temperatures.

Gill ATPase activities were determined in several groups of steelhead supplied by the Dworshak National Fish Hatchery with the following results (ATPase activity in  $\mu$ moles ATP hydrolyzed/mg protein per hour): normal parr, 15; precocious males, 15; migrants from hatchery, 24; wild migrants, 29; and



Obtaining a sample of gill from an anesthetized fish. Gill tissue is used to determine Na, K<sup>+</sup>-ATPase activity, an index to the development of the smolt stage (about 2 years old) in salmonids. (Western Fish Nutrition Laboratory photo)

hatchery fish trucked to Bonneville Dam for release, 20. These results confirm observations from other studies that gill NaK-ATPase activity is elevated in migrating juvenile steelhead.

Wild yearling spring chinook salmon in some tributaries of the Snake River move downstream in late fall as rivers become cold. However, it is not known if these movements represent a true seaward migration. Tests of wild salmon (8.7 to 10.4 cm long) and some hatchery-reared spring chinook (13.0 to 16.3 cm long) which showed similar movement patterns when released in the fall, showed that both groups had about the same low ATPase activities (5 to 10  $\mu$ moles ATP hydrolyzed/mg protein per hour)—suggesting that these fish were not smolts. Movements of these fish in the fall probably do not represent a true seaward migration, but a relocation to deeper water.

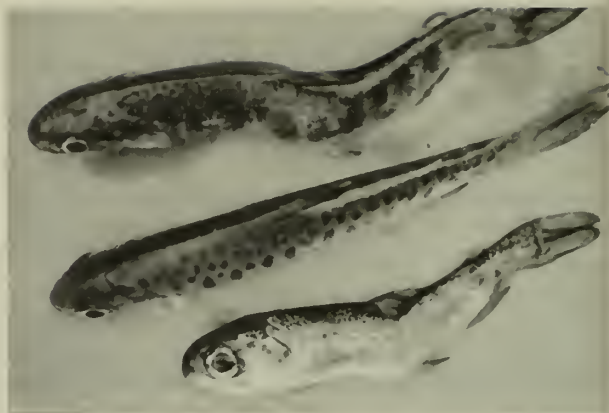
*Blood ATP levels.*—Blood ATP (adenosine-triphosphate) levels were obtained on five groups of steelhead held at constant temperatures of 6, 10, 12, 14 and 15° C, and coho salmon held at 10° C. Steelhead held at 6° C and the coho salmon showed an increase in blood ATP levels during April, May, and June (the highest level occurred at the end of May) and a decrease in July and August. Thus, blood ATP levels in these fish followed a pattern of changes similar to that in gill

ATPase activity during parr-smolt transformation, and may provide an additional means of smolt identification.

*Benzidine oxidation in blood of salmonids.*—The mechanism of benzidine oxidation in blood has been studied and enzymes have been identified which are responsible for the marked difference between steelhead and coho salmon in the degree and rate of oxidation of organic dyes. These tests have a significant bearing on the ability of fish to detoxify certain toxic materials and may indicate why rainbow trout are more susceptible than coho salmon to these toxicants.

*Vitamin C activity of ascorbate compounds.*—Ascorbic acid, ascorbate-2-sulfate ( $C_2$ ), ascorbate-6-sulfate ( $C_6$ ), and iso-ascorbate-2-sulfate (iso- $C_2$ ) were fed as the sole vitamin C source to groups of rainbow trout and coho salmon from first feeding. At the termination of the feeding trials representative groups from each treatment were held without feed to test stamina. It appeared that  $C_2$  was equal to ascorbic acid on an equimolar basis, but that iso- $C_2$  and  $C_6$  had very little activity. Coho salmon have a lower requirement or are better able to conserve stores than are rainbow trout, as indicated by later discoloration and deformities. The requirement for good appetite and growth appeared to be near the equivalent of 5 mg L-ascorbic acid per 100 g of diet. However, for maximum stamina the requirement is somewhat higher.

*Histopathology of wound healing.*—The histopathology of wound healing was investigated with rainbow trout and coho salmon reared on test diets containing 5, 10, and 100 mg ascorbic acid/100 g dry diet. After 45 weeks on test, the skin of all fish was punctured in the midventral line and in the region midway between the lateral line and the dorsal fin. Wounds were closed with a single suture. After 21 days, all fish were sacrificed and examined for repair. The amount of healing varied, depending on the nature of the wound, i.e., whether or not scales were driven into the wound and whether or not appreciable amounts of clotted blood remained in the wound when samples were taken. Regardless of the diet, none of the wounds were entirely healed. Healing was



Symptoms of scurvy in coho salmon induced by a dietary deficiency of vitamin C. The deficiency has caused curvature of the spine in the top and bottom fish; the center fish is normal. (Western Fish Nutrition Laboratory photo)

most advanced in control fish (100 mg ascorbic acid) and least advanced in fish fed 5 mg ascorbic acid/100 g dry diet. There appeared to be no significant difference between coho salmon and rainbow trout in degree of wound healing.

*Scurvy symptoms in rainbow trout.*—After 34 weeks on a test diet containing no ascorbic acid, rainbow trout showed hemorrhagic areas on lips, gums, roof of mouth, and thymus gland. Massive hemorrhages were consistently found in areas of spine curvature. Tissues involved in these hemorrhages included spinal cord, spinal column, adjacent skeletal muscle, and kidney. After 35 weeks on test these fish showed some classical signs of scurvy, including defects or hemorrhages in cartilage bone, gums, and teeth.

*Spawning saltwater salmonids.*—Forty-three 4-year-old chinook salmon that had been raised in seawater for 3 years were spawned successfully directly from the seawater. The adults were returned to seawater after spawning but failed to survive longer than 60 days.

*Ascorbate-2-sulfate filed for patent.*—A patent was filed on August 8, 1972, on the synthesis and use of the ascorbate sulfates in various biological systems. Vitamin  $C_2$  (ascorbate-2-sulfate), iso- $C_2$  (the mirror image of  $C_2$ ), and ascorbate-6-sulfate were synthesized

and tested as sources for vitamin C for rainbow trout and coho salmon. The synthesis, biological testing, and chemical analysis of intermediates in tissues and metabolic end products was a cooperative effort between the U.S. Army Medical Research and Nutri-

tion Laboratory, Denver, Colo., University of Colorado, Boulder, and the Western Fish Nutrition Laboratory. Considerable interest has been generated throughout the world on the discovery of a biologically active and chemically stable form of ascorbic acid.

