AN EVALUATION OF THE INTRODUCTION OF FLORIDA BASS INTO AN OKLAHOMA RESERVOIR RECEIVING A HEATED EFFLUENT

By

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May, 1974

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1976

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PREFACE

Financial support for this study was provided by Federal Aid Project (F-33-R); the Oklahoma Fish and Game Council in cooperation with the Oklahoma Department of Wildlife Conservation; the U.S. Department of Interior, Fish and Wildlife Service; and the Oklahoma State University Research Foundation. The study was coordinated through the Oklahoma Cooperative Fishery Research Unit; cooperators are the Oklahoma Department of Wildlife Conservation, the Oklahoma State University, and the U.S. Fish and Wildlife Service.

I would like to acknowledge Dr. Austin K. Andrews, Dr. Robert C. Summerfelt, Dr. Ronald McNew, and Dr. Dale W. Toetz for their suggestions and assistance and for serving on my committee. I would also like to thank personnel of the Oklahoma Cooperative Fishery Research Unit who assisted me on this project.

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CHAPTER I

INTRODUCTION

Because of our expanding population with an increasing demand for recreational activities such as fishing, which also supplements food supplies, the need for enhancement and not degradation of our fishery resources is manifest. Fishing in the United States has increased at a rate faster than population growth; between 1960 and 1970, fishing trips doubled in the U.S., and are predicted to redouble by the year 2000 (Jenkins 1976). Much of our aquatic resources, however, are also needed for other requisites of our increasing population and threaten the quality and quantity of our existing fishery resources.

An even faster increase in per capita demand for electrical energy creates the market for electrical generating plants, which produce a concomitant increase in need for cooling water. The United States Water Resources Council (1972) predicted that of the predicted 507% increase in U.S. water needs between 1965 and 2020, 162% would be required for fresh water cooling in steam powered electrical power generation. An additional 223% of the total increase will be saline cooling water.

Water temperature is believed to be one of the major factors affecting aquatic environments (Welch 1952). Zweiacker (1976) listed several potential ecological effects of the heated discharges of once through cooling systems on aquatic systems:

1) direct mortality of organism through physiological shock;
2) indirect mortality of organisms through reduction of food; decrease in dissolved oxygen, synergistic effects of toxins, and increased incidence of bacteria and predation;
3) effect on gonadal development and change in biological life cycle;
4) change in species diversity toward more thermophilic species;
5) effect on growth rate (positive or negative); and
6) increased rate of eutrophication.

Because of such potential problems, the Environmental Protection Agency, on 2 October 1974, announced new guidelines to restrict the use of public waters for once through cooling systems. Because of these new guidelines, the utility industry will now require cooling towers or utility owned, man-made lakes for a source of cooling water. Which of the alternatives is used will depend upon local meteorological, physiographical, and economic conditions. Undoubtedly more privately owned lakes and ponds will be created for this purpose. Environmental studies on these utility owned impoundments would provide insight as to how fisheries management may optimize sport and commercial fishing in the United States.

Utilization of these man-made environments to enhance sport fishing in the U.S. is possible by reduction of detrimental impact of cooling waters on aquatic communities. This may be done in part by identifying and solving the biological problems incurred by the effects of physical and chemical factors on aquatic habitats, and by better comprehension of the interrelationships between fish populations and aquatic communities. Based on biological, chemical, and physical studies, limiting conditions can be established, and in many cases fish production and ecological efficiency can be enhanced through manipulation of fish populations to accommodate the particular environment of each site.

Such manipulations have recently been focused on special adaptive characteristics of various strains, subspecies and species of *Micropterus* basses. In particular it has been observed that the introduction of the Florida bass, *Micropterus salmoides floridanus*, in warmwater environments may have potential benefits to the ecological stability of those environments as well as provide more and larger game fish for enjoyment by fishermen. Introductions of the Florida subspecies, because of its evolutionary development in the subtropical waters of Florida, may be especially beneficial to the specialized environments of reservoirs receiving heated effluents. It is therefore the purpose of this study to determine which subspecies of largemouth bass may be better adapted or have the potential for adaption to an aquatic habitat such as Boomer Lake, a 102-hectare reservoir in Stillwater, Oklahoma, receiving a heated effluent from a steam-electric generating plant.

CHAPTER II

LITERATURE REVIEW

Largemouth bass, *Micropterus salmoides*, have been desirable to fishermen for many years because of predaceous habits, desirable sporting qualities and high food value. In fact, Horvath (1974) indicated that about 24% of all fishing trips in southeastern U.S. were specifically for largemouth bass (cited by Jenkins 1975). For these reasons, the northern subspecies, *Micropterus salmoides salmoides*, has been widely distributed throughout the contiguous 48 states as well as many other countries. The Florida subspecies, *Micropterus s. floridanus*, appears to have certain uniquely advantageous phenotypic traits that warrant their introduction in many warm-water environments outside their native habitat:

1) they appear to live longer;
2) they attain larger sizes; and
3) they may be more thermophilic than the northern subspecies.

Definition of differences between the two subspecies of largemouth bass is of value in determining the situations where introductions of the Florida subspecies may be advantageous to an aquatic system.

Meristic and Morphological Characteristics

Florida bass were first described as a separate subspecies by Baily and Hubbs (1949). Significant meristic and morphological differences between Florida and northern largemouth bass have since been reported by many authors. The most reliable methods for separation of the two appear to be lateral line scale counts, caudal peduncle scale counts, and number of pyloric caeca. Data accumulated by Johnson (1975) show the Florida subspecies having lateral line scale counts ranging from 65-75 with an average of 70 and pyloric caeca counts ranging from 26-53 with an average of 37. The northern subspecies is reported to have 58-68 (average of 63) lateral line scales and 14-35 (average of 23) pyloric caeca tips.

Baily and Hubs (1949) stated that both caudal peduncle scale rows and number of scales along the lateral line could be used to differentiate between Florida bass and northern bass. Buchanan (1968) regarded the count of pyloric caeca as the best individual meristic characteristic. Addison and Spencer (1972) also used pyloric caeca counts to separate the two subspecies. Thrasher (1974) stated that identification could be made with a high degree of certainty by using the following equation: X = 2.77 (no. of lateral line scales from unknown fish) + 0.58 (no. of caudal peduncle scales) + (no. of pyloric caeca tips); Florida bass have an X >225.41, northern bass <225.41.

Although reliable identification of the two subspecies can be made by careful attention to selected meristic characteristics, some differences in coloration and general body shape are also helpful. Buchanan (1968) observed that the length of the upper jaw was greater in Florida bass than in northern bass. Robert Chew (personal commuication, 1974, Texas Resources Director) noticed that although when length differences between the two subspecies in Texas waters were not significantly different, the Florida bass tended to be heavier, and deeper bodied than the northern bass.

The general coloration of largemouth bass is dark olive-green on the dorsum, grading progressively to a pale greenish-white on the venter (Gresham 1966). Based on personal observations during this study, it appears that this pattern is different between the two subspecies. In the Florida bass, the progression from dark green to the lighter whitish ventral color is more abrupt, the light greenish white background predominating even above the lateral line (Figure 1). The northern bass generally has a more progressive change from dark to light, with the light, greenish-white color not being obvious until well below the lateral line (Figure 2).

Bottroff (1967) noted that the lateral "stripe" of the young Florida bass was more a series of 13-15 elliptical blotches rather than a continuous stripe as is the general pattern in the northern subspecies. This difference appears quite obvious in age I and II specimens of both subspecies removed from clear water study ponds (Figures 1 and 2); however, fish collected from Boomer Lake, which was highly turbid throughout this study were not distinguishable by this method. Florida bass from the more turbid conditions have a washed-out appearance, and coloration differences between the northern and Florida bass were not distinct.

