Panfish literature review. Report 71 1971

Beard, Thomas D.
Madison, Wisconsin: Dept. of Natural Resources, 1971

https://digital.library.wisc.edu/1711.dl/AWKTX3X2JRKI68P r.v. 71

Loan c 10

PANFISH LITERATURE REVIEW*

By Thomas D. Beard

Wisconsin Department of Natural Resources
Box 450
Madison, Wisconsin 53701
1974

ABSTRACT

To provide direction for the development of a comprehensive study of slow-growing panfish populations, a review of the literature was made. The 8 species of panfish discussed in the review are bluegill, white crappie, black crappie, yellow perch, pumpkinseed, green sunfish, redear sunfish and longear sunfish.

Most of the bibliography is comprised of management oriented publications covering five major topics: population dynamics, environmental influences, biological influences, life history studies and current management techniques. Information from publications which appeared from the late 1920's through 1956 was obtained indirectly from the biological abstracts and directly from various serial publications and journals. Information from publications which appeared between 1956 and 1969 was obtained from Sport Fisheries Abstracts and miscellaneous publications, the most important of which were irregularly published papers by various state conservation agencies.

Hopefully this literature review will provide the fish manager with a reference source for information that may help him in developing management plans for various bodies of water. Of the major management techniques, liberalized fishing regulations and mechanical panfish removal show little promise of being able to control panfish densities. The success of drawdown and predator stocking seem to vary with the species composition and densities in individual lakes.

Guidelines for future research are apparent. The key to good panfish management appears to be the elimination of year classes. If so, the factors responsible for reducing or eliminating year classes under natural conditions must be determined. Secondly, inasmuch as chemical reclamation seems to be the best available management tool for panfish control, more work is needed on developing and testing certain chemicals that show promise as selective fish toxicants.

1000-56

---

*NOTE: This publication originally appeared as Research Report No. 71 in 1971. Although now out of print, copies of this report have been xeroxed in order to make it again available to interested biologists. In order to save paper, the original cover of the report has been omitted and bibliographic details added above. Otherwise, the xeroxed copies are identical to the original publication. Persons citing this report should use the first date of publication (1971) and the series number (Res. Rep. 71).

ACKNOWLEDGMENTS

I wish to thank all the people who have contributed in various ways to this project. Special thanks are due to Mrs. Penelope Black and Mr. Victor Fesolowitz for compiling the literature review material from the various abstracts and publications. Thanks are due to Howard E. Snow for advice in planning the review. I am indebted to Mr. Gordon R. Priegel for his advice in planning the review, aid in gathering reference material and review of the final manuscript.

I gratefully acknowledge the help of Mrs. Gen Morehead in locating material in the fishery research library. Thanks are also due to Mr. Lyle M. Christenson for his critical review of the manuscript.

This study was supported in part by funds from the Federal Aid to Wildlife Restoration Act, under Dingell-Johnson project F-83-R.

The author is a Fishery Biologist in the Bureau of Research, Spooner, Wisconsin.

Edited by Susan Hickey

CONTENTS

Introduction 4

Population Dynamics 4
    Population Size 4
    Age and Growth 5
    Assessment of Angler Harvest 6
    Summary 7

Environmental Influences 7
    Physical Features of the Lake Basin 7
    New Impoundments 8
    Temperature 8
    Water Chemistry 9
    Photoperiod 10
    Turbidity 10
    Summary 10

Biological Influences 11
    Feeding Habits 11
    Interspecific and Intraspecific Competition 13
    Behavior 13
    Disease 14
    Parasites 14
    Summary 15

Life History 16
    Early Life History 16
        Spawning Behavior 16
        Egg and Fry Production 16
        Feeding Habits 16
        Factors Involved in Year Class Formation 16
    Complete Life History 17
    Summary 18

Current Management Techniques 19
    Direct Action 19
        Chemical Reclamation 19
        Removal 21
        Liberalized Fishing Regulations 21
        Hybridization 22
        Hormone Injection 23
        Supplemental Feeding 23
        Stocking of Different Sex Ratios 23
    Indirect Action 23
        Drawdown 23
        Fertilization 24
        Aquatic Vegetation Control 24
        Predator Stocking 24
    Summary 25

Management Implications 27

Research Implications 27

Literature Cited 28

INTRODUCTION

Slow-growing panfish populations are a problem in many lakes, reservoirs, and farm ponds throughout the state, and indeed, the country. The Wisconsin Department of Natural Resources has proposed to conduct an intensive research program investigating this problem. The following literature review is the first step in developing a program that may provide a better insight into the problems concerning slow-growing panfish and improved direction to the research effort.

This review deals with the following species of panfish: bluegill, Lepomis marcrochirus Rafinesque; white crappie, Pomoxis annularis Rafinesque; yellow perch, Perca flavescens (Mitchill); black crappie, Pomoxis nigromaculatus (LeSueur); pumpkinseed, Lepomis gibbosus (Linnaeus); longear sunfish, Lepomis megalotis (Rafinesque); redear sunfish, Lepomis microlophus (Gunther) and green sunfish, Lepomis cyanellus Rafinesque.

To encompass the entire range of information on every subject dealing with panfish would be a tremendous task, so most of the bibliography is comprised of management orientated publications. Based upon this, the bibliography was divided into five major parts and only papers concerned with the following subjects were considered: population dynamics, environmental influences, biological influences, life history studies and current management techniques.

The bibliography covers the period from the late 1920's to early 1969. The material was obtained from over 70 different sources, the majority of which were serial publications, rather than one-time reports or reprints.

Information was first collected from a review of Sport Fisheries Abstracts for all panfish literature published in 1956 through early 1969. Other material from this period was obtained by a review of publications not summarized in the abstracts. The most important of these miscellaneous publications were irregularly published papers by various state conservation agencies.

Publications which appeared prior to 1956 were then reviewed and information was obtained indirectly from the biological abstracts and directly from journals, publications and articles that were known to deal with fishery research and management. The journals most frequently used were: Transactions of the American Fisheries Society, Progressive Fish-Culturist, Journal of Wildlife Management, Journal of the Fisheries Research Board of Canada, Investigations of Indiana Lakes and Streams and Journal of the Tennessee Academy of Science. Other sources which contained a number of the fishery studies cited in this report were: Proceedings of the Annual Conference of The Southeastern Association of Game and Fish Commissioners, Proceedings of The Oklahoma Academy of Science, Illinois Natural History Survey Bulletins, Ecology, and state and federal fisheries publications.

POPULATION DYNAMICS

POPULATION SIZE

Petersen (1896) began the practice of marking and then recapturing fish, using the number of marked fish recaptured to compute the total fish population within an enclosed body of water. His method of making a population estimate is currently known as the Petersen method. Schnabel (1938) modified the Petersen method by designing a means of making a population estimate based on concurrent mark and recapture periods.

Two other methods of making population estimates have been proposed by Schumacher and Eschmeyer (1943) and DeLury (1947). The Schumacher and Eschmeyer estimate is similar to the Schnabel population estimate except that it assumes that the weight, or value, of each sample is proportional to the number of fish in the sample. The DeLury population estimate is based upon the direct relationship between the decrease in the catch per unit of effort as the population becomes depleted and the extent of the depletion. This method cannot be used unless a large number of fish are removed from the population. The Schnabel, Schumacher and Eschmeyer, and DeLury methods have not received wide use in fishery investigations due to the simplicity of the Petersen estimate.

A number of authors have compared the different methods of making estimates and marking and recapturing fish. Cooper (1951) compared the Schnabel with the Schumacher and Eschmeyer method in Sugarloaf Lake, Michigan. The three-year averages for the estimates computed by the Schnabel method were generally a little higher than those computed by the Schumacher and Eschmeyer method. Gerking (1953) compared the Petersen, Schnabel and DeLury formulas for making population estimates in Gordy Lake, Indiana. He found good agreement between the three methods.

Lawrence (1952) compared the selectivity of seines versus wire traps in making population estimates in farm ponds. He concluded that errors due to selectivity are less when one method is used to collect the fish for marking and the other method in recapture. Barry (1967) evaluated the use of the following methods for marking and recapturing fish for population estimates: rotenone embayment, gill nets, traps and electrofishing gear. He found that the use of gill nets, traps and electrofishing gear gave a better estimate of the fish population with respect to relative abundance of various species. The rotenone embayment samples gave a better estimate of total pounds per acre.

One of the best books available for information on methods of conducting population studies is by Ricker (1958). The author summarizes the statistical methods used in dealing with fish yield, marking, recruitment, growth and survival.

AGE AND GROWTH

The most universal method used in aging panfish is the scale method. The scale, an impression on a soft plastic strip, is aged under a low-power microscope or on a scale reading projector. Regier (1962) in working with known-age bluegills in New York farm ponds, found the scale method a generally valid means of making age and growth determinations of bluegills. Lagler (1952) points out that in order to be comparable, scales must be removed from the same region of the body of each fish. Joeris (1956) showed that the best location to take scales on yellow perch is above the lateral line because of the more sharply defined circuli.

When back calculations on the scale are made to determine the length of a certain fish at the time of annulus formation, the length of the fish when the scale develops should be considered. For example, Ward and Leonard (1952) found that black crappies were approximately 0.7 inches long before scales appeared. Another method of aging reported by some authors involves using the opercular bone to age perch, Perca fluviatilis (LeCren, 1947) and Perca flavescens (Bardach, 1955).

A number of age and growth studies have been made on lakes in a particular state or a region of a state. These studies establish an average growth rate for a species over the area and can be used by other investigators for a comparison with the particular population with which they are working. Mackenthun (1946 and 1948) compiled age and growth data on bluegills, black crappies, rock bass, northern pike, walleyes and largemouth bass in southern Wisconsin lakes. A complete age and growth study was conducted in Pennsylvania for all species of panfish and game fish by Miller and Buss (1960). Snow (1969) conducted a comparative growth study on eight species of fish in a number of northern Wisconsin lakes. He found that growth of bluegills in drainage lakes was significantly faster than growth of bluegills in seepage lakes. Similar but smaller growth differences were noted for rock bass, black crappies, pumpkinseeds and yellow perch.

Some studies have concentrated on comparing the age and growth of one species within a certain area. Studies such as these are valuable to the biologist if he is working only with one species. Ricker (1942a) found that after three growing seasons in northern Indiana lakes, bluegill length ranged from 3.5 to 6.3 inches with a mean of 4.7 inches. Mackenthun (1947) found that the average length of age III bluegills in southern Wisconsin lakes was 6.3 inches. Similar growth comparisons for other species of fish have been made by Thompson et al. (1951) in a study of the white crappie in four small Oklahoma lakes and by Miller and Buss (1961) in their study of age and growth of the pumpkinseed in Pennsylvania lakes.

Other studies have gathered age and growth data on one species in the same lake. Studies conducted on yellow perch in Saginaw Bay (Hile and Jobes, 1940) and Green Bay (Flakas, 1947) showed that it took four summers for the perch to reach 8.0 to 8.5 inches. Carlander (1949) showed that female yellow perch grew more rapidly and were more abundant in all except the 0 age group, in Lake of the Woods, Minnesota. In 1940, Schoffman found that black crappies reached 9.0 inches in length during the fifth summer of life and white crappies reached this length during the fourth summer in Reelfoot Lake, Tennessee. In 1948 he made an intensive study of bluegill growth from 1937 to 1947 in Reelfoot Lake. He found the average bluegill reached 6.0 inches in 2 to 3 summers (Schoffman, 1948). Schoffman (1951) also studied the age and growth of the white crappie from 1938 to 1948. He found that the average white crappie reached 8.0-9.0 inches in 2 to 3 summers, completing 60-66 percent of its total growth in length during its first summer.

With commercial fishing in Reelfoot Lake, Tennessee, Schoffman (1952) found that game fish have maintained their normal growth rate and in some cases have increased it. In followup studies after commercial fishing became more restricted and finally abolished in 1955, he found that the average growth rate of bluegills decreased over this same period (Schoffman, 1959). This finding indicated that thinning of the population by commercial fishing was probably beneficial to the bluegill population. Louder and Lewis (1957) compared the growth rates of the bluegill and redear sunfish after stocking in Lake Murphysboro, Illinois. The growth and coefficient of condition studies revealed the redear to be faster growing and more plump than the bluegill.

Eschmeyer (1940) suggested that a decrease in the rate of growth of fish suggests an increase in the size of the fish population or a decrease in the supply of food. This conclusion was later supported in part by Stroud (1949) who found that growth rates were slower for those species with a high population density than for species with a low population density.

Gerking (1966) has made a detailed study of the annual growth cycle, growth potential and growth compensation in the bluegill in northern Indiana lakes. He found that the growing season started in April 8 in 1962 and in April 26 in 1963, and 90 percent of the annual growth had been achieved by September 10 in 1962 and by September 27 in 1963. The length of the growing season ranged from 98 to 189 days, with an average of 152 days. Gerking also found that populations with a rapid growth rate had a longer growing season than those with a slow growth rate.

Coefficients of conditions have been used in age and growth studies to indicate the suitability of an environment for a species by a comparison of the value for a specific locality with that for the region (Beckman, 1945). Chase (1946) outlines a method of calculating fish condition from scale dimensions in the bluegill. Bennett (1962) discusses a number of methods used for measuring relative conditions of fish. The different methods vary due to the type of measurement of the body length used and the method of measuring and weighing the fish.

Another measurement used in age and growth studies is length-weight relationships. In fisheries studies, it is often very useful to be able to determine the weight of a fish when length alone is known or vice versa. Mackenthun (1948) reported the length-weight relationship for largemouth bass, black crappies, bluegills, smallmouth bass, rock bass, walleyes, northern pike, pumpkinseeds and yellow perch collected from southern Wisconsin lakes. Two papers which discuss the use of the length-weight equation with perch are: LeCren (1951), *Perca fluviatilis* and Parsons (1951), *Perca flavescens*.

One of the most comprehensive books on age and growth was published in 1953 by Carlander. The author has made an effort to cover as completely as possible all data on the growth, length, weight and various length relationships for all species of fresh water fishes found in the United States and Canada.

ASSESSMENT OF ANGLER HARVEST

Some of the first work on creel census methods was made by Ricker (1942b). Studies conducted by the author on Shoe Lake, Indiana, showed that 46 pounds per acre of fish were removed by the anglers during the summer. The rate of exploitation of bluegills was 36 percent. Ricker (1945) found that in the Indiana sport fisheries, the bluegill plays a leading role by contributing

45 to 77 percent of the total weight of fish caught during six years of observations in two northern lakes and one southern one. Studies in Spear Lake, Indiana, by Ricker (1955) showed that the catch of fish varied from 44 to 68 pounds per acre over a five-year period. Of the fish caught, bluegills comprised more than half by weight.

Moore et al. (1937) conducted a creel census on Chautauqua Lake, New York, during the first five days of the season. The analysis of the creel census data for the five-day period showed that a total of 3,732 legal fish were taken in 1,488 fisherman days, or 6,788 fisherman hours--an average of 0.55 fish per fisherman hour. Panfish made up 80.3 percent of the catch reported. Taliaferro and Nolting (1954) conducted a creel census at Jumbo Reservoir, Colorado. The yellow perch made up 89 percent of the total catch during 1952 and 193 percent during 1953.

From these publications on the assessment of angler harvest, ideas can be obtained on (1) how to conduct a creel census and (2) what type of data can be collected from it.

Two recent publications that discuss creel censuses are by Lambou (1966) and Emig (1969). The major objective of Lambou's paper was to present a standard method of reporting creel survey data and more specifically to recommend the types of creel survey data to be collected and reported. Emig's publication deals with a selectively annotated bibliography of creel census methodology. The bibliography is organized into the following sections: (1) postal card surveys, (2) rental and charter boat catch records, (3) experimental angling and complete creel censuses (4) partial creel censuses and combination methods and (5) statistical methods.

SUMMARY

1. The Schumacher and Eschmeyer, Peterson, Schnabel and DeLury methods have all been used to estimate fish populations. The Petersen estimate is the most widely acceptable method due to the simplicity of making the estimate.

2. One of the best single publications concerning fishery population dynamics is the Handbook of Computations for Biological Statistics of Fish Populations by Ricker (1958). The author discusses the statistical methods used in dealing with fish marking, yield, recruitment, growth and survival.

3. The most universal method used in aging panfish is the scale method.

4. There have been a large number of publications dealing with growth, length, weight, and various length relationships on all species of fresh water fish in the United States. This type of publication is useful because the data can be used by other investigators for a comparison with the particular population with which they are working.

5. One of the best single publications dealing with growth is The Handbook of Freshwater Fishery Biology With The First Supplement by Carlander (1953).*

6. To manage or to do research on a fishery, the biologist must know how many fish are in the population, the rate of growth of the various species and what affect man has on the fishery. Thus, the importance of this section is to provide an understanding of the methods available to monitor fish populations.

PHYSICAL FEATURES OF THE LAKE BASIN

Gerking (1950) considered the physical features of Oliver Lake, a deep marl lake in Indiana, to be the chief known cause of poor panfish productivity. The data agreed with the general idea expressed by Rounsefell (1946) that

---

* Dr. Carlander is now in the process of revising the publication into two volumes. The first volume of the revision was published in 1969.

production of fish increases as the ratio of shoreline to area increases. Gerking's study also produced a quantitative expression of the fact that marl lakes are poor fish producers.

