GROWTH, PRODUCTION AND MORTALITY OF LARGEMOUTH BASS DURING THEIR FIRST YEAR OF LIFE IN LAKE CARL BLACKWELL, OKLAHOMA

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PREFACE

The objectives of this study were to estimate population, mortality rates, growth rates and production of young-of-the-year largemouth bass in Lake Carl Blackwell.

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CHAPTER I

INTRODUCTION

The largemouth bass, Micropterus salmoides (Lacépède), is one of the most important game fish in the United States because of its sporting qualities and food value. Often, however, a body of water will yield too few largemouth bass of desirable sizes to the angler because of too many fish and consequent stunting, or because of too few fish. The latter may be the result of over-harvest of the large bass or because there are too few largemouth bass of all sizes even though the average size is adequate.

At the beginning of this project, Lake Carl Blackwell had the latter problem which appeared to result from inadequate spawning or meager survival of eggs, fry or fingerlings. At that time, the largemouth bass population density was low, apparently due to the effects of a severe natural drawdown. From 1961 through 1972, below average rainfall, especially the lack of rainfall sufficient to produce substantial runoff, resulted in a 6-meter decline in water level. This exposed the shoreline to the high winds common to the Great Plains and resulted in high turbidity and the absence of vascular aquatic vegetation. Thus, the lack of littoral zone cover, high turbidity and lack of inflow would be expected to reduce the availability of organic matter and reduce the abundance of invertebrate food of young-of-the-year (YOY) largemouth bass.

In the first few years after impoundment, the lake was considered a good largemouth bass lake (Loomis 1951), but in 1968-1969 the catch rate was only 0.05 largemouth bass per hour (Zweiacker 1972). In two local fishing contests the catch rates for largemouth bass were 0.007/hr in May 1969 (Zweiacker 1972) and 0.03/hr in May 1973. According to Bennett (1970), a catch rate of 0.04/hr was insufficient to stimulate any interest in a bass fishery.

The low catch rates were due to a low population of catchable bass. Using mark-recapture methods, Zweiacker (1972) estimated the population of bass larger than 176 mm at 1822 or 1.67/hectare with a standing crop of 0.97 kg/ha. The average standing crop for Oklahoma ponds is 49 kg/ha (Jenkins 1958). Because the mortality rate of adult largemouth bass was not abnormally high and few young bass were captured during that project, it was hypothesized that the sparse population was due to poor recruitment of largemouth bass at the end of the first year of life. This project was designed to test the hypothesis that the small population of adult bass was due to high mortality of YOY largemouth bass between the time they reach 50 mm and the end of their first year of life. Specific objectives of this project were to describe and evaluate: 1) gross and net production, 2) growth, and 3) mortality rates of the 1972 and 1973 year-classes of largemouth bass during their first year of life in Lake Carl Blackwell.

CHAPTER II

LITERATURE REVIEW

Spawning success can be influenced by a number of ecological factors including temperature, wave action, fluctuations in water level, cover and substrate. Largemouth bass normally begin spawning during the spring when the water temperature exceeds 60^{o}F for 2 to 5 days (Kramer and Smith 1962) but they will cease spawning if the water temperature suddenly drops. Kramer (1961) and Bross (1969) observed low year-class strength in years when low water temperatures occurred during and after spawning. Summerfelt (1975) presented evidence that indicated that decreasing water temperature during the spawning season could result in disjunctive spawning and several size classes. In Lake George, Minnesota, eggs in all 44 observed nests perished when the water temperature decreased to 50^{o}F three days after spawning (Kramer 1961). He also observed that temperature during and after spawning was inversely proportional to the length of the combined egg-sac fry period. He hypothesized that a decrease in the time of this period would reduce the mortality during these stages. Although largemouth bass eggs and fry are fairly resistant to the temperature fluctuations expected in nature, a rapid decrease in water temperature will cause the male bass to abandon the nest and this may cause the nest to fail from predation and disease (Jurgens and Brown 1954, Kelly 1968).

Wave action can reduce spawning success in some waters. Kramer and Smith (1962) gave wave action as the most important factor causing nest failure in the open water of Lake George. The molar action of waves destroyed the needle rush mats on which bass laid their eggs, covered the nests with sand or vegetation or scoured them clean of eggs. Open water nests were successful only in years of low wind velocity or if protected by overhead cover.

Fluctuations in water level may influence nest survival by altering the effects of wave action and temperature fluctuations upon the nests. Decreasing water levels make the nests more susceptable to wave action and temperature fluctuations (Von Geldern 1971) and in extreme cases may even leave the nest dry. Rising water levels increases cover for nesting sites and decreases effects of wave action and temperature fluctuations (Walburg and Nelson 1966, Bross 1969).

Spawning success is also influenced by the substrate. Largemouth bass may spawn on rocks, rubble (Miller and Kramer 1971), roots, vegetation and sand (Kramer 1961). Kramer (1961) observed the highest egg survival (in successful nests) on vegetation and the lowest in sand. The highest percentage of successful nests was in pits and the lowest on sand. Robinson (1961) and Clugston (1964) stated that bass will not spawn on silt bottoms even if there is no alternative. Therefore, in the absence of suitable substrate, largemouth bass will not spawn.

Other factors reducing nesting success include predation by fishes (Bennett 1954) and invertebrates (Bennett 1970, Miller and Kramer 1971, Eckblad and Shealy 1972) and disease (Kramer 1961).

After yolk sac absorption, the most important factors influencing survival of young largemouth bass are turbidity, temperature, water level fluctuations, food and cover. Buck (1956) observed that highly turbid ponds tended to have small year-classes of largemouth bass and poor first year growth. Buck characterized turbid waters as having small populations of adult bass (Age III and up) with little recruitment. The effect of turbidity on year-class strength is not clear; however, it probably does not cause direct mortality of young largemouth bass but decreases primary productivity. Therefore, the food supply and abundance of aquatic macrophytes which provide cover for young bass are reduced and survival is low. Natural fluctuations in water temperature have not been implicated as a major cause of mortality of juvenile largemouth bass but it is directly correlated with growth (Kramer 1961, Strawn 1968). Strawn found that bass fry grew best at 27.5°C to 30°C. A rapid growth rate would be beneficial by reducing the time during which the juvenile bass would be susceptable to predation.

Food, cover and water level fluctuations are closely interrelated factors influencing survival of juvenile largemouth bass. Water level fluctuation has been recognized as a major factor influencing year-class strength in many species of fish (Wood 1951, Walburg and Nelson 1966). Jackson (1958) reported that high summer water level after a prolonged drawdown was associated with large year-classes of largemouth bass. Bross (1969) and Aggus and Elliot (1975) found direct correlations between water level and year-class strength of largemouth bass. Aggus and Elliot (1975) found a significant direct correlation between the population density of YOY largemouth bass in fall cove rotenone samples at Bull Shoals Reservoir and the amount and duration of flooded terrestrial vegetation. They found that the period after the schools of fingerlings break up (approximately 1 June) was the most important period. They attributed the correlation to cover afforded by the flooded vegetation reducing predation on young bass. They also felt that newly flooded shoreline would provide more food.

CHAPTER III

DESCRIPTION OF THE STUDY AREA

Lake Carl Blackwell is a turbid reservoir formed by the impoundment of Stillwater Creek in north-central Oklahoma. It is located 12.8 kilometers west of Stillwater in Payne County, Oklahoma. When the reservoir is full, one arm extends into southern Noble County. Construction was begun in 1936 and completed in 1938 by the Works Progress Administration and the reservoir has been used as a recreational facilitysince then. The reservoir was leased to Oklahoma State University in 1948 and deeded to Oklahoma State University in 1954. From 1950 to 1974, it also served as the sole water supply for municipal Stillwater but with the completion of nearby Lake McMurtry, it now serves as an alternate water supply.

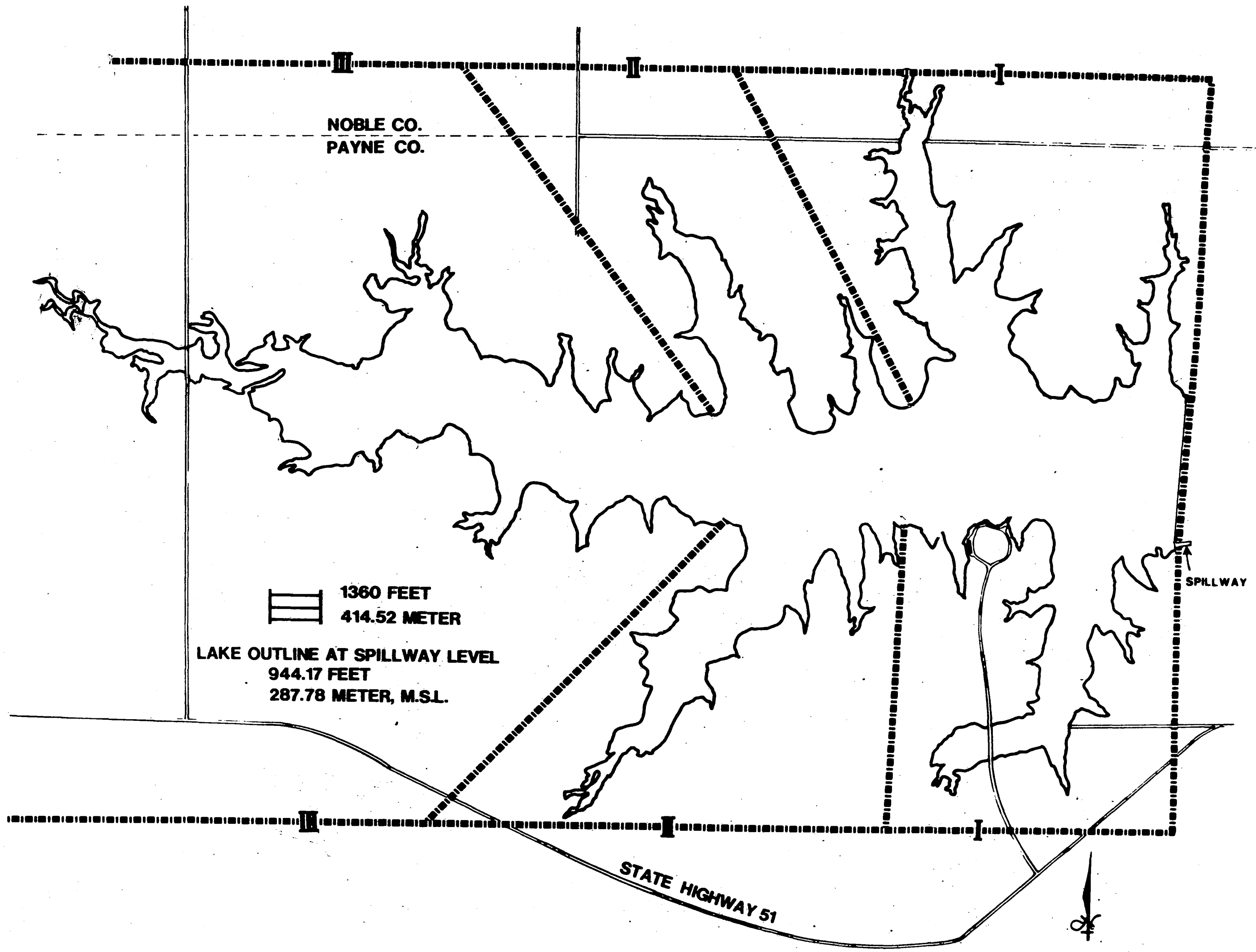
At spillway elevation, 287.78 meters above mean sea level (m.s.l.), the surface area is 1400.58 hectares with a shoreline length of 90.41 kilometers, a volume of 67.84 million cubic meters, and a shoreline development index (S.D.I.) of 6.8 (Table 1). Beginning with the thesis research by Zweiacker (1972), the lake has been stratified into three regions (Figure 1) which differ in depth, turbidity and shoreline steepness. Region I encompasses the main pool and adjacent arms and is deepest, has the steepest shoreline and generally has clearer water than the other regions. The delta area is in Region III which is shallow, usually more turbid and at low lake levels becomes extensive

Table 1. Morphometric characteristics of Lake Carl Blackwell at the mid-point of each sample period. Area is in hectares, volume is in million cubic meters and shoreline distance is in kilometers.