Growth and Survival

Interest in the Florida bass has been recently stimulated by catches of 6.8-9.1 kg Florida bass in southern California where they were introduced in 1959. McClane (1965) stated that the Florida bass is known to attain sizes of over 9.1 kg, and is frequently caught at

Figure 1. The Florida subspecies of largemouth bass, *Micropterus salmoides floridanus* (Le Sueur)

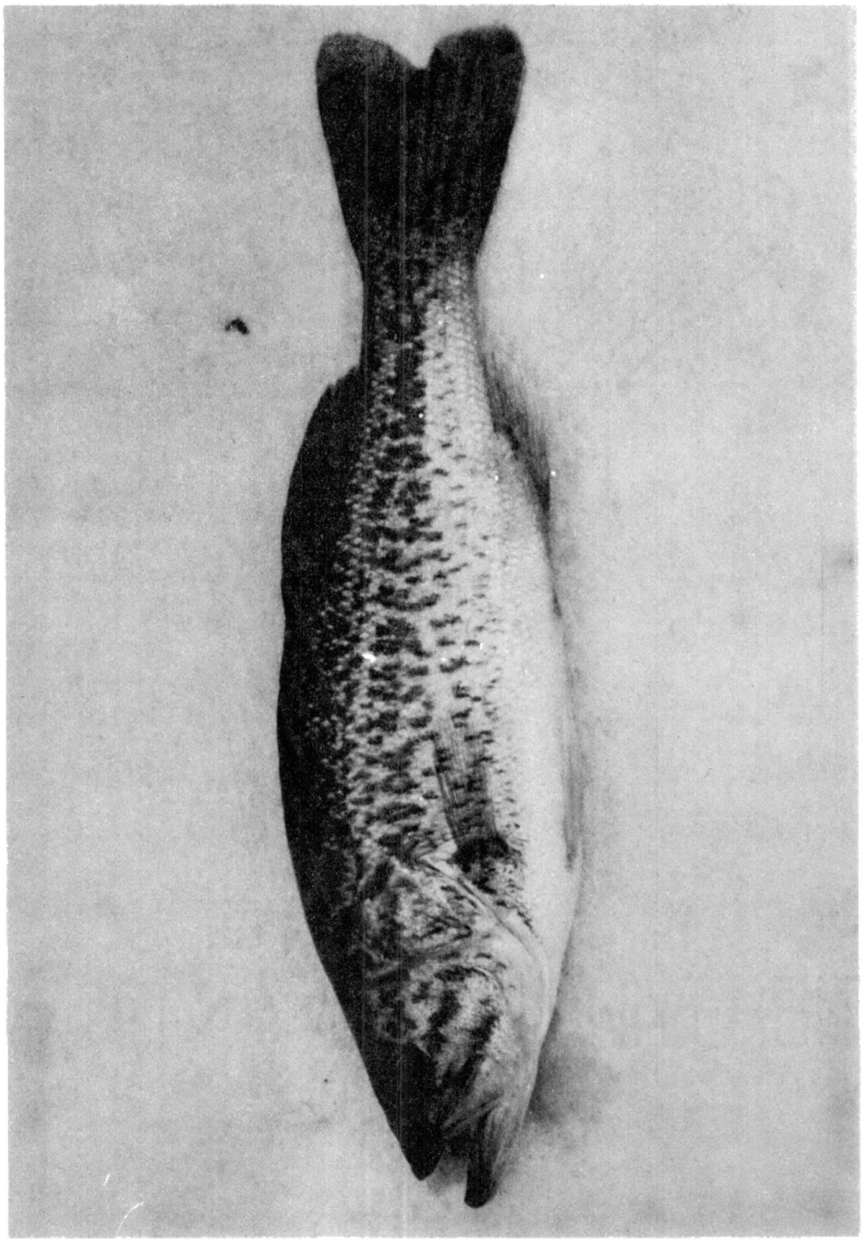
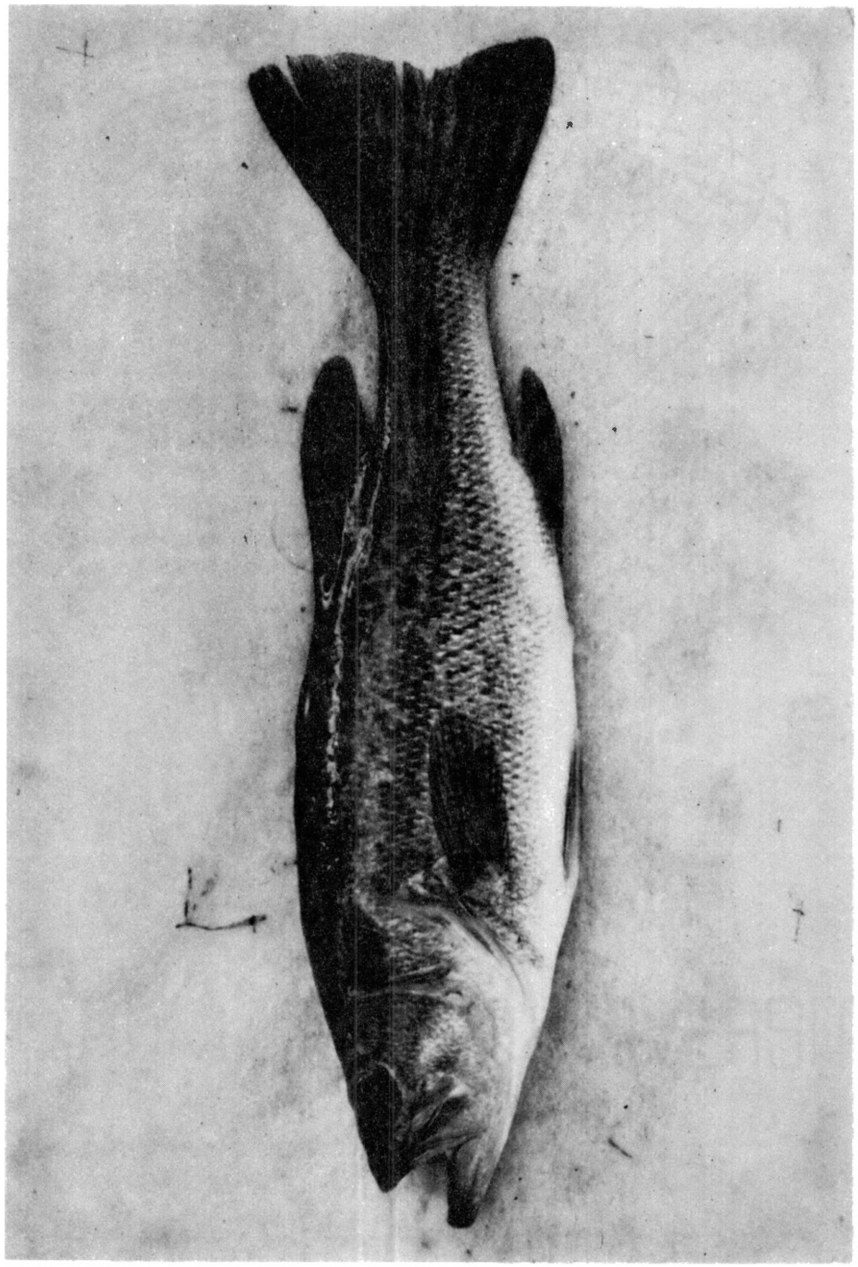


Figure 2. The northern subspecies of largemouth bass, *Micropterus salmoides salmoides* (Lacépède).



2.27-4.54 kg, whereas the northern bass rarely exceed 4.54 kg, and ones weighing 0.9-1.4 kg are considered a good catch. The size difference here has created a demand for stocking the Florida bass in many states. However, it is the opinion of many biologists that intraspecific variation in size is primarily due to environmental relationships (i.e., longer growing seasons) rather than genetic differences (Sasaki 1961, Clugston 1964, Buss 1965, and Miller 1965). Several studies have shown no significant difference in growth between the two subspecies during the first 1-3 years of life (Sasaki 1961, Clugston 1964, Miller 1965, Graham 1972, Davies 1973, and Johnson 1975). However, Florida bass could still have a genetic potential for a longer life span, accounting for larger maximum sizes than the northern bass would attain in the same environment.