## FISH CULTURE

Commercial production of warmwater fishes constitutes a growing source of income for farmers in the southern United States. Research supported by the Bureau provided the basis for the early growth and development of this industry. Research on problems associated with the intensive production of fish—culture, selective breeding, nutrition, disease control, harvesting, water use, and pond management—is conducted at the Fish Farming Experimental Station, Stuttgart, Ark.; its field station, the Fish Farming Development Center, Rohwer, Ark.; and the Southeastern Fish Cultural Laboratory, Marion, Ala.

*Winter rearing of trout.*—Ponds used to produce channel catfish often lie idle during late fall, winter, and early spring. In an effort to develop a winter use for such facilities, six 0.04-ha ponds were stocked November 16, 1971, with rainbow trout weighing 23 g each and averaging 11.4 cm total length. They were fed a low-cost commercial catfish ration. At harvest on March 20, 1972, their average weight and total length were 54 g and 18 cm. Gross yield ranged from 600 to 1,010 kg/ha. Food conversion averaged 1.18. This value does not reflect an unknown amount of natural food gleaned from the ponds. Survival approached 100% in all ponds.

*Buffalofish culture.*—Hybrid buffalo consistently yield better growth than do the parent species. Because of increasing market demand for buffaloes, an interest has developed in producing these hybrids for human consumption and in determining if they might be reared in ponds with catfish without detrimental effects.

Hybrid buffalo were stocked at 494/ha in 0.1-ha ponds with 4,938 channel catfish per

hectare. The presence of the buffalo had no effect on the growth of catfish and the growth of the buffalo was similar to that of fish in ponds that contained only buffalo. An average of 200 kilograms of buffalo was harvested from ponds stocked with the combined species.

*White amur as a biological control for vegetation.*—The white amur was introduced into the United States from Asia by the Bureau in 1963 and more recently by private fish farmers. This exotic fish feeds on aquatic vegetation and has been proposed for use to control weeds in ponds on fish farms or in sport-fishing waters.

Inasmuch as the effects of white amur on native sport fish and fish farming could be predicted if its food requirements were known, studies were conducted to determine food utilization and nutritional requirements of white amur fed either fresh aquatic vegetation (*Elodea*) or pelleted feeds.

A study of nutrient cycling revealed that white amur excreted all of the nitrogen and 56% of the phosphorus in aquatic plants they consumed. This resulted in an increased rate of recycling of these elements.

Energy metabolism studies suggested that white amur effectively convert vegetation into fish flesh. Their relatively inefficient digestion is apparently compensated by a low rate of respiration. White amur fed mature aquatic vegetation were unable to maintain nitrogen balance, suggesting that their diet must include animals or vigorously growing vegetation.

The best weight gain of small (3-g) white amur fed various artificial feeds was made by fish fed diets containing expanded vegetable protein concentrates (cottonseed and soybean meals). Fish averaging 100 g reached a

weight of over 200 g in 6 weeks on processed feeds. Growth was improved when synthetic enzymes were added to the feeds.

*Fish as biological controls for mosquitoes.*—Mosquitoes produced in rice fields are a nuisance and health hazard in the lower Mississippi River Valley. Fish have been proposed as biological controls for these pests, to reduce the use of chemical insecticides.

Seven species of fish were produced for use in field tests conducted in cooperation with the University of Arkansas, related to mosquito control studies in rice fields. Fingerling fish were released in 15.3 m-square rice plots, replicated three times. Plots were drained, reflooded and stocked with fish three times during the season.

Mosquitofish (*Gambusia affinis*), carp, and white amur were most effective and produced 100% control of mosquito larvae 48 hours after introduction. Bigmouth buffalo were least effective, giving less than 10% control. Carp X goldfish hybrids, goldfish, and black buffalo afforded 40% control.

Mosquitofish were released in four fields of 8 ha each at rates of 125, 250, 500, and 750 per hectare. A 16-ha field was stocked at 1,625 per hectare and several 1-acre fields at 2,500, 5,000, or 12,500 fish per hectare. It was demonstrated that mosquito fish can live under conditions existing in Arkansas rice fields and that they will disperse throughout a field, reproduce, and effectively control mosquitoes.

*Effects of stocking density and water exchange rate in container culture of channel catfish.*—Effects of various stocking densities and exchange rates on net yield, average size, feed conversion, and survival were determined for channel catfish reared in 1.6-m<sup>3</sup> tanks. Net production was highest at densities between 360 and 576 fish/m<sup>3</sup>, decreased at densities below 360 fish/m<sup>3</sup>, and was nil at 706 fish/m<sup>3</sup>. As stocking density increased, average size, feed conversion efficiency, and survival all decreased.

Water exchange rate in the tanks had less effect than stocking density. Exchange rates of 1.5, 1.0, 0.75, and 0.5 hours per exchange yielded equally good growth and survival; a rate of 2 hours per exchange depressed production, average size, and feed conversion.

*Effects of stocking size and rate on growth of channel catfish in raceways.*—The effects of stocking size and stocking rate on the growth of channel catfish were studied in raceways 2.8 m long, 46 cm wide, and 22.9 cm deep, each having a water inflow of about 23 l per minute. Water for the raceway system was pumped from a 0.04-ha pond. Water levels in the pond were maintained by water from a 214-m-deep well or from a 7.2-ha storage reservoir.

Two sizes of catfish, 272 and 181 g, were stocked at rates of 66 or 33 fish per tank. Three replications of each of the four combinations were used. Prior to stocking, and at four other periods during the growing season, samples of the effluent water from each tank were analyzed for dissolved oxygen; BOD; pH; alkalinity; ammonia-, urea-, nitrate-, and nitrate-nitrogen; ortho-phosphate; temperature; and coliform bacteria. The fish in each tank were fed twice daily, 5 days per week, at the rate of 3% of body weight per day. All fish were harvested after 198 days.