Period	Area I	Area II	Area III	Total
Fall 1972 (Lake level on 6 Oct. 1972=281.91 meters above m.s.l., 5.87 meters below spillway)				
Area	297.7	127.4	78.3	503.4[1]
Volume				14.2
Shoreline	14.9	6.7	6.5	28.2
SDI				3.5
Spring 1973 (Lake level on 28 May 1972=285.54 meters above m.s.l., 2.24 meters below spillway)				
Area	461.4	273.5	273.8	1008.7
Volume				42.5
Shoreline	28.6	21.8	29.4	79.8
SDI				7.0
Fall 1973 (Lake level on 30 Sept. 1973=286.67 meters above m.s.l., 1.11 meters below spillway)				
Area	521.5	325.0	355.0	1201.5
Volume				54.4
Shoreline	30.6	22.3	32.9	85.8
SDI				6.9
Spring 1974 (Lake level at or near spillway level, 287.78 meters above m.s.l. for entire period)				
Area	602.2	372.0	426.3	1400.6
Volume				67.8
Shoreline	34.5	23.0	32.8	90.4
SDI				6.8

[1]Values in Regions I, II and III do not necessarily total to exactly the total values due to rounding error.

Figure 1. Lake Carl Blackwell showing the three regions.

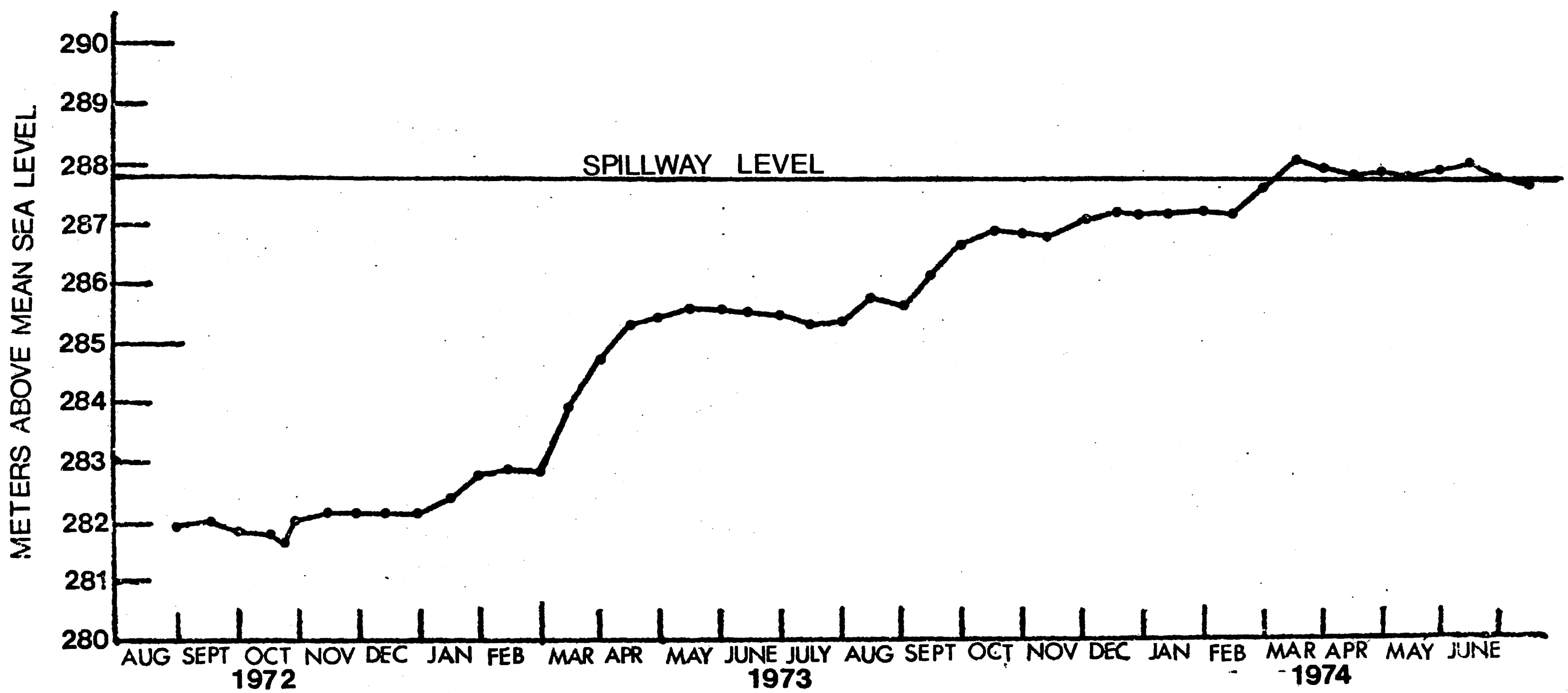

III
II
I
NOBLE CO.
PAYNE CO.
1360 FEET
414.52 METER
LAKE OUTLINE AT SPILLWAY LEVEL
944.17 FEET
287.78 METER, M.S.L.
SPILLWAY
III
II
I
STATE HIGHWAY 51

mud flats. Region II is intermediate in these factors.

Between 27 January 1961, when the lake reached spillway elevation, and 20 October 1972 when the lake reached its lowest level since initial filling, prolonged drought and increasing municipal water usage resulted in a downward trend in lake level. At the record low level (281.25 m, m.s.l.), the lake had a surface area of 491.7 ha, a shoreline distance of 27.7 km, a volume of 13.3 million cubic meters and a shoreline development index of 3.5. This was 35.1, 30.6, 19.6 and 48.5 percent of the respective maxima. During winter 1972 and spring 1973, heavy rains increased the water level to 285.54 m on 28 May 1973 which was the mid-point of the spring sampling interval. By the mid-point of the fall collection, the lake level was 286.67 m, m.s.l. and on 10 March 1974, the lake reached spillway elevation for the first time since 1961 and remained at or near that level for the remainder of this project (Figure 2).

At the start of this project (fall 1972) the shoreline was without any aquatic macrophytes. Cover consisted of a few old building foundations, the rock rip-rap of the dam and dead trees which lined the old creek channels. Much of the west end of the lake and the upper ends of the major coves were shallow mud flats. Because of high winds and lack of cover, turbidity was high. Hysmith (1975) found turbidities ranging from 17.0 to 109.7 ppm SiO_2 and averaging 42.5 ppm. After the rise in water level during winter 1972, flooded terrestrial vegetation was present in the lake at the start of the spring 1973 sampling period and remained there for the remainder of the project. By the end of the spring 1973 sampling period, aquatic macrophytes had begun to appear and quickly became abundant in the protected areas.

Figure 2. Lake level fluctuation between August, 1972 and June 1974. Lake level data courtesy of Water Conservation Structure Laboratory, U.S. Department of Agriculture.


METERS ABOVE MEAN SEA LEVEL
290
289
288
287
286
285
284
283
282
281
280
SPILLWAY LEVEL
AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE
1972
1973
1974

Because of its close proximity to the Oklahoma State University campus, Lake Carl Blackwell has been extensively studied in the past. Studies pertinent to this investigation include: depth distribution of fishes (Loomis 1951), effects of water level fluctuations upon higher plants (DeGruchy 1952), turbidity-productivity relationships (Claffy 1955), distribution and character of sediments (Norton 1966), production of largemouth bass (Zweiacker and Brown 1971), population dynamics of largemouth bass (Zweiacker 1972), age and growth of largemouth bass in relation to mean pool depth (Zweiacker et al. 1973), effects of water level fluctuations on abundance, standing crop and growth of fishes (Johnson 1974) and influence of sediment cycling on primary productivity (Hysmith 1975).

CHAPTER IV

PROCEDURES

Population Estimation

The number of YOY largemouth bass in Lake Carl Blackwell was estimated five times from fall 1972 to spring 1974. Population estimates were made by mark-recapture techniques on the 1972 year-class during fall 1972 and spring 1973 and on the 1973 year-class during summer 1973, fall 1973 and spring 1974. Mark-recapture methods have been commonly used in the past to estimate bass populations (Mraz and Threinen 1957, Maloney et al. 1962, Cooper et al. 1963, Hanson 1965, McCann and Carlander 1970). In experiments where mark-recapture estimates were checked by draining, it has been found that these estimates are valid. For example, Cooper et al. (1963) found that five of six separate estimates of a bass population in a small pond included the true population within the confidence intervals and the inaccurate value could be traced to the dual factors of: 1) large mesh size allowing the smaller bass to escape the seine, and 2) a portion of the population being off shore where they could not be effectively seined. Buck and Thoits (1965) found that 63 estimates averaged 28% more or less than the true population but only twice did the true population lie outside confidence intervals calculated from their data. Swingle et al. (1967) also found that the true population was included in the confidence interval although the estimate was somewhat low.

During falls 1972 and 1973 and springs 1973 and 1974, the populations of YOY bass were estimated using the shoreline electrofishing combined with mark-recapture technique developed by Lewis et al. (1962). Zweiacker (1972) used this method to estimate the population of bass over 176 mm in length in Lake Carl Blackwell but it had not been used to estimate the population of YOY bass in a large reservoir prior to this project even though electrofishing has been used to collect YOY bass for other purposes (Applegate et al. 1967, Von Geldern 1971). Collection of YOY bass was made by maneuvering the electrofishing boat along the shoreline in shallow water (about one meter deep) and netting stunned bass. A few small areas of shallow mud flats had to be sampled too far from shore to effectively obtain fingerling bass. The entire shoreline was sampled during each unit of effort (one completed trip around the lake). Current was supplied by a 230 volt 3000 watt A.C. generator mounted in a boom-type electrofishing boat.