Florida bass have been known to survive to an age of 14-15 years in heavily fished southern lakes (Bottroff 1967), whereas northern bass live that long only in northern waters where growth rates are slow and maximum sizes are usually less than 2.0 kg (Bennett 1970). In contrast, high overwinter mortalities of stocked Florida bass in Missouri, Ohio, and Michigan have indicated a susceptibility of the Florida subspecies to decreasing or low temperatures. Apparently, genetic isolation of the Florida bass in the subtropical Florida environment has created a more thermophilic or stenothermic physiology in the Florida bass. A specific study of the tolerances of Florida bass to changes in water temperature was done by Johnson (1975). A 100% mortality of Florida bass was observed when controlled temperatures were lowered to 4°C, while only 16% mortality was seen in northern bass.

Behavior

Although differences in spawning activity, habitat preferences, and vulnerability to angling have not been evaluated as thoroughly as anatomical and physiological differences, there is some indication that the Florida subspecies differs substantially from the northern bass in certain behavioral traits. Some behavioral differences are indicated that may create niche specificity which may provide ecological separation of the two subspecies in the same environment.

Several reports have indicated the Florida bass to be more difficult to catch, a feature which may be quite desirable in certain waters with a high density of fishermen. It is believed that Florida bass have dominated some lakes in southern California because of a lower vulnerability to fishermen than for northern bass (Thrasher 1974 and Johnson 1975). Stevenson (1973) reported that in Ohio ponds, artificial lures were almost totally ineffective in capturing Florida bass and that only live baits such as minnows and small frogs were consistantly effective. Thrasher (1975) reported that in Alabama experimental ponds, systematic angling yielded more northern than Florida bass. Differences in vulnerability to angling may relate to different food preferences or the Florida bass may be more alert or wary as reported by Johnson (1975).

Florida bass may also spawn earlier than northern bass. McClane (1965) stated that Florida bass mature as early as 9 months and are known to spawn year-round, while northern bass only spawn in the spring. Bottroff (1967) observed that when Florida bass were placed in reservoirs in southern California with northern bass, they tended to spawn about two weeks earlier than the northern bass, but that spawning periods still overlapped considerably. If the Florida bass do consistantly nest earlier than the northern bass, nest site competition would become a factor favoring the Florida bass fingerlings in food availability and survival from predation and other environmental factors. Also because the weather conditions in early spring are highly variable, with sudden temperature changes being quite common and reported to result in largemouth bass year-class failure (Summerfelt 1975), having a longer period of spawning activity because of a Florida bass population may alleviate the possibility of year-class failure.

In summary, there appears to be sufficient evidence of phenotypic deviation of the Florida subspecies from the more widespread northern largemouth subspecies of largemouth bass. Many of these differences such as larger maximum sizes, decreased vulnerability to angling, and advanced time of spawning may serve as advantageous fishery management tools in both naturally occurring warmwater environments, or in man-made lakes receiving heated effluents. However, there is substantial evidence to indicate that the viability of Florida bass in an aquatic system will be limited by low water temperatures.

CHAPTER III

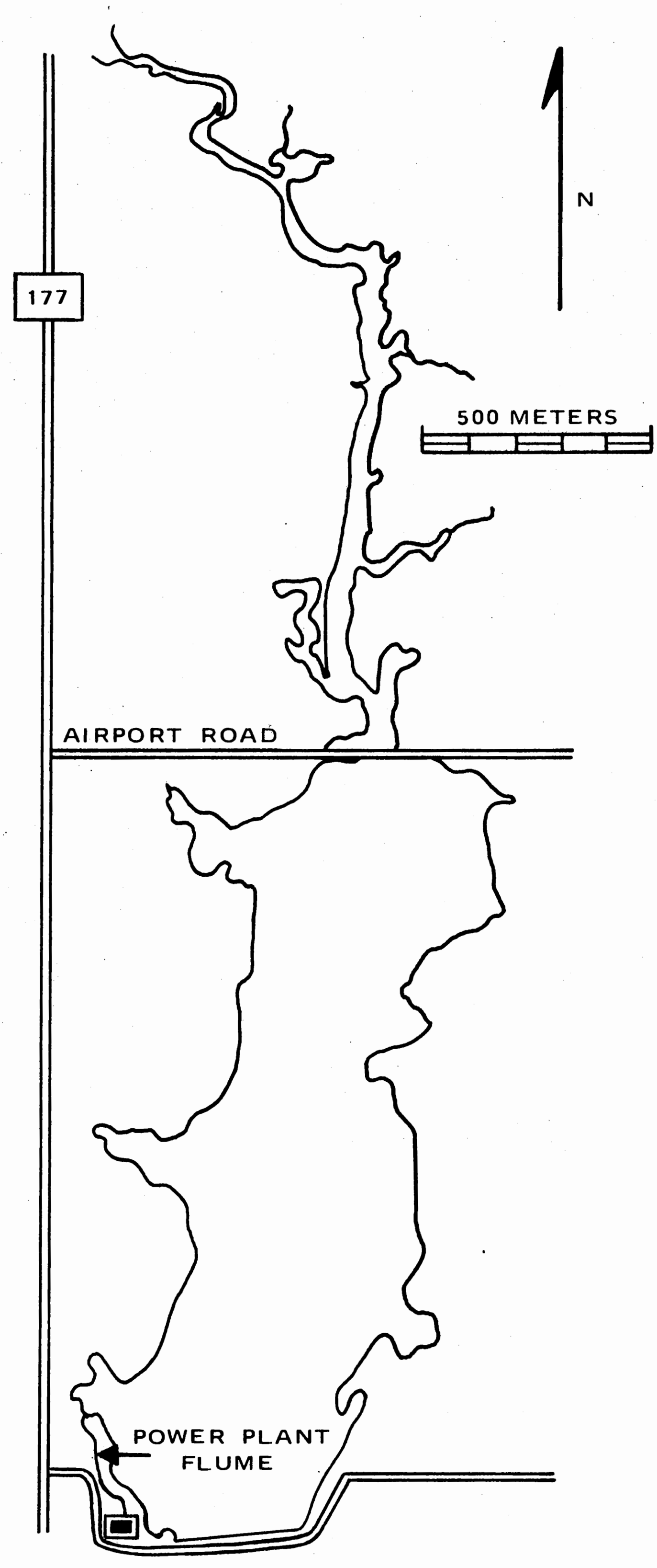
DESCRIPTION OF STUDY AREA

Boomer Lake (Figure 3) located at the northeast edge of Stillwater, in Payne County, Oklahoma was completed in 1925 with an original storage capacity of 251 ha-m and a surface area of 92 hectares. In 1933 the spillway level was raised 0.61 meters which increased the storage capacity to 308 ha-m and the surface area to 102 hectares (Craven 1968).

Lake water is presently used for irrigation of a city park located along the lake shore, and for cooling water by Boomer Lake Power Station. The power plant was completed in 1956 and has an electrical output varying from 9 MW/hr to 23 MN/hr depending upon local electrical needs. The plant uses us to 106.4 m^3/min of cooling water for the natural gas fired steam turbines during peak operating periods and about 76.0 m^3/min under normal operating conditions. The cooling water intake is located near the bottom of the southwest corner of the lake, and the heated effluent is returned to the lake via a 305 meter concrete flume. The daily temperature gradient between intake and outflow of water of the power plant is dependent upon local electrical needs and the local climatic conditions at any given time, but is usually about 4.0-6.5^{o}C.

Analysis of temperature data indicates that the lake water is in almost constant circulation and that definite stratification occurs only for very short periods of time during the warmer months (Craven

Figure 3. Boomer Lake.


N
177
500 METERS
AIRPORT ROAD
POWER PLANT
FLUME

1968). This lack of stratification is likely due to the shallowness of the lake and wind action. The original creek channel was about 10.8 meters deep, but as a result of silt deposition it was decreased to 7.6 meters by 1966 (Wade 1968).