Two authors have reported the effect of lake depth on fish productivity. Hayes (1957) studied the bottom fauna in 250 lakes in several regions and could not find any indication of a relation between depth and productivity. However, a twenty-year study of the bluegill in Reelfoot Lake, Tennessee, has shown a gradual decrease in the length of each age group (Schoffman, 1966). The author suggests that this decrease in growth rate may be due to sedimentation from timber cutting and from farm drainage over the years.

NEW IMPOUNDMENTS

A number of authors have shown that when panfish are introduced into a new impoundment they exhibit a fast initial growth rate, followed by a marked decline in the rate of growth. Sprugel (1953) found that in McFarland Pond, Iowa, bluegills grew rapidly for two years after stocking, but during the third year the bluegills were severely stunted and showed little growth after they reached one year of age. Tharratt (1966) found that the growth rate of bluegills in Folsom Lake, California declined markedly throughout the seven years after impoundment, but he also reported that redear sunfish showed a stable growth pattern for the five year classes studied. Hansen (1966) stocked bluegills and largemouth bass in Lake Glendale, Illinois. He found that the standing crop in pounds per acre observed 6 years after the first stocking was 1/2 to 1/3 that of neighboring farm ponds. Similar increases and declines in production and growth rates were also noted for crappies (Thompson, 1950 and Jenkins, 1953). Lane (1954) suggested the decreased growth rates of bluegills in a new flood-control reservoir may be explained in terms of an increasing population of bluegill and other species of fishes, a restricted food supply, and delayed nesting due to fluctuating water levels. LaFaunce et al. (1964) found that after the introduction of fish into Sutherland Reservoir, California, the fishery continued to improve through the first six years rather than reaching an early peak and then declining, as other researchers have reported.

Smith and Miller (1942) conducted an interesting experiment on the hoop net catch of fish in pre-impoundment areas versus impoundment areas. In one pre-impoundment area (Holston River) 107 net lifts yielded 321 fish; in the other pre-impoundment area (Tennessee River) 583 fish were taken in 148 net lifts. The four major habitat areas in the impoundments each yielded 17,087, 877, 1,590 and 947 fish respectively, per 100 lifts.

TEMPERATURE

Several authors have investigated the relationship between water temperature and fish distribution. Ferguson (1958) found that fish with colder preferences showed the same thermal distribution in the field that they did in the laboratory: Salvelinus fontinalis, Salvelinus namaycush, Salvelinus hybrid and Coregonus clupeaformis. Fish with warmer water preference, such as Micropterus salmoides, Micropterus dolomieu and Lota lota lacustris, showed higher temperature preference in the laboratory than in the field. Young Perca flavescens showed the same results as the fish with warm water preference did, but experiments with older perch showed excellent agreement between laboratory results and field observations. The lack of agreement between laboratory results and field observation was attributed to age differences, laboratory experiments being performed with young fish and field observations being made on older fish.

Hergenrader and Hasler (1968) demonstrated a relationship between temperature and schooling behavior of yellow perch. In the winter the fish-to-fish distances often were greater than 1.5-2.0 feet, while during the summer, the fish-to-fish distances were less than 1.5-2.0 feet. The mean distance from the top fish to the bottom fish in a school during winter was 22.1 feet; while in summer it was only 8.5 feet.

Weatherly (1963) reports that hills and mountains limit the distribution of perch (*Perca fluviatilis* and *P. flavescens*) which are unable to persist in rapid-flowing streams. The author also presents evidence to show that in North America and Australia, high temperatures may be a factor in determining the proximity of both species of perch to the equator.

A study was conducted by Mayhew (1962) on thermal stratification in Red Haw Lake, Iowa, and its effects on fish and fishing. The author found that thermal stratification is primarily responsible for the confinement of fish into narrow, shallow water strata. When anglers utilized the information on thermal stratification to locate the best fishing depth, their catch rates were 8 times greater than those anglers who ignored the information.

A number of studies relate water or air temperatures to fish growth or food consumption. Hathaway (1927) working with pumpkinseeds, bluegills, and largemouth bass found that they consumed about three times as much food per day at water temperatures at 20 C than at 10 C. Jobes (1952) found a significant positive correlation between growth of yellow perch and mean air temperatures for the following combinations of months: May, July and September; May and September; July and September. Mean air temperature in August and yellow perch growth exhibited a negative correlation. LeCren (1958) showed that considerable year-to-year variations occurred in growth of all ages of perch (*Perca fluviatilis*) and these were correlated with variations in summer water temperatures measured in degree-days over 14 C. Growth regressions caused by low temperature accounted for up to two-thirds of the year-to-year variation in growth. Total yearly growth of female yellow perch, in South Bay, Lake Huron, showed a marked relationship to mean water temperature at a depth of 20 feet (Coble, 1966).

Mayhew (1962) found that a majority of bluegills develop false annuli just at the time of severe stratification and hypolimnion stagnation. At this approximate time, growth was also greatly retarded in relation to growth exhibited prior to stratification. Later during summer, growth increased significantly with the advent of epilimnion expansion. The author feels that this information strongly indicated stratification was the primary controlling factor in growth of bluegills.

WATER CHEMISTRY

Inhibiting Factors

Turner (1960) estimated the standing crops of fish in 22 Kentucky farm ponds. He found a positive correlation between size of the standing crop and the total alkalinities in the ponds, and between the size of the standing crop and the amounts of potassium and phosphorus present in the soils of the watershed. In general, the higher the total alkalinities and the greater the amount of potassium and phosphorus in the watershed, the higher the standing crop.

Trama (1954a) determined the pH tolerance of the bluegill. He found that the tolerance limits using a single acid or base and a continuous flow method were pH 4.00 ± 0.15, and pH 10.35 ± 0.15. Trama (1954b) also found that the acute toxicity level of copper to bluegills at 96 hours TL_M and 48 hours TL_M were estimated as 0.74 and 0.90 mg Cu/l, respectively. These median toxicity limit values are the concentrations of copper at which 50 percent of the fish survived for 96 and 48 hours.

Wiebe (1931) found that at dissolved oxygen levels of 5 ppm, bluegills that ranged in size from 2 to 4 inches showed distinct signs of discomfort and several were lost when pH was raised rapidly from 7.9 to 9.6. With oxygen levels at 24 ppm, the fish stood the change in pH with no trouble. Clausen (1936) worked with oxygen consumption in fish. He found that there seems to be a relationship between the amount of oxygen consumed by unit weight of fish and the longitudinal position of the fish in the stream. Tiemeier (1962) found that during much of the summer, deeper waters of many ponds are not suitable habitat because of lack of oxygen, low temperatures and high carbon dioxide content.

Lethal Factors

In southern Michigan, winter-kill of fish provided Cooper and Washburn (1946) with an opportunity to study the effects of varying oxygen concentrations on mortality and survival of several common species of fish. Among bluegills and largemouth bass, mortality was greatest--

apparently 100 percent in some lakes. Among pumpkinseeds, mud pickerel, chub suckers, northern pike, bullheads and golden shiners, survival was good even in lakes where the oxygen was reduced to 0.3 or 0.2 ppm. Beckman (1948) found that in a number of lakes where partial winter-kill occurred, the remaining fish showed an increase in growth rate. The increase in growth rate in most species was not maintained, however, for longer than a year. Berg (1969) found that yellow perch from lakes where winter-kill occurs have higher tolerance for low oxygen concentrations than do yellow perch from lakes where winter-kill is not a problem.

Summer-kill of fish in lakes can take place in a number of ways: (a) Woodbury (1941) reported a sudden mortality of fish in Lake Waubesa, Wisconsin. The fish affected were mainly black crappies, although bluegills, northern pike, yellow pike perch, common suckers and carp were killed to a lesser extent. This summer-kill was attributed to a heavy algal bloom which resulted in extremely high (30-32 ppm) oxygen content in the surface water; death of affected fish was caused by oxygen gas bubbles which blocked circulation of water through the gills and caused respiratory failure. (b) O'Donnell (1941) reported a sudden mortality of yellow perch in Yellow Lake, Burnett County, Wisconsin. Mortality apparently occurred after a violent storm and a sudden shift of wind caused a disturbance over part of the muck bottom area, creating a temporary high oxygen demand, and resulting in death of the perch by suffocation. (c) Mackenthun and Herman (1945) reported a heavy loss of fish on the Yahara River below Lake Kegonsa, Wisconsin. The loss was attributed mainly to the depletion of the oxygen supply by a decomposing algal mass.

PHOTOPERIOD

Not much work has been done on the effects of photoperiod on a panfish population. Greenbank (1956) found that the movement of fish under the ice was conditioned by a reduction in light intensity. Gross et al. (1965) working with the green sunfish found that varying day length exerts a greater influence on fish growth than a constant day length. Increasing photoperiod stimulates growth and decreasing photoperiod inhibits growth. This result suggests that the lack of growth of warm water fish in fall when water temperatures and average day length correspond to those in spring is largely due to the influence of decreasing day length.

TURBIDITY

Van Oosten (1945) did not find turbidity to be a factor in the decline of fish in the Great Lakes, particularly in Lake Erie. Hennemuth (1955) reported a definite acceleration of growth of white and black crappies, bluegills, and warmouth accompanying a decrease in turbidity and increase in volume of the lake. Elder and Lewis (1955) compared two ponds in the same watershed for growth rates and coefficient of condition values for white crappies and bluegills. They found that the growth rates were faster in some years and the fish were in better condition in the pond with the least turbidity. Hall and Finell (1954) and Neal (1962 and 1963) found that in turbid lakes, white crappies would become dominant over black crappies, although their growth rate was slower than the growth rate of species in clear water lakes.

SUMMARY

1. When panfish are stocked in a new impoundment, there is an initial period when the fish grow rapidly. Also, if there is a natural reduction of a population by a winter-kill or summer-kill, there is a period of rapid growth by the remaining fish. This rapid growth rate will take place until the population increases to the point when competition for food and space results in a decrease in the rate of growth.

2. Air and water temperatures have been shown to have an effect on the growth rates of perch. Low air and

water temperatures can slow down the growth rate. Thus it is possible to get considerable year-to-year variations occurring in the growth of all ages of perch (*Perca fluviatilis* and *P. flavescens*).

3. Evidence was presented to show that the growth rate of bluegills can be retarded by severe thermal stratification and hypolimnion stagnation.

4. Pumpkinseeds, mud pickerel, chub suckers, northern pike, bullheads and golden shiners have been found to survive with oxygen concentrations as low as 0.3 to 0.2 ppm.

5. Summer-kills can take place due to a number of causes: (1) respiratory failure due to high levels of oxygen (30-32 ppm) in the water, the high levels being produced by very heavy algal blooms; (2) loss of oxygen from large mats of decomposing algae which can cause the fish to suffocate; and (3) violent storm and a sudden shift of wind which can cause a disturbance over part of a muck bottom area creating temporary high oxygen demand and resulting in death of fish by suffocation.

6. Increased turbidity causes a decrease in the growth rates of white and black crappies, bluegills, and warmouth.

BIOLOGICAL INFLUENCES

FEEDING HABITS

Food Items

Considerable work has been done on the feeding habits of bluegills throughout the country. O'Donnell (1942a) examined a number of bluegill stomachs and found that 50 percent of the food consisted of insects of numerous species; 25 percent of aquatic plants and 25 percent of mites, crayfish, amphipods, cladocerans and snails. Studies conducted on the winter feeding habits of bluegills in Clear Lake, Michigan, showed that bluegills fed very little during the winter. The average stomach contained 133 organisms, 124 of which were plankton. Foods consumed were predominantly aquatic insects (mayfly nymphs) in early winter, plankton (Cladocera) in midwinter and insects again in spring (Moffett and Hunt, 1943). Turner (1955) sampled 143 stomachs from bluegills in 18 Kentucky farm ponds and found that the greatest volume of food for all size classes was composed of insects, with chironomid larvae comprising more than 50 percent by volume and being found in more than three-fourths of the fish. Crustaceans and plants also were eaten. Dendy (1956) found that bluegills fed heavily on bottom organisms in ponds. Food habit studies on Tuckahoe Creek, Virginia, indicated that insects (65 percent) and crustaceans (29 percent) were major food items consumed by bluegills. Of the insects and crustaceans consumed, tendipedids and copepods were some of the particularly important food items. The selection of the food items by the bluegills was a probable reflection of the general availability of potential food. Young bluegills (age groups 0 and 1) fed more often on microcrustaceans and dipteran larvae than did older fish (Flemer and Woolcott, 1966).

Doxtater (1964) studied the seasonal and size class feeding habits of bluegills. He found that chironomid larvae were the dominant food item for bluegills collected from Acton Lake, Ohio, and that there was a definite change of food habits with an increase in size and a seasonal variation of food types. Applegate (1966) reports that sunfish in Bull Shoals Reservoir used the bryozoan *Fredericella sultana*, as food.

A number of feeding habit studies have been conducted on the black and white crappie, pumpkinseed, and the yellow perch throughout the United States and Canada. Reid (1949) found that in Orange Lake, Florida, gizzard shad were the most important item consumed by black crappies between 31-291 millimeters. The only time that crappies fed more heavily on another item was from February through April when the major food item was Malacostraca. In summer and fall, black crappies fed largely upon fish and, to a lesser extent, upon Malacostraca, dipterous larvae, pupae and adults, and Entomostraca. In the winter, fish constituted the main food of the black crappie. The chief food of young crappies was Entomostraca.

Marcy (1954) studied the feeding habits of the white crappie in Pymatuning Lake, Pennsylvania and Ohio. He found that among smaller individuals, the most common food item was cladocerans and the second most frequently utilized item was copepods. Notonecta, Chironomus larvae and adults, and unidentifiable insect fragments were also found in the stomachs of small individuals. Stevens (1959) found that in the stomachs of black and white crappies in the Santee-Cooper Reservoir, South Carolina insects occurred 77.1 percent of the time and fish, 55.7 percent of the time. Goodson (1965) found that black crappies in Pine Flat Lake, California, fed mainly on threadfin shad except in spring, when small crappies ate Chironomid larva, cladocerans and copepods. Keast (1968) found that in Lake Opinicon, Ontario, the diet of the black crappie undergoes a progressive change in which planktonic crustaceas and small-bodied diptera larvae predominate in the diet of fish 60-115 mm in length, and insect larvae and fish are important items for crappies 160-240 mm in length. Most food items proved to be midwater forms and the diptera larvae were mostly Chaoborus and Procladius, which are free swimming in the water column at night.

Pearse (1924) showed that pumpkinseeds, when fed a choice of food, preferred the items in the following descending order: snails, minnows, amphipods, dragon fly nymphs, caddis fly larvae, grasshoppers and crayfishes. Pumpkinseeds around 119 mm in total length in Lake Erie had the following stomach contents: mayflies, caddis-worm and some plant fragments and debris (Boesel, 1937).

O'Donnell and Roecker (1940) found that yellow perch preyed heavily upon walleye and muskellunge eggs. As much as 9.1 percent of the diet of the yellow perch in the spring consisted of eggs. In studies in Costello Lake, Ontario, Langford and Martin (1940) determined that the period of maximum growth of yellow perch changed progressively from July (for fish in age group I) to August (for fish in age group III). These seasonal changes in growth increments were directly related to seasonal variations in the volumes of stomach contents. Coots (1956) could find no evidence of the yellow perch feeding on salmon and steelhead fingerlings in the Klamath River, California.

Rate of Digestion

The rate of absorption and digestion of different natural food organisms by panfish have been reported by a number of authors. Moore (1941) found that yellow perch maintain a quantitatively constant weekly level of food ingestion, regardless of whether the feedings were once or several times daily. Ricker (1949) found that when bluegills were kept at an average temperature of 20.5 C they would consume up to 7 percent of their body weight in earthworms each day. At this consumption rate (and at consumption rates near 5 percent), 15 percent of the food was converted to body substance. Seaberg and Moyle (1964) found that digestive rates for centrarchid panfish were faster than digestive rates for larger game fish. At water temperatures between 64 and 74 F, the panfish digested 50 percent of their stomach volumes in 5 hours, 75 percent in 12 hours, and nearly 100 percent in about 21 hours. Animal foods were digested more rapidly than plant materials and digestive rates for the same kinds of foods were similar for different sizes of panfish. Windell (1966) found that bluegills which were fed natural food organisms, required about 18 hours for complete digestion. Digestion was most rapid during the first six hours, during which time the digestible organic matter in the stomachs decreased by about 50 percent. In 18 hours, meals of mayfly naiads, crayfish and darters were completely digested, whereas meals of chironomids and oligochaetes were 92.9 and 97.8 percent digested, respectively.

Amount of Consumption

Gerking (1954) estimated that about 156.8 kg of protein were consumed by the bluegill population in Gordy Lake, Indiana, in 1950. About 47.9 kg of protein were added to the population in growth, and the remainder (108.9 kg) was used for the metabolic expenditure of energy. It was estimated that the total amount of food organisms consumed by the bluegill population was 1635 kg or 142 kg per hectare (126 pounds per acre). Under the observed conditions of mortality and growth, recruitment into the population must replace about one half the average standing crop per year.