YOY bass captured by electrofishing were measured to the nearest millimeter (total length) and weighed to the nearest gram. Scales were taken from the left side of the body below the lateral line where the distal end of the pectoral fin touched the body (Lagler 1956). They were then marked by punching a hole in the caudal fin with a paper punch. According to Stott (1971), this mark is suitable for short-term experiments but may not be recognized in long-term experiments. Since there was no desire for the marks to last longer than two months, this method was acceptable. To prevent possible confusion of marks between sampling periods, the location of the mark was alternated between the ventral and dorsal lobes of the caudal fin. The capture location of each bass was recorded on a map of the lake and the fish were released within 100 meters of the point of capture.

Because of the exceptional abundance of the 1973 year-class, several short-cuts were taken. First, fish were held in the holding tank until a group could be worked at one time (usually within a shoreline distance of 100 m). Therefore, the capture location of each individual was not recorded, but the location where the group was released was recorded. Second, after examining scales from about 500 YOY bass to determine the point separating the 1972 and 1973 year-classes, no scales were taken from bass less than 200 mm since no member of the 1972 year-class less than 250 mm had been found in these first samples. Also, on windy days it was impossible to accurately weigh bass so on those days, bass less than 200 mm were not weighed.

Population estimates of YOY bass in Lake Carl Blackwell for fall 1972 (1972 year-class), fall 1973 and spring 1974 (1973 year-class) were derived from the Schnabel formula (Ricker 1958):

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

where:

$\hat{N}$ = the estimated population

C_t = the number of YOY bass captured during the tth unit of effort, a unit of effort being one completed trip around the lake

M_t = the number of marked YOY bass in the population at the start of the tth unit of effort

R_t = the number of marked YOY bass recaptured during the tth unit of effort

The population estimate ($\hat{N}$) applies to the mid-point of the sampling interval. Because the distribution of $\hat{N}$ about the true population is skewed rather than a normal curve, confidence intervals (C.I.) about $\hat{N}$ were calculated using a Poisson distribution. They were calculated by assuming ΣR_t to be a Poisson variable and substituting the appropriate values obtained from a Poisson table into the Schnabel equation (Ricker 1958):

$$95\%\ \text{C.I.} = \frac{\Sigma(C_t M_t)}{\Sigma R_{t\ high}} \text{ to } \frac{\Sigma(C_t M_t)}{\Sigma R_{t\ low}}$$

Separate Schnabel estimates were made for each region of the lake and summed for the whole lake. An unstratified estimate was also calculated for the entire lake. During fall 1972, a total of 8 units of effort averaging 16.2 hours per unit of effort were completed. During spring 1973, fall 1973 and spring 1974, there were 6, 7 and 4 units of effort averaging 19.5, 31.6, and 60.5 hours per unit of effort, respectively (Table 2).

No Schnabel estimate could be calculated for the 1972 year-class in spring 1973 because only one indigenous largemouth bass of that year-class was captured. However, the Fishery Unit had stocked 862 marked largemouth of that year-class prior to the sampling interval which allowed a Petersen estimate to be made. Petersen estimates were made on the 1972 year-class during spring 1973 and on the 1973 year-class during summer 1973 and fall 1973. In this method, a known number of marked fish were stocked and the population was estimated using the Petersen formula (Ricker 1958):

$$\hat{N} = \frac{M\ C}{R}$$

where: $\hat{N}$ = the estimated population including marked fish

C = the total number of YOY bass captured

M = the number of marked bass stocked into the population

R = the number of marked bass captured during the sampling interval

Confidence intervals about $\hat{N}$ were obtained by the same procedure used

Table 2. Dates, number of units of effort, and total and average electrofishing time during each sample period.

Period[1]		Shoreline distance		Average hrs./trip
Fall 1972 (8)				
Area I	5 Sept. - 28 Oct.	14.9	68.75	8.59
Area II	17 Sept. - 23 Oct.	6.7	39.92	4.99
Area III	25 Sept. - 6 Nov.	6.5	21.25	2.66
Total	5 Sept. - 6 Nov.	28.2	129.92	16.24
Spring 1973 (6)				
Area I	26 Apr. - 25 June	28.6	52.92	8.82
Area II	26 Apr. - 2 July	21.8	29.83	4.97
Area III	27 Apr. - 2 July	29.4	34.34	5.72
Total	26 Apr. - 2 July	79.8	117.09	19.51
Fall 1973 (7)				
Area I	5 Sept. - 25 Oct.	30.6	82.85	11.84
Area II	4 Sept. - 23 Oct.	22.3	76.08	10.87
Area III	5 Sept. - 22 Oct.	32.9	62.25	8.89
Total	4 Sept. - 25 Oct.	85.8	221.18	31.60
Spring 1974 (4)				
Area I	11 Apr. - 10 J-ne	34.5	121.26	30.32
Area II	5 Apr. - 11 June	23.0	63.09	15.77
Area III	10 Apr. - 7 June	32.8	57.59	14.40
Total	5 Apr. - 11 June	90.4	241.94	60.49

[1] The number in ( ) indicates the number of trips around the lake.

for the Schnabel estimates. Since $\hat{N}$ includes the introduced largemouth bass as well as the indigenous population, estimates of the indigenous population were obtained by subtracting the number stocked fron $\hat{N}$. Confidence intervals about the estimates of the indigenous populations were obtained by proportioning the C.I.'s of the total $\hat{N}$ by the fraction $\hat{N}$ (indigenous)/$\hat{N}$ (total). Petersen estimates apply to the date the marked fish were stocked.

The first Petersen estimate was made during spring 1973 using two size groups of pond reared Age 0+ largemouth bass. On 23 March 1973, 862 fingerling largemouth bass were marked and released into Lake Carl Blackwell. Of these, 593 fish averaging 157 mm and 37 g (small-size group) were marked by clipping the ventral lobe of the caudal fin and the balance, 269 fish averaging 235 mm and 163 g (large-size group) were marked by clipping the dorsal lobe of the caudal fin. Collections were made from 26 April to 2 July to obtain estimates of the ratio of marked to unmarked bass in the population using both the total marked population (since both the small and large groups were from the 1972 year-class) and the small group alone. This strategy was used because of the large size difference between the larger size group and the native largemouth bass of the same age which might result in a systematic error in the estimate due to a potential difference in vulnerability of the two size groups to electrofishing. When captured by electrofishing, the stocked fish were treated the same as the indigenous bass. Their marks were recorded and they were considered recaptures for the Petersen estimates.

In mid-summer 1973, two additional groups of hatchery raised fingerlings (1973 year-class) were stocked after having been marked by spray applied fluorescent pigments using the technique developed by Jackson (1959) and refined by Andrews (1972). The first stocking of pigment-marked YOY bass was on 15 June 1973 when 8435 largemouth bass (mean weight of 1.17 grams) were marked and released. Of these, 5971 were marked with red pigments and scattered along the shoreline in Region I, 720 were marked with yellow pigments and released into Region II and 1736 were marked with green pigments and released in Region III. Subsequent examination revealed that the yellow pigments were difficult to distinguish from the green so thereafter, green and yellow pigment bearing fish were considered as a single group. On 5 July 1973, a second group of 2927 YOY largemouth bass (mean weight = 1.64 grams) were marked and released into the lake. Of these, 1924 were marked with orange pigments and released into Region II and 1003 were marked with blue pigments and released into Region I. In conjunction with these releases, 1150 pigment marked bass were held in ponds for determination of mark-retention. M in the Petersen estimates was adjusted for mark loss.

After these releases, YOY largemouth bass were collected by shoreline seining and cove poisoning. From 12 July to 20 August 1973, 115 shoreline seine hauls were made with a 7.6 m minnow seine. All areas of the shoreline which could be effectively seined were sampled twice. The YOY bass obtained by seining were examined in a dark box under a battery operated ultraviolet light to determine the presence or absence of fluorescent pigments. Random samples were weighed and measured and the small fish were released at the point of capture.

On 13, 14 and 15 August 1973, three coves were poisoned with rotenone. All YOY largemouth bass obtained on the first day were taken to a freezer and stored until they could be examined for pigments in the laboratory. YOY bass obtained on the second and third day were unsuitable for Petersen estimates because of decomposition.

Petersen estimates of the 1973 year-class were applied to 26 June 1973 which was the midpoint between the two stockings of pigment-marked fish. Estimates were stratified by pigment color and lake region and an unstratified estimate was made for the entire lake.

On 1 and 5 September 1973, an additional 671 bass were added to the existing population to provide a means of obtaining another Petersen estimate of the population of the 1973 year-class. This provided an independent estimate for comparison with the Schnabel estimate made by mark-recapture in conjunction with electrofishing. Six hundred of these fish were Age 0 and had a mean length of 148 mm and weight of 46 g; 71 of the group were Age I and averaged 216 mm and 124 g. Both the Age 0 and Age I bass were marked by punching the anal fin with a paper punch. The Age I group also had a previously applied caudal fin clip. Petersen estimates of the 1973 year-class were made using both: 1) the YOY bass alone (since they were the same age as the native population), and 2) with both groups (since some of the native YOY largemouth bass were as large as the stocked Age I bass).

Population estimates were compared using the statistical model:

$$t = \frac{1/\hat{N}_A - 1/\hat{N}_B}{\sqrt{\text{Var } (1/\hat{N}_A) + \text{Var } (1/\hat{N}_B)}}$$

where: $\hat{N}_A$ and $\hat{N}_B$ = the two population estimates

$\text{Var } (1/\hat{N}) = \frac{R(C-R)}{M^2C^3}$ for Petersen estimates (Ricker 1958)

$\text{Var } (1/\hat{N}) = \frac{\Sigma R_t}{(\Sigma C_t M_t)^2}$ for Schnabel estimates (Ricker 1958)

Comparisons were made between the fall 1972 and spring 1973 estimates of the 1972 year-class, fall 1972 estimate of the 1972 year-class and fall 1973 estimate of the 1973 year-class, and between summer and fall 1973, fall 1973 and spring 1974, and summer 1973 and spring 1974 estimates of the 1973 year-class. Separate comparisons were made for each region as well as for the unstratified estimates.

Evaluation of Assumptions for Population Estimates

Mark-recapture estimates are valid only if certain assumptions are met (Ricker 1958):

(1) that the marked fish suffer the same natural mortality as the unmarked fish;

(2) that the marked fish are as vulnerable to the fishing being carried on as are the marked fish;

(3) that the marked fish do not lose their marks;

(4) that the marked fish become randomly mixed with the unmarked; or that the distribution of fishing effort (in subsequent sampling) is proportional to the number of fish present in different parts of the body of water;

(5) that all marks are recognized and reported on recovery;

(6) that there is only a negligable amount of recruitment to the catchable population during the time the recoveries are being made.

Assumption number 1 was not tested and remained as an assumption in the present study. The few fish which were seriously injured or killed by electrofishing were returned to the water unmarked and not considered a capture. Delayed mortality of apparently unharmed marked fish cannot be evaluated without removing some of the fish and holding them for long periods of time; however, this method would not give adequate estimates of mortality since the mortality factors would be different in holding ponds (less predation, differences in handling, etc.). However, no recaptured bass appeared ill or injured due to prior handling and care during marking together with immediate release should have minimized this problem. Higher mortality of marked fish would result in an overestimation of the true population because it would reduce the opportunity for recapture of marked bass without affecting the recorded number of marked fish.