A relation between stocking size and stocking rate on the standing crop at harvest was noted. At the low stocking rate (33 fish), the standing crop was approximately 65 kg/m<sup>3</sup> regardless of the size of fish stocked. At the high stocking rate (66 fish), the larger fish reached a greater standing crop (122 kg/m<sup>3</sup>) than did smaller fish (107 kg/m<sup>3</sup>). Stocking at the lower rates or with the larger fish both resulted in larger fish at harvest.

When water characteristics were correlated with the standing crop of fish, ortho-phosphate and pH were negatively correlated and total coliform counts and alkalinity were positively correlated. No other significant correlations were noted. The results suggested that little damage is likely to be caused in the environment by effluents from raceways such as those used in this study. Maximum BOD added to the environment was 1 kg/100 kg of fish per day.

*Selective vs. "one-time" harvesting.*—Four 1.6-m<sup>3</sup> circular tanks were each stocked with 288 channel catfish (i.e., 180 fish/m<sup>3</sup>). When individual fish reached the marketable size of 454 g, 10 of the larger individuals were removed from two tanks biweekly until the

final harvest at 177 days. The 10 fish removed were replaced each time with 7 small fish. Fish in the other two tanks were harvested after 177 days. Although total yield per tank was similar for all four tanks, net yield was greatest for the "one-time" harvest units. Production in these tanks was 88.0 kg compared to 74.5 kg for tanks in which fish were selectively harvested. Average weight was 504 g in the "one-time" harvest tanks and 476 g in the selectively cropped units. The selectively harvested fish, however, were much more uniform in weight and consumed less feed, apparently because of the periodic removal of the more aggressive fish.

*Culture of game fishes in raceways.*—Attempts were made to rear game fishes in small rectangular raceways of 1.6 m<sup>3</sup> capacity. White crappies refused to take pelleted feed and failed to grow. Largemouth bass taken from a pond at a length of 3.8 to 5.7 cm were trained to take 1.6-mm diameter pellets, and grew well; this species shows good potential for raceway culture. Striped bass grew to a size of only 12 g during their first year in a pond, but achieved good growth when fed pellets in a raceway during their second growing season.

*Development of inbred lines by gynogenesis.*—Inbred lines are used in breeding systems in which males of one line are crossed with females of a different line to produce progeny which show heterosis and are genetically uniform. Inbred lines require 15 to 20 generations of brother-sister mating; many of the lines die before reaching useful levels of inbreeding. Gynogenesis is a method by which highly inbred individuals can be produced in one generation.

In preliminary work, sperm of blue catfish and channel catfish were exposed to 100,000 R of X-ray. This dosage destroyed the chromosomes of the spermatozoa but did not immobilize them. The irradiated sperm was water-activated and placed in contact with hormone-ovulated eggs from channel catfish. The eggs were later "heat-shocked" or "cold-shocked" to cause absorption of the second polar body and thus bring about the usual diploid condition.

About 20 variables were tested. In some

tests, embryonic development was noted but no eggs hatched. Life span of the irradiated sperm in the excised testes exceeded 3 days when refrigerated. Motility of the water-activated irradiated sperm was identical to that of nonirradiated sperm.

*Physical and chemical properties of the immunoglobulins of channel catfish.*—Rainbow trout and channel catfish produce two types of immunoglobulins. Channel catfish produce immunoglobulins of different molecular weights—14S and 7S—when injected with dinitriphenylated proteins. When catfish immune macroglobulin labeled with iodine-125 was passively administered to six adult channel catfish, periodic removal of blood followed by gel filtration of the samples on Sephadex® G-200 revealed no conversion of 14S to 7S immunoglobulin. Clearance of the passively administered macroglobulin was linear with time. Extrapolated half-life of the radiolabeled macroglobulins ranged from 100–118 hours.

*Nutrition of channel catfish.*—Feed costs make up 35 to 50% of the expense of producing channel catfish, and represent the largest single expense. Improved efficiency must be developed if fish farmers are to meet rising costs of production. Variations in feeding patterns, formulation, and processing represent possible ways to cut costs.

Inasmuch as channel catfish grow slowly at low water temperatures, the feeding of high nutrient-density rations during the winter may not be economical. To test growth response to selected protein levels at different water temperatures, we stocked 0.1-ha ponds with channel catfish fingerlings at the rate of 4,938 per hectare. Protein content of the feed was held at 25% (by replacing some soybean meal with cereal filler) when water temperature was below 24° C; at 30% when water temperature was 24–27° C; and at 35% when temperatures rose above 27° C. This program of "phase feeding" was reversed in the fall as water temperatures fell. As controls, similarly stocked ponds were fed continuous rations of 25, 30, and 35% protein. All treatments were run in triplicate. Total time on feed was 182 days.

Fish growth improved with each increase in protein in the feed, and the amount of

protein fed and fish production were significantly correlated. No other relationships were statistically significant. Feed cost per pound of gain was lowest in the phase-feeding program, but income was highest when the 35% protein ration was fed.

Modifications of the formula for the standard station diet were tested in an attempt to increase growth and reduce cost. Results indicated that a "new standard" formula in which some fish meal was replaced with equivalent protein from poultry byproduct meal and whey, and to which dicalcium phosphate was added, provided fish growth equal to that provided by the "old" standard formula (which contained 12% fish meal). When fish meal was replaced with dried brewer's yeast, growth decreased below that provided by the old standard formula, possibly due to the lower protein content. Cottonseed meal cannot be used to completely replace soybean meal although previous tests have shown that half (10% of the total formula) may be replaced with cottonseed meal with no reduction in fish growth. A commercial feed containing 30% protein did not produce growth comparable with that of test feeds produced at the laboratory.

Hardness and stability of pellets were improved by oven-drying after extrusion. Moisture content of oven-dried pellets was 5%. The increased surface hardening resulting from the drying process decreased the amount of fines usually present in pelleted feeds. Oven drying did not reduce nutrient value of feeds. The addition of 1-1.5 kg/metric ton of "Por-Rok," a cement concentrate, improved pellet hardness, decreased fines, and increased water stability.