Gerking (1955a) conducted studies to describe the influence of the rate of feeding on the body composition and the utilization of protein in bluegills. Considerable change in the body composition was induced by the different rates of feeding. The principal modification was an increase in fat content, which was accompanied by a decrease in moisture content. A relatively small decrease occurred in the percent protein and ash. He found that the absorption rate of protein was about 97 percent. Gerking (1955b) used feeding experiments to measure the maintenance level of protein for bluegills. He found that bluegills excreted three and a half times more nitrogen (about 7 mg/kcal) than do homoiothermous animals. Thus, there may be a fundamental difference in the protein metabolism of homoiothermous and poikilothermous animals.

INTERSPECIFIC AND INTRASPECIFIC COMPETITION

Jenkins (1955a) compared the standing crop of fish from two small Oklahoma lakes, one of which had a population of gizzard shad, carp and green sunfish. He found that the faster growth, plumper condition and greater average length of bluegills, black and white crappies and redear sunfish in the lake without gizzard shad indicated that direct interspecific competition occurs between these centrarchids and gizzard shad in small lake populations.

Lydell (1938) concluded that there was a relationship between crayfish and bluegills in ponds. The author found that when crayfish numbers were high, weight of bluegills was low. Leonard (1939) concluded bluegills in Ford Lake, Michigan were causing a decline in the grayling population through competition for food. Ricker (1942c) studied the fish populations in two artificial lakes in Indiana. He found the bluegills to be the dominant species in one lake, while in the other lake, they were less numerous. He concluded that this may be due to the competition with more abundant populations of green sunfish and black bullheads. Rosebery (1950) found that the bluegill population of Claytor Lake, Virginia may be restricted by competition with channel catfish and white crappie for food.

Eschmeyer (1937) found that trout, (chiefly brook trout) grew and survived well in those lakes which did not contain yellow perch, but were relatively unsuccessful in the lakes with yellow perch. Hunt (1950) reports that yellow perch were the most important fish predator on young northern pike in Houghton Lake, Michigan. El-Zarka (1958) discusses the decline in growth of yellow perch in Saginaw Bay. He concluded that competition for space rather than competition for food may account for the decline in growth rate.

A number of authors have concluded that competition between rough fish and panfish usually tends to favor the rough fish. Ricker and Gottschalk (1940) found that removal of rough fish resulted in an increase in the abundance of yellow perch, bluegills and black crappies. Tarzwell (1941) believed that through removal of the rough fish in Wheeler Reservoir, Alabama, the total productive capacity of the water would be used in the production of desirable species and the yield of these species would be greatly increased. Moyle et al. (1948) concluded that, in general, rough fish have little effect on the total poundage of game fish in southern Minnesota lakes. Rough fish are, however, usually associated with large populations of white and black crappies and somewhat reduced populations of yellow perch. Rose and Moen (1952) found that following intensive rough fish removal, there was a significant increase of game fish. Patriarche (1952) recommended that commercial fishery be used for nongame fish to eliminate some of the competition between these species and game fish species. Hacker (1952a and 1952b) noticed in two southern Wisconsin lakes that when carp populations were high, game fish and panfish populations were low. Scidmore and Woods (1960) found that the unilateral removal of rough fish per se to reduce competition for food was not a good management technique. They suggested that removal should be aimed at the kinds and sizes of rough fish which are the principal food competitors of the desired game fish.

Larkin (1963) reports on the consequences of exploiting either or both of a pair of competing species using the Lotka-Volterra equations for competition. He found that the removal of a fixed proportion of a population on an instantaneous basis shifts the equilibrium population sizes for both the exploited species and its competitor. Similar shifts occur when both species are exploited.

BEHAVIOR

Byrd (1951) found that the critical depth distribution of bluegills in ponds depended on the water depths where the dissolved oxygen concentration was

0.3 ppm or less and where the carbon-dioxide concentration was 4.4 ppm or more. This critical depth during the period of summer stratification was normally 5 feet in the 2-acre pond studied and 7 feet in the 22-acre pond. Thus, during this summer stratification period, bluegills were found in the greatest numbers in shallow waters. A study conducted on the home range of bluegills and longear sunfish showed that short-term occupancy of home range for both species could easily be demonstrated, but continuous occupancy for a period of several months was difficult to prove (Gunning, 1963).

Gunning (1959) concluded that the olfactory mechanism of the longear sunfish mediates homing. The fish search for their home range and apparently recognize it by a characteristic odor, or possibly a combination of odors. Huck and Gunning (1967) studied the behavior of the longear sunfish and reported on year-to-year occupancy of home range, spawning in the home range, and reproductive, feeding and aggressive behavior, as well as laboratory work on aggressive behavior.

Odell (1932) discusses the depth distribution of yellow perch and other species of fish in some New York lakes. He found that 75.8 percent of the yellow perch collected were captured between zero and 15 feet and 12.8 percent were captured in 15 to 30 feet of water.

Mraz (1951) found that a large majority (79.5 percent) of the 127 tagged yellow perch recaptured in southern Green Bay were retaken at the tagging station at which they were released. Scott (1955) concluded that light influenced the time at which the day's activity for yellow perch began and ended. Hergenrader and Hasler (1966) studied the diel activity and vertical distribution of yellow perch under the ice. The activity patterns generally agreed with those reported by investigators for other lakes, in that yellow perch were active during the day and relatively inactive at night. Comparison of nocturnal and daily depth distributions revealed no well-defined changes from the distribution observed during the day with that observed during the night.

Funk (1955) reported on the movement of fish captured in a Missouri stream. The rock bass, smallmouth bass, spotted bass, longear sunfish and yellow bullheads traveled very little from the point of tagging while the freshwater drum, channel catfish and white crappie were quite mobile and were captured a greater distance from the tagging point.

DISEASE

Little information has been published on the diseases of freshwater fish. A few of the articles dealing with diseases in panfish are discussed below.

Davis (1947) reported a mortality of white crappies in McKay Reservoir, Oregon. The mortality was caused by an epidemic of Cytophaga columnaris, a myxobacterium. Flakas (1950) reported that a number of black crappies from Waupaca County, Wisconsin were killed by bacteria belonging to the family Spherophoraceae, genus Spherocillus. Nigrelli (1953) published a paper on tumors and other atypical cell growths in temperate freshwater fishes of North America. Bluegills and black and white crappies are mentioned as being susceptible to "fish pox", gill disease myxoma (tumors in the mucoid material) and lymphocystis. Witt (1955) reported on the seasonal occurrence of lymphocystis in the white crappie from the Niangua arm of the Lake of The Ozarks, Missouri. The incidence of disease was greatest in July, decreased in October, and increased again in November. Over winter, the incidence of disease gradually decreased and reached a low in April, after which it increased again. Ross et al. (1960) reported a new bacterial disease in yellow perch believed to be previously undescribed.

PARASITES

O'Donnell (1938) reported a mortality of bluegills in Lake Chetac, Wisconsin. Gross examination of dead bluegills showed an extremely heavy infestation of larval trematodes, probably Neascus, encysted in the fish. Woodbury (1938) reported a heavy loss of bluegills in Proctor Lake, Waupaca County, Wisconsin;

the loss was caused by an infestation with Ergasilus sp., a small copepod parasite. An epidemic of the protozoan parasite, Cyclochaeta, was responsible for a mortality of bluegills in Lake Delevan, Wisconsin (Herman, 1944).

Bangham (1938) reported on the parasites of centrarchids from southern Florida waters. Larval nematodes encysted in the fish, strigeid flukes and gill flukes made up the majority of the parasites. Several authors have reported on the parasites of northwest Wisconsin fishes (Bangham, 1943 and Fischthal, 1944). They found that black spot, Neascus sp., was found on the skin and flesh of bluegills as was the liver grub, Posthodiplostomum minimum. The larval eye fluke, Diplostomus sp., was also a common parasite of bluegills. Lewis (1950) found the bluegills in Red Haw and East Lake, Iowa to be infected with a metacercariae of Posthodiplostomum minimum. The author also found an outbreak of Saprolegnia sp., parasitic fungus, on the larger bluegills in the same lake during May and early June.

Lewis and Nickum (1964) found that an infestation with the metacercariae of Posthodiplostomum minimum did not affect the relative plumpness of the bluegill. Hoffman et al. (1965) described a chlorella parasite in bluegills. Kelly and Allison (1965) reported an infestation of marine copepod, Ergasilus lizae, in bluegills in Lake Shelby, Alabama. Gerking (1962) found that in Wyland Lake, Indiana, natural mortality of the bluegill population increased as the fish grew older. He states that disease and parasitism were probably the primary causes of death, since the population was overcrowded and undernourished and parasitic infection appeared severe.

Parnell (1934) mentions many fish parasites and names yellow perch as a host for some of them. The yellow grub, Clinostomum marginatum, is one of the most common parasites of the yellow perch. Bangham (1940) discusses the distribution of fish parasites from 11 lakes in Algonquin Park, Ontario. Woodbury (1940) attributed the loss of a number of yellow perch in Lake Mendota, Wisconsin, to a sporozoan parasite belonging to the genus, Myxobolus. Bangham and Fischthal (1944) reported a mortality of young yellow perch (5-8 cm) in Sturgeon Bay. Mortality was apparently caused by the protozoan Trichodina sp. and Scyphidia sp.

SUMMARY

1. Small bluegills fed heavily on planktonic crustaceans while large fish fed mainly on both crustaceans and insect larvae. Chironomids comprised a large number of insects consumed.

2. Black and white crappies between 60-115 mm in total length fed heavily on planktonic crustaceans with larger fish (160-240 mm) feeding mainly on insect larvae and fish.

3. Feeding habits of panfish vary with an increase in size, with the seasonal variation of food types and with the availability of potential food in the environment.

4. Digestive rates for centrarchid panfish were faster than digestive rates for larger game fish. It was found that bluegills could digest natural occurring food items in 18 hours.

5. It was concluded by a number of authors that competition between rough fish (carp and gizzard shad) and panfish usually tends to favor the rough fish.

6. Studies with bluegills and longear sunfish demonstrate a short-term occupancy of home range, but long-term occupancy for several months was difficult to demonstrate.

7. Gunning (1959) concluded that the olfactory mechanism of the longear sunfish mediates homing.

8. The activity patterns of yellow perch are influenced by light, the perch being less active at night than in the day time.

9. Very little work has been published on the diseases of panfish. Work by Nigrelli (1953) shows that bluegills and black and white crappies are susceptible to "fish pox", gill disease, myxoma (tumors in the mucoid material) and lymphocystis.

10. Some of the more common parasites of panfish are: black spot, Neascus sp.; liver grub, Posthodiplostomum minimum; larval eye fluke, Diplostomus sp.; a small copepod, Ergasilus sp.; and the yellow grub, Clinostomum marginatum.

EARLY LIFE HISTORY

Spawning Behavior

Studies on the spawning behavior of panfish have been mainly concerned with time of spawning, location of the nest, and length of nesting periods. Some of the reproductive behavior of the bluegill has been described by Coggeshall (1924); he determined that more than one female laid eggs in a single nest. Morgan (1951a) made a comparative study of the spawning periods of the bluegill, black crappie and white crappie in Buckeye Lake, Ohio. Bluegills were found to spawn from early May until the middle of August. The black crappie spawning period ran from the last of March through the first of June and the white crappie spawned from the last of March through mid-July. Hansen (1943) suggests that the reasons for the scarcity of observations of white crappie nestings may be due to fish: (1) nesting more or less apart from one another, (2) sometimes failing to excavate a nest and (3) nesting under objects.

Balon (1959) describes the spawning behavior of the pumpkinseed. He found that most pumpkinseeds spawned between May 25 and June 20, with nests in colonies or in groups of 2 or 3. The male seemed to watch the nest only before the eggs hatched. Hunter (1963) found that green sunfish nested in colonies. The length of time that nests were occupied varied from 1 to 15 days. Nest recognition by the male appeared to be partially dependent upon the presence of small landmarks near the nest site.

Egg and Fry Production

Ulrey et al. (1938) reported on the number of eggs produced by some of the common freshwater fishes. The authors found that a bluegill about 7.3 inches long produces an average of 19,169 eggs. Langlois (1939) found that a bluegill 5.5 inches long will produce an average of 11,267 eggs. Langlois (1945) also reported that a white crappie 7.5 inches in length can produce an average of 14,750 eggs.

Carbine (1939) made some observations on the number of fry produced per nest by bluegills, pumpkinseeds, rock bass and largemouth bass. The average number of fry per nest produced by bluegills was 17,914; by pumpkinseeds, 8,074; by rock bass, 796 and by largemouth bass, 4,977.

Feeding Habits

A number of studies have been reported on the feeding habits of small fish. Ewers (1933) completed a feeding habit study on 3 species of 1- to 3-inch fish (white crappie, black crappie, and yellow perch) from the western end of Lake Erie. All three species preferred crustaceans over insects. Ewers and Boesel (1935) completed a study of the feeding habits of young-of-the-year pumpkinseeds, white crappies, yellow perch and bluegills from Buckeye Lake, Ohio. Stomachs from white crappies were found to contain 91.2 percent crustaceans and 3.6 percent insects. There seems to be little correlation between food of the white crappie and its size, its place of capture, or the season. The author found both copepods and cladocerans to be very important in the diet of the yellow perch. The bluegills fed largely on small crustaceans and the diet of the common sunfish consisted mainly of cladocerans and midge larvae.

Pycha and Smith (1954) made an intensive early life history study of the yellow perch in the Red Lakes, Minnesota. Stomach analyses indicated that plankton is the primary food, but in some seasons, the perch may be strongly dependent on bottom forms. Variation in food availability appears to be associated with changes in growth and may have a major influence on survival. Maloney and Johnson (1955) found that yearling yellow perch in two Minnesota lakes fed principally on insects and planktonic crustaceans during the first part of the summer and shifted somewhat to fish as the season progressed. Muncy (1962) conducted a study on the spawning behavior and food habits of young-of-the-year yellow perch in the estuarine waters of the Severn River, Maryland. He found that the food habits of perch were similar to those of the same species in freshwater habitat.

Factors Involved in Year Class Formation

A few studies have proposed possible factors affecting year-class formation. LeCren (1955) suggested that year-class strength in perch (Perca fluviatilis) may be due to some climatic conditions. Mraz and Cooper (1957) found no relationship between the number of adult bluegills stocked in ponds and the strength of the resulting year class. Lux (1960) found that the first year growth of yellow perch, bluegills and pumpkinseeds was the most rapid from mid-June to mid-August in Linwood Lake, Minnesota. Clady and Ulrikson (1968) described the mortality caused by hydra in an artificial situation, with several broods of newly hatched bluegills.

Two outstanding studies were completed recently dealing with formation of year classes in bluegills. Toetz (1966) reported that numerical strength of a year class of fish is probably established before metamorphosis from larvae to adult. Factors investigated that affect the survival of bluegill larvae were the characteristics of the ova, fertility, hatching and the events marking the "critical period" when the larvae switch from endogenous to exogenous nutrition. Werner (1967 and 1969) found that bluegill fry in Crane Lake, Indiana abandon littoral spawning areas shortly after yolk sac absorption and migrate to the limnetic zone of the lake. They remain in the limnetic zone for approximately a month and a half, growing at a rate of 0.4 mm per day and returning to the littoral zone when they reach an average size of 22 to 25 mm. Werner emphasizes that the assessment of ecological factors affecting year-class size in bluegills will have to include the limnetic conditions impinging on the fry during the summer. Faber (1967) also found larval yellow perch, sunfish and black crappies in the limnetic region of several lakes in Wisconsin.

May and Gasaway (1967) have published a key on the identification of larval fishes of Oklahoma. This key has been very useful in many studies of early life history of warm water fishes.

COMPLETE LIFE HISTORY

Most complete life history publications concerning a species of fish discuss the following subjects: spawning behavior, egg and fry production, feeding habits of the fingerling and adult fish growth rates, and some papers report on angler harvest.

Morgan (1951b) gives a complete description of the early life history of the bluegill in Buckeye Lake, Ohio, plus data on growth, feeding habits and parasites of adult bluegills. The author found that most bluegills spawned from early May to the middle of August. The number of eggs produced varied with the size of the fish, from 2,540 in 4.0- to 4.5-inch fish to 49,400 eggs in an 8.5- to 9.0-inch fish. The mortality between the eggs produced and the number of fry was quite high. The author reported that the average rate of growth of male bluegills of Buckeye Lake is below that of female bluegills. Chironomids make up the greatest percentage of food of the bluegill. Parasites were found in 34 of the 39 bluegills examined.

Snow et al. (1960) describe the distribution, behavior, reproduction, growth, populations, harvest, ecology, values angling and management of bluegills in Wisconsin. This is a descriptive article produced primarily for people outside the field of biology. The authors stated that young bluegills eat plankton, principally small copepods and cladoceran crustaceans; as they become larger, they eat larger units of food, such as insects, or an occasional small fish or frog. It was also stated that a female bluegill, weighing 4 ounces, produced about 12,000 eggs. Larger fish have carried as many as 38,184 eggs. The smallest, a 4.5-inch fish, carried 2,540 eggs. This is about the minimum size for sexual maturity. From 4,670 to 61,815 fry have been taken from a single nest; the average number of fry found was 18,000. In waters in Wisconsin where bluegills have good growth, it will take at least three and generally four years for bluegills to attain a length of 6.0 inches.