Unequal vulnerability of marked and unmarked fish to capture (assumption 2) could result in either over- or underestimation. If the marked fish learned to avoid recapture, then an overestimation would result. If marked fish failed to randomly disperse after release but remained in the area of capture, they might be more vulnerable to subsequent capture and an underestimation would result (assumption 4). In examples where a body of water was drained after mark-recapture estimation, it is more common to underestimate the population than to overestimate it (Cooper et al. 1963, Buck and Thoits 1965, Swingle et al. 1967) and this bias was believed to be caused by nonrandom dispersal. In this project, this problem was minimized by sampling the entire littoral area of the lake rather than just random sample areas.

Mark loss or non-recognition (assumptions 3 and 5) was not a problem for any fin-clips or punches since these marks were clearly visible throughout each sampling interval. With both punches and clips, regeneration closed the hole or reduced the size of the clip but the marks remained visible by the shape of the rays and the presence of a visible scar. Pigment marked fish were a greater problem. Examination of the fish retained for mark-retention revealed a significant percentage of mark loss. To compensate for this loss, the number of marked bass introduced (M in the Petersen formula) was adjusted (reduced) for mark loss.

Recruitment into the population (assumption 6) was minimized by sampling over a short period of time (2 months). Recruitment from immigration into the population might have occurred if non-indigenous bass entered the population from farm ponds in the Lake Carl Blackwell watershed. However, heavy rains during the winter 1972 and spring 1973 apparently did not result in significant recruitment since the rarity of the 1972 year-class would have made a population change obvious. The catch rate of native 0+ bass during spring 1973 was lower than in fall 1972 and the population estimates were almost identical.

Mortality Rates

Mortality rates between population estimates were estimated using the repeated census method developed by Ricker (1945). In this method, survival (s) is:

$$s = \frac{\hat{N}_2}{\hat{N}_1}$$

The mortality rate between estimates is 1 - s. The daily instantaneous mortality rate is (Chapman 1971):

$$i = \frac{-(\text{Ln } \hat{N}_2 - \text{Ln } \hat{N}_1)}{\Delta t}$$

where: i = the daily instantaneous mortality rate

Δt = the number of days between population estimates 1 and 2

In all mortality estimates, the unstratified estimates of $\hat{N}_1$ and $\hat{N}_2$

were used. They were considered the best estimates of $\hat{N}$ since the amount of migration between regions was unknown and because no confidence intervals could be calculated for the sum of the stratified estimates. No overwinter mortality rate could be calculated for the 1972 year-class since the spring 1973 estimate was slightly higher than the fall 1972 estimate. Mortality rates were calculated for the 1973 year-class for the intervals between: 26 June 1973 to 30 September 1973, 30 September 1973 to 12 May 1974, and 26 June 1973 to 12 May 1974.

Differences between i values obtained in this project and those observed in the literature for similar periods in the life of YOY bass were tested statistically using the formula:

$$t = \frac{\bar{i}_1 - \bar{i}_2}{\sqrt{\frac{[(n_1-1)\ SD_1^2 + (n_2-1)\ SD_2^2]}{n_1 + n_2 - 2}\ \frac{1}{n_1} + \frac{1}{n_2}}}$$

where: $\bar{i}_1$ = the mean of the literature i's

$\bar{i}_2$ = the mean of the i from 26 June - 30 September and the i from 30 September to 12 May

n_x = the number of observations in $\bar{i}_x$

SD_x = the variance of $i_x = \dfrac{\Sigma i^2 - \dfrac{(\Sigma i)^2}{n}}{n - 1}$

Growth

Most YOY bass captured during this project were weighed to the nearest gram and measured (total length) to the nearest millimeter. Occasionally, weights of the smaller bass (less than 200 mm) were not taken due to high winds. In the summer 1973, only random samples of YOY bass were weighed and measured to minimize handling stress. Average lengths and weights were calculated for each sample period and for each unit of effort (1 trip around the lake) during fall 1973 and spring 1974. Growth was estimated by increment and percent increment in length and weight for each interval delineated by estimates of mean length and weight. For estimates of gross production, it is also necessary to calculate the instantaneous coefficient of growth using the exponential formula (Chapman 1971):

$$g = \frac{\text{Ln } \bar{w}_2 - \text{Ln } \bar{w}_1}{\Delta t}$$

where: g = the daily instantaneous rate of growth

$\bar{w}_1$ and $\bar{w}_2$ = the mean weight of YOY bass captured in periods 1 and 2

Δt = the time in days between periods 1 and 2

The only growth estimates obtained on the 1972 year-class were the increments in length between spawning (approximately 15 May 1972) and the mid-point of the fall 1972 sample (6 October 1972). Since only 1 native bass of that year-class was collected during the spring 1973 sample interval, no acceptable mean length and weight could be obtained for that period.

For the 1973 year-class, 14 growth estimates were obtained for the following intervals: 1) spawning (15 May 1973) to 26 June 1973, 2) 26 June to 12 July, 3) 12 July to 14 August, 4) 14 August to 6 September, 5) 6 September to 14 September, 6) 14 September to 21 September, 7) 21 September to 1 October, 8) 1 October to 6 October, 9) 6 October to 14 October, 10) 14 October to 22 October, 11) 22 October to 14 April 1974, 12) 14 April to 1 May, 13) 1 May to 21 May, and 14) 21 May to 1 June.

Production

Both net and gross production of YOY largemouth bass were estimated in this project. Net production (P_n) is equal to $B_2 - B_1$ where B_1 and B_2 are the biomass ($N\bar{w}$) at times 1 and 2. Gross production (Pg) was estimated using the equation (Chapman 1971):

$$P_g = g \times \bar{B}$$

where: $$\bar{B} = \frac{B_1(e^{g-i}-1)}{g-i} \text{ if g is greater than i}$$

or alternatively: $$\bar{B} = \frac{B_1(1-e^{-(i-g)})}{i-g} \text{ if i is greater than g}$$

The components are:

$\bar{B}$ = the average biomass between times 1 and 2

g = the instantaneous rate of growth between times 1 and 2

i = the instantaneous rate of mortality between times 1 and 2

No instantaneous mortality or growth rates could be calculated for the 1972 year-class therefore, only net production between spawning (15 May) and the mid-point of the fall 1972 sampling interval (6 October) was calculated for the 1972 year-class. For the 1973 year-class, net production was estimated for the intervals: 1) spawning to 26 June, 2) 26 June to 30 September, 3) 30 September to 12 May 1974, 4) spawning to 30 September, and 5) spawning to 12 May. Net production from spawning (15 May 1973) to 30 September was considered the estimate of net production during the first growing season and net production from spawning to 12 May is considered net production during the first year of life. Gross production estimates were made for the 1973 year-class for two periods: 1) 26 June 1973 to 30 September 1973, and 2) 30 September to 12 May 1974.

CHAPTER V

RESULTS AND DISCUSSION

Population Estimates

During this project, the population of the 1972 year-class was estimated two times (fall 1972 and spring 1973) and the population of the 1973 year-class was estimated three times (summer 1973, fall 1973 and spring 1974). When possible, a separate estimate was made for each of the three lake regions as well as an unstratified estimate for the entire lake. Only unstratified estimates were made for the 1972 year-class because no member of that year-class was captured outside Region I. During fall 1972, only 10 YOY largemouth bass were captured in 8 units of effort totaling 129.92 hours of electrofishing for a catch rate of 0.077 YOY bass per hour (Table 3). All of these fish were captured in Region I, therefore no population estimates were obtained for Regions II and III. The Schnabel estimate of the YOY largemouth bass population was 29 ($C.I._{.05}$ = 5 - 290, Table 4). The following spring, a Schnabel estimate could not be obtained due to the low catch rate. Only 1 native largemouth bass of the 1972 year-class was captured in 6 units of effort totaling 117.09 hours (catch rate = 0.0085/hr). However, the addition of 862 marked bass to the population allowed a Petersen estimate to be made. Of the 26 Age I bass captured during the spring 1973, 25 had been marked (Table 5). The Petersen estimate for all age group I fish captured in spring 1973 was 896 ($C.I._{.05}$=422-1383)

Table 3. Catch rates of YOY bass by electrofishing at Lake Carl Blackwell.

Period	Total shoreline distance	Total hours	Total catch	Catch/ hour	Catch/ km
Fall 1972	225.6	129.92	10	0.0770	0.0443
Spring 1973	478.8	117.09			
Total			21	0.2221	0.0543
Native			1	0.0085	0.0021
Fall 1973	600.6	221.18			
Total[1]			2754	12.4166	4.5854
Native			2541	11.4884	4.2308
Spring 1974	361.6	241.94			
Total[1]			2113	8.7336	5.8435
Native			1960	8.1012	5.4204

[1]The number of native bass captured was estimated by multiplying the number captured by .9274281, the ratio of native bass to the total population in the summer 1973 estimate. This assumes no differential mortality between the pigment marked fish and the native population.

Table 4. Schnabel estimate of the 1972 year-class of largemouth bass in Lake Carl Blackwell during fall 1972.

Unit of effort	Date	C_t	M_t	C_tM_t	ΣC_tM_t	R_t	ΣR_t	$\hat{N}$	C.I.$_{.05}$
Fall 1972 estimate of the 1972 year-class (entire lake)[1]									
1	1 Sept. - 19 Sept.	0	0	0	0	-	-	-	-
2	19 Sept. - 1 Oct.	2	0	0	0	-	-	-	-
3	4 Oct.	0	2	0	0	0	0	-	-
4	5 Oct.	0	2	0	0	0	0	-	-
5	5 Oct.	0	2	0	0	0	0	-	-
6	5 Oct.	1	2	2	2	0	0	-	-
7	6 Oct.	1	3	3	5	0	0	-	-
8	9 Oct. - 28 Oct.	6	4	24	29	1	1	29	5 - 290

[1]Since all YOY largemouth bass were captured in Region I, the estimate applies to both the entire lake and Region I.

Table 5. Petersen estimates of the largemouth bass population at Lake Carl Blackwell.