*Nutrition of striped bass.*—Yolk-sac striped bass fry were stocked in linear troughs supplied with aerated well water at about 21° C. Several methods of agitation and aeration were developed that kept the fry dispersed, and reduced mortality from smothering.

A slight feeding response was observed 5 days after hatching. A ration consisting of fresh shrimp, raw liver, cooked fish, fish oil, and crystalline vitamins bound with carboxymethyl cellulose (CMC) was offered. During the same period, a CMC-bound purified diet was also offered. Most fish vigorously at-

tacked the food particles but amounts actually consumed could not be determined. Acceptance of the rations appeared to increase through day 5, but decreased during days 6 and 7 and ceased on day 8. Extensive mortality occurred during days 8-10 but some fry were still alive as late as day 15.

In companion studies, 6,700 pond-reared striped bass about 1 inch long were stocked in circular tanks 4 or 5 feet in diameter, supplied with well water at about 21° C. Fish were initially trained to eat CMC-bound beef liver and later a CMC-bound 40% casein purified ration. Thus, it appears that it will be possible to determine the nutritional requirements of this species.

*Disease control in tanks and raceways.*—Over a 2-year period, channel catfish, channel catfish X blue catfish hybrids, white catfish, black bullhead, largemouth bass, striped bass, and white crappie were cultured in both well water and recycled water. The following pathogens have been encountered in the tanks and raceways: *Aeromonas liquifaciens*, myxobacteria, *Trichodina* sp., *Chilodonella* sp., *Costia* sp. and an unidentified parasitic alga.

Channel catfish were particularly susceptible to *Aeromonas liquefaciens* and *Chilodonella*. Striped bass were highly susceptible to myxobacteria. Catfish hybrids appeared to be resistant to *A. liquefaciens*, but acquired all other infections of channel catfish. Largemouth bass appeared most resistant to parasites and diseases that were identified.

Nitrofurazone® in the ration and Combiotic® as a water additive temporarily controlled *A. liquefaciens* and myxobacteria, respectively. A mixture of 0.1 ppm malachite green and 25 ppm formalin provided excellent control for protozoan parasites and 1.0 ppm copper sulphate inhibited growth of parasitic algae.

*Plistophora ovariae*, a sporozoan parasite which destroys the ovaries of golden shiners, is considered a limiting factor in the production of this important baitfish. As part of a search for control measures, six 0.04-ha ponds were stocked with adult golden shiners infected in *P. ovariae*. From February 14 to March 13, these fish were fed rations containing nitrofurazone at rates of 2.75, 1.38, or 0



g/kg of feed. Each treatment was done in duplicate. Examinations made in April, June, and September revealed no trophozoites or spores in fish receiving nitrofurazone. Spawning occurred in all ponds and abundant fry were observed on May 15. However, production was significantly higher in the control ponds than in the treatment ponds. Thus, while it appears that nitrofurazone effectively inhibited development of *P. ovariae*, further study is needed to determine if the drug reduced production.

*Thelohania*, a species of microsporidia that is the causative agent of porcelain disease of crayfish in Europe, caused large-scale losses of crayfish on a private fish farm in Arkansas. Transmission was achieved in the laboratory by feeding spore-laden tissues to healthy crustaceans. Medication with nitrofurazone at 2.75 g/kg of feed had no effect on the course of experimental infections.

*Ophryoglena* (a ciliated protozoan parasite closely related to *Ichthyophthirius*), which causes major losses of guppies, was observed on all developmental stages of fish. It was most prevalent in the uterus of adult females; males and juveniles were often free, or nearly free, of parasites. Trophozoites were observed encysted in gill tissue; adults and tomites were abundant on the gills and body of moribund fish. Sodium chlorite applied at rates up to 15 ppm failed to kill or inhibit *Ophryoglena* on guppies and also had no effect on *Ichthyophthirius* infections in channel catfish.

Ciliate-infected golden shiners were reported during the year from separate locations in Arkansas. The causative agent was identified as a species of *Hemiophrys*, a protozoan parasite of white amur in the USSR. The parasite was controlled successfully by the application of 2 ppm potassium permanganate in one case, and 0.1 ppm malachite green in the other.

*Effect of endrin on the reproduction of warmwater fish.*—Largemouth bass, goldfish, and channel catfish were stocked into six 0.1-acre earthen ponds during November–December, 1971. Endrin was added to the water in two ponds and to the feed (1.0  $\mu\text{g/g}$ ) offered the fish in two ponds; the remaining two ponds served as controls.

Weekly addition of 0.1  $\mu\text{g}$  endrin per liter of water cumulated and reached 0.25  $\mu\text{g}$  in 21 days. Bass and goldfish exhibited erratic behavior, including swimming in circles, loss of equilibrium, or rapid swimming for several minutes, followed by a complete loss of swimming ability, failure to feed, and death. Analysis of dead fish showed concentrations as high as 2.4  $\mu\text{g}$  endrin per gram of tissue. Weekly additions of 0.05  $\mu\text{g}$  endrin per liter of water were tolerated by the fish, and erratic behavior and mortality ceased.

In March 1972, goldfish from the control ponds and the endrin-fed ponds were paired and hormone-spawned in aquariums. Egg mortality ranged from 2.8 to 4.0%. Differences between groups were not statistically significant. Hatching success of the control group, and control male or female paired with an endrin-fed male or female, ranged from 70.5 to 76.3%. In contrast, hatching success of endrin-fed pairs averaged 55.8%.

Also in March, the largemouth bass were stocked into 0.05-acre ponds containing spawning mats. Spawning by groups exposed to endrin in the food or water was insufficient to permit statistical analysis. In general, however, spawning success and hatchability appeared to be better among the controls, followed by the endrin-fed group and then the endrin-water-treated group. Inasmuch as percentage of spawns and hatchability were much lower when the treated male was one of the spawning pair, males may be more susceptible than females to the effects of the pesticide. Eggs from bass exposed to endrin in the diet and in the water averaged 0.56 and 0.29  $\mu\text{g}$  endrin per gram of tissue, respectively.