CHAPTER IV

PROCEDURES

The primary objective of this study was to determine if Florida largemouth bass are adaptive or have the potential for adaption to an environment such as Boomer Lake, a 102-hectare reservoir in northern Oklahoma which receives a heated effluent from the condenser discharge of an electric power plant. To accomplish this objective, Florida bass were introduced into Boomer Lake during the summers of 1974 and 1975. An evaluation of these introductions was primarily based on the comparative survival and growth of the introduced Florida bass populations and similarly introduced populations of northern bass fingerlings. Therefore, differences between growth and survival of the two subspecies could be used to evaluate the potential of the Florida largemouth bass in Boomer Lake.

Introduction of the Two Subspecies

Hatchery raised stocks of both Florida and northern largemouth bass fingerlings were obtained and transported to Stillwater in an aerated live tank carried on the bed of a pick-up truck. Prior to being stocked at various locations along the shore of the main body of the lake, the fish were marked for later identification, average lengths and weights as well as numbers stocked were recorded. In both years, the northern bass were transported, marked, and stocked, all in one day with little difficulties or mortalities due to transportation or marking. However, difficulties and heavy mortalities, primarily due to marking and handling were encountered both year with stocking of Florida bass.

Marking Procedures

The introduced largemouth bass populations were marked by methods which were regarded as having minimal effect on the survival or growth of the marked fish, yet would still allow easy identification and separation of the two subspecies while sampling. Spray-applied fluorescent pigment granules were chosen to mark northern bass and injected magnetized wire tags for the Florida bass.

Fluorescent Pigments. Sprayed from a compressed air driven sand blast gun, the fluorescent pigments are forced through the epidermis and into the dermis of the fish where they lodge against fin rays, bones in the head, or scales (Phinney et al. 1967) and are indentifiable under ultraviolet light. In some cases, this method has allowed marking large numbers of small fish with little handling and a small effort per man-hour with low mortality (Andrews 1972). Phinney and Matthews (1969) found that fluorescent pigments marked fish grew as well as non-marked fish in a 6-month study of age 0 coho salmon, while fin clipped fish exhibited slower growth than either of the two previous groups. However, the length of mark retention for largemouth bass is not known.

The fish were marked in a shallow dip net in lots of 15-25 fish. Red granular fluorescent pigments with a 80% grit size of 50-350 microns (Scientific Marking Materials, Seattle, Washington) were sprayed onto the fish with a low pressure (125 p.s.i.) sandblasting gun from a distance of approximately 30-40 cm. Presence of the pigments in the bass collected in the field was determined in a portable darkbox illuminated by ultraviolet light (Figure 4).

Magnetic Wire Tags. Magnetic wire tags were used to mark Florida bass in 1974. The tags (1 mm by 0.25 mm stainless steel wires) were injected into the nose cartilage of each fish by a wire tag injector. Although not as easily applied as the fluorescent pigments, these tags are easily applied to large numbers of small fish and the presence of the tag has no apparent affect on the growth or mortality of the tagged fish and is presumable a permanent mark (Bergman et al. 1968). In the present study however, high mortality resulted from the handling of individual fish which were only available during hot weather.

Before the fish were tagged they were tranquilized with 7 ppm quinaldine in batches of about 50 fish. In tag application, the nose of each fish was pressed firmly into a soft plastic head mold made especially for the size and type of fish being tagged. As the head mold is depressed by the head of each fish, the injection mechanism of the wire tag injector is triggered and the wire is injected, cut, and released into the nose cartilage. Each fish was then dropped into a stream of water flowing through a PVC tube which transported it through a magnetic field, permanently magnetizing the tag and making it detectable with a wire tag detector.

The detector consists of an audio unit and a sensing head with connecting cable (Figure 5). The audio unit is powered by four internal mercury batteries and contains the electronics which converts an electronic impulse to an audio signal. The sensing head used in this

Figure 4. Use of a portable "darkbox" illuminated by ultraviolet light to observe fluorescent pigments on fish.

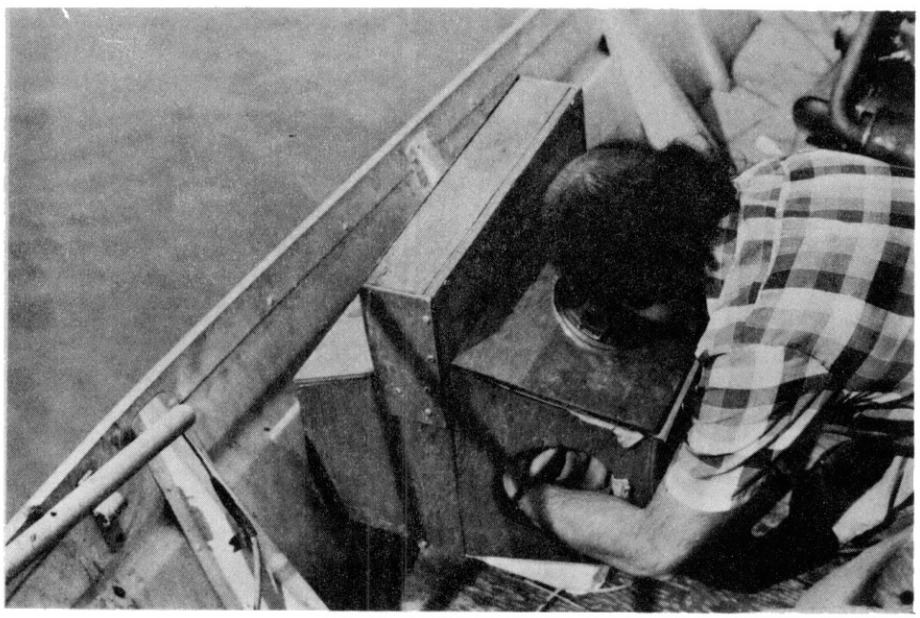
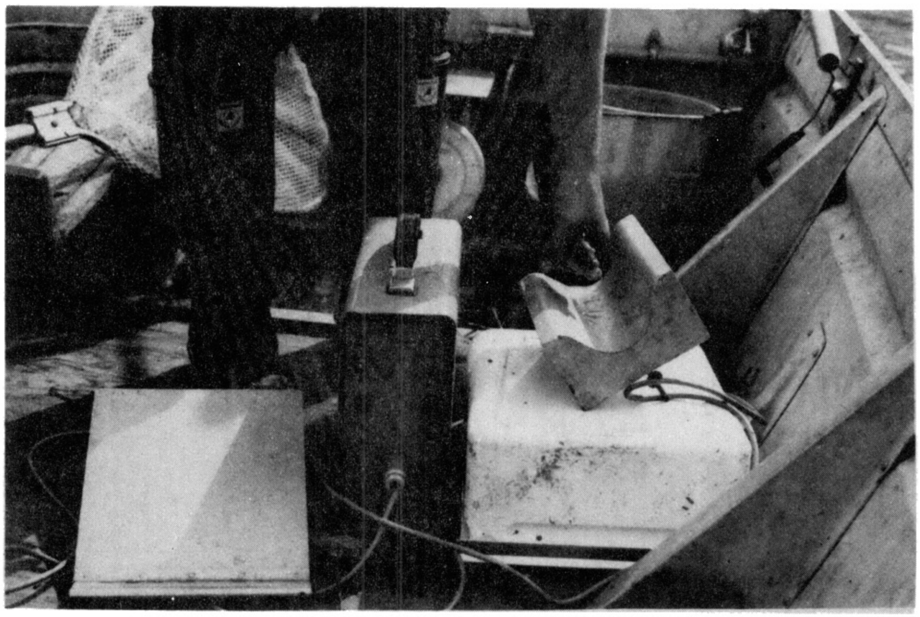


Figure 5. Use of a U-shaped sensing head and connecting detector to determine presence of a magnetic nose tag in fish.



study was U-shaped which permits usage with fish of any size. When the head of a fish containing a magnetized metal tag was moved rapidly past the sensing head at a distance of about 1-10 cm, the audio unit emmitted an audible response.

In 1975, the Florida bass were too small to mark with the magnetized nose tags (less than 60 mm); therefore, they were marked with yellow fluorescent pigments by the same method as described previously for the northern bass.