Date of stocking	M[1]	C	R	$\hat{N}$ (total)	C.I.$_{.05}$	$\hat{N}$ (native)[2]	C.I.$_{.05}$
Spring 1973 estimate of the 1972 year-class using only the small bass							
23 March	593	18	17	628	393 - 1,078	35	22 - 60
Spring 1973 estimate of the 1973 year-class using all the marked bass							
23 March	862	26	25	896	422 - 1,383	34	16 - 53
Summer 1973 estimate of the 1973 year-class-Area I (using blue pigments only)							
5 July	621	405	1	251,505	44,911 - 2,515,050	244,523	43,664 - 2,445,230
Summer 1973 estimate of the 1973 year-class-Area I (using red pigments only)							
15 June	1,967	405	13	61,280	35,724 - 111,748	54,298	31,654 - 99,016
Summer 1973 estimate of the 1973 year-class-Area I (using all marked fish)							
26 June	2,588	405	14	74,867	44,601 - 136,122	67,885	40,442 - 123,427
Summer 1973 estimate of the 1973 year-class-Area II (using all marked fish)							
26 June	2,070	66	3	45,540	15,525 - 227,700	42,896	14,623 - 214,480
Summer 1973 estimate of the 1973 year-class-Area III (using all marked fish)							
26 June	884	94	3	27,699	9,443 - 138,493	25,963	8,851 - 129,813
Summer 1973 estimate of the 1973 year-class--unstratified							
26 June	5,542	565	20	156,562	101,663 - 256,658	145,200	94,285 - 230,032

Table 5 (Continued)

Date of stocking	M	C	R	$\hat{N}$ (total)	C.I.$_{.05}$	$\hat{N}$ (native)	C.I.$_{.05}$
Fall 1973 estimate of the 1973 year-class (using small bass only)							
1 Sept.	600	2,754	14	118,029	70,315 - 214,597	117,428	69,957 - 213,506
Fall 1973 estimate of the 1973 year-class (using all marked bass)							
1 Sept.	671	2,754	14	131,995	78,635 - 239,991	131,324	78,236 - 238,771

[1]For estimates using pigment marked fish (summer 1973) M has been adjusted for mark loss.

[2]The native population estimate is derived by subtracting the number of marked fish released into the population from the estimate. Confidence intervals around the estimate of native bass are obtained by proportioning the C.I. around the original estimate by the fraction of the total population made up of the native bass.

which included the 862 marked bass. An estimate of 34 indigenous bass is obtained when these bass are subtracted from the total estimate. An estimate using only the 593 small bass (since that group was approximately the same size as the native population) was 35 indigenous bass. Because the fall estimate was based on a single recapture, little statistical significance can be placed upon its point value but the corroboration between the fall and spring estimates lends credibility to their accuracy. These estimates and the low electrofishing catch rates indicate that the true population was extremely low.

Due to a larger 1973 year-class, separate estimates could be made for each of the three regions during all three sampling intervals. In summer 1973, 565 YOY largemouth bass were collected in 115 seine hauls and 3 cove rotenone jobs. Examination under ultraviolet light indicated 20 were fish sprayed with fluorescent pigments. Originally, 11,362 pigment marked YOY bass had been released in Lake Carl Blackwell but subsequent examination of marked bass retained in ponds revealed that many of these fish lost their marks. As a result, M in the Petersen estimates had to be adjusted for mark loss (Table 6).

The stratified Petersen estimates of the total population of YOY largemouth bass (summer 1973) were 74,867 ($C.I._{.05}$ = 44,602 - 136,122) for Region I, 45,540 ($C.I._{.05}$ = 15,525 - 227,700) for Region II and 27,699 ($C.I._{.05}$ = 9,443 - 138,493) for Region III (Table 5). These estimates summed to 148,106 for the entire lake. The unstratified estimate was 156,562 ($C.I._{.05}$ = 101,663 - 256,658, Table 5). Since these estimates include the stocked fish, the estimates were adjusted by subtracting the number of stocked largemouth bass to obtain estimates of the indigenous population at the time of stocking. The

Table 6. Mark retention and adjusted M for Petersen estimates using pigment marked bass.

Region and color	No. marked	Percent retention	Adjusted M
Region I - Red	5,979	32.9	1,967
Region II - Green	720	50.9	366
Region III - Green	1,736	50.9	884
Region I - Blue	1,003	61.9	621
Region II - Orange	1,924	88.5	1,704
Total	11,362		5,542

adjusted unstratified estimate was 145,200 (Table 5).

Population estimates during fall 1973 were made using both Schnabel and Petersen methods. The Petersen estimates were not stratified by region since the fish were stocked at a single point in Region I. However, the estimate was applied to the entire lake since subsequent sampling revealed that the stocked fish immediately scattered throughout the lake. Within three days, stocked bass were captured over 2 miles from the release point. In 221 hours of electrofishing, 2754 YOY largemouth bass were captured (catch rate = 12.5/hr), and of these, 14 were from the 600 Age 0 fish stocked earlier in the fall. None of the 71 Age I bass were recaptured. A Petersen estimate of 118,029 ($C.I._{.05}$ = 70,315 - 214,597, Table 5) was obtained using the marked age-group 0 bass. When the 600 stocked bass and the pigment marked fish were subtracted from this value, the indigenous population was estimated at 108,906.

The unstratified Schnabel estimate of the total population of YOY largemouth bass during fall 1973 was 119,436 ($C.I._{.05}$ = 81,720 - 182,677, Table 7). Adjustment of this estimate to the number of indigenous bass would need to account for mortality of the stocked fish; therefore, the indigenous population was estimated by assuming equal mortality rates for stocked and native populations and proportioning later population estimates by the fraction 145,200/156,562, the ratio of the estimated indigenous population at the date of stocking divided by the estimated total YOY largemouth bass population. This gave an estimate of 110,768 indigenous YOY largemouth bass.

During spring 1974, the population was again estimated using the Schnabel formula. In four units of effort, 2113 bass of the 1973 year-

Table 7. Schnabel estimates of the 1973 year-class during fall 1973.

Unit of effort	Date	C_t	M_t	C_tM_t	ΣC_tM_t	R_t	ΣR_t	$\hat{N}$	C.I.$_{.05}$
Fall 1973 estimate of the 1973 year-class (entire lake)									
1	4 Sept. - 7 Sept.	563	0	0	0	-	-	-	-
2	10 Sept. - 17 Sept.	236	558	131,688	131,688	2	2	65,844	18,290 - 658,440
3	17 Sept. - 25 Sept.	412	789	325,756	456,756	2	4	114,189	44,780 - 456,756
4	26 Sept. - 5 Oct.	442	1,199	529,958	986,714	3	7	140,959	68,522 - 352,398
5	3 Oct. - 8 Oct.	614	1,638	1,005,732	1,992,446	7	14	142,318	84,785 - 258,759
6	9 Oct. - 20 Oct.	294	2,245	660,030	2,652,476	9	23	115,325	77,107 - 181,673
7	20 Oct. - 25 Oct.	179	2530	452,870	3,105,346	3	26	119,436	81,720 - 182,667
Fall 1973 estimate of the 1973 year-class-Area I									
1	4 Sept. - 7 Sept.	109	0	0	0	-	-	-	-
2	10 Sept. - 17 Sept.	82	106	8,692	8,692	1	1	8,692	1,552 - 86,920
3	17 Sept. - 25 Sept.	115	187	21,505	30,197	0	1	30,197	5,392 - 301,970
4	26 Sept. - 5 Oct.	197	302	59,494	89,691	0	1	89,691	16,016 - 896,910
5	3 Oct. - 8 Oct.	221	499	110,279	199,970	1	2	99,985	27,774 - 999,850
6	9 Oct. - 20 Oct.	150	719	107,850	307,820	4	6	51,303	23,498 - 139,918
7	20 Oct. - 25 Oct.	63	865	54,495	362,315	1	7	51,759	25,160 - 129,398

Table 7 (Continued)

Unit of effort	Date	C_t	M_t	C_tM_t	ΣC_tM_t	R_t	ΣR_t	$\hat{N}$	C.I.$_{.05}$
Fall 1973 estimate of the 1973 year-class-Area II									
1	4 Sept. - 7 Sept.	121	0	0	0	0	0	-	-
2	10 Sept. - 17 Sept.	110	121	1,331	1,331	0	0	-	-
3	17 Sept. - 25 Sept.	176	229	40,304	53,614	0	0	-	-
4	26 Sept. - 5 Oct.	131	405	53,055	106,669	0	0	-	-
5	3 Oct. - 8 Oct.	235	536	125,960	232,629	5	5	46,530	19,883 - 145,393
6	9 Oct. - 20 Oct.	80	766	61,280	293,909	3	8	36,739	18,602 - 86,444
7	20 Oct. - 25 Oct.	71	843	59,853	353,762	1	9	39,307	20,688 - 88,440
Fall 1973 estimate of the 1973 year-class-Area III									
1	4 Sept. - 7 Sept.	333	0	0	0	0	0	-	-
2	10 Sept. - 17 Sept.	44	331	14,564	14,564	1	1	14,564	2,601 - 145,640
3	17 Sept. - 25 Sept.	121	373	45,133	59,697	2	3	19,899	6,784 - 99,495
4	26 Sept. - 5 Oct.	114	492	56,088	115,785	3	6	19,297	8,834 - 52,630
5	3 Oct. - 8 Oct.	158	603	95,274	211,059	1	7	30,151	14,657 - 75,378
6	9 Oct. - 20 Oct.	64	760	48,640	259,699	2	9	28,885	15,187 - 64,925
7	20 Oct. - 25 Oct.	45	822	36,990	296,689	1	10	29,669	16,124 - 63,125

class (now Age I) were captured in 241.94 hours of electrofishing (catch rate = 8.7/hr, Table 3). The three stratified estimates were 56,595 (C.I.$_{.05}$ = 28,656 - 133,165) for Region I, 23,890 (C.I.$_{.05}$ = 10,209 - 74,657) for Region II and 8221 (C.I.$_{.05}$ = 3,224 - 32,884) for Region III. The unstratified estimate was 85,287 (C.I.$_{.05}$ = 55,765 - 146,453, Table 8). The estimated indigenous population was 79,098.

For calculation of mortality rates and production estimates, single estimates of the population during each interval were chosen as the best estimate. Since only one estimate of the 1972 year-class was obtained during fall 1972, no choice in estimators was possible and the estimate was 29 YOY largemouth bass. In spring 1973, two estimates of the 1972 year-class were made using: 1) the 593 small size group, and 2) all 862 stocked bass as M in Petersen estimates. Since no significant difference in catch rates was observed between the small and large groups (the small bass made up 69% of those stocked and 65% of the catch), the estimate using both groups was considered the best estimate since it had a tighter confidence interval. The $\hat{N}$'s (34 using both groups and 35 using the small fish only) were virtually the same because the catch rates were so similar. The unstratified estimates of the 1973 year-class (summer 1973, fall 1973 and spring 1974) were considered the best estimates for two reasons: 1) because acceptable confidence intervals could not be calculated on the summed estimates, and 2) because it was not determined that a separate population existed in each region. Instead, sampling indicated that movement did occur between sampling periods (fall 1973 to spring 1974) since the percentage of the population estimates in each region changed between periods. Also, in two periods, spring 1973 and fall 1973, marked non-indigenous

Table 8. Schnabel estimates of the 1973 year-class during spring 1974.