Snow et al. also state that data on the annual natural mortality and survival rate of catchable fish at Murphy Flowage, Wisconsin for two consecutive years, revealed that 38 percent of the pre-season stock in 1955 survived one year. Out of the 62 percent total mortality, 15 percent was due to angling and 47 percent, to natural mortality.

Hansen (1951) reported on the biology of the white crappie in Illinois. The author found that white crappies spawn under a variety of bottom conditions, water depth and proximity to vegetation, embankments and wooden structures. They seemed to show a preference for depositing their eggs on plant material, but they did not require aquatic plants for that purpose. Lymphocystis, the most common disease observed in white crappies, was found in 19.5 percent of the white crappies in one locality. Lake Decatur crappies were generally short lived and usually were not conspicuous in net catches beyond the second or third year of life. One year class disappeared completely at the age of 3 years and 3 months; another year class disappeared at 4 years and 4 months.

Morgan (1954) gives a good description of the spawning behavior and habits of the fry of the white crappie plus information on growth rates and feeding habits of small and adult white crappies in Buckeye Lake, Ohio. The author found that Buckeye Lake white crappies did not mature until they were two years old and some did not mature until they were three years old. The height of the spawning period was May and early June. The number of eggs produced varied from 1,908 in fish 5 and 7/8 inches in length to 325,677 in fishes 13 inches in length. The yearly growth increment for the first year was greater than in other succeeding years. After the first year's growth there was a gradual decrease in yearly increment during each ensuing year, with the exception of the fourth and seventh years. The predominant food of the white crappie was the gizzard shad, followed by midge pupae and cladocera.

Huish (1953 and 1958) reported on the growth rate and sex ratio aspects of the life history of the black crappie in Lakes George, Eustis and Harris, Florida. In Lake George, black crappies reached a length of 4.4 inches at the end of the first year, while in Lakes Eustis and Harris, they reached lengths of 2.0 and 1.9 inches, respectively. At the end of the fifth year, black crappies were 12.5 inches long in Lake George, 9.4 inches in Lake Eustis and 9.8 inches in Lake Harris. In Lake George female black crappies outnumbered males in every month but July and August during 1950. It was found that in Lakes Eustis and Harris that females outnumbered males during the study period.

Herman et al. (1959) discusses the following aspects of yellow perch life history: classification, distribution, description, behavior, reproduction, growth, mortality rates and yields, ecology, angling and commercial harvest, economic value and management. This article is also a descriptive article produced primarily for people outside the field of biology. Yellow perch may become mature in southern Wisconsin when they are two years old and sometimes males will be mature when one year old. In northern Wisconsin, they reach maturity when they are two or three years old. Spawning normally occurs in April or early May, when water temperatures are 45 to 52 F; female perch have been known to deposit as many as 48,000 eggs, but the average is 23,000. The number of eggs deposited is a function of size and condition of the female.

The authors point out that the growth rate of yellow perch varies greatly from one body of water to another, and may vary in a given body of water from decade to decade. Age distribution suggests a 50 percent annual mortality among adult yellow perch in Lake Mendota, Wisconsin, but angling based on tag returns was estimated to account for only 5 percent of the mortality.

SUMMARY

1. Most panfish spawn sometime during a two-month or longer period in the spring and summer. Yellow perch spawn the earliest at water temperatures from 45 to 52 F. Of the panfish studied, bluegills have the longest spawning period; depending on the water temperature, it can extend from May through August.

2. Egg production by bluegills usually ranges from 2,000 to 50,000 eggs depending on the size of the fish. It was reported that white crappie egg production can vary from 1,900 to 325,677 eggs, again, depending on the size of the fish. Yellow perch egg production was reported as high as 48,000, but the average was around 23,000.

3. The average number of fry produced per nest by bluegills was 17,914, pumpkinseeds-8,074, rock bass-796 and by largemouth bass-4,977.

4. Young-of-the-year bluegills, white crappies, black crappies, pumpkinseeds and yellow perch prefer the following food items: bluegills prefer crustaceans, white crappies and black crappies prefer crustaceans over insects, pumpkinseeds prefer cladocerans and midge larvae, and yellow perch prefer crustaceans and insects but shift somewhat to fish as the season progresses.

5. The following hypotheses have been proposed as causes for year-class fluctuations in small fish: (1) climatic conditions, (2) food availability at the time when the larvae fish switch from endogenous to exogenous nutrition, and (3) limnetic conditions impinging on the fry during the summer.

6. May and Gasaway (1967) have pub-

lished a very useful key on the identification of some larval freshwater fish.

7. The annual natural mortality and survival rates of catchable fish at Murphy Flowage, Wisconsin, for two consecutive years revealed that 38 percent of the 1955 pre-season stock survived one year. Out of the 62 percent total mortality, 15 percent was due to angling and 47 percent, to natural causes.

8. In Lake Mendota, Wisconsin, there was an annual total mortality of 50 percent among adult yellow perch. Angling accounted for only 5 percent of this mortality.

CURRENT MANAGEMENT TECHNIQUES

To be able to effectively manage a panfish population for a satisfactory sustained yield to the angler, the fish manager should have a thorough knowledge of the type of information presented in the first four sections. Once equipped with knowledge about the population structure of the fish population he is working with, the environmental and biological factors that pertain to the population and something about the life history of the fish population, the fisheries biologist can turn to current management techniques.

There are basically two ways of managing a fish population: (1) by direct action upon or involving the fish species themselves, and (2) through indirect action brought about by modifying the fish's environment or by introducing other fish species.

DIRECT ACTION

Chemical Reclamation

Rotenone. The use of chemicals to treat lakes for complete or partial removal of panfish is the most popular method of panfish control, today. Of the various fish toxicants, rotenone seems to be the one most commonly used. In the late 30's and 40's when rotenone was first being used in problem lakes, scientists investigated the possibility of using the toxicant to make standing crop estimates of the fish populations in these lakes (O'Donnell, 1942b; Ball, 1945a and 1945b, and Carbine and Applegate, 1945).

Other workers have studied the toxicity of rotenone to different fish species and to other aquatic organisms. Brown and Ball (1942) found that different species of fish showed little variation in their tolerance to rotenone. The authors also made observations and conducted experiments to test the effect of rotenone on lake organisms other than fish. *Corethra*, *Daphnia*, *Diaptomus* and most other zooplankters were very greatly reduced as a result of the treatment. Phytoplankton counts showed no significant reduction in number. Burdick et al. (1956) studied the toxicity of rotenone to yellow perch under controlled laboratory conditions. The authors found that there was no relationship between length of the fish and time of death in the five concentrations of rotenone used.

Several studies have investigated the depth distribution and detoxification processes of rotenone. When Greenbank (1940) applied derris root (rotenone) to the warmer surface waters of two small trout lakes, comparatively little rotenone seemed to penetrate to the colder, deeper water. Apparently yellow perch, rock bass and largemouth bass were destroyed, but trout were not. Clemens (1952) also found that in thermally stratified ponds, rotenone did not penetrate to the bottom of these shallow ponds which ranged in depth from 6 to 13 feet. Rotenone in clear waters of low alkalinity (16 ppm) became detoxified in 3 to 6 days depending on the concentration used. In clear ponds of high alkalinity (60-284 ppm), when similar concentrations were used, rotenone became detoxified in 1 to 3 days during the summer, and in 9 to 10 days during the winter. In turbid waters of high alkalinity, dissipation took from 2 to 5 days during the summer.

A number of studies have been conducted on the growth of a fish population after a lake has been completely or partially treated with rotenone. Jenkins (1955b) partially treated Ardmore City Lake, Oklahoma, with rotenone. The most striking result of this treatment was the production of a large number of crappies by a very limited number of adults. Grice (1959) found that resident adult fish remaining after treatment and adult fish stocked showed marked increase in growth, after the population density of fish was reduced by a partial treatment with rotenone. Riel (1965a) also found a marked increase in the growth rate of yellow perch after pound nets were used to reduce the adult fish population and rotenone was used to destroy the bulk of the annual egg production. Kempinger (1969) found that in a lake completely treated by rotenone and then restocked, the fishery was greatly improved and the rate of angling success was doubled. Sandoz (1960) concluded that in southern Oklahoma, two years is the maximum length of time that most ponds should be closed to angling after being chemically rehabilitated.

Antimycin. One of the newest fish toxicants on the market is antimycin. By varying the concentrations used, this toxicant has showed some promise of being selective for certain sizes and species of fish.

Walker et al. (1964) made some preliminary observations on the toxicity of antimycin to fish and other aquatic life. The authors found that antimycin breaks down rapidly in water, especially in the presence of free hydroxide and that carp and other rough fish were killed by short exposures at small concentrations in cool and warm lakes. Plankton, aquatic plants, bottom fauna, salamanders, tadpoles and turtles were not harmed by the concentration tested. Herr et al. (1967) concluded that in view of the high specificity of this agent for fish, the rapidity with which it breaks down and the safety of its degradation products, antimycin would appear to have marked advantages over fish eradicators now in use.

Antimycin has been used successfully by several investigators to selectively remove rough fish. Lennon (1966) noted that antimycin showed promise as a means of carp control. Avault and Radonski (1967) found that antimycin was a valuable tool in removing rough fish from catfish ponds. Hacker (1969) treated streams in the winter with antimycin to eliminate carp and buffalo. In water temperatures of 32.0 to 39.2 F, the fish were killed with 10 ppb concentration, dripped into the streams over a 24-hour period.

Selectivity of antimycin to fish other than rough fish has also been studied. Radonski and Wendt (1966) and Radonski (1967) found that low dosages of antimycin could be used in soft water lakes to kill yellow perch while not affecting any companion species. Callaham and Huish (1967) attempted to selectively kill bluegills and redears in lakes with pH values ranging from 6.4 to 9.6 units. The treatment with antimycin showed size selectivity as well as species selectivity at the various concentrations used. The treatment of Dakin Lake, Iowa with antimycin selectively killed young-of-the-year bluegills, but spared older bluegills (Iowa Conservation Department, 1969). Another way to selectively remove certain species or year classes of fish would be to treat their eggs before they hatch. Vezina (1967) found that antimycin causes sterility of fish eggs.

Antimycin has a distinct advantage in that it does not irritate or repel fish; furthermore, most treated fish appear to incur a lethal dose before they become aware that anything is amiss. The amount of antimycin required varies with water temperature and quality. In general, more toxicant is required in cold, hard alkaline water (pH above 8.5) than in warm, soft water of low alkalinity (Burress, 1968).

Other Chemicals. Toxaphene has had limited use as a fish toxicant because of the fact that it does not dissipate as fast as rotenone and antimycin. Johnson et al. (1966) found that in Wisconsin lakes, toxaphene may persist for several years after its application in fish eradication programs. Schoettger and Olive (1961) found that a single, sublethal dosage of toxaphene was inadequate to produce accummulations in fish-food organisms which would cause mortality among the test fish. Dietz (1962 and 1963) worked with the mean lethal dosages (MLD_{50}) of toxaphene on various fish. He found the MLD_{50} for sunfishes to be between 110 and 130 ppb toxaphene at temperatures between 75 and 85 F with the 96th hour as the end point.

Copper sulfate has also been used as a fish toxicant. Gray (1962) conducted studies on five lakes in Texas to find out if copper sulfate could be used for complete kills as well as selective kills in these lakes. He found that concentrations of 1.8 to 2.0 ppm copper sulfate would produce effective selective kills. Poor results were obtained on lakes where a complete kill was attempted. It was evident that a 5.0 ppm concentration of copper sulfate was not enough to bring about a complete kill in some cases. Allison (1964) treated bluegill nests in Allen Lake, Ohio (2.75 surface acres) with copper sulfate in an effort to kill the eggs and fry on the nest. Applications of copper sulfate killed bluegill eggs and fry and prevented renesting during the summer months. The author concluded that this method of control would not be practical on large bodies of water because of the difficulty in locating bluegill nests. Beyerle and Williams (1967) attempted to control the size of an entire bluegill year class in four Michigan lakes by applying copper sulfate to bluegill nests. They found that this type of treatment required considerable continuous effort to locate and treat all the nests. It is possible that bluegill reproduction could be controlled with copper sulfate in ponds and small lakes that have well-defined, easily located spawning areas. However, great care must be taken to locate and treat all nests semi-weekly during the spawning season. The number of young produced on a few untreated nests could over populate a small body of water.

A number of other fish toxicants have been tested and are presently being used on an experimental basis in the field. Jackson (1956) used sodium hydroxide pellets to kill eggs and fry on pumpkinseed nests. Grice (1962) field tested a fish toxicant called Ortho Fish Thinner in four Massachusetts lakes. In the lakes treated, the sunfish population was greatly reduced, but the largemouth bass was not. Louder and McCoy (1965) tested Aqualin as a possible fish toxicant that could be used for collecting fishes from lotic waters. They concluded that there is a narrow range of toxicity between the fish tested (largemouth bass, bluegill, bowfin, mosquito fish and fathead minnow) with Aqualin and that, in no case was the toxicity level wide enough to indicate any promise for collecting fishes in lotic waters.

Removal

Of various attempts to remove fish from lakes where panfish were slow growing and over abundant, none have been particularly successful. Churchill (1949) concluded that removal operations of yellow perch in a small northeastern Wisconsin lake did not improve perch growth and was an expensive operation. Parker (1956 and 1958) tried to increase the growth rate of fish in Flora Lake, Wisconsin, by using fyke nets to remove fish and thereby decrease their density. The author found that after removal, the remaining bluegills, pumpkinseeds and hybrids of these two species belonging to recent year classes (1953 and 1954) responded favorably in linear rate of growth after their reduction in numbers, but only the pumpkinseeds were heavier at the overall mean length. Yellow perch were thinner and grew more slowly after the initiation of removal operations than they did before.

To improve average size and rate of growth of bluegills, sunfish were removed from five Minnesota lakes with over crowded panfish populations (Scidmore, 1960). Removal of 1.3 to 21.3 pounds per acre of sunfish was ineffective in increasing average size or rate of growth of bluegills. Houser and Grinstead (1961) concluded that removal of various numbers of bluegills and black bullheads from a small Oklahoma lake may not always produce greatly improved fish populations. Carter (1963) conducted a study to determine the effectiveness of gill nets and hoop nets for crappie removal in Dewey Reservoir. Netting success was poor, and the total harvest of crappies was below that considered necessary to significantly reduce competition within the population. Only 1,374 crappies were harvested--4.04 per net day. White crappies comprised the greatest percentage (33.7 percent) of the total number of fish taken in gill nets, while bluegill (49.3 percent) dominated the hoop net harvest. Snow (1962) showed that the five-year removal by anglers of 15 percent of the panfish population, along with the two-year removal of 30 percent of the panfish by anglers, fyke nets and electroshocking equipment did not increase the growth rates of bluegills in Murphy Flowage, Wisconsin.

Liberalized Fishing Regulations

A number of investigators have studied the effect of liberalized fishing regulations (no bag limit, size limit or closed seasons) on panfish populations. They have concluded that regulations could be liberalized to provide better utilization of the fishery. However, if liberalized regulations were the only management technique aimed at reducing panfish numbers, it is doubtful whether actual reduction would occur.

Lagler and Ricker (1942) concluded that with the single exception of the relatively scarce largemouth bass, none of the species of game fish or food fish in Foots Pond, Indiana were being efficiently exploited at that time. Some of their suggestions for adequate utilization of the pond's fishes included a more intensive fishery for white and black crappies and a reduction of the size limit on yellow bass to permit its being taken by fishermen. Bennett (1943) suggest that intensive hook-and-line fishing should be encouraged on ponds to increase the harvest of panfish before the ponds become over populated. Sanderson (1959) suggested that unless harvest of fish was increased by angling and other methods, in the Savage River Reservoir, Maryland, panfish growth rate would decrease and the reservoir would eventually support fish of sizes too small to provide good sport fishing.

In spite of the above studies which advocate the use of liberalized fishing regulations to reduce panfish numbers, other studies have found that such regulations are not an effective means of controlling panfish numbers. Bennett (1945) found that in spite of heavy fishing, natural reproduction of panfish was obviously sufficient to insure replacement of those fish removed in a small artificial lake in Illinois. Even though largemouth bass have been protected since 1939 in Reelfoot Lake, Tennessee, Schoffman (1964) found that the bass have been decreasing in length and weight. The majority caught by anglers were in the lower age groups, and the number being caught is decreasing. Pelton (1948) concluded that liberalized fishing (no length limits, bag limits, nor closed seasons) had no measurable effects on the fish population or angling success in Lake Alma, Ohio. Churchill (1957) concluded that after ten years of no angling restrictions on Escanaba Lake, Wisconsin, there was no evidence of depletion of the fish population. Snow (1960) found that under heavy fishing pressure and without a bag limit, the bluegills in Murphy Flowage, Wisconsin, showed no sign of being "fished out". Churchill and Snow (1964) again concluded that a bag limit would have had little effect on the total catch of fish from these lakes because few anglers caught more than the usual limits. The main exception would have been the catch of bluegills from Murphy Flowage, where these fish are exceedingly abundant. Even though a few anglers caught a large number of bluegills from Murphy Flowage the population showed no signs of being reduced.