Marking and Stocking Mortality and Mark Retention

To estimate the short-term mortalities due to the mark application and stocking stresses, a sample of marked bass was put into holding tanks for a period of approximately three days. At the end of this period the fish remaining alive were counted and examined for the type of mark used. Percent mortality and mark retention was determined and assumed to be similar to that in the stocked population. Initial mark retention was 100% in all cases.

Since retention of the marks used in this study are not well known, the fish from the holding tanks were then put into 0.1 hectare ponds to be examined at later intervals for determination of long-term mark retention.

Sampling Methods

After marking and stocking populations of both Florida and northern bass, Boomer Lake was sampled at various intervals to obtain estimates of growth and survival of each stocked population. This was primarily done by mark-and-recapture shoreline electrofishing as described by Lewis et al. (1962). Seining was also utilized to aid in sampling the stocked bass in many areas where seining was convenient.

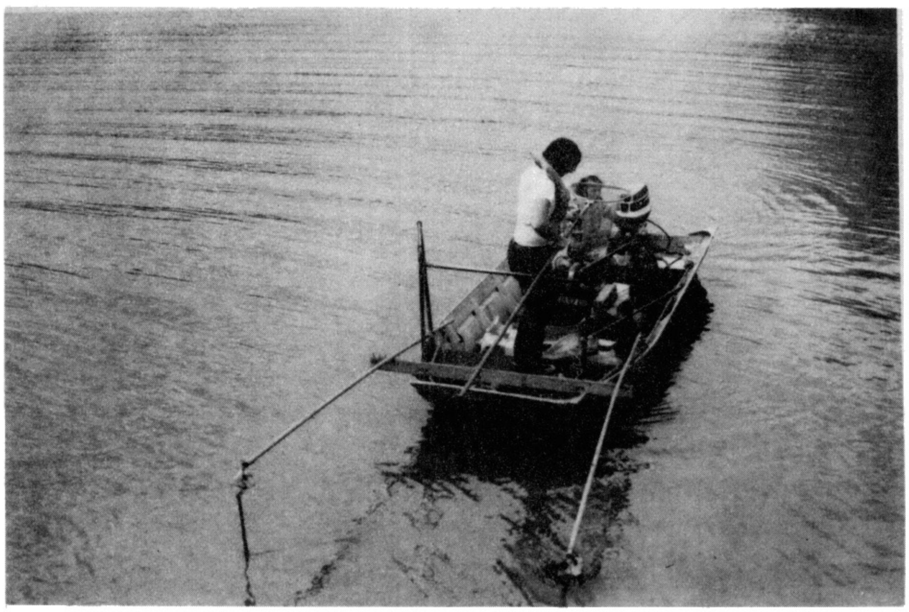
Electrofishing

A boat containing a gasoline powered, 3000 watt electrical generator, equipped with electrodes suspended by booms approximately two meters in front of the boat (Figure 6) was used in electrofishing. Sampling was done by circumferential trips around the lake. Stunned bass were netted and kept in tubs of water, then weighed, measured and marked by punching a hole in the caudal fin. The approximate location of capture was also recorded to indicate any differences in habitat selection that may have occurred between the two subspecies of largemouth bass.

Seining

Electrofishing was not very effective in capturing the smaller largemouth bass, perhaps because of the high turbidity of Boomer Lake, which made the smaller bass difficult to see. Therefore, a 30.5 m X 1.2 m X 6 mm bag seine was also utilized to collect fish. Seining was only possible in selected areas of shallow depth, and free of obstructions. Fish captured by seining were marked, and added to the marked population to be used in the electrofishing mark-and-recapture method of making population estimates. Seining also provided additional size data for estimates of growth of the two subspecies of largemouth bass.

Figure 6. Electrofishing boat used to collect largemouth bass (LMB) in Boomer Lake.



Growth

From the individual weights of each fish collected from the introduced populations of largemouth bass in each sample period, the daily instantaneous growth rate (g) was calculated for intervals between each major sampling period and from the time of stocking until the following spring by the following formula:

$$g = \frac{\overline{\log_e W_2} - \overline{\log_e W_1}}{\Delta \text{ days}}$$

where: $\log_e$ = natural log

W_2 = weight of each fish at end of growth period

W_1 = weight of each fish at beginning of growth period.

Growth rates of the two subspecies were statistically compared to determine if the estimates of growth were significantly different. Since growth of individual fish was not known, the variance (v) for instantaneous growth was estimated from instantaneous rate of change in the sample variance of individual weights:

$$v(g) = \frac{v \log_e W_2/n + v \log_e W_1/n}{\Delta \text{ (days)}}$$

A one tailed t-test of significance of difference in growth was done by utilizing the following to calculate "t":

$$t = \frac{\text{Florida bass (g)} - \text{northern bass (g)}}{\text{v Florida bass (g)} + \text{v northern bass (g)}}$$

The calculated t was compared with tabulated t values (Steel and Torrie 1960) to determine the level of significance (P) of the difference between growth rates.

Survival

Each sample period, the population sampled was marked, and recapture data was used to make population estimates of the largemouth bass in the expected size range of introduced largemouth bass. A Chapman modification of the Schnabel multiple census formula was used:

$$N = \frac{\Sigma(C_t M_t)}{\Sigma R_t + 1}$$

where: N = the estimated number in the population sampled

C_t = the total number of fish caught each trip

M_t = the total number of fish marked each trip plus fish marked since the last electrofishing trip

R_t = the number of fish recaptured each trip

After obtaining a population estimate of the largemouth bass of suitable size range, population estimates of each subspecies were obtained as a percentage of the relative catch of each collected during the interval when the estimate was made:

$$N_m = (\%\text{ of catch})\ (N)$$

where: N_m = the estimate of those in the population retaining the original mark

This N_m is then corrected for mark retention:

$$N_f \text{ or } N_n = \frac{N_m}{\%\text{ retention}}$$

where: N_f = an estimate of the Florida bass in the lake

N_n = an estimate of the northern bass in the lake

The percent survival within each subspecies was then calculated from one population estimate to the next: $s = \frac{N_1}{N_2} \text{ X } 100.$

A statistical test of differences in survival between subspecies was made based on a Chi-square analysis (X^2) where the observed frequency was based on the relative catch of each subspecies as compared to expected frequencies derived from relative abundance of each at the time of stocking. This X^2 value was compared to tabulated values in Steel and Torrie (1960) to determine approximate values as a test of significance.

CHAPTER V

RESULTS AND DISCUSSION

Introduction of Marked Largemouth Bass Populations

Marking and handling mortalities of the introduced fingerlings were estimated from retained samples. The percent of mortality within each of these samples was then assumed to be similar to mortality from handling and marking stresses of the introduced fingerlings. The number stocked were then corrected for this mortality to provide the best estimate of the actual numbers of surviving stocked largemouth bass in Boomer Lake (Table 1).

During both years, the northern bass were transported, marked, and stocked all in one day, and no mortality was observed in the retained samples. However, large numbers of the magnetic nose tagged Florida bass died, largely due to stresses of handling and marking during hot weather. Most of the mortality of these nose-tagged bass occurred immediately following marking, before they were transported to the lake for stocking. The nose-tagging operation lasted for several hours, and then only those fingerlings still alive were transported to Boomer for stocking. From these, a sample was retained, and two days later 6% mortality was observed in the retained sample.

In 1975, it was also initially proposed to mark the Florida bass

Table 1. Source and estimation of numbers of largemouth bass stocked into Boomer Lake, Oklahoma in 1974 and 1975.

Source of bass fingerlings	Subspecies	Date stocked	Type of mark	Number stocked	Estimate of mortality	$\hat{N}$
Federal fish hatchery Tishomingo, OK	northern	06-27-74	red pigment	3871	0	3871
Federal fish hatchery, Tyler, TX	Florida	07-02-74	magnetic nose tag	1623	6%	1525
Federal fish hatchery, Uvalde, TX	northern	06-12-75	red pigment	4796	0	4796
Federal fish hatchery, Tyler, TX	Florida	07-02-75	yellow pigments	3780	70%	1126
Okla. State fish hatchery, Durant, OK	Florida	07-22-75	yellow pigments	2391	0	2391

with magnetic nose tags; however, the Florida bass were too small upon delivery (less than 60 mm) to allow easy tag implantation; and also the tagging machine was not operating properly. It was therefore decided to mark these fish with yellow fluorescent pigments, which would still allow identification and separation of the two subspecies in Boomer Lake. However, the necessary holding of these fish in overcrowded holding tanks for two days apparently created additional stresses, resulting in these fish being in such poor condition when marked and stocked that in the retained sample, 70% mortality was observed.