Unit of effort	Date	C_t	M_t	C_tM_t	ΣC_tM_t	R_t	ΣR_t	$\hat{N}$	C.I.$_{.05}$
Spring 1974 estimate of the 1973 year-class (entire lake)									
1	5 Apr. - 23 Apr.	527	0	0	0	-	-	-	-
2	22 Apr. - 8 May	1,031	527	543,337	543,337	9	9	60,371	31,774 - 135,834
3	10 May - 3 June	449	1,549	695,501	1,238,838	7	16	77,427	47,648 - 131,791
4	23 May 11 June	106	1,991	211,046	1,449,884	1	17	85,287	55,765 - 146,453
Spring 1974 estimate of the 1973 year-class-Area I									
1	5 Apr. - 23 Apr.	279	0	0	0	0	0	-	-
2	22 Apr. - 8 May	536	279	149,544	149,544	4	4	37,386	14,661 - 133,166
3	10 May - 3 June	295	811	239,245	388,789	3	7	55,541	26,999 - 138,853
4	23 May - 11 June	58	1,103	63,974	452,763	1	8	56,595	28,656 - 133,166
Spring 1974 estimate of the 1973 year-class-Area II									
1	5 Apr. - 23 Apr.	183	0	0	0	0	0	-	-
2	22 Apr. - 8 May	329	183	60,207	60,207	4	4	15,052	5,902 - 60,207
3	10 May - 3 June	93	508	47,244	107,451	1	5	21,490	9,184 - 67,157
4	23 May - 11 June	20	600	12,000	119,451	0	5	23,890	10,209 - 74,657

Table 8 (Continued)

Unit of effort	Date	C_t	M_t	C_tM_t	ΣC_tM_t	R_t	ΣR_t	$\hat{N}$	$C.I._{.05}$
Spring 1974 estimate of the 1973 year-class-Area III									
1	5 Apr. - 23 Apr.	65	0	0	0	0	0	-	-
2	22 Apr. - 8 May	166	65	10,790	10,790	1	1	10,790	1,927 - 107,900
3	10 May - 3 June	61	230	14,030	24,820	3	4	6,205	2,433 - 24,820
4	23 May - 11 June	28	288	8,604	32,884	0	4	8,221	3,224 - 32,884

bass were captured outside the area of their release although it was not demonstrated that the indigenous population was also mobile.

In the fall 1973, there was a third choice - between the unstratified Schnabel estimate and the Petersen estimate derived from the 600 YOY bass stocked earlier that fall. The Schnabel estimate was considered the best estimate because the stocked bass might be more vulnerable to electrofishing as they moved from the point of their release[1] and because they underwent extensive handling during hot weather which might have caused a higher mortality rate than the native population. Thus, the best estimates of the native populations were 29 in fall 1972 and 34 in spring 1973 for the 1972 year-class and 145,200 in summer 1973, 110,768 in fall 1973 and 79,098 in spring 1974 for the 1973 year-class. The best estimates of the total (including stocked bass) populations were 29; 896; 156,562; 119,436; and 85,287, respectively (Table 9).

The relative accuracy of these estimates was validated by the independent estimates of the same group of fish by different estimators. Although the spring 1973 estimate of the 1972 year-class was higher than the fall 1972 estimate, the closeness of the two values (34 versus 29) validates the accuracy of the estimates. In fall 1973, the Petersen estimate was 117,428 (including pigment marked fish) and the Schnabel estimate was 119,436, only a trivial difference.

Tests of the difference in population estimates (Table 10) demonstrate that the 1973 year-class was significantly larger than the 1972 year-class at the 0.001 level. They also revealed a significant

[1]Zweiacker (1972) found that displaced largemouth bass were more susceptable to electrofishing than non-displaced bass.

Table 9. Density of YOY largemouth bass at each estimate.

Period	Date of estimate	Estimate	Lake area (ha)	No./ha
Fall 1972	6 Oct.	29	503.4	0.052
Spring 1973	23 March	34	880.0	0.039
Summer 1973	26 July		1,078.0	
Total		156,562		145.234
Native		145,200		134.694
Fall 1973	30 Sept.		1,201.5	
Total		119,436		99.406
Native		110,768		92.191
Spring 1974	8 May		1,400.6	60.893
Total		85,287		60.893
Native		79,098		56.474

Table 10. Statistical comparisons of the population estimates.

Periods	Regions	N		d.f.	Probability
Fall 1972- Spring 1973	Entire lake	29 34	0.14706	12	0.086
Fall 1972- Fall 1973	Entire lake	29 119,436	-[1]	13	-
Spring 1973- Spring 1974	Entire lake	34 85,287	670.54787	8	<0.001
Summer 1973- Fall 1973	I	74,867 51,579	0.74443	7	0.519
Summer 1973- Fall 1973	II	45,540 39,307	0.23196	7	0.823
Summer 1973- Fall 1973	III	27,699 29,699	0.01630	7	0.987
Summer 1973- Fall 1973	Entire lake	156,562 119,436	0.90943	7	0.393
Fall 1973- Spring 1974	I	51,579 56,595	0.17179	9	0.867
Fall 1973- Spring 1974	II	39,307 23,890	1.25174	9	0.242
Fall 1973- Spring 1974	III	29,669 8,221	1.42412	9	0.188
Fall 1973- Spring 1974	Entire lake	119,436 85,287	1.02091	9	0.334
Summer 1973- Spring 1974	I	74,867 56,595	0.69029	4	0.528
Summer 1973- Spring 1974	II	45,540 23,890	0.88654	4	0.425
Summer 1973- Spring 1974	III	27,669 8,221	1.40546	4	0.233
Summer 1973- Spring 1974	Entire lake	156,562 85,287	1.87703	4	0.134

[1]The model failed to give a realistic t value because the fall 1972 estimate was based on a single recapture.

decrease in the population of the 1973 year-class between 26 June 1973 and 8 May 1974. However, due to high variances inherent in mark-recapture population estimates the model for comparison of population estimates was not sensitive to most changes in population.

It is obvious from comparing the fall recruitment estimates for the 1972 and 1973 year-classes (29 versus 110,768) that the 1972 year-class was a failure while the 1973 year-class was a success. The fall 1973 estimate was 3,800 times greater than the fall 1972 estimate and the spring 1974 estimate was 2,300 times higher than the spring 1973 estimate. For comparison with other waters, it was necessary to convert these estimates to density in number per hectare (Table 9). In fall 1972, the density estimate was 0.052 YOY bass/ha and the following spring, the estimate was 0.039 bass/ha. The estimates of the 1973 year-class were 134.7 native YOY bass/ha during summer 1973, 92.2 native YOY bass/ha during fall 1973 and 56.5 native bass during spring 1974. The density of the largemouth bass population during fall 1973 was 1,800 times greater than in fall 1972 and 1,400 times greater during spring 1974 than spring 1973.

Density estimates of YOY largemouth bass reported in the literature range from 13.6 to 11,632 YOY bass/ha (Table 11) but the larger values, 7,441/ha (Bennett 1950) and 11,632/ha (Cooper et al. 1963) were in smaller environments where competing and carnivorous fishes were limited. The population density of the 1972 year-class was lower than either the lowest value reported in the literature and even lower than the estimate of Age I bass in Lake Carl Blackwell (Zweiacker and Brown 1971). The least dense YOY bass population reported in the literature was 260 times more dense than the estimate of the 1972 year-class at

Table 11. Population estimates of YOY bass in various waters.

Reference	Water	Method	No./ha
Present study	Lake Carl Blackwell, OK	Mark-recap.	
Fall 1972			0.05
Spring 1973			0.04
Summer 1973			145.23
Fall 1973			99.41
Spring 1974			60.89
Patriarche (1953)	Lake Wappapello, MO	Cove Rotenone	210.00
Sheddan (1972)	Ft. Loudan Res., TN	Cove Rotenone	123.50
Bross (1969)	Canton Res., OK	Cove Rotenone	
Fall 1965			136.32
Fall 1966			14.04
Fall 1967			24.91
Aggus and Elliot (1975)	Bull Shoals Res., MO	Cove Rotenone	
Fall 1968			223.00
Fall 1969			52.00
Fall 1970			112.00
Fall 1971			38.00
Fall 1972			160.00
Fall 1973			1,789.00
Fall 1974			309.00
Cooper et al. (1963)	Breon's Pond, PA	Mark-recap.	11,632.00
Bennett (1950)	Ridge Lake, IL	Draining	7,441.00
Lewis et al. (1962)	Isaac Walton Lk., IL	Mark-recap.	51.40
Green (1971)	Dryden Lake, NY	Mark-recap.	
1967			18.22
1968			28.31
1969			79.80
1970			13.60
Zweiacker & Brown (1971) Age I	Lake Carl Blackwell, OK	Mark-recap.	0.70

Lake Carl Blackwell.

The 1973 year-class was exceeded by several reported densities obtained from cove rotenone samples but these estimates tend to approximate the ecological density (the number per unit of area of adequate habitat) while the estimates obtained in the present study are the crude density (the number per unit of total area, the entire lake) since cove rotenone samples include a high percentage of littoral environment.

Mortality Rates

Because the spring 1973 estimate of the 1972 year-class was higher than the fall 1972 estimate, no mortality rates could be calculated for the 1972 year-class. Although the spring estimate was higher, it is impossible that the true population was higher unless some young bass entered Lake Carl Blackwell from farm ponds in the watershed. The increase was probably due to sampling error since the fall 1972 estimate was based on a single recapture and the estimates were so close.

Mortality rates for the 1973 year-class were calculated for three time periods: 1) 26 June 1973 (the date of the summer estimate) to 30 September 1973 (the date of the fall estimate), 2) 30 September 1973 to 12 May 1974 (the date of the spring estimate), and 3) 26 June 1973 to 12 May 1974. The first period represents the mortality rate from the time the YOY bass reach 50 mm to the end of their first growing season, the second period represents the overwinter mortality rate and the third period represents the mortality rate from the time the YOY bass reach 50 mm to the end of their first year of life. Between 26

June 1973 and 30 September 1973, the estimated native population decreased from 145,200 to 110,768, estimated mortality was 24% and the daily instantaneous mortality rate was 0.00282. Overwinter, the population estimate decreased from 110,768 to 79,098, mortality was 29% and the daily instantaneous mortality rate was 0.00150. The total decrease from 26 June 1973 to 12 May 1974 was 46% with a daily instantaneous mortality rate of 0.00190 (Table 12).

Although the period before largemouth bass enter the fishery is important to that fishery, relatively little investigation of mortality rates and production during that period has been done. Kramer (1961) found an average mortality rate of 20% in the 4-day egg period and 54% in the 10-day fry period with large variations between years, location of nests (substrate, cover and topography all affected survival) and individual broods. No reference was found to mortality rates between the fry period and the end of the first summer in natural waters. Mortality rates during that period had to be calculated (Table 13) from data obtained in artificially controlled experiments. Using Swingle's (1946) farm pond data, daily instantaneous mortality rates ranging from 0.00032 to 0.00770 and averaging 0.00279 were obtained from a series of production experiments with combinations of largemouth bass fingerlings and other species. Using the data of Snow (1960, 1965 and 1968), daily instantaneous mortality rates ranging from 0 to 0.1077 were obtained from a series of experiments on artificial feeding of largemouth bass fingerlings. Green (1971), using repeated mark-recapture census found an overwinter mortality rate of 19% in Dryden Lake, N.Y. but he did not give the dates of the estimates so no instantaneous mortality rates could be calculated. The mean daily instantaneous

Table 12. Mortality rates of YOY largemouth bass at Lake Carl Blackwell.