Hybridization

Bailey and Lagler (1938) were some of the first researchers to describe a hybrid panfish population in any detail. Krumholz (1949) stocked a number of redear sunfish and bluegill hybrids in a number of small, southern Indiana ponds. He found that the hybrids were relatively larger and heavier for their length than individuals of the same age groups in either of the parent species taken from similar ponds. Lagler and Steinmetz (1957) crossed bluegills with pumpkinseeds in an effort to produce a hybrid of very low fertility for stocking in farm ponds. The cross was termed unsuccessful because of the high degree of fertility of the F_1 offspring.

Childers and Bennett (1967) discussed the results of the stocking of a redear and green sunfish hybrid in a small one-acre pond along with largemouth bass in Illinois. The yield two years after introduction was 417 pounds per acre under a fishing pressure of 312.5 man-hours per acre (the highest hook-and-line yield of fish recorded for any water in Illinois), and the average rate of catch was 6.2 fish per man-hour (the highest rate recorded for any Illinois water from which a complete creel record was available). Although redear x green sunfish hybrids were capable of producing an F_2 generation, few of the second generation of fish were able to survive bass predation; 2 seasons after the year the maximum yield was made, only 71 hybrids were caught. Childers (1967) isolated adult males of one species and adult females of another species in ponds to determine which of 12 possible crosses may occur in nature. Only the redear male and green sunfish female, green sunfish male and bluegill female, and warmouth male and green sunfish female crosses produced large F_1 hybrid populations. Also, the author stocked equal numbers of relatively equal-sized green sunfish males and redear female F_1 hybrids in one pond and bluegill males and green sunfish female F_1 hybrids in another pond. When fish in the ponds were removed at a later date, the average increases in total lengths of hybrids were not significantly different from those of their parental species.

Smitherman and Hester (1962) successfully made all possible crosses among three species of sunfishes (bluegill, redear, and redbreast) in the laboratory. The comparisons of the offsprings showed that they were generally intermediate between their parent species in most toxonomic characters. Birdsong and Yerger (1967) reported on a natural population of bluegill and warmouth hybrids in Ocheese Pond, Florida. The authors made a comparison of meristic, morphometric and osteological characters of a cross between the bluegill and warmouth. The characters studied showed a striking intermediacy of the hybrid between the two parental types. Clark and Keenleyside (1967) found that under normal conditions there may be a reproductive isolation between pumpkinseeds and bluegills. The probable cause is an ethological isolation, through visual recognition of potential conspecific mates. This probably is the major barrier to hybridization under field conditions.

Hormone Injection

Gross et al. (1963) found that the differences in growth of fish given injections of thyroxine (hyperthyroid), radioiodine (hypothyroid), and saline solution (control) demonstrated that the hyperthyroid fish attained the greatest growth and hypothyroid fish, the least. Engel and Brynildson (1967) made a literature review of the value of testosterone as a means of controlling fish reproduction. They concluded that much work must be done before androgens such as testosterone can be used as a control technique since at present, it does not meet the minimum health standards as set forth by the Federal Food and Drug Administration.

Supplemental Feeding

Investigators in Illinois have tried to increase growth rates of bluegills and largemouth bass by feeding them prepared foods in certain locations in lakes and ponds. Bennett and Adkins (1968) used a fall drawdown plus supplemental feeding in an effort to increase the average size of bluegills in Ridge Lake, Illinois. Using the drawdown to maintain the number of bluegills at less than 20,000 individuals instead of 50,000 to 90,000, the range of "normal" population size, they fed the bluegills a high protein food. The average size of the bluegills caught by anglers increased by 100 percent. Lewis et al. (1969) found that when largemouth bass were held at high densities in ponds, some of the bass could be conditioned to accept nonliving food. Under these conditions the fish accepted prepared foods as well as dead forage. Bass that become conditioned to accept such food showed good growth and high coefficient of condition.

Stocking of Different Sex Ratios

A few investigators have tried to vary the sex ratio of panfish or stock only fish of one sex into lakes or ponds in an effort to cut down on the high reproductive capacity of most panfish and to increase growth rates. Some authors have studied the naturally occurring sex ratios of panfish. Schneberger (1935) found that sex ratios of yellow perch in Nebish, Weber and Silver lakes in northeastern Wisconsin varied with the lake. In Nebish the ratio of females to males was 1:1.26, while the ratio of males to females was 1:1.31 and 1:1.40 in Weber and Silver lakes, respectively. Beckman (1946) studied the sex ratios of some panfish in some Michigan lakes. He found that the percentage of males varied from 39 percent for yellow perch to 52 percent for pumpkinseeds and black crappies. Schmittou (1967) speculated that a bluegill population with a high ratio of males would be desirable because male bluegills grow faster and larger than females.

INDIRECT ACTION

Drawdown

Several studies have investigated the effect of fall, summer or overwinter drawdowns on different species of panfish. Johnson (1945) noted that a summer drawdown of Greenwood Lake, Indiana in 1940, caused the disappearance of the 1940 year classes of both black and white crappies. Bennett (1954) found that a fall drawdown on Ridge Lake, Illinois had a much more adverse effect on bluegills than on bass. The author concluded that it seemed probable that effects of drawdown will vary considerably with individual lakes containing various species of fish. Brasch (1958) noted that under certain conditions, drawdowns favor game fish by control of carp and panfish. Bow Lake, New Hampshire, was used as a water reservoir. Each fall, the lake was drawn down for the water supply. For many years this had the effect of forcing yellow perch into deeper water, where they were subjected to greater predation. As the years passed, less use was made of the water storage facilities, and the perch apparently found cover in the coves, thereby enabling them to escape from their predators and increase in abundance (Riel, 1965b).

Increased growth rates for certain panfish following drawdown has been reported by numerous researchers. Viosca (1952) noted a rapid growth rate of black crappies in a reservoir at Springhill, Louisiana. The lake basin was filled in April and drained in September or October. Bennett et al. (1969) found that early fall drawdowns drastically reduced the number of small bluegills, but allowed the remaining bluegills to increase in growth rates. Herman et al. (1969) conducted a summer drawdown on Little Dixie Lake in Missouri. They found that the density of bluegill fry and intermediate-sized bluegills was reduced. Drawdown was felt to be at least partially responsible for this density reduction by increasing predation, by exposing nests and by stranding small bluegills in weed beds and shallow pools.

Lantz et al. (1964) worked with summer drawdowns in a number of Louisiana lakes. They concluded that the timing of the drawdown is very important. Neither extensive drawdowns through the spring months or short drawdowns were found to be very effective. Cooper (1966) noted that periodic water level fluctuations dislodges prey species from ecological niches, resulting in more predation, lower population densities and better growth rates of sunfishes and perch, all of which improves the sport fish population.

Fertilization

Some investigators have added various organic and inorganic fertilizers to ponds and lakes to determine if the fertilizer would increase the production of fish by increasing the phytoplankton and, in turn, the aquatic animals at various trophic levels between the phytoplankton and fishes. Smith and Swingle (1939) compared the use of organic and inorganic fertilizers in southern ponds for increasing a crop of bluegills. They found that the two types of fertilizers produced about the same yield of fish. Smith and Swingle (1940) concluded that bluegills do grow during the winter in the south, but the growth is so slow that winter fertilization of ponds is generally not practical. Howell (1941) found that fertilizers more than doubled the weight of fish, plankton and bottom organisms in a fertilized pond as compared with those in an unfertilized pond. Ball (1948) treated two natural lakes in Michigan with an inorganic fertilizer. One lake was a 4.3-acre cold water lake and the other a 27.5-acre warm water lake. Fertilizer brought about a plankton-algae bloom the first summer in the warm water lake and produced a very heavy growth of filamentous algae the second summer. Fertilizers added to the cold water lake produced much less of a response. Waters and Ball (1957) treated a small, soft water lake in northern Michigan with an application of hydrated lime. As a result, increases were noted in the number of phytoplankton blooms, in the abundance of one species of aquatic plant (Myriophyllum tenellum), in the standing crop of bottom organisms at one sampling station which had been invaded by Myriophyllum tenellum and in the growth of stunted yellow perch in their first year of life.

Aquatic Vegetation Control

Some investigators have speculated that during the growing season, dense stands of rooted aquatic vegetation may bind up nutrients so that they are not available for the production of phytoplankton. This would effect the entire food chain from phytoplankton to fish and might result in decreased growth rates of the fish. It is also possible that dense mats of vegetation might provide places for small prey species to hide from their predators.

Eicher (1945) concluded that the removal of small areas of weeds from fishing waters with dense growths of aquatic weeds permits the resumption of fishing and helps maintain a balanced fish population by creating openings where largemouth bass can feed on small fish emerging from weed banks. Dicostanzo (1957) found that fluctuations in abundance of bluegills and pumpkinseeds appear to be closely associated with changes in the density of aquatic vegetation in Clear Lake, Iowa. Moorman (1957) concluded that aquatic vegetation was not important in determining success of fish populations in some Iowa farm ponds.

Predator Stocking

One of the most common predator-prey combinations in warm water lakes and ponds is the largemouth bass and bluegill. A number of investigators have studied the effectiveness of the largemouth bass in controlling panfish densities when the bass are introduced into a lake or pond with a dense panfish population. Lewis and Helms (1964) found that when six different forage organisms were available to the largemouth bass, that black bullhead and crayfish were utilized to a greater extent than were green sunfish and tilapia, while golden shiner and bluegills were not utilized at all. Clark (1964) also found that the largemouth bass was not a very effective predator on bluegills.

Effectiveness of another panfish predator, northern pike, has also been evaluated by several investigators. Churchill (1947) stocked adult male northern pike in Little Gypsy Lake, Wisconsin to control populations of stunted bluegills and pumpkinseeds. A survey four months later showed a slight improvement in average size of small bluegills but results of the survey were inconclusive. McCarraher

(1959) reported that stocking combinations of northern pike and bluegills in north-central Nebraska farm ponds seemed to have promise as a panfish control technique. Lawler (1965) found that yellow perch and trout-perch were the main diet of northern pike in Heming Lake, Manitoba. Other fish eaten were common suckers, spottail shiners, burbot, sticklebacks, northern pike, whitefish, tullibee and yellow walleye. Doxtater (1967) found that of five predator species tested, the northern pike was the most successful in controlling the number of bluegills in small ponds. He also found some evidence to indicate that channel catfish might be a good predator to stock for bluegill control. Beyerle and Williams (1968) found that northern pike selected chubsuckers and minnows over centrarchids and yellow perch in aquaria studies. Their results increase doubt as to the effectiveness of stocking northern pike to control panfish populations in lakes. Gulish (1968) found that northern pike rarely reproduce in ponds and thus appear to have very limited applicability for bluegill control in ponds.

Stocking of several other predators has been tried. Threinen (1960) found that in only one Wisconsin lake out of ten, was the stocking of walleye fingerlings termed beneficial for both walleye and panfish. The one successful plant was in a lake in which yellow perch were the dominant panfish; in the other lakes where bluegills were dominant, plants were unsuccessful. Gammon and Hasler (1965) and Schmitz and Hetfield (1965) have shown that growth rates of yellow perch increased while their numbers declined after muskellunge were introduced into two largemouth bass-yellow perch bog lakes in northern Wisconsin.

A number of authors have tried to find a given number or ratio of predator to prey fish that can be stocked so that predator fish can keep the prey species in check. Surber (1947) tried various stocking combinations for bluegill and largemouth bass. Bluegill-bass ratios varying from 8:1 to 15:1 were used. The average size of bluegills varied inversely with the number stocked. The smallest bluegills, produced in the 15:1 bluegill-bass ratio, averaged about 5.7 inches in fork length, compared with about 6.5 inches from the 8:1 ratio. Largemouth bass failed to exhibit good growth in the 15:1 ratio, averaging only 9.3 inches compared with 10.2 inches in the 8:1 ratio. Morgan (1958) concluded the best largemouth bass to bluegill stocking ratios in terms of producing desirable sized fish were 200 bass to 1,000 bluegills. Lopinot (1967) recommended the stocking rate for fingerling largemouth bass in Illinois ponds of 100 fish per acre. The recommended stocking rate for fingerling bluegills in ponds and watersheds with fair fertility is 100 per surface acre and in ponds and watersheds with excellent fertility, 400 bluegills should be stocked per surface acre. Thus, in a pond of fair fertility and in a watershed with fair fertility, the stocking rate would be 100 largemouth bass fingerlings to 100 fingerling bluegills per surface acre, while in an area where both ponds and watershed have excellent fertility, the stocking rate would be 100 bass to 400 bluegill per surface acre.

A few authors have tried to evaluate stocking of any predator, in general, for the control of panfish. Carlander (1958) suggests that if a predator-prey relationship is disturbed in some manner, it may result in increased angler success and may sometimes provide an effective means of increasing the harvest of certain species of fish. For example, the exceptional harvest of walleyes in Clear Lake, Iowa, in 1951 was perhaps explained by reproductive failure of yellow perch in 1950 and by elimination of young yellow bass through more than normal predation.

Attention is called to a number of studies which demonstrate that prey species vary in their susceptibility to capture by predacious fishes. The variation in vulnerability of forage species should be taken into consideration in the stocking of lakes. A species that is highly vulnerable will be eliminated; a species that has very low vulnerability will be poorly utilized (Lewis, 1968). Snow (1968) suggests that when the density of a bluegill population is above a certain unknown level, predator stocking can exert little if any control on the population.

SUMMARY

1. Of the various fish toxicants, rotenone appears to be the one most commonly used.

2. It has been found that different species of fish show little variation in their tolerance to rotenone. Also,

it was suggested that there is no relationship between length of yellow perch and time of death after rotenone treatment. Thus, it is very difficult to selectively kill a certain species or size of fish by varying the concentration of rotenone.

3. Rotenone detoxifies in 3 to 6 days in low alkalinity (16 ppm) waters depending on the concentration used. In high alkalinity (60-284 ppm) water it takes 1 to 3 days to detoxify in the summer and 9 to 10 days during the winter depending on the concentration used. In turbid waters of high alkalinity, dissipation takes from 2 to 5 days during the summer.

4. Antimycin is one of the newest fish toxicants on the market. Unlike rotenone, by varying the concentration used, antimycin has showed some promise of being selective for certain sizes and species of fish.

5. Antimycin has a distinct advantage over other toxicants in that it does not irritate or repel fish; thus, most fish appear to incur a lethal dose before they become aware that anything is amiss. Also, antimycin degrades rapidly in water.

6. The concentration of antimycin required to selectively kill a certain size or species of fish varies with water temperature and quality. In general, more toxicant is required in cold, hard alkaline water (pH above 8.5) than in warm soft water of low alkalinity.

7. Toxaphene has had limited use as a fish toxicant because it does not dissipate as fast as rotenone and antimycin. It was found that in some Wisconsin lakes, toxaphene persisted for several years after its application.

8. Copper sulfate has been used to kill eggs and fry on panfish nests and control the density of a year class in small ponds, but this type of treatment is very difficult in larger bodies of water because of the problem of finding all of the nests.

9. Of various attempts to remove fish mechanically from lakes to decrease the density of the population, none have been particularly successful.

10. It is very doubtful whether or not liberalized fishing regulations (no bag limit, size limit or closed seasons) on panfish can control the density of the population. Most panfish have the reproductive capacity to produce many more fish than can be taken by the angler.

11. Two years after the introduction of redear and green sunfish hybrids into a one-acre pond in Illinois, the pond produced the highest hook-and-line yield of fish recorded in Illinois, and the highest catch rate for any Illinois water with a complete creel census. The redear and green sunfish hybrid produced an F_2 generation in the pond but bass predation was heavy and few F_2 hybrids survived.

12. Some work has been done on the use of hormone injections to increase growth and also to decrease the reproductive capacity of fish. This method of control is still in the experimental stages of development.

13. Bennett and Adkins used a fall drawdown to keep bluegills below normal population levels and fed them a high protein food. They found that the size of the bluegills caught by anglers increased by 100 percent.

14. The effects of a drawdown to reduce the density of panfish populations will vary considerably with individual lakes containing various species of panfish.

15. The addition of fertilizers to increase the growth rate of panfish has met with some success in small lakes and ponds.

16. Some authors have proposed that dense stands of aquatic vegetation bind up nutrients during the growing season and also provide hiding places for small fish, making them unavailable to the predators. The elimination of vegetation from ponds has had varying degrees of success in controlling panfish populations.

17. The largemouth bass is not an effective predator in the control of panfish densities.

18. It has been found that northern pike selected minnows and chub suckers over centrarchids and yellow perch in aquaria studies. These results increase doubt as to the effectiveness of stocking northern pike to control panfish populations in lakes.

19. It is very doubtful that once a panfish population reaches a certain unknown level that predator stocking can control the density of the population.