Channel catfish were netted from the ponds in mid-May, paired, and stocked into aquariums. Females were injected with human chorionic gonadotropin to induce ovulation, and the spawns removed from the aquariums for artificial incubation. Spawning and hatching success were best for the control fish, followed by control males crossed with endrin-exposed females, and poorest for endrin-exposed males crossed with control females or with females exposed to endrin. From 10 to 31% of the fry from broodfish containing the higher levels of

stored endrin showed spinal curvature. Endrin content of eggs from catfish exposed to endrin in the diet and in the water ranged as high as 0.10 and 0.45  $\mu\text{g}$  endrin per gram of tissue, respectively.

*Tag retention.*—A tag retention study was begun to determine if “anchor” tags applied with a Dennison tagging gun would be suitable for identifying individual channel catfish. Two hundred channel catfish averaging 454 g were individually weighed, tagged, and released into a 0.1-ha pond. Floy FD-67 anchor tags were inserted at a 45° angle into the left side of each fish just below the dorsal fin. Care was taken to position the tag in such a way that the anchor was past the dorsal fin rays. Tag retention was monitored weekly by examining samples of fish seined from the pond; then after 12 weeks, the pond was drained.

About half the tags were lost during the first 2 weeks of the test, and 70% by the end of 12 weeks. Tags worked best on small fish: tags were retained by 36% of the fish weighing less than 454 g and only 18% of the fish weighing 454 g or more.

Examination of the Floy FD-67 tag indicated that the leader between the spaghetti tubing and the toggle-like anchor was often too short to allow the toggle to open behind the dorsal fin rays. This deficiency would account for the difference in tag retention in relation to fish size, since the probability of the anchor locking behind the fin rays was higher for the smaller fish.

*Trapping pond-raised channel catfish.*—Experiments were conducted with traps for harvesting pond-raised channel catfish. These traps were enclosures constructed of nylon webbing (drop seines) or of screen-covered panels (panel traps) placed around demand feeders in a 64.8-ha pond.

Fish were captured as they congregated to feed. The most effective procedure seemed to be that of withholding feed for 24 hours, then offering a limited amount 5 to 20 minutes before harvest; catches ranged from 226.8 to 3,323.5 kg of channel catfish in the drop seine

and from 278.5 to 1,714.6 kg in the panel trap. It took 3 to 7 days for normal feeding to resume within the enclosures after a trapping operation.

*Electrical grading of fish.*—Attempts were made to utilize electrical stimuli to separate fish according to size. Channel catfish were placed in an electrical field which stimulates electrotaxis toward an open-bar anode consisting of vertical parallel conduit spaced 4.5 cm apart. Small fish can pass between the bars into an electricity-free area while larger fish are retained. In tests, the electro-bar grader was up to 90% effective in separating fish weighing less than 454 g from those weighing more than 454 g. Both constant DC and pulsed DC proved effective but pulsed DC gave more predictable results.

*Increasing capacity of hauling equipment.*—Methods of increasing payloads in hauling catfish are under study in an artificial device designed to simulate hauling conditions. Test periods of 4 hours are used with the simulator adjusted to duplicate a truck speed of 80.5 km per hour. Channel catfish are loaded into the simulator tanks and control groups of fish are held in similar tanks located beside the machine. After testing, fish are returned to holding facilities for 30 days post-treatment observation. During the tests,  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{CO}_2$ , pH, and water temperatures are monitored at 1/2-hour intervals. Test results are judged on these physical-chemical factors and fish survival during the test and 30-day post-treatment holding periods.

Although most of the effort on this project was devoted to establishing test procedures and obtaining and installing equipment, several groups of fish have been tested. The following data illustrate water quality changes recorded over a 4-hour test period. For fish loaded at 1.4 kg per 3.8 l of water,  $\text{N}_2$  rose from 0.50 ppm to 6.25 ppm,  $\text{O}_2$  dropped from 8 ppm to 4 ppm,  $\text{CO}_2$  rose from 5 ppm to 25 ppm, and the water temperature ranged between 24.5 and 25.5° C. Overall survival for this group of fish was 84%.

## FISH GENETICS

*Development of rainbow trout control populations.*—Two random-bred laboratory control populations were established during the past 1-1/2 years. All unselected stocks were sampled biweekly throughout the spawning season from August 1971 through March 1972. These samples (each representing 10 or more parents) were reared to 1 year of age, then systematically pooled to form a fall (August through mid-December) and a winter (mid-December through March) spawning group, with each group containing 500 fish representing at least 200 pairs of parents. This procedure was repeated in 1972-73 to generate a replicate set of lines for each season. These two populations are expected to serve the control function effectively (without significant effects of inbreeding or natural selection) for 20 to 30 years. Random-bred pools of fish of the 1971 year-class are being maintained until the control populations are established.

*Some effects of inbreeding in rainbow trout.*—Study of the effects of inbreeding continues. Data collected during the past 3 years from 146 inbred (25.0%) and outbred half-sib pairs from both male and female common parents indicates that the overall effects of inbreeding depression are considerable. Inbreeding depression in percent hatch, percent fingerling survival, and weight gain resulted in a 36.4% loss in total fish weight at 150 days.

*Selection for growth in rainbow trout.*—The growth selection program entered the third generation of selection in September with the start of breeding for 1973 fiscal-year-class experimental siblots. The fall spawning segment of this program was completed in December after production of 150 siblots for early growth evaluation. After 150 days, the mean fish weight of the 1972 lots from good-growth matings averaged 2.5 times greater than that of lots from poor-growth matings; fish in the formalin-tolerance groups and control lines exhibited intermediate growth. Thirty-nine growth lots (28 good and 11 poor) were retained for further evaluation or future breeding; the good-growth fish averaged 4.1 times heavier than poor-growth fish.

The measurement of the 1-year performance of 1971 lots in the growth selection program was completed. The mean fish weights for good growth (67 lots) and poor growth (32 lots) were 203.2 and 32.8 g, respectively—a 6.2-fold difference.