Mark Retention

Since the fluorescent pigments used to mark the introduced populations of largemouth bass were not permanent, and retention is not well defined, long-term mark retention of fluorescent pigments was evaluated to adjust the population estimates for each sample interval (Table 2).

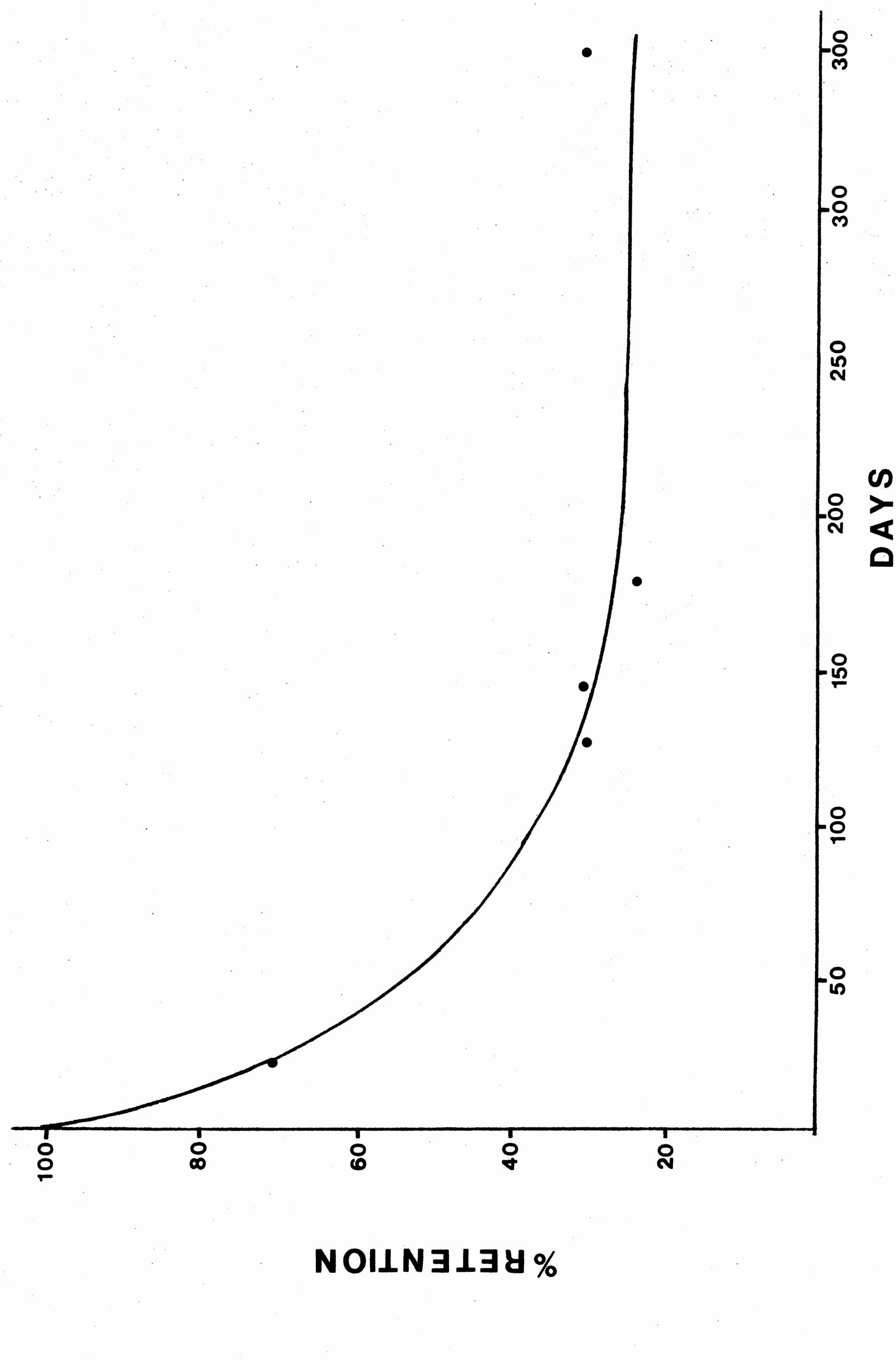
Fluorescent pigment retention was 100% in all groups of marked fish when examined after a three day period. Within five months, retention had generally decreased to about 24-32% in the fish marked in this study. One group, examined a year after being marked still had 32% retention, indicating an exponential decrease in retention with time (Figure 7). Examination of the pigmented bass in the latter sample indicated that although the pigments were visible under ultraviolet light, they were becoming obscured by epidermal tissues, and although present, were more difficult to see than those that had been examined in November.

Magnetic nose tags were proposed to be permanent marks if suc-

Table 2. Retention of fluorescent pigments on young-of-the-year largemouth bass.

Date marked	Date of sample	Time interval (days)	Subspecies	Retention
27 June 1974	18 July 1974	22	northern	71%
27 June 1974	20 Nov. 1974	145	northern	32%
27 June 1974	6 June 1975	350	northern	32%
12 June 1975	17 Nov. 1975	176	northern	24%
22 July 1975	17 Nov. 1975	127	Florida	31%

Figure 7. The apparent exponential decrease in fluorescent pigment retention on largemouth bass.


% RETENTION
100
80
60
40
20
DAYS
50
100
150
200
250
300
300

cessfully implanted. However, since presence of the tags in each fish was not verified at the time of marking, a sample of the marked fish was retained for later tag verification, and tag retention was 90% after a period of five months.

Ichthyofauna of Boomer Lake

Collections by seine and electrofishing during the two-year period of this study allowed not only collection of samples of the introduced populations of largemouth bass, but also identification of other fish species in Boomer Lake and a description of the structure of the endemic largemouth bass population.

Because of the possible success of an introduction of Florida bass into Boomer Lake, with possible resulting changes in the other fish populations, it may serve future endeavors to have a description of the existing ichthyofauna of Boomer Lake.

The following 17 fish species in Boomer Lake were identified from electrofishing and seining during the two years of the present study, and are listed in order of decreasing relative abundance based on general perception of catch composition.

	Scientific Name	Common Name
1)	Dorsoma cepedianum (LeSueur)	Gizzard shad
2)	Lepomis macrochirus (Rafinesque)	Bluegill
3)	Pomoxis annularis (Rafinesque)	White crappie
4)	Menidia audens (Hay	Mississippi silversides
5)	Notropis lutrensis (Baird and Girard)	Red shiner
6)	Notemigonus chrysoleucas (Mitchell)	Golden shiner
7)	Lepomis microlophus (Gunther)	Redear sunfish

8) Lepomis cyanellus (Rafinesque) — Green sunfish

9) Lepomis megalotis (Rafinesque) — Longear sunfish

10) Gambusia affinis (Baird and Girard) — Mosquito fish

11) Lepomis humilis (Girard) — Orangespotted sunfish

12) Micropterus salmoides (Lacepede) — Largemouth bass

13) Lepomis gulosus (Cuvier) — Warmouth

14) Cyprinus carpio (Linneaus) — Carp

15) Ictalurus punctatus (Rafinesque) — Channel catfish

16) Pylodictus olivaris (Rafinesque) — Flathead catfish

17) Ictalurus natalis (LeSueur) — Yellow bullhead

In addition to these, Wade (1968) also listed the following species as being present during 1966-1967.