MANAGEMENT IMPLICATIONS

This review is intended to provide the fish manager with a reference source for information that may help him in developing management plans for various bodies of water. Of major interest to the manager is the section on current management techniques. The following discussion is my personal appraisal of the current management techniques and their potential values in Wisconsin waters.

1. Chemical Reclamation - It is the best management tool available for the control of panfish populations. Although it is the one management technique which is most successful in controlling panfish numbers, it provides only a temporary cure to the slow-growing panfish population problem, unless chemical treatment is repeated periodically.

2. Removal - Mechanical removal of panfish requires a number of men and a considerable amount of time each year. Even with a major removal effort, it is doubtful that enough panfish could be removed to decrease the density of the population sufficiently to increase growth rates in most lakes and ponds.

3. Liberalized Fishing Regulations - Such regulations do help the panfish problem some, but angler harvest alone cannot remove enough panfish to decrease the population density.

4. Hybridization - Some researchers have tried to develop hybrid panfish which have a low reproductive potential and a better-than-average rate of growth. These studies are still in the experimental stage and are not of potential value for fish managers at this time.

5. Hormone Injection - This method of control is also still in the experimental stages. Most of the hormones used in the laboratory to increase growth or to reduce panfish reproductive potential have not been cleared for use in the field by the Federal Food and Drug Administration.

6. Supplemental Feedings - This method for increasing growth rates of panfish is not practical on large bodies of water.

7. Sex Ratios - The stocking of one sex of panfish is a put-and-take fishery. The fish manager must be able to answer two basic questions if he is to use this type of control: how many fish must be stocked to produce good fishing and how much of an effort is it going to take to maintain the fishery. This method of panfish control is not practical in a large body of water.

8. Drawdown - The effectiveness of a drawdown is dependent upon the composition of the fish population and on the size of reservoir. For example, in a flowage with a high population of panfish and a low population of predators, it is doubtful that the predators could eat enough panfish, even though the panfish and predators are concentrated. To reduce the density in a large flowage, the water level cannot be drawn down as fast as in a small flowage, thus the possibilities of stranding fish are not as great in large flowages as they are in a smaller one.

9. Fertilization - The fertilization of ponds and lakes has not met with much success outside the southeastern United States, because the results are too uncertain. In northern Wisconsin, for example, the suffocation of fish under the ice is common during severe winters with heavy snowfall. Fertilization of ponds and lakes in this region increases the danger of winterkill. Also, with heavy blooms of algae, the danger of summerkill is ever present and the lake or pond is made undesirable for boating, swimming and other recreational purposes.

10. Aquatic Vegetation Control - This type of panfish control is not practical on large bodies of water.

11. Predator Stocking - This management technique for controlling panfish numbers has been tried many times with very little success in reducing panfish densities. When a panfish population reaches an unknown level, predators cannot reduce the density enough to offset the reproductive ability of the panfish.

RESEARCH IMPLICATIONS

The literature review was also conducted to help provide insight into the areas of panfish research which would be the most beneficial in helping to formulate plans to manage panfish populations for maximum substained yields. The following are my opinions of what appear to be the most lucrative areas of research at the present time.

All the management techniques now in use are only temporary cures unless repeated periodically. The major reason for this is that we are trying to cure a disease (slow-growth) without knowing its cause. We know that the apparent problem is high densities of panfish, but we do not know why in some lakes we have densities at levels that produce a desirable panfish fishery and why in other lakes we continually have dense populations of small fish.

I feel the key to good panfish management is the elimination of year classes. For example, in the better panfish lakes, there seems to be two or three dominant year classes with the remaining year classes missing from the population. In these lakes, this reduction or elimination of year classes happens as a result of natural mortality during the first summer. In poor panfish lakes, there seems to be a stable production of year-classes, year after year. Thus research is needed to determine what factors are responsible for reducing or eliminating year classes under natural conditions during this first summer. If a number of these factors could be isolated, it may be possible to formulate methods of better managing panfish populations.

Another area in which research could be directed involves the use of selective fish toxicants which appear to be the best available management tool we have today for eliminating certain year classes of panfish. Antimycin has been the only toxicant on the market which has shown some promise of being a selective toxicant for certain sizes of fish and species of fish. More research is needed on the effects of different concentrations of antimycin on certain species of fish. Also, work is needed on the effects of water temperature, conductivity, alkalinity, pH and other physical and chemical properties of the lake on the concentration of antimycin applied. In addition to research on antimycin, more work is needed to develop and test other chemicals that show promise as selective fish toxicants.

LITERATURE CITED

Allison, D.
1964. Copper sulfate used in bluegill population control. Ohio Dep. Nat. Resour. Publ. W-10. 6 p.

Applegate, R. L.
1966. The use of a bryozoan, Fredericella sultana, as food by sunfish in Bull Shoals Reservoir. Limnol. & Oceanogr. 11(1):129-130.

Avault, James W. Jr. and Gilbert C. Radonski
1967. Use of antimycin, fintrol, as a fish toxicant with emphasis on removal of trash fish from catfish ponds. Proc. 21st Annu. Conf. Southeast. Assoc. Game & Fish Comm. pp. 25-27.

Bailey, Reeve M. and Karl F. Lagler
1938. An analysis of hybridization in a population of stunted sunfishes in New York. Mich. Acad. Sci., Arts & Lett. 23:577-606.

Ball, Robert C.
1945a. Recovery of marked fish following a second poisoning of the population in Ford Lake, Michigan. Trans. Am. Fish. Soc. 75:36-42.

1945b. Summary of experiments in Michigan lakes on the elimination of fish populations with rotenone, 1934-1942. Trans. Am. Fish. Soc. 75:139-146.

1948. Fertilization of natural lakes in Michigan. Trans. Am. Fish. Soc. 78:145-155.

Balon, E.
1959. Spawning of Lepomis gibbosus acclimatized in the back waters of the Danube and its development during the embryonic period. Vest. Cesk. Spol. Zool. 23(1):1-22.

Bangham, Ralph V.
1938. Parasites of Centrarchidae from southern Florida. Trans. Am. Fish. Soc. 68:263-268.

1940. Parasites of fish of Algonquin Park Lakes. Trans. Am. Fish Soc. 70:161-171.

1943. Report on survey of fish parasites in northwest area. Wis. Conserv. Dep. Rep. 7 p.

Bangham, Ralph V. and Jacob H. Fischthal
1944. Fungused perch in Sturgeon Bay, Wisconsin. Wis. Conserv. Dep. Invest. Rep. 391. 2 p.

Bardach, John E.
1955. The opercular bone of the yellow perch (Perca flavescens) as a tool for age and growth. Copeia. 2:107-109.

Barry, James J.
1967. Evaluation of creel census, rotenone embayment, gill net, traps and electro-fishing gear samples, by complete drainage of Lenape and Bischoff Reservoirs. Indiana Dep. Nat. Resour. Fish. Res. Sect. Bull. 18 p.

Beckman, William C.
1945. The length-weight relationship, factors for conversions between standard and total lengths, and coefficients of condition for seven Michigan fishes. Trans. Am. Fish. Soc. 75:237-256.

1946. The rate of growth and sex ratio for seven Michigan fishes. Trans. Am. Fish. Soc. 76:63-81.

1948. Changes in growth rates of fishes following reduction in population densities by winterkill. Trans. Am. Fish. Soc. 78:82-90.

Bennett, George W.
1943. Management of small artificial lakes. Ill. Nat. Hist. Surv. Bull. 22(3):357-376.

1945. Overfishing in a small artificial lake. Bull. Ill. State Lab. Nat. Hist. 23:375-406.

1954. The effects of a late-summer drawdown on the fish population of Ridge Lake, Coles County, Illinois. Trans. 19th North Am. Wildl. Conf. pp. 259-270.

1962. Management of artificial lakes and ponds. N. Y., Reinhold Books. 283 p.

Bennett, George W. and H. Wickliffe Adkins
1968. The dynamics of a bluegill population fed on a prepared food and subjected to an annual fall drawdown. Ill. Nat. Hist. Surv. Bull. 13 p.

Bennett, George W., H. Wickliffe Adkins and William F. Childers
1969. Largemouth bass and other fishes in Ridge Lake, Illinois, 1941-1963. Ill. Nat. Hist. Surv. Bull. 30(1):1-67.

Berg, Ronald J.
1969. Low oxygen tolerance by yellow perch (Perca flavescens) from winterkill and nonwinterkill lakes. M. S. Thesis. Univ. Wis. 33 p.

Beyerle, George B. and John E. Williams
1967. Attempted control of bluegill reproduction in lakes by the application of copper sulfate crystals to spawning nests. Prog. Fish-Cult. 29(3): 150-155.

1968. Some observations of food selectivity by northern pike in aquaria. Trans. Am. Fish. Soc. 97(1):28-31.

LITERATURE CITED

CONTINUED

Birdsong, R. S. and R. W. Yerger
1967. A natural population of hybrid sunfishes. Copeia. 1:62-71.

Boesel, M. W.
1937. The food of nine species of fish from the western end of Lake Erie. Trans. Am. Fish. Soc. 67:215-223.

Brasch, John G.
1958. Drawdowns: fish management tool. Wis. Conserv. Bull. 23(12):4.

Brown, C. J. and R. C. Ball
1942. An experiment in the use of derris root (rotenone) on the fish and fish-food organisms of Third Sister Lake. Trans. Am. Fish. Soc. 72:267-284.

Burdick, G. E., Howard J. Dean and Earl F. Harris
1956. Toxicity of emulsifiable rotenone to yellow perch. N. Y. Fish & Game J. 3(1):75-80.

Burress, Ralph M.
1968. Antimycin for controlling sunfish populations in ponds. Farm Pond Harvest. 2(1):11-22.

Byrd, I. B.
1951. Depth distribution of the bluegill *Lepomis macrochirus* (Rafinesque) in farm ponds during summer stratification. Trans. Am. Fish. Soc. 81:162-178.

Callaham, Mac A. and Melvin T. Huish
1967. An evaluation of antimycin as a selective bluegill toxicant under varying conditions of pH. Proc. 21st Annu. Conf. Southeast. Assoc. Game & Fish Comm. 11 p.

Carbine, W. F.
1939. Observations on the spawning habits of Centrarchid fishes in Deep Lake, Oakland County, Michigan. Trans. 4th North Am. Wildl. Conf. pp. 275-287.

Carbine, W. F. and Vernon C. Applegate
1945. The fish population of Deep Lake, Michigan. Trans. Am. Fish. Soc. 75:200-227.

Carlander, Kenneth D.
1949. Growth rate studies of saugers (*Stizostedion canadense canadense*) (Smith) and yellow perch (*Perca flavescens*) (Mitchill) from Lake of the Woods, Minnesota. Trans. Am. Fish. Soc. 79:30-42.

1953. Handbook of freshwater fishery biology with the first supplement. W. C. Brown Co., Dubuque, Iowa. 429 p.

1958. Disturbance of the predator-prey balance as a management technique. Trans. Am. Fish. Soc. 87th Annu. Meet. 1957. pp. 34-38.

Carter, J. P.
1963. Experimental crappie removal. Ky. Dep. Fish & Wildl. Completion Rep. Proj. F-21-R. 18 p.

Chase, Herman B.
1946. Calculations of fish condition from scale dimensions in the bluegill, *Lepomis macrochirus*. Ecology. 27(2):182-184.

Childers, William F.
1967. Hybridization of four species of sunfishes (Centrarchidae). Ill. Nat. Hist. Surv. Bull. 29(3);159-211.

Childers, William F. and G. W. Bennett
1967. Hook and line production of largemouth bass and redear X green sunfish hybrids in a one-acre pond. Prog. Fish.-Cult. 29(1):27-35.

Churchill, Warren
1947. Experimental management of Little Gypsy Lake. Wis. Conserv. Dep. Invest. Rep. 506. 4 p.

1949. The effect of perch removal on a small northeastern Wisconsin lake. Wis. Conserv. Dep. Invest. Rep. 714. 7 p.

1957. Conclusions from a ten year creel census on a lake with no angling restrictions. J. Wildl. Manage. 21(2):182-188.

Churchill, Warren and Howard Snow
1964. Characteristics of the sport fishery in some northern Wisconsin lakes. Wis. Conserv. Dep. Tech. Bull. 32. 44 p.

Clady, Michael D. and Gerald U. Ulrikson
1968. Mortality of recently hatched bluegill fry as a result of hydra. Prog. Fish-Cult. 30(1):39-40.

Clark, C. F.
1964. Bluegill control experiment in Hamler Lake, Ohio. Ohio Dep. Nat. Resour. Publ. W-335. 5 p.

Clark, Francis W. and Miles H. A. Keenleyside
1967. Reproductive isolation between the sunfish, Lepomis gibbosus and Lepomis macrochirus. Fish. Res. Board Can. 24(3):495-514.

Clausen, Ralph G.
1936. Oxygen consumption in fresh water fishes. Ecology. 17(2):216-225.

Clemens, Howard P.
1952. Effectiveness of rotenone in pond reclamation. Trans. Am. Fish. Soc. 82:166-177.

Coble, Daniel W.
1966. Dependence of total annual growth in yellow perch on temperature. Fish. Res. Board Can. 23(1):15-20.

Coggeshall, Lowell T.
1924. A study of the productivity and breeding habits of the bluegill, Lepomis pallidus (Mitch.). Proc. Indiana Acad. Sci. Vol. 33.

Cooper, Gerald P.
1951. Estimation of fish populations in Michigan lakes. Trans. Am. Fish. Soc. 81:4-16.

1966. Fish production in impoundments. Mich. Dep. Conserv. Res. & Dev. Rep. 104. pp. 1-21.

Cooper, Gerald P. and George N. Washburn
1946. Relation of dissolved oxygen to winter mortality of fish in Michigan lakes. Trans. Am. Fish. Soc. 76:23-33.

Coots, Millard
1956. The yellow perch, Perca flavescens, (Mitchill), in the Kalmath River. Calif. Fish & Game. 42(3):219-228.

Davis, H. S.
1947. Cytophaga columnaris as a cause of fish epidemics. Trans. Am. Fish. Soc. 77:102-104.

De Lury, D. B.
1947. On the estimation of biological populations. Biometrics. 3:145-167.

Dendy, J. S.
1956. Bottom fauna in ponds with largemouth bass only and with a combination of largemouth bass plus bluegill. Tenn. Acad. Sci. 31(3):198-207.

Dicostanzo, C. J.
1957. Growth of bluegill, Lepomis macrochirus, and pumpkinseed, Lepomis gibbosus of Clear Lake, Iowa. Iowa State Coll. J. Sci. 32(1):19-34.

Dietz, Elgin M. C.
1962. Experimental chemical control of undesirable fish species. Texas Game and Fish Commission. Job Completion Rep. Fish. Invest. & Surv. of Waters of Region 7-B. Job No. E-5. 10 p.

1963. Experimental control of undesirable fish species. Texas Game and Fish Commission. Job Completion Rep. Fish. Invest. & Surv. of Waters of Region 5-A. Job E-5. 13 p.

Doxtater, Gary D.
1964. Food habits of the bluegill as influenced by season and size class. 26th Midwest Wildl. Conf. 14 p.

1967. Experimental predator-prey relations in small ponds. Prog. Fish-Cult. 29(2):102-104.

Eicher, George J., Jr.
1945. Localized weed control in management of game fish. Trans. Amer. Fish. Soc. 76:177-182.

Elder, D. E. and W. M. Lewis
1955. An investigation and comparison of the fish populations of two farm ponds. Am. Midl. Nat. 53:390-395.

El Zarka, Salah
1958. Fluctuations of the yellow perch in Saginaw Bay. Diss. Abstr. 18(5):P-1904.

Emig, John W.
1969. Selectively annotated bibliography of creel census methodology. Calif. Dep. Fish & Game. Inland Fish. Admin. Rep. 69-1. 40 p.

Engel, Dennis R. and C. L. Brynildson
1967. A literature review on the value of testosterone to control the reproduction of fish. Wis. Dep. Nat. Resour. Fish Manage. Rep. 13. 12 p.

Eschmeyer, R. W.
1937. Experimental management of a group of small Michigan lakes. Trans. Am. Fish. Soc. 67:120-129.

1940. Growth of fishes in Norris Lake, Tennessee. Tenn. Acad. Sci. 15:329-341.

Ewers, Lela A.
1933. Summary report of crustacea used as food by the fishes of the western end of Lake Erie. Trans. Am. Fish. Soc. 63:279-300.

Ewers, Lela A. and M. W. Boesel
1935. The food of some Buckeye Lake fishes. Trans. Am. Fish. Soc. 65:57-70.

Faber, Daniel J.
1967. Limnetic larval fish in northern Wisconsin lakes. Fish. Res. Board Can. 24(5):927-937.

Ferguson, R. G.
1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. Fish. Res. Board Can. 15(4):607-624.

Fischthal, Jacob H.
1944. Parasites of northwest Wisconsin fishes. Wis. Conserv. Dep. Invest. Rep. 412. 10 p.

Flakas, Kenneth G.