Correlations of 150-day weight with 189-day and 364-day weight were 0.80 and 0.39, respectively, for the 1971 lots, after removal of gross selection program effects. These values, which represent relatively uniform groups, show that the 150-day weight is a valid indicator of later growth. A comparison of lot ranking at the 150-day and 364-day ages revealed that changes in rank were limited primarily to lots differing by less than 1.0 g in average 150-day fish weight.

Heritability estimates of 150-day weight were updated during the past year. For 603 progeny families out of 85 parental families, estimates were 0.29 ( $\pm 0.11$  S.E.) for the parent-offspring regression and 0.26 ( $\pm 0.12$  S.E.) for the half-sib correlation analyses. These estimates were made after removal of the effects of spawning seasons and parent age, which have tended to bias previous estimates.

*Selection for formalin tolerance in rainbow trout.*—Formalin tolerance at 150 days of age, measured by LC<sub>50</sub> value based on the 24-hour mortality resulting from 6-hour exposure to six flowing test concentrations, was determined for most of the 1972 fiscal year-class lots. The formalin tolerance of growth lots ranged from resistant to susceptible, with most tending to fall in the intermediate category, as did the control lines. Random mating of selected lots within the populations being studied for formalin tolerance shows that the two populations are continuing to diverge, though ranges of tolerance still overlap. The mean LC<sub>50</sub> value of the resistant population was 2.4 times greater than that of the susceptible population. Of the lots selected for future breeding, the LC<sub>50</sub> of the resistant group averaged 3.5 times that of the susceptible group.

A series of studies were conducted during the spring of 1972 to find the relationship between the laboratory standard test (6-hour

flowing test at 150 days) and four test situations at 108 days of age (6-hour flowing test and 1-, 6-, and 24-hour static tests). Results indicate that standard test values can satisfactorily be used to predict 108-day 6-hour flowing ( $r=0.91$ ) and 6-hour static ( $r=0.65$ ) tests, but cannot be used to predict 1- or 24-hour static tests.

Production of the 1973 fiscal year-class siblots for formalin tolerance evaluation was started in the fall of 1972 and is still in progress. All parents in the 1973 mating designs were selected on the basis of their lot performance measured by  $LC_{50}$  determinations, as opposed to survival in a single concentration (the selection criteria used until 1969). The results obtained from the evaluation of these progeny should permit the calculation of better estimates for the heritability of formalin tolerance.

*Blue color variant in rainbow trout.*—A blue color variant has been observed from time to time during the past several years, particularly in fall spawning fish derived from Manchester and Wytheville stocks. The trait, a deep metallic blue color over the entire body, first appears at approximately 10 to 14 months of age and disappears shortly before the onset of maturity at 2 years of age. Only a small fraction of fish retain the blue color after 2 years of age and in these the color tends to fade into lighter shades of blue and blue-brown. During the fall of 1971, when a record was first made of the frequency of occurrence and growth rate of the blue fish, it was observed that they tended to be larger than their normally colored sibs. Forty lots—12 in 1971 and 28 in 1972—contained from 2 to 28% blue fish. The mean year weight of the blue fish of these lots was 22.5% heavier than that of their normally colored sibs in 1971 and 25.8% heavier in 1972.

During the fall of 1972, 40 mixed 2- and 3-year-old fish known to have been blue at 1 year of age were checked for sexual maturity. Of the 40 fish, 34 ripened and were spawned to produce 21 progeny lots of blue x blue or blue x normal matings. None of these fish produced sterile sex products and all produced viable progeny up to the fingerling stage. Average percent hatch was 66.1

(range, 21.4–92.8%). Six fish (one 3-year-old and five 2-year-olds) did not mature, but none were diagnosed as sterile. The planned evaluation of these lots for blue color should yield substantial information on the mode of inheritance of this variant.

*Rainbow trout swimming performance.*—Performance curves, based on swimming time in a stamina tunnel, were established for random-bred pools of three rainbow trout strains (Manchester, Sand Creek, and New Zealand). Three stamina tests (50 fish per test) were run at biweekly intervals for 22 weeks to establish these curves; fish sizes ranged from 3 to 30 g. No difference in slope of the curves was found between strains although the performance for any particular sized fish was slightly higher for the semi-wild New Zealand and Sand Creek strains than for the more domesticated Manchester strain. All 1972 experimental lots (families kept for fast growth, poor growth, formalin resistance, or formalin susceptibility) reaching 189 days of age were stamina tested. The results indicated that swimming ability was not correlated with formalin tolerance or growth traits, but reflected lot origin. Manchester, New Zealand, and Sand Creek family performance approximated that established for the respective pools of these strains. These results suggest that the stamina tunnel may be a useful tool for the characterization of strains.

*Rearing units for fingerling rainbow trout.*—Loading capacity studies of three circular rearing units for small fingerlings were conducted last year with random-bred fish from fall and spring matings. Three rearing units were used: Unit 1 was a plastic pail 9 inches deep and 10.5 inches in diameter, with perforated bottom. Inflow rate was 3.0 l per minute gravity flow. Groups of 10 pails each were immersed in a 4-foot circular tank with center standpipe and drain. Unit 2 was a polyethylene tub 14 inches deep and 11 inches in diameter, with perforated bottom. Inflow rate was 3.0 l per minute gravity flow. Groups of five tubs each were immersed in a 3-foot circular tank with centered outlet and outside standpipe. Unit 3 was a polyethylene tub 18 inches deep and 15 inches in diameter, with centered screened bottom outlet and

outside standpipe. Inflow of 1.8 l per minute was introduced under 35 psi by flexible-orifice flow regulators.

Fingerling growth at different loading levels was assessed for each of the rearing units in two series (spring and fall) of tests. The results, coupled with growth data for intervening periods and measurements of fingerling mortality and water quality, permit the following conclusions: (1) Unit 1 is suitable for rearing fingerlings from 77 to 168 days of age without significant adverse effects on growth if the load does not exceed 0.5 kg; (2) unit 2 with either 12.5 or 17.1 l of water is suitable for rearing fingerlings from 77 to 210 days of age without significant adverse effect on growth if the load does not exceed

1.0 kg; (3) unit 3 is suitable for rearing fingerlings from 126 to 231 days of age without significant adverse effect on growth if the load does not exceed 2.0 kg; and (4) a general trend was observed for reduced attained weights to be reduced as loading densities increased in all three rearing units, with a significant increase in the rate of depression when the above loads were exceeded.