1) Carpiodes carpio (Rafinesque) — River carpsucker

2) Carassius auratus (Linneaus) — Goldfish

3) Pimephales promelas (Rafinesque) — Fathead minnow

4) Ictalurus melas (Rafinesque) — Black bullhead

5) Roccus chrysops (Rafinesque) — White bass

6) Pomoxis nigromaculatus (LeSueur) — Black crappie

Brown and Jossel (1970) reported that the white crappie population of Boomer Lake was stunted, and proposed that a reduction in population numbers would decrease intraspecific competition for food and improve growth. Seining and electrofishing in 1974-75 produced crappie catches predominantly of sizes less than 150 mm, indicating that the size composition had not changed appreciably since 1968.

Even larger numbers of small (less than 100 mm) bluegill were common, and no bluegill greater than approximately 125 mm were ever seen in any of the collections. This size distribution indicated an unbalanced, stunted bluegill population. Johnson and Anderson (1974) suggested that bluegill populations may be considered balanced when the population has a size distribution of 75% = 75-150 mm, and 25% = greater than 150 mm. Wade (1968) mentioned that the forage fish population had expanded due to earlier absence of predatory fishes and the introduction of additional forage species.

Indigenous largemouth bass were collected by shoreline electrofishing while searching for the introduced largemouth bass. A numerical estimate was made of the population of indigenous bass by mark-and-recapture procedures. Using age determination by scale analysis, a general description of the population structure of the indigenous largemouth bass was made (Table 3).

It was noticed early in the sampling period of 1974 that the portion of the lake north of airport road (Figure 1) appeared to have a larger density of the larger largemouth bass than the rest of the lake. Therefore, separate estimates were also made for the two portions of the lake (Table 4). Although the northern portion of the lake has only about 24 surface hectares, it has nearly as much shoreline as the main body of the lake. Additionally, the shoreline of the northern end was heavily wooded with less wind action on the water. Also, many large trees had been felled into the water, apparently to provide structure for attracting fish. More of the larger bass were collected in and around these submerged trees. The larger, main body of the lake had a more open, wind swept shoreline with little cover in only a few coves.

Table 3. Population structure of indigenous largemouth bass in Boomer Lake from collections made in September and October of 1974.

Age class	$\hat{N}$	Length (mm) Range	Length (mm) Avg.	Weight (g) Range	Weight (g) Avg.	Total weight (grams)
I	755	125-250	185	19- 200	79	59645
II	511	176-348	242	80- 681	192	98112
III	532	220-414	300	100-1220	391	208012
IV	561	232-400	340	168-1135	629	352869
V	302	320-455	396	458-1816	1104	333408
VI	194	348-505	427	710-2270	1140	279360
VII	58	396-511	462	1135-2270	1801	104458
VIII	21	400-530	465	1135-2724	1853	38913
Total = 2938						1474777
						11.7 kg/ha

$$\hat{N} = \frac{C_t M_t}{R_t}$$

Table 4. Difference of largemouth bass population in upper and main portions of Boomer Lake in fall, 1974.

Portion of lake	$\hat{N}$*	Grams of bass collected	No. bass collected	Avg. wt. (grams)	Kg of bass/hectare
Upper	591	115951.6	130	892	22.359
Lower	2429	148912.0	452	329	7.891

$^{*}\hat{N} = \Sigma \frac{CM}{R+1}$

Variation of Distribution of the Two Subspecies of Largemouth Bass

It was presumed that the Florida bass may be more thermophilic than the northern bass because of their isolation in subtropical Florida. Therefore, given the temperature heterogeneity in Boomer Lake, the two subspecies of bass may not have the same spatial distribution, and subsequently not have the same susceptibility to the sampling gear used in the present study during certain times of the year.

During the first winter of this study (from 22 January to 1 March 1975) spatial sampling in and out of the warmer water afforded by the heated effluent allowed calculation of the numerical relationship between catch per unit effort and temperature at site of capture. The correlation coefficient for the Florida bass with temperature was 0.783 ($p=0.004$), whereas for the northern bass no such correlation was observed ($r= 0.161$ and $p=0.635$). These findings may indicate:

1) that the Florida bass were less susceptable to capture by seining in the cooler subsets of environment than in the warmer subsets that were influenced by the heated effluent, while no such apparent difference existed with the northern bass; or
2) Florida bass were attracted to the warmer waters near the heated effluent; or
3) the only surviving Florida bass in Boomer Lake by the time of this sample were those living in and near the heated effluent.

Any of these conclusions indicate a differential temperature related distribution of the two subspecies in relation to water temperatures. During this interval (22 January to 1 March 1975) water temperatures of the effluent ranged from 11.1-13.3^{o}C, while water temperatures at other sample sites were as low as 3.8^{o}C.

During wintertime sampling in 1975-76, only three Florida bass were captured; only one was captured in the vicinity of the heated effluent. The lack of the concentration of Florida bass in the heated portion of the lake during the second winter may have been because of higher water temperatures during 1975-76. The minimum observed water temperature during the second winter was 9^{o}C, and the observed effluent temperatures were never less than 15^{o}C. The difference in these temperatures and those recorded in 1974-75 are likely a result of the second winter being warmer than the first winter. Air temperatures taken at a meteorological station approximately 5 miles from Boomer Lake show that the months of December, January, and February had an average air temperature of 2.97^{o}C in 1974-75, while the average temperature was 5.66^{o}C in 1975-76; a difference of 2.68^{o}C (Climatological Data of Oklahoma).

Although there was no apparent concentration of the Florida bass in the heated portion of the lake during the second winter, a Chi-Square analysis of relative catch during 1975-76 showed that the seasonal catch rates for the two subspecies were significantly different ($P \approx 0.018$) than they should have been by chance alone. The Florida bass appeared to be more susceptible to electrofishing and seining in September and again in May, but less susceptible from October through April; with the greatest difference occurring in February and March (Table 5). These results indicate that more of the Florida bass than northern bass are moving offshore into deeper

Table 5. Chi-square analysis of catch rates for Florida and northern largemouth bass collected by electrofishing and seining from September-May, 1975-76.

Sample period		Northern bass		Florida bass	
From	To	Observed catch	Expected catch	Observed catch	Expected catch
09-11-75	10-07-75	7	12.40	16	10.59
10-15-75	10-29-75	11	10.24	8	8.75
02-18-76	03-16-76	11	7.54	3	6.45
03-22-76	04-08-76	16	12.40	7	10.59
05-03-76	05-11-76	10	12.40	13	10.59

Chi Square $\Sigma \frac{(O-E)^2}{E} = 12.11$ $P \simeq 0.018$

water during the colder months.

Growth

The growth rate of the 1974 year-class of northern and Florida bass between July, 1974 and February, 1975 was 0.860 and 0.970, respectively (Table 6), but the difference between growth rates was not significant ($P \simeq 0.40$).

The growth rate of the 1975 year-class of Florida and northern bass from the summer of 1975 to May 1976 was 0.632 for Florida bass and 0.383 for northern bass; this difference was highly significant ($P \simeq 0.01$). This difference in growth in the 1975 year-class apparently resulted largely from a substantial difference in growth of the two subspecies during the first three months following stocking. From the time of stocking until November, 1975, the Florida bass had a growth rate of 2.58 while the northern bass had a growth rate of only 1.03; the difference between these growth rates was highly significant ($P=0.01$). However, since the northern bass were larger than the Florida bass when stocked in 1975 (7.1 grams as compared with 3.65 grams), the initial difference in growth rates could possibly have been attributed to an expected faster rate of growth in the smaller fish rather than genetic potential. Growth rates for the two subspecies of the 1975 year-class were not significantly different for the other intervals; in fact, during the 30 March through 8 May 1976 interval, the growth rates of the two subspecies were both 1.115.

In summary, no significant difference in growth between the two subspecies was observed that could be conclusively attributed to differences in genetic potential of either subspecies.

Table 6. A comparison of the growth of stocked young-of-the-year Florida and northern largemouth bass in Boomer Lake, Oklahoma.