1947. An age group growth survey of Green Bay yellow perch. Wis. Conserv. Dep. Invest. Rep. 581. 18 p.

1950. A bacterial disease found in the black crappie Poxomis nigromaculatus. Prog. Fish-Cult. 12(2):87-88.

Flemer, D. A. and W. S. Woolcott

1966. Food habits and distribution of the fishes of Tuckahoe Creek, Virginia with special emphasis on the bluegill. Chesapeake Sci. 7(2):75-89.

Funk, John L.

1955. Movement of stream fishes in Missouri. Trans. Am. Fish. Soc. 85:39-57.

Gammon, James R. and Arthur D. Hasler

1965. Predation by introduced muskellunge on perch and bass, I: years 1-5. Trans. Wis. Acad. Sci., Arts & Lett. 54:249-272.

Gerking, Shelby D.

1950. Populations and exploitation of fishes in a marl lake. Invest. Indiana Lakes & Streams. 3(11):389-434.

1953. Vital statistics of the fish population of Gordy Lake, Indiana. Trans. Am. Fish. Soc. 82:48-67.

1954. The food turnover of a bluegill population. Ecology. 35(4):490-498.

1955a. Influence of rate of feeding on body composition and protein metabolism of bluegill sunfish. Physiol. Zool. 28(4):267-282.

1955b. Endogenous nitrogen excretion of bluegill sunfish. Physiol. Zool. 28(4):283-289.

1962. Production and food utilization in population of bluegill sunfish. Ecol. Monogr. 32(1):31-78.

1966. Annual growth cycle, growth potential, and growth compensation in the bluegill sunfish in northern Indiana lakes. Fish. Res. Board Can. 23(12):1923-1956.

Goodson, Lee F.

1965. Diets of four warm-water game fishes in a fluctuating, steep-sided, California reservoir. Calif. Fish & Game. 51(4):259-269.

Gray, Charles E.

1962. Experimental use of copper sulphate in killing undesirable fish species. Texas Game and Fish Commission. Segment Completion Rep. Fish. Invest. & Surv. of Waters of Region 5-B. Job E-1. 12 p.

Greenbank, John

1940. Selective poisoning of fish. Trans. Am. Fish. Soc. 70:80-86.

1956. Movement of fish under the ice. Copeia. 3:158-162.

Grice, F.

1959. Elasticity of growth of yellow perch, chain pickerel and largemouth bass in some reclaimed Massachusetts waters. Trans. Am. Fish. Soc. 88(4):332-335.

1962. Field tests of Ortho Fish Thinner in Massachusetts. Proc. Northeast Fish & Wildl. Conf. pp. 1-19.

Gross, W. L., P. O. Fromm and E. W. Roelofs

1963. Relationship between thyroid and growth in green sunfish, Lepomis cyanellus (Rafinesque). Trans. Am. Fish. Soc. 92(4):401-408.

1965. Influence of photoperiod on growth of green sunfish, Lepomis cyanellus. Fish. Res. Board Can. 22(6):1379-1386.

Gulish, William J.
1968. The predation rate of three species of fish upon bluegills in ponds. Initial Progress Rep. Indiana Dep. Nat. Resour. Div. Fish & Game Prog. Rep. 12 p.

Gunning, Gerald E.
1959. The sensory basis for homing in the longear sunfish, Lepomis megalotis megalotis (Rafinesque). Invest. Indiana Lakes & Streams. 5(3):103-130.

1963. Occupancy of home range by longear sunfish, Lepomis megalotis and bluegill, Lepomis macrochirus. Anim. Behav. 11(2/3):325-330.

Hacker, V. A.
1952a. An analysis of Lake Monona rough fish daily catch reports for the period 1934 to 1951. Wis. Conserv. Dep. Invest. Rep. No. 666. 23 p.

1952b. An analysis of Lake Kegonsa rough fish daily catch reports for the period 1937 to 1951. Wis. Conserv. Dep. Invest. Rep. 667. 29 p.

1969. The winter chemical treatment of streams with antimycin. 31st Midwest Fish & Wildl. Conf. 7 p.

Hall, G. E. and J. C. Finell
1954. The influence of environmental conditions upon the growth of white and black crappie in Oklahoma waters. Okla. Fish. Res. Lab. Rep. 40. 56 p.

Hansen, Donald F.
1943. On nesting of the white crappie, Pomoxis annularis. Copeia. No. 4:259-260.

1951. Biology of the white crappie in Illinois. Ill. Nat. Hist. Surv. Bull. 25(4):211-265.

1966. Stocking and sportfishing at Lake Glendale (Illinois). Ill. Nat. Hist. Surv. Bull. 29(2):105-158.

Hathaway, Edward S.
1927. The relation of temperature to the quantity of food consumed by fishes. Ecology. 8(4):428-434.

Hayes, F. R.
1957. On the variation in bottom fauna and fish yield in relation to trophic levels and lake dimensions. Fish. Res. Board Can. 14(1):1-32.

Hennemuth, Richard C.
1955. Growth of crappies, bluegill, and warmouth in Lake Ahquabi, Iowa. Iowa State Coll. J. Sci. 30(1):119-137.

Hergenrader, Gary L. and Arthur D. Hasler
1966. Diel activity and the vertical distribution of yellow perch under the ice. Fish. Res. Board Can. 23(4):499-509.

1968. Influence of changing seasons on schooling behavior of yellow perch. Fish. Res. Board Can. 25(4):711-716.

Herman, Elmer F.
1944. Bluegill mortality at Lake Delevan. Wis. Conserv. Dep. Invest. Rep. 351. 1 p.

Herman, Elmer, Warren Wisby, Lawrence Wiegert and Milton Burdick
1959. The yellow perch: its life history, ecology, and management. Wis. Conserv. Dept. Publ. 228. 14 p.

Herman, Leroy, Robert S. Campbell and Lee C. Redmond
1969. Manipulation of fish populations through reservoir drawdown. Trans. Am. Fish. Soc. 98(2):293-304.

Herr, F., E. Greslin and C. Chappel
1967. Toxicology studies of antimycin, a fish eradicant. Trans. Am. Fish. Soc. 96(3):320-326.

Hile, Ralph and F. W. Jobes
1940. Age, growth and production of the yellow perch (Perca flavescens) (Mitchill), of Saginaw Bay. Trans. Am. Fish. Soc. 70:102-122.

Hoffman, G. L., G. W. Prescott and C. R. Thompson
1965. Chlorella parasitic in bluegills. Prog. Fish-Cult. 27(3):175.

Houser, A. and B. Grinstead
1961. The effect of black bullhead catfish and bluegill removal on the fish population of a small lake. Proc. 15th Annu. Conf. Southeast. Assoc. Game & Fish Comm. pp. 193-200.

Howell, Henry H.
1941. Bottom organisms in fertilized and unfertilized fish ponds in Alabama. Trans. Am. Fish. Soc. 71:165-179.

Huck, Lois Lee and Gerald E. Gunning
1967. Behavior of the longear sunfish (Lepomis megalotis) Rafinesque. Tulane Stud. Zool. 14(3):121-131.

Huish, Melvin T.
1953. Life history of the black crappie of Lake George, Florida. Trans. Am. Fish. Soc. 83:176-193.

1958. Life history of the black crappie of Lakes Eustis and Harris, Florida. Proc. 11th Annu. Conf. Southeast. Assoc. Game & Fish Comm. pp. 302-312.

Hunt, Burton P.
1950. Food of young pike, Esox lucius L., and associated fishes in Peterson's Ditches, Houghton Lake, Michigan. Trans. Am. Fish. Soc. 80:67-83.

Hunter, John R.
1963. The reproductive behavior of the green sunfish, (Lepomis cyanellus). Zoology. 48(2):13-24.

Iowa Conservation Department
1969. Selective reduction of a bluegill population in Dakin Lake, Story County, Iowa. Conserv. Bull. 2 p.

Jackson, C. F.
1956. Control of the common sunfish or pumpkinseed, Lepomis gibbosus in New Hampshire. N. H. Fish & Game Dep. Tech.-Circ. 12. 16 p.

Jenkins, Robert M.
1953. An eleven-year growth history of white crappie in Grand Lake, Oklahoma. Proc. Okla. Acad. Sci. 34:40-47.

1955a. The effect of gizzard shad on the fish population of a small Oklahoma lake. Trans. Am. Fish. Soc. 85:58-74.

1955b. Expansion of the crappie population in Ardmore City Lake following a drastic reduction in numbers. Proc. Okla. Acad. Sci. 36:70-76.

Jobes, Frank W.
1952. Age, growth and production of yellow perch in Lake Erie. U. S. Fish and Wildl. Serv. Fish. Bull. 52:205-264.

Joeris, Leonard S.
1956. Structure and growth of scales of yellow perch of Green Bay. Trans. Am. Fish. Soc. 86:169-194.

Johnson, Welburne D., G. F. Lee and Demetrios Spyridakis
1966. Persistence of toxaphene in treated lakes. Air & Water Pollut. Inst. J. Vol. 10. pp. 555-560.

Johnson, Wendell L.
1945. Age and growth of the black and white crappies of Greenwood Lake, Indiana. Invest. Indiana Lakes & Streams. 2(15):297-324.

Keast, Allen
1968. Feeding biology of the black crappie, *Pomoxis nigromaculatus*. Fish. Res. Board Can. 25(2):285-297.

Kelly, H. D. and R. Allison
1965. Observations on the infestation of a fresh water fish population by a marine copepod. Proc. 16th Annu. Conf. Southeast. Assoc. Game & Fish Comm. Oct. 14-17,1962. pp. 236-239.

Kempinger, James J.
1969. Experimental management of Spruce Lake, a small bog lake in northeastern Wisconsin. Wis. Dep. Nat. Resour. Res. Rep. No. 40. 15 p.

Krumholz, Louis A.
1949. Further observations on the use of hybrid sunfish in stocking small ponds. Trans. Am. Fish. Soc. 79:112-124.

LaFaunce, D. A., J. B. Kimsey and H. K. Chadwick
1964. The fishery at Sutherland Reservoir, San Diego County, California. Calif. Fish & Game. 50(4):271-291.

Lagler, K. F.
1952. Freshwater fishery biology. W. C. Brown Co., Dubuque, Iowa. 360 p.

Lagler, Karl F. and W. E. Ricker
1942. Biological fisheries investigations of Foots Pond, Gibson County, Indiana. Invest. Indiana Lakes & Streams. 2:47-72.

Lagler, Karl F. and C. Steinmetz
1957. Characterisitics and fertility of experimentally produced sunfish hybrids, *Lepomis gibbosus* x *Lepomis macrochirus*. Copeia. 4:290-292.

Lambou, Victor W.
1966. Recommended methods of reporting creel survey data for reservoirs. Okla. Fish. Res. Lab. Bull. 4. 40 p.

Lane, Charles
1954. Age and growth of the bluegill, *Lepomis macrochirus* (Rafinesque) in a Missouri impoundment. J. Wildl. Manage. 18(3):359-365.

Langford, R. R. and W. R. Martin
1940. Seasonal variations in stomach content in a population of yellow perch. Trans. Am. Fish. Soc. 70:436-440.

Langlois, T. H.
1939. Ohio fish management progress report. Ohio Conserv. Bull. 3(1):16-19.

1945. Ohio's fish program. Ohio Div. Conserv. and Nat. Resour. 40 p.

Lantz, Kenneth E., James T. Davis, Janice S. Hughes and Harry E. Schafer, Jr.
1964. Water level fluctuation - its effects on vegetation control and fish population management. Proc. 18th Annu. Conf. Southeast. Assoc. Game & Fish Comm. 12 p.

Larkin, P. A.
1963. Interspecific competition and exploitation. Fish Res. Board Can. 20(3):647-678.

Lawler, G. H.
1965. The food of the pike, *Esox lucius*, in Heming Lake, Manitoba. Fish. Res. Board Can. 22(6):1357-1377.

Lawrence, John M.
1952. A trapping experiment to estimate the bluegill population in a farm pond. Proc. Iowa Acad. Sci. 59:475-479.

Le Cren, E. D.
1947. The determination of the age and growth of the perch (Perca fluviatilis) from the opercular bone. J. Anim. Ecol. 16(1):188-203.

1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). J. Anim. Ecol. 20(2):201-219.

1955. Year to year variation in the year-class strength of Perca fluviatilis. Proc. Int. Assoc. Theor. & Appl. Limnol. 12:187-192.

1958. Observations on the growth of perch over twenty-two years with special reference to the effects of temperature and changes in population density. J. Anim. Ecol. 27(2):287-334.

Lennon, R. E.
1966. Antimycin - A new fishery tool. Wis. Conserv. Bull. 31(2):4-5.

Leonard, Justin W.
1939. Further observations on the feeding habits of the Montana grayling (Thymallus montanus) and the bluegill (Lepomis macrochirus) in Ford Lake, Michigan. Trans. Am. Fish. Soc. 69:244-256.

Lewis, William M.
1950. Fisheries investigations on two artificial lakes in southern Iowa II fish populations. Iowa State Coll. J. Sci. 24(3):287-324.

1968. Predation as a factor in fish populations. Reprint. Reservoir Fish. Resour. Symp. April 5-7, 1967.

Lewis, W. M., Roy Heidinger and Mark Konikoff
1969. Artificial feeding of yearling and adult largemouth bass. Prog. Fish-Cult. 31(1):44-46.

Lewis, W. M. and D. R. Helms
1964. Vulnerability of forage organisms to largemouth bass. Trans. Am. Fish. Soc. 93(3):315-318.

Lewis, William M. and John Nickum
1964. The effect of Posthodiplostomum minimum upon the body weight of the bluegill. Prog. Fish-Cult. 26(3):121-123.

Lopinot, A. C.
1967. Pond fish and fishing in Illinois. Ill. Dep. Conserv. Div. Fish. Bull. 5. 62 p.

Louder, D. E. and W. M. Lewis
1957. Study of a stocking of the redear and bluegill in southern Illinois. Prog. Fish-Cult. 19(3):140-141.

Louder, D. E. and E. G. McCoy
1965. Preliminary investigations of the use of aqualin for collecting fishes. Proc. 16th Annu. Conf. Southeast. Assoc. Game & Fish Comm. pp. 240-242.

Lux, Fred E.
1960. Notes on first-year growth of several species of Minnesota fish. Prog. Fish-Cult. 22(2):81-82.

Lydell, Claude
1938. Crayfish affects fish production. Prog. Fish-Cult. 41:22-23.

Mackenthun, Kenneth M.
1946. A preliminary report on the age, growth and condition factor of southern Wisconsin fishes. Wis. Conserv. Dep. Invest. Rep. 574. 22 p.

1947. Age and growth of bluegills. Wis. Conserv. Bull. 12(5):1-4.

1948. Age-length and length-weight relationship of southern area lake fishes. Wis. Conserv. Dep. Revision of Invest. Rep. 580. 7 p.

Mackenthun, Kenneth M. and Elmer F. Herman
1945. A heavy mortality of fishes resulting from the decomposition of algae in the Yahara River, Wisconsin. Trans. Am. Fish. Soc. 75:175-180.

Maloney, J. E. and F. H. Johnson
1955. Life history and inter-relationships of walleye and yellow perch, especially during their first summer, in two Minnesota lakes. Trans. Am. Fish. Soc. 85:191-202.

Marcy, Donald E.
1954. The food and growth of the white crappie, (Pomoxis annularis), in Pymatuming Lake, Pennsylvania and Ohio. Copeia. 3:236-239.

May, Edwin B. and Charles R. Gasaway
1967. A preliminary key to the identifications of larval fishes of Oklahoma, with particular reference to Canton Reservoir, including a selected bibliography. Okla. Fish. Res. Lab. Bull. 5. 33 p.

Mayhew, Jim
1962. Thermal stratification and its effects on fish and fishing in Red Haw Lake, Iowa. Iowa State Conserv. Comm. Biol. Sect. Bull. 23 p.

McCarraher, D. B.
1959. The northern pike-bluegill combination in north-central Nebraska farm ponds. Prog. Fish-Cult. 21(4):188-189.

Miller, Jack and Keen Buss
1960. The age and growth of the fishes in Pennsylvania. Public Relat. Div. Pa. Fish Comm. 15 p.

1961. The age and growth of the pumpkinseed in Pennsylvania part V. Pa. Angler. 30(2):8-9.

Moffett, James W. and Burton P. Hunt
1943. Winter feeding habits of bluegills, Lepomis macrochirus Rafinesque, and yellow perch, Perca flavescens (Mitchill), in Cedar Lake, Washtenaw County, Michigan. Trans. Am. Fish. Soc. 73:231-242.

Moore, Emmeline and Staff
1937. A creel census at Chataqua Lake, New York. Trans. Am. Fish. Soc. 67:130-138.

Moore, Walter G.
1941. Studies on the feeding habits of fishes. Ecology. 22(1):91-96.

Moorman, R. B.
1957. Some factors related to success of fish populations in Iowa farm ponds. Trans. Am. Fish. Soc. 86th Annu. Meet. pp. 361-370.

Morgan, George D.
1951a. A comparative study of the spawning periods of the bluegill, Lepomis macrochirus, the black crappie, Pomoxis nigromaculatus (LeSueur), and the white crappie, Pomoxis annularis (Rafinesque) of Buckeye Lake, Ohio. Denison Univ. Bull. 42(11-14):112-117.