Date	N	Percent mortality	Number of days	Daily instantaneous mortality rate	Percent of total mortality
26 June 1973	145,200	24	96	0.00282	52
30 Sept. 1973	110,768	29	224	0.00150	48
12 May 1974	79,098				
26 June 1973	145,200	46	320	0.00190	100
12 May 1974	79,098				

Table 13. Mortality rates of YOY bass in other waters.

Reference	Location	Percent mortality	Daily instantaneous mortality rate
Swingle (1946)	Experimental Farm Pond		
High		73	0.00770
Low		7	0.00032
Mean (N=12)		36	0.00279
Snow (1968)	Hatchery Ponds		
High		61	0.01077
Low		13	0.00150
Mean (N=10)		40	0.00584
Snow (1965)	Hatchery Ponds		
High		39	0.05501
Low		0	0.00000
Mean (N=7)		6	0.00975
Snow (1960)	Hatchery Ponds	54	0.00735
Green (1971)	Dryden Lake, N.Y.		
Overwinter		19	-
Mean of the four experimental populations			0.00558

mortality rate calculated from the literature (Swingle 1946, Snow 1960, 1965 and 1968) was 0.00558, higher than the mean of the two rates calculated in the present study (0.00216) but no statistical difference was found when these two values were compared. The t value was 0.469 with 30 degrees freedom. Thus, the null hypothesis that the low population of adult bass was not due to high mortality between the time the YOY bass reach 50 mm and the end of their first year of life was not disproven.

In two experiments (Snow 1960, 1965), the same group of fingerling bass was counted a series of times during their first summer and calculated i values for these fish were highest in the youngest fish; therefore, the mortality rate decreased as the summer progressed. In one of these experiments (Snow 1960), the i value was 0.02688 during the first 10 days of the fingerling stage and only 0.0027 during the last 10 days. In the other experiment (Snow 1965), the i values during the first two 7-day intervals were 0.00766 and 0.0109 while the i values of 0.00068 and 0.00195 were observed during the last two 7-day periods of the growing season. In both cases, there was an order of magnitude difference between the mortality rate at the beginning of the growing season and those at the end. The data obtained in the present study also indicate that mortality rate decreases with age. The summer rate was almost twice that of the winter rate (Table 12). This indicates that the mortality after 50 mm is not sufficient to cause the low population of adult bass. However, since the 1973 year-class was larger than those on which the original hypothesis was based no definite conclusions about past year-classes can be made.

Growth

Because only the fall 1972 sample contained enough fish for an adequate estimate of size, no overwinter growth rate or instantaneous growth rates were calculated for the 1972 year-class. The total increment in length and weight between spawning and the mid-point of the fall sample (6 October 1972) were calculated. The average total length of YOY largemouth bass captured during the fall 1972 sample was 143.1 mm and the mean weight was 28.9 g (Table 14). These values were considered to be the total growth during the first growing season although it is possible that some growth did occur between the date of the estimates and the end of the first year of life.

Growth rates for the 1973 year-class were obtained from the mean lengths and weights of young bass collected in a series of samples (Figures 3 and 4, Table 14). The first sample was on 12 July 1973 when 29 YOY bass obtained in seine hauls had a mean length of 72 mm and a mean weight of 4.8 g. Between 12 July and 21 August, 41 YOY bass obtained in seine hauls had a mean length of 85 mm and 70 YOY bass had a mean weight of 7 g (some groups were not measured). On 13, 14 and 15 August, 142 YOY bass collected during cove rotenone samples had a mean length of 95 mm and a mean weight of 13 g. In fall 1973 and spring 1974, mean lengths and weights were calculated on bass collected during each unit of effort. During fall 1973, the YOY bass averaged 153 mm and 58 g during the first unit of effort and 189 mm and 99 g during the last unit of effort. Overwinter, however, the bass decreased in both length and weight. During spring 1974, the bass averaged 185 mm and 81 g during the first unit of effort but in the second unit of effort averaged only 169 mm and 65 g. Although individual bass may lose

Table 14. Average lengths and weights of largemouth bass captured during the present study.

Sample	Average date		$\bar{L}$ (mm's)	C.I. .05	$\bar{W}$ (g)	C.I. .05
Fall 1972	6 Oct.	10	143	127-160	29	16-42
Summer 1973	12 July	29	72	-	5	-
	27 July	70	-	-	7	-
	8 Aug.	41	85	78-92	-	-
	14 Aug.	142	95	91-99	13	11-15
Fall 1973						
Unit of effort 1	6 Sept.	631	153	150-156	58	55-61
Unit of effort 2	14 Sept.	166	170	164-176	68	62-74
Unit of effort 3	21 Sept.	408	180	176-184	82	78-86
Unit of effort 4	1 Oct.	437	181	178-184	81	77-85
Unit of effort 5	6 Oct.	186	175	169-181	81	74-88
Unit of effort 6	14 Oct.	291	185	180-190	92	86-98
Unit of effort 7	22 Oct.	179	189	184-195	99	91-107
Mean	30 Sept.	420	176	172-180	77	72-82
Spring 1974						
Unit of effort 1	14 Apr.	394	185	182-188	81	76-86
Unit of effort 2	1 May	974	169	166-172	65	62-68
Unit of effort 3	21 May	448	174	170-178	71	66-76
Unit of effort 4	1 June	103	177	169-186	74	70-76
Mean	12 May	912	176	173-179	73	70-76

Figure 3. Mean lengths of the 1973 year-class captured in each sampling interval.

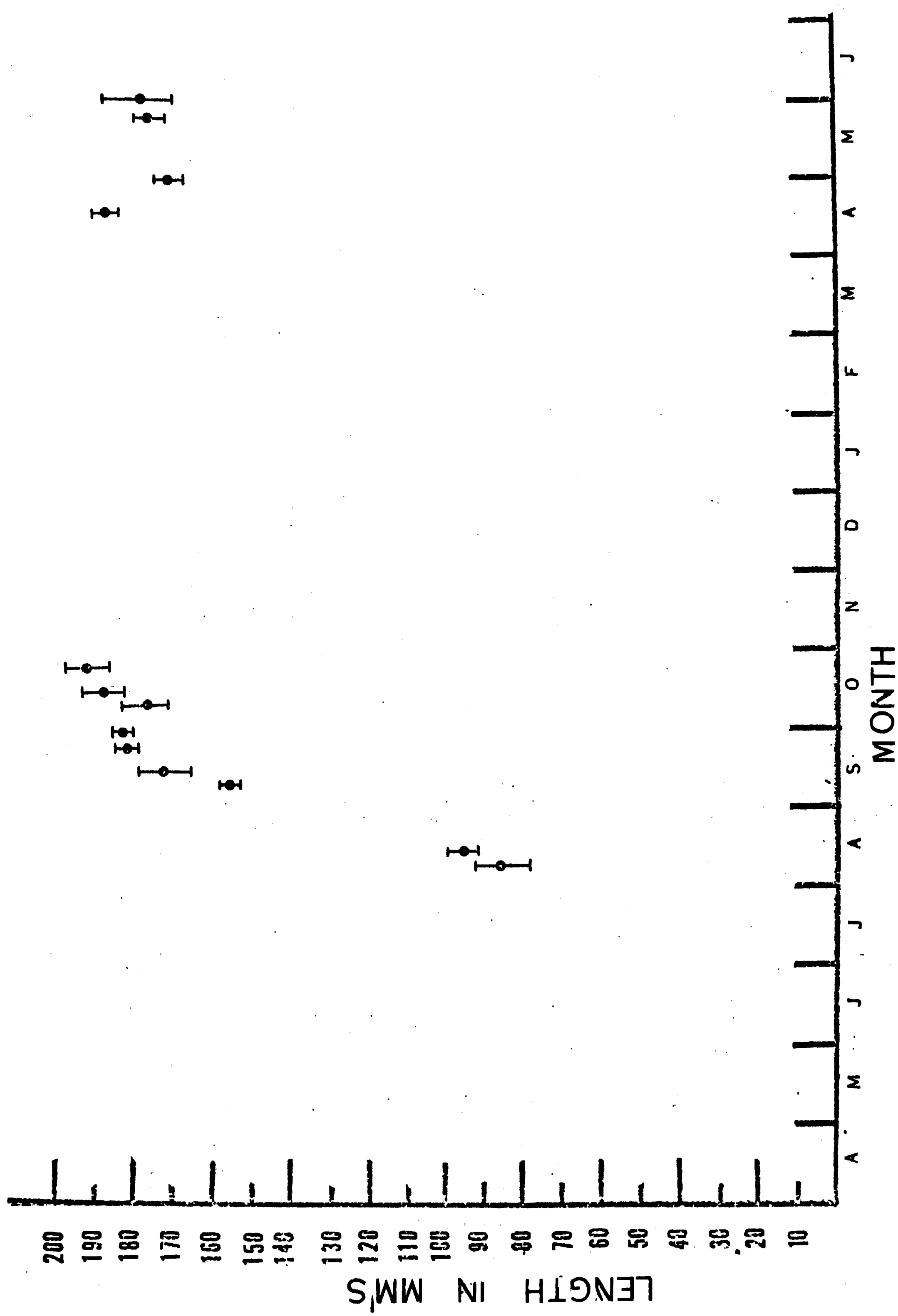
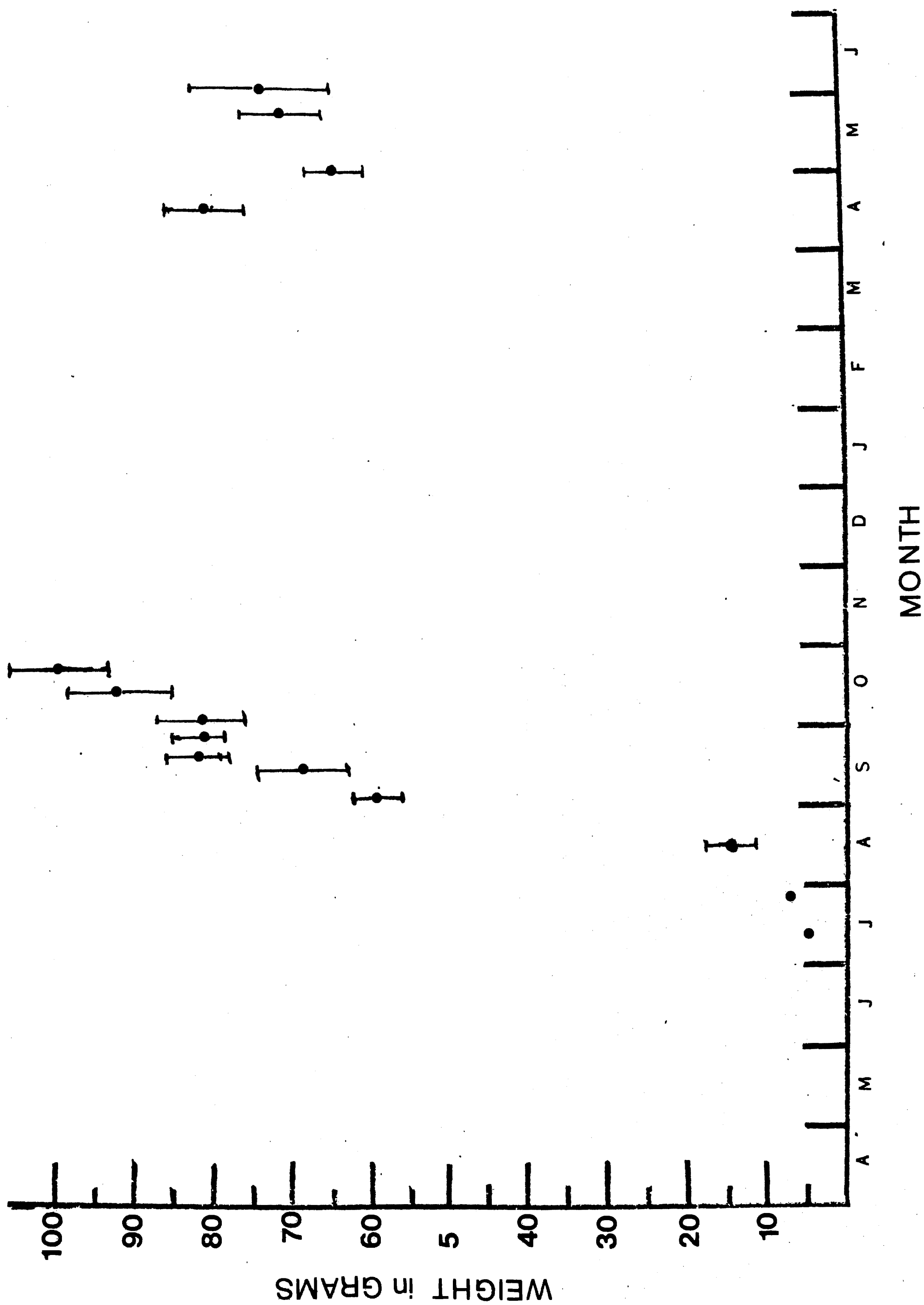