In supplemental tests, fish reared at the lowest levels (0.5, 0.5, and 1.0 kg) in each of the three rearing units to 150 or 189 days of age were transferred to 4-foot circular tanks. Growth measurements in the 4-foot tanks to 238 days of age revealed no significant differences in attained weight.

### SIERRA NEVADA AQUATIC RESEARCH LABORATORY

The Sierra Nevada Aquatic Research Laboratory is in the Sierra Nevada Mountain Range near Bishop, Calif. The current research program is designed to obtain fundamental knowledge of fish biology and to apply such knowledge to beneficial management practices. At the present time a reprogramming of the function of this facility is being considered.

*Effects of hatchery-reared rainbow trout on stream ecology.*—The impact of hatchery-reared rainbow trout on stream food supply was determined by stocking replicate groups of 4, 8, 16, 24, and 32 fish in a 15 m section of stream and evaluating both food organisms escaping downstream and stomach content of the fish. Average feeding rate declined with increased density whereas total food eaten per group was highest at 24 fish. Hatchery-reared fish apparently have limited impact on stream food supply but through social interactions effectively limit individual ration.

To determine whether density equalizing mechanisms work more effectively in riffle

habitat than in pool habitat, populations of rainbow trout were established in an observation stream and then periodically removed. The result of this study indicates that point of stocking is very important in determining subsequent distribution.

*Pond evaluation studies.*—A comparison of feeding and growth between the Whitney and Coleman Kamloops strains of rainbow trout revealed no detectable differences between strains.

Comparisons of interactions and food preferences of rainbow trout and Sacramento perch revealed that both species utilized essentially the same food and that the perch could spawn successfully in the presence of rainbow trout.

*Physiological studies.*—A study of serological differences of trout strains using the endangered Lahontan cutthroat is currently being evaluated. Stress studies in stamina tunnels indicate that cumulative stress could prove lethal to released hatchery-reared Lahontan cutthroat trout.

## COOPERATIVE WILDLIFE RESEARCH UNITS

In its 38th year, the Cooperative Wildlife Research Unit Program is operating in 20 States. Each Unit is supported and administered under a memorandum of agreement signed by the Bureau, the Wildlife Management Institute, and the respective universities and fish and game departments of the cooperating States. Objectives of the program remain unchanged in 1972; they are to: (1) conduct research basic to the management of wildlife resources, (2) facilitate the training of wildlife personnel at the graduate level, (3) provide technical assistance to conservation agencies in wildlife management programs, and (4) promote education in natural resources through demonstration, lecture, and publication. Unit leaders and assistant leaders are employed by the Bureau.

*Training and research accomplishments.*—The direct contribution of the Units to training and research is largely at the graduate level. During the 1971-72 school year universities in the Unit program graduated 112 wildlife students with master's degrees and 33 with doctor's degrees. Approximately 53% of the recipients of advanced degrees received financial or other aid from the Units. The total of 145 recipients of advanced degrees represents a slight decrease over the total of 156 for the 1970-71 school year.

Research in the Unit program is carried out by the Unit leaders, assistant leaders, and faculty members as well as by the graduate students who must submit theses for their degrees. During the 1971-72 school year, the 20 Units listed 440 research projects of which 88 were completed. These projects included studies of a wide variety of birds and mammals and a few reptiles and amphibians. They were directed toward studies of life history, biology, ecology, animal damage control, wildlife administration, effects of environmental pollutants on wildlife,

and recreational aspects of the wildlife resource.

Results of some of the projects are reported under appropriate activities of the Division in this report. Publications resulting from the Unit program are listed.

*Employment of Unit graduates.*—Of the 8,143 individuals trained in wildlife conservation at Unit schools since the program began in 1935, many now hold responsible positions in State and Federal agencies charged with natural resources administration, management, and research. About 83% of the students graduating in 1971-72 obtained employment in wildlife or related fields:

Wildlife or fisheries research or management ..	79
Teaching wildlife, fisheries, or related subjects	11
Law enforcement .....	1
Public relations .....	4
Related fields .....	2
Returned to college for additional studies ----	23
Other fields, military service, or unknown ----	25



Biologists of the State University and the Cooperative Wildlife Research Unit in South Dakota provide in-service training for personnel of the Department of Game, Fish and Parks. (Photo by Donald C. Hales)

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# APPENDIXES

## A. DIRECTORY<sup>1</sup>

### Division of Fishery Research

#### Washington Office

Hester, Dr. F. Eugene -----Chief -----Room 552, Matomic Bldg., Washington, D.C. 20240

#### Eastern Fish Disease Laboratory

Wolf, Dr. Ken -----Director -----R.D. 1, Box 17, Kearneysville, W. Va. 25430

#### Western Fish Disease Laboratory

Rucker, Dr. Robert R. -----Director -----Sand Point Naval Air Station, Seattle, Wash. 98115

#### Tunison Laboratory of Fish Nutrition

Rumsey, Dr. Gary L. -----Director -----Cortland, N.Y. 13045

#### Western Fish Nutrition Laboratory

Halver, Dr. John E. -----Director -----Cook, Wash. 98605

#### Fish Genetics Laboratory

Bridges, Walter R. -----Acting Director -----Beulah, Wyo. 82712

#### Sierra Nevada Aquatic Research Laboratory<sup>2</sup>

Reimers, Norman -----Director -----Star Route 3, Box 198, Bishop, Calif. 93514

#### Fish Farming Experimental Station

Sneed, Kermit E. -----Director -----Box 860, Stuttgart, Ark. 72160

#### Southeastern Fish Cultural Laboratory

Dupree, Dr. Harry K. -----Director -----Marion, Ala. 36756

<sup>1</sup> As of the end of 1972.

<sup>2</sup> Discontinued, June, 1973.