Average sample date	Growth interval (days)	Sample size	Average weight (grams)	(g) X 100 Seasonal growth	(g) X 100 Total growth
		Northern bass (1974-75)			
07-17-74		50	3.00		
	85			3.450	
10-09-74		8	24.40		0.860
	122			-0.245	
02-09-75		8	17.75		
		Florida bass (1974-75)			
07-02-74		60	4.50		
	100			2.250	
10-09-74		16	24.75		0.970
	122			-0.080	
02-09-75		11	20.00		
		Northern bass (1975-76)			
06-12-75		50	710		
	115			1.030	
10-04-75		19	28.60		
	121			-0.350	
02-02-76		11	17.60		0.383
	56			0.098	
03-30-76		16	20.75		
	39			1.115	
05-08-76		10	31.80		
		Florida bass (1975-76)			
07-28-75		45	3.65		
	69			2.580	
10-04-75		25	28.50		
	121			-0.540	
02-02-76		3	14.30		0.632
	56			0.410	
03-30-76		7	18.00		
	39			1.115	
05-08-76		13	27.92		

Survival

Estimates of the survival of Florida and northern bass were made for as long as individuals from the introduction populations could be collected and identified by their original mark (Table 7). Because of the method used to compute the population estimates for each subspecies, it was not possible to statistically compare the survival rates of the two subspecies directly; however, a Chi-square analysis was used to determine if the proportion of numbers of each subspecies captured in each sample period changed significantly during the year as compared with the proportion at which the two subspecies were stocked (Table 8).

Chi-square analysis of the relative catch of the 1974 year-class of the two subspecies in Boomer Lake showed strong evidence ($P \simeq 0.018$) of a significant change in abundance of the two subspecies from the time of stocking until the spring sample. Interpretation of this difference indicates that the initial survival rates (from the time of stocking until November) for the two subspecies of the 1974 year-class were not significantly different ($X^2 = 2.718$, $P=0.099$) when the Florida bass had a survival of 7.6% and northern bass 4.4%; however, intensive sampling during the spring of 1975 produced only one Florida bass as compared with 21 northern bass identified during the same period and overwinter survival of Florida bass was subsequently estimated to be only 1.6% as compared with 65.9% for the northern bass. Therefore, apparently the major contribution of the significant difference in survival of the 1974 year-class was during the winter, when the Florida subspecies had a much lower survival than the northern bass.

In contrast, Chi-square analysis of the relative catch during

Table 7. A comparison of the survival of stocked young-of-the-year Florida and northern largemouth bass in Boomer Lake, Oklahoma.

Average sample date	Time interval (days)	Sample size	Population estimate	Percent survival Seasonal	Total
		Northern bass (1974-75)			
06-27-74		50	3871		
	104			4.4	
10-09-74		8	170		2.90
	225			65.9	
05-22-75		21	112		
		Florida bass (1974-75)			
07-02-74		60	1525		
	99			7.6	
10-09-74		16	129		0.13
	225			1.6	
05-22-75		1	2		
		Northern bass (1975-76)			
06-12-75		50	4757		
	114			12.4	
10-04-75		19	588		12.40
	191			100.3	
04-13-76		26	590		
		Florida bass (1975-76)			
07-16-75		45	3517		
	80			23.7	
10-04-75		25	834		13.10
	191			55.1	
04-13-76		20	460		

Table 8. Chi-square (X^2) analysis of the relative abundance of the 1974 and 1975 year-classes of stocked Florida and northern bass in Boomer Lake, Oklahoma.

Subspecies	Number stocked	Percent of total	Sample period: Observed catch	Sample period: Expected catch	$\frac{(O-E)^2}{E}$
		1974 Year-class (fall sample)			
Northern bass	3871	71.74	24	28.696	0.768
Florida bass	1525	28.26	16	11.304	1.951
					X^2=2.718
					p =0.099
		1974 Year-class (spring sample)			
Northern bass	3871	71.74	21	15.783	1.724
Florida bass	1525	28.26	1	6.217	4.378
					X^2=6.102
					p =0.018
		1975 Year-class (fall sample)			
Northern bass	4757	57.49	19	25.296	1.567
Florida bass	3517	42.51	25	18.704	2.119
					X^2=3.686
					p =0.055
		1975 Year-class (spring sample)			
Northern bass	4757	57.49	26	26.445	0.007
Florida bass	3517	42.51	20	19.554	0.010
					X^2=0.017
					p =0.9

1975-76 for the 1975 year-class of both subspecies showed no evidence ($P \approx 0.9$) of any significant difference in abundance of the two subspecies. In fact, the estimates of overall survival from the time of stocking until the last sample in May, 1976, also showed very similar survival rates for both subspecies (12.4% for the northern bass and 13.1% for Florida bass). Greater differences were observed in seasonal survival, with the Florida bass having higher survival initially following stocking (12.4% for northern bass and 23.7% for Florida bass from the time of stocking until November); however, this difference was not supported by strong evidence from the Chi-square analysis ($P \approx 0.055$). The greatest difference in survival was again over the winter period. From the fall, 1975 until spring, 1976, overwinter survival of Florida bass was only 55.1% as compared with an estimated 100.3% for northern bass. However, because of the Chi-square test, these differences are not supported by strong evidence, and also, there may have been differential susceptibility to sampling as a result of different responses to seasonal water temperatures rather than actual changes in numbers present in Boomer Lake.

The lack of an observed high overwinter mortality of the Florida subspecies during the second winter as compared with the apparent extreme overwinter mortality of the Florida bass during the first winter may be accounted for by the differences in winter severity which resulted in lower winter water temperatures during the first winter as discussed in the previous section, Distribution of Introduced Largemouth Bass. Nevertheless, in the 1975 year-class overwinter survival of Florida bass was still lower than for northern bass, indicating that although possible decreasing winter water temperatures did not have the same impact on the Florida bass population as during the first, colder winter; the overwinter mortality of the Florida subspecies still may have been substantial in comparison to northern bass overwinter mortality, even during a mild winter.

Therefore, it appears that the major difference in survival between the two subspecies in Boomer Lake was probably higher wintertime mortality of the Florida subspecies. This difference was only statistically significant however during the first, colder winter, when presumably nearly all of the stocked Florida bass died, and those surviving were probably living in or near the heated effluent, since that was the only location they were captured after the fall, 1974 sample.

CHAPTER VI

CONCLUSIONS

Although some differences in growth and survival of the two subspecies of largemouth bass in Boomer Lake were observed, small sample sizes and conflicting results from one year to the next make it difficult to draw clear-cut conclusions. However, the following more obvious conclusions appear to have the most support.

1. Overwinter mortality during both years of this study was greater in the Florida bass populations than in the northern bass populations. The greatest difference in survival was during the first, colder winter, when apparently nearly all of the Florida bass died. Apparently, low or rapidly decreasing wintertime water temperatures in Boomer Lake are not tolerable by the Florida subspecies, probably as a result of a more thermophilic or stenothermic physiology. However, the better survival of Florida bass during the second, warmer winter, indicates that wintertime water temperature regimes of Boomer Lake may be marginal to Florida bass viability.
2. A substantial difference was observed in the distribution of the two subspecies in Boomer Lake. During the winter of 1974-75, Florida bass were collected only in the vicinity of the heated effluent, while northern bass were collected in all areas of the lake. Also, during the second year, catch rates

of Florida bass were higher than for northern bass during the warmer months, but lower during the colder months. Such observations are significant, and indicate differential behavioral responses to water temperatures within the same reservoir.

Based on these conclusion, it is probable that the introduction of Florida bass into a reservoir may expand the ecological niche previously occupied by northern largemouth bass because of a more thermophilic behavior of the Florida subspecies. This difference could help stabilize the fish populations of certain reservoirs by allowing more, and perhaps larger predators to inhabit the same environment because of a possible expansion of the habitat utilized by largemouth bass. However, due to the apparent temperature related limiting factor, which has not yet been clearly defined (Boomer Lake appears to represent a borderline environment in regard to wintertime temperatures), the introduction of Florida bass would be ecologically and economically practical only in more southern waters, or those reservoirs large enough or receiving enough heated effluent to provide the temperature regimes allowing overwinter survival of a significant portion of the Florida bass population.

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