1951b. The life history of the bluegill sunfish, Lepomis macrochirus, of Buckeye Lake, Ohio. Denison Univ. Bull. 42(4):21-63.

1954. The life history of the white crappie (Pomoxis annularis) of Buckeye Lake, Ohio. J. Sci. Lab. Denison Univ. 43(6-8):113-144.

1958. A study of six different pond stocking ratios of largemouth bass and bluegill; and the relation of the chemical, physical and biological data to pond balance and productivity. J. Sci. Lab. Denison Univ. 44:151-202.

Moyle, John B., Jerome H. Kuehn and Charles R. Burrows
1948. Fish-populations and catch data from Minnesota lakes. Trans. Am. Fish. Soc. 78:163-175.

Mraz, Donald
1951. Movements of yellow perch marked in southern Green Bay, Lake Michigan in 1950. Trans. Am. Fish. Soc. 81:150-161.

Mraz, D. and L. E. Cooper
1957. Reproduction of carp, largemouth bass, bluegills, and black crappies in small rearing ponds. J. Wildl. Manage. 21(2):127-133.

Muncy, R. J.
1962. Life history of the yellow perch, Perca flavescens, in estuarine waters of the Severn River, a tributary of Chesapeake Bay, Maryland. Chesapeake Sci. 3(3):143-159.

Neal, R. A.
1962. White and black crappies in Clear Lake, summer 1960. Proc. Iowa Acad. Sci. 68:247-253.

1963. Black and white crappies in Clear Lake, 1950-1961. Iowa State Coll. J. Sci. 37(4):425-445.

Nigrelli, Ross F.
1953. Tumors and other atypical cell growths in temperate freshwater fishes of North America. Trans. Am. Fish. Soc. 83:262-296.

Odell, Theodore T.
1932. The depth distribution of certain species of fish in some of the lakes of New York. Trans. Am. Fish. Soc. 62:331-335.

O'Donnell, D. John
1938. Investigation of bluegill mortality in Lake Chetac. Wis. Conserv. Dep. Invest. Rep. 147. 2 p.

1941. A sudden mortality of perch in Yellow Lake, Burnett County, 1941. Wis. Conserv. Dep. Invest. Rep. 151. 2 p.

1942a. Species of fish. Wis. Conserv. Dep. Invest. Rep. 141. 3 p.

1942b. The fish population in three small lakes in northern Wisconsin. Trans. Am. Fish. Soc. 72:187-196.

O'Donnell, D. John and A. W. Roecker
1940. The spring food of the fishes of thirty-three northwestern Wisconsin lakes. Wis. Conserv. Dep. Invest. Rep. 128.

Parker, R. A.
1956. A contribution to the population dynamics and homing behavior of northern Wisconsin lake fishes. Diss. Abstr. 16(11):2248-2249.

1958. Some effects of thinning on a population of fishes. Ecology. 39(2):304-317.

Parnell, I. W.
1934. Fish parasites and their importance. Trans. Am. Fish Soc. 64:390-400.

Parsons, John W.
1951. Growth studies of the yellow perch, Perca flavescens (Mitchill) in three northwest Iowa lakes. Iowa State Coll. J. Sci. 25(3):495-500.

Patriarche, Mercer H.
1952. The fishery in Lake Wappapello, a flood-control reservoir on the St. Francis River, Missouri. Trans. Am. Fish. Soc. 82:242-254.

Pearse, A. S.
1924. Amount of food eaten by four species of fresh-water fishes. Ecology. 5(3):254-258.

Pelton, John Z.
1948. Three years of liberalized fishing at Lake Alma, Ohio. Trans. Am. Fish. Soc. 78:64-69.

LITERATURE CITED

CONTINUED

Petersen, C. G.
1896. The yearly immigration of young plaice into the Limfjord from the German Sea, etc. Rep. Dan. Biol. Sta. for 1895. 6:1-48.

Pycha, Richard L. and Lloyd L. Smith, Jr.
1954. Early life history of the yellow perch (Perca flavescens), in the Red Lakes, Minnesota. Trans. Am. Fish. Soc. 84:249-260.

Radonski, Gilbert C.
1967. Antimycin: useful in perch control? Wis. Conserv. Bull. 32(2):4.

Radonski, Gilbert C. and Richard W. Wendt
1966. The effects of low dosage application of fintrol (active ingredient - antimycin A) on the yellow perch (Perca flavescens). Wis. Conserv. Dep. Fish Manage. Rep. 10. 8 p.

Regier, H. A.
1962. Validation of the scale method for estimating age and growth of bluegills. Trans. Am. Fish. Soc. 91(4):362-374.

Reid, George K., Jr.
1949. Food of the black crappie (Pomoxis nigromaculatus) (LeSueur), in Orange Lake, Florida. Trans. Am. Fish. Soc. 79:145-154.

Ricker, William E.
1942a. The rate of growth of bluegill sunfish in lakes of northern Indiana. Invest. Indiana Lakes & Streams. 2(12):161-214.

1942b. Creel census, population estimates and rate of exploitation of game fish in Shoe Lake, Indiana. Invest. Indiana Lakes & Streams. 2(12):215-253.

1942c. Fish population of two artificial lakes. Invest. Indiana Lakes & Streams. 2:255-265.

1945. Fish catches in three Indiana lakes. Invest. Indiana Lakes & Streams. 2(16):325-344.

1949. Utilization of food by bluegills. Invest. Indiana Lakes & Streams. 3(8):311-318.

1955. Fish and fishing in Spear Lake, Indiana. Invest. Indiana Lakes & Streams. 4(5):117-175.

1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Board Can. Bull. 119. 300 p.

Ricker, William E. and John Gottschalk
1940. An experiment in removing coarse fish from a lake. Trans. Am. Fish Soc. 70:382-390.

Riel, Arthur D.
1965a. The control of an overpopulation of yellow perch in Bow Lake, Strafford, New Hampshire. Prog. Fish-Cult. 27(1):37-41.

1965b. The control of an overpopulation of yellow perch in Bow Lake, Strafford, New Hampshire. N.H. Fish & Game Dep. Tech.-Circ. 21. 5 p.

Rose, Earl T. and Tom Moen
1952. The increase in game-fish populations in the East Okoboji Lake, Iowa, following intensive removal of rough fish. Trans. Am. Fish. Soc. 82:104-114.

Rosebery, Dean A.
1950. Fishery management of Claytor Lake, an impoundment on the new river in Virginia. Trans. Am. Fish. Soc. 80:194-209.

Ross, John A., and Phyllis R. Mordstorm, Jack E. Baily and John R. Heaton
1960. A bacterial disease of yellow perch (Perca flavescens). Trans. Am. Fish. Soc. 89(3):310-312.

Rounsefell, George A.
1946. Fish production in lakes as a guide for estimating production in proposed reservoirs. Copeia. (1):29-40.

Sanderson, Albert E., Jr.
1959. Savage River Reservoir age and growth determinations. Md. Inland Fish. Invest. Proj. No. F-10-R. Job No. 1B. 6 p.

Sandoz, O'Reilly
1960. Fish populations of four ponds and two lakes two years after rehabilitation by rotenone treatment. Proc. Okla. Acad. Sci. 40:137-143.

Schmittou, H. R.
1967. Sex ratios of bluegill in four populations. Trans. Am. Fish. Soc. 96(4):420-421.

Schmitz, W. R. and Roland E. Hetfield
1965. Predation by introduced muskellunge on perch and bass, II: years 8-9. Trans. Wis. Acad. Sci., Arts & Lett. 54:273-282.

Schnabel, Zoe E.
1938. The estimation of the total fish population in a lake. Am. Math. Mon. 45:348-352.

Schneberger, Edward
1935. Growth of the yellow perch (*Perca flavescens*)(Mitchill) in Nebish Silver and Weber Lakes, Vilas County, Wisconsin. Trans. Wis. Acad. Sci., Arts & Lett. 29:103-130.

Schoettger, Richard A. and John R. Olive
1961. Accumulation of toxaphene by fish-food organisms. Limnol. & Oceanogr. 6(2):216-219.

Schoffman, Robert J.
1940. Age and growth of Reelfoot Lake fishes. Tenn. Acad. Sci. 15:22-41.

1948. Age, growth and size distribution of bluegills in Reelfoot Lake for 1937 and 1947. Tenn. Acad. Sci. 23(1):12-19.

1951. Age and growth of white crappie in Reelfoot Lake for 1938 and 1948. Tenn. Acad. Sci. 26(1):26-31.

1952. Growth of the bluegills and crappies in Reelfoot Lake, Tennessee. Tenn. Acad. Sci. 27(1):15-26.

1959. Age and rate of growth of the bluegills in Reelfoot Lake, Tennessee, for 1950 and 1958. Tenn. Acad. Sci. 34(1):73-77.

1964. Summary of the age and rate of growth of game fish in Reelfoot Lake, Tennessee, from 1937 through 1961. Tenn. Acad. Sci. 39(1):11-15.

1966. Age and rate of growth of bluegills in Reelfoot Lake, Tennessee, for 1958 and 1965. Tenn. Acad. Sci. 41:32-34.

Schumacher, F. X. and R. W. Eschmeyer
1943. The estimate of fish population in lakes and ponds. Tenn. Acad. Sci. 18:228-249.

Scidmore, W. J.
1960. Evaluation of panfish removal as a means of improving growth rates and average size of stunted fish. Minn. Dep. Conser. Fish & Game Invest. 2:42-51.

Scidmore, W. J. and D. E. Woods
1960. Some observations on competition between several species of fish for summer foods in four southern Minnesota lakes in 1955, 1956, and 1957. Minn. Dep. Conserv. Fish & Game Invest. Fish. Ser. 2. pp. 13-24.

Scott, Donald C.
1955. Activity patterns of perch (*Perca flavescens*) in Rondeau Bay of Lake Erie. Ecology. 36(2):320-327.

Seaberg, K. G. and J. B. Moyle
1964. Feeding habits, digestive rates, and growth of some Minnesota warmwater fishes. Trans. Am. Fish. Soc. 93(3):269-285.

Smith, Charles G. and Lawrence F. Miller
1942. A comparison of the hoop net catch on several waters in the Tennessee Valley before and after impoundment. Trans. Am. Fish. Soc. 72:212-219.

Smith, E. V. and H. S. Swingle
1939. Effect of organic and inorganic fertilizers on plankton production and bluegill bream carrying capacity of ponds. Trans. Am. Fish. Soc. 69:257-262.

1940. Winter and summer growth of bluegills in fertilized ponds. Trans. Am. Fish. Soc. 70:335-338.

Smitherman, R. O. and E. R. Hester
1962. Artificial propogation of sunfishes, with meristic comparisons of three species of *Lepomis* and five of their hybrids. Trans. Am. Fish. Soc. 91(4):333-341.

Snow, Howard
1960. Bluegill at Murphy Flowage. Wis. Conserv. Bull. 25(3):4.

1962. A comparison of the fish population in Murphy Flowage before and after a panfish removal program. 24th Midwest Fish & Wildl. Conf. 5 p.

1968. Stocking of muskellunge and walleye as a panfish control practice in Clear Lake, Sawyer County. Wis. Dep. Nat. Resourc. Res. Rep. 38. 18 p.

1969. Comparative growth of eight species of fish in thirteen northern Wisconsin lakes. Wis. Dep. Nat. Resourc. Res. Rep. 46. 23 p.

Snow, Howard, A. Ensign and J. Klingbiel
1960. The bluegill: its life history, ecology and management. Wis. Conserv. Dep. Publ. No. 230. 16 p.

Sprugel, George, Jr.
1953. Growth of bluegills in a new lake, with particular reference to false annuli. Trans. Am. Fish. Soc. 83:58-75.

Stevens, R. E.
1959. The black and white crappie of the Santee-Cooper Reservoir. Proc. 12th Annu. Conf. Southeast. Assoc. Game & Fish Managers. pp. 158-168.

Stroud, Richard H.
1949. Rate of growth and condition of game and panfish in Cherokee and Douglas Reservoirs, Tennessee and Hiwassee Reservoir, North Carolina. Tenn. Acad. Sci. 24(1):60-74.

Surber, Eugene W.
1947. Results of varying the ratio of largemouth black bass and bluegills in the stocking of experimental farm ponds. Trans. Am. Fish. Soc. 77:141-151.

Taliaferro, R. and D. Nolting
1954. Creel census at Jumbo Reservoir. Colo. Conserv. 3(3):20-22.

Tarzwell, Clarence M.
1941. Fish populations in the backwaters of Wheeler Reservoir and suggestions for their management. Trans. Am. Fish. Soc. 71:201-214.

Tharratt, R. C.
1966. The age and growth of Centrarchid fishes in Folsom Lake, California. Calif. Fish & Game. 52(1):4-16.

Thompson, William H.
1950. A ten-year creel census on Lake Pawhuska, Oklahoma. Trans. Am. Fish. Soc. 80:11-27.

Thompson, William H., H. C. Ward and J. F. McArthur
1951. The age and growth of white crappie, *Pomoxis annularis* (Rafinesque) from four small Oklahoma Lakes. Proc. Okla. Acad. Sci. 30:93-101.

Threinen, C. W.
1960. Results of walleye fingerling stocking in lakes with stunted panfish. Summary Rep. Wis. Conserv. Dept. 4 p.

Tiemeier, O. W.
1962. Survival of fish in deep water of farm ponds during the summer. Trans. Kans. Acad. Sci. 65(4):463-466.

Toetz, Dale W.
1966. The change from endogenous to exogenous sources of energy in bluegill sunfish larvae. Invest. Indiana Lakes & Streams. 7:115-146.

Trama, Francesco B.
1954a. The pH tolerance of the common bluegill. Acad. Natl. Sci. Phila. 256:1-13.

1954b. The acute toxicity of copper to the common bluegill. Acad. Natl. Sci. Phila. 257:1-13.

Turner, William R.
1955. Food habits of the bluegill (*Lepomis macrochirus macrochirus*) (Rafinesque) in eighteen Kentucky farm ponds during April and May. Trans. Ky. Acad. Sci. 16(4):98-101.

1960. Standing crops of fishes in Kentucky farm ponds. Trans. Am. Fish. Soc. 89(4):333-337.

Ulrey, Lorraine, Clifford Risk and Will Scott
1938. The number of eggs produced by some of our common fresh-water fishes. Invest. Indiana Lakes & Streams. 1(6):73-78.

Van Oosten, John
1945. Turbidity as a factor in the decline of Great Lakes fishes with special reference to Lake Erie. Trans. Am. Fish. Soc. 75:281-332.

Vezina, Claude
1967. Antimycin A, a teleocidal antibiotic. Amer. Soc. Microbiol. 757-766.

Viosca, Percy Jr.
1952. Growth rates of black basses and crappie in an impoundment of northwestern Louisiana. Trans. Am. Fish. Soc. 82:255-264.

Walker, Charles R., Robert E. Lennon and Bernard L. Berger
1964. Preliminary observations on the toxicity of antimycin A to fish and other aquatic animals. U. S. Bur. Sport Fish. & Wildl. Circ. 186. 17 p.

Ward, H. C. and Edgar Leonard
1952. Order of appearance of scales in the black crappie, *Pomoxis nigromaculatus*. Proc. Okla. Acad. Sci. 33:138-140.

Waters, T. F. and R. C. Ball
1957. Lime application to a soft-water, unproductive lake in northern Michigan. J. Wildl. Manage. 21(4):385-391.

Weatherly, A. H.
1963. Zoogeography of *Perca flavescens* (Mitchill) and *Perca fluviatilis* (Linnaeus) with special reference to the effects of high temperature. Proc. Zool. Soc. Lond. 141(3):557-576.

Werner, Robert G.

1967. Intralacustrine movements of bluegill fry in Crane Lake, Indiana. Trans. Am. Fish. Soc. 96(4):416-420.

1969. Ecology of limnetic bluegill (Lepomis macrochirus) fry in Crane Lake, Indiana. Am. Midl. Nat. 81(1):164-181.

Wiebe, A. H.

1931. Notes in the exposure of several species of fish to sudden changes in the hydrogen ion concentration of the water and to an atmosphere of pure oxygen. Trans. Am. Fish. Soc. 61:216-222.

Windell, John T.

1966. Rate of digestion in the bluegill sunfish. Invest. Indiana Lakes & Streams. 7:185-214.

Witt, Arthur, Jr.

1955. Seasonal variation in the incidence of lymphocystis in the white crappie from the Niangua Arm of the Lake of the Ozarks, Missouri. Trans. Am. Fish. Soc. 85:271-279.

Woodbury, Lowell A.

1938. Heavy loss of bluegills in Proctor Lake, Waupaca County. Wis. Conserv. Dep. Invest. Rep. 253. 2 p.

1940. Loss of fish in Lake Mendota. Wis. Conserv. Dep. Invest. Rep. 245. 1 p.

1941. A sudden mortality of fishes accompanying a supersaturation of oxygen in Lake Waubesa, Wisconsin. Trans. Am. Fish. Soc. 71:112-117.

150--66--D9035