### **National Reservoir Research Program**

Jenkins, Robert M. -----Director -----113 South East St., Fayetteville,  
Ark. 72701

### **North Central Reservoir Investigations**

Benson, Dr. Norman G. -----Chief -----Box 139, Yankton, S.D. 57078

### **South Central Reservoir Investigations**

Duncan, Thomas O. -----Chief -----113 South East St., Fayetteville,  
Ark. 72701

### **Great Lakes Fishery Laboratory**

Tait, Dr. Howard -----Director -----Box 640, Ann Arbor, Mich. 48107

### **Southeast Reservoir Investigations**

Talbot, G. B. -----Chief -----Box 429, Clemson, S.C. 29631

## **Division of Wildlife Research**

### **Washington Office**

Baskett, Dr. Thomas S. -----Chief -----Room 515, Matomic Bldg., Washing-  
ton, D.C. 20240

### **Bird and Mammal Laboratories**

Banks, Dr. Richard C. -----Director -----Museum of Natural History, Wash-  
ington, D.C. 20560

### **Denver Wildlife Research Center**

Scott, Dr. Thomas G. -----Director -----Bldg. 16, Federal Center, Denver,  
Color. 80225

### **Migratory Bird and Habitat Research Laboratory**

Smith, Dr. Robert I. -----Director -----Laurel, Md. 20810

### **Northern Prairie Wildlife Research Center**

Nelson, Harvey K. -----Director -----Box 1672, Jamestown, N.D. 58401

### **Patuxent Wildlife Research Center**

Dustman, Dr. Eugene H. -----Director -----Laurel, Md. 20810

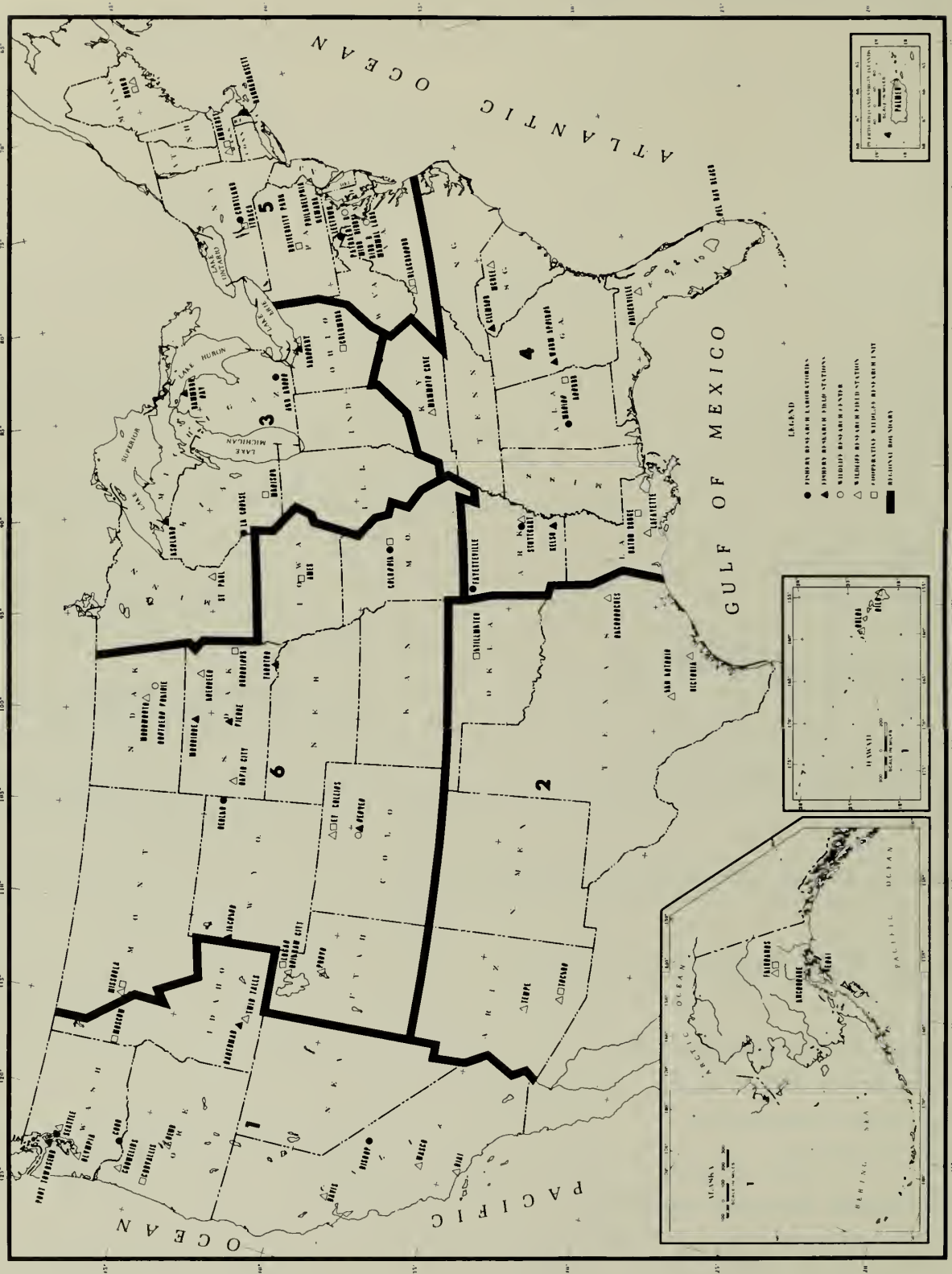
### **Fish Control Laboratories**

Lennon, Dr. Robert E. -----Director -----Box 862, LaCrosse, Wis. 54601

### **Fish Pesticide Research Laboratory**

Schoettger, Richard A. -----Director -----Route 1, Columbia, Mo. 65201

# B—LOCATION OF FISHERY AND WILDLIFE RESEARCH ACTIVITIES





The rare monkey-eating eagle is indigenous to the Philippine Islands where the population is estimated to be 20 to 40 individuals. (Photo by Glenn A. Hood)



Fishing on the Des Moines River (above), and hunting clapper rails in a Maryland marsh (below). Results of research are used in wildlife and fishery management to produce opportunities for recreational enjoyment of fish and wildlife. (Photos by Arnold O. Haugen, above; Brooke Meanley, below)