LENGTH IN MM'S
MONTH
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J

Figure 4. Mean weights of the 1973 year-class captured in each sampling interval.


WEIGHT in GRAMS
100
90
80
70
60
5
40
30
20
10
A M J J A S O N D J F M A M J
MONTH

weight overwinter (the average condition factor, K, decreased from 1.46 in the final fall unit of effort to 1.27 in the first spring unit of effort), the loss in length is more difficult to explain. Perhaps individual bass shrunk somewhat in length but some form of differential mortality or sampling bias would seem more plausible. Differential mortality seemed more likely since the 1973 year-class exhibited two distinct size classes and in the fall 1973 sample, the large size group made up 80.1% of the catch while in spring 1974, the same size group made up only 74.5% of the catch. This change in composition appears to be responsible for the smaller mean size of bass in the spring collections. Probably, this was due to fishing which would be selective for the larger group since the small group was less than 145 mm and probably were not harvested to any extent. However, the large size group ranged up to 295 mm and would be acceptable to some fishermen.

Most literature estimates of first year growth are obtained from back-calculated length at annulus I using scale analysis (Table 15). Data obtained in the present study were calculated from direct measurements of length and weight, therefore, a judgement must be made as to what is the best estimate of first year growth. No choice is necessary for the 1972 year-class since only one length value was obtained for that year-class (143 mm). However, several values may be chosen for the 1973 year-class. The average length of all YOY bass captured during the fall sample (176 mm) would be most comparable to the 1972 year-class but some growth occurred after that estimate so it would not be an accurate estimate of the total growth during the first growing season. The best estimate of the total annual growth would be the mean length of YOY bass captured during the final unit of effort during fall

Table 15. Total lengths in millimeters of largemouth bass at the end of the first year of life in various waters.

Authors	Location	Year-class	Length
Present study	Lake Carl Blackwell, OK	1973	
		1972	143
Zweiacker et al. (1973)	Lake Carl Blackwell, OK	1970	118
		1969	114
		1968	128
		1967	129
		1966	149
		1965	153
		1964	160
		1963	152
		1962	168
		1961	145
		Ave.	140
Houser & Bross (1963)	Oklahoma waters		
	Average		140
	Slowest		64
	Fastest		284
Jenkins (1949)	Claremore City Lake, OK		114
	Great Salt Plains, OK		241
Jackson (1966)	Lake Eucha, OK		163
	Spavinaw Lake, OK		155
Leonard & Jenkins (1954)	Illinois River, OK		117
	Lake Texoma, OK		221
	Claremore City Lake, OK		94
	Lake Shawnee, OK		127
Thompson (1950)	Grand Lake, OK		160
Finnell (1954)	Stringtown Sub-prison Lake, OK		124
Jackson (1958)	Lower Spavinaw Lake, OK		137
Finnell (1955)	Little River Oxbows, OK		109
King (1954)	Lake Hiwassee, OK	1951	91
		1952	132
		1953	137
		1954	180
Brown & Logan (1960)	3 Montana ponds		48

Table 15 (Continued)

Authors	Location	Year-class	Length
Emig (1966)	Minnesota		89
	Minnesota		94
	Wisconsin		86
	Ohio		89
	California		107
	Connecticut		129
Lagler & DeRoth	Loch Alpine Ponds, MI		84
Lambou (1958)	Lake Providence, LA		89
	Clear Lake, LA		102
	Lake Bistineau, LA		114
Bennett (1937)	Wisconsin waters		84
Grice (1959)	3 Massachusetts ponds		94
Mraz & Threinen (1954)	Browns Lake, WI		91
McCaig & Mullan (1960)	Quabbin Res., MA		102
Thompson (1964)	Clear Lake, IA		104
Schultze (1974)	3 California ponds		130
Patriarche (1953)	Lake Wapapello, MO		137
Tharratt (1966)	Folsom Lake, CA		147
Applegate et al. (1967)	Bull Shoals Res., MO		152
Stroud (1959)	Cherokee Lake, TN		163
	Douglass Lake, TN		157
	Hiwassee Lake, TN		117
Hanson (1965)	Bull Shoals, MO		165
LaFaunce et. al. (1964)	Sutherland Res., CA		170
Stroud (1948)	Norris Res., TN		175
Bennett (1954)	Ridge Lake, IL		205
Muncy (1965)	Louisiana ponds		208

1973 (189 mm). This estimate included the largest amount of the first growing season but does not contain any 1974 observations which were affected by the differential mortality.

Back-calculated lengths at the end of the first year of life for largemouth bass in Oklahoma waters range from 64 mm to 284 mm and average 140 mm (Houser and Bross 1963, Table 15). Zweiacker et al. (1973) also found the average length at annulus I for Lake Carl Blackwell to be 140 mm, ranging from 114 mm (1969 year-class) to 168 mm (1962 year-class). They concluded that growth was positively correlated with water level. The 1972 year-class had about average growth for both Lake Carl Blackwell and Oklahoma waters in general. It was higher than for Claremore City Lake (Jenkins 1949), Lake Shawnee (Leonard and Jenkins 1954), Lake Hiwassee (King 1954), and Stringtown Lake (Finnell 1955). It was also higher than values observed in more areas north of Oklahoma including Massachusetts (Grice 1959, McCaig and Mullan 1960), Montana (Brown and Logan 1960), Iowa (Thompson 1965), Minnesota, Wisconsin and Ohio (Emig 1966). It was lower than the growth in Great Salt Plains Reservoir (Jenkins 1949), Grand Lake (Thompson 1950), Lake Texoma (Leonard and Jenkins 1954), Lake Eucha and Lake Spavinaw (Jackson 1966) in Oklahoma and for the states of Tennessee (Stroud 1948, 1949), Missouri (Hanson 1965, Applegate et al. 1967), and Louisiana (Muncy 1966). The size of the 1973 year-class from Lake Carl Blackwell exceeded the Oklahoma average and any previous year-class at Lake Carl Blackwell (Zweiacker et al. 1973). It was exceeded only by growth reported for largemouth bass in the Great Salt Plains Reservoir and Lake Texoma in Oklahoma and Ridge Lake, Illinois (Bennett 1954) and Louisiana ponds (Muncy 1965) in other states.

Plots of the average lengths (Figure 3) and weights (Figure 4) during each sample of the 1973 year-class and the calculated daily instantaneous growth rates (g) (Table 16) revealed that the highest rate of growth was early in the summer. Between 26 June and 12 July 1973, g was 0.08310. Between the final two units of effort during fall 1973, g was 0.01592, a five fold decrease in g over the summer. Snow (1960, 1965) weighed the YOY largemouth bass in two experimental populations at 7 to 14 day intervals and I calculated growth rates from his data which revealed that in his experimental populations, the growth rate also decreased throughout the summer. Daily instantaneous growth rates at the start of those two experiments were 0.05577 and 0.05124 and at the end of those experiments were 0.00896 and 0.01399.

Bimodal Growth

After plotting number of YOY bass per each 10 mm length class, it was found that the size of the fish did not follow a normal distribution but was bimodal (Figures 5 a-h and 6 a-e). During the first unit of effort in fall 1973, the modes were at 115 mm and 175 mm; by the last unit of effort, the modes were at 115 mm and 215 mm. This indicates that the larger size group was growing while the smaller size group was not. Probably, the larger size group was feeding on the abundant YOY gizzard shad while the small group were too small to take advantage of that food source. The pattern of bimodal growth has been observed in other waters as well. Kramer (1961) was able to distinguish between populations of YOY largemouth bass resulting from weather interrupted spawning. He found that if the water temperature rapidly decreased during the spawning season, spawning would be interrupted and the two popu-

Table 16. Observations on growth of the 1973 year-class of largemouth bass in Lake Carl Blackwell from 26 June 1973 through 1 June 1974.

Date	Days[1]	$\bar{L}$	Increment mm	Increment %	$\bar{W}$	Increment grams	Increment %	g[2]
26 June		-			1.27			
	16		-	-		3.53	277	0.08310
12 July		72			4.80			
	33		23	31		8.27	172	0.03035
14 Aug.		95			13.07			
	23		58	61		45	346	0.06479
6 Sept.		153			58			
	8		17	11		10	17	0.01988
14 Sept.		170			68			
	7		10	6		14	21	0.02674
21 Sept.		180			82			
	10		1	1		-1	21	-0.00123
1 Oct.		181			81			
	5		-6	-3		0	0	0.00000
6 Oct.		175			81			
	8		10	5		11	14	0.01592
14 Oct.		185			92			
	8		4	2		7	8	0.00917
22 Oct.		189			99			
	174		-4	2		-8	-8	-0.00115
14 Apr.		185			81			
	17		-16	9		-16	-20	-0.01294
1 May		169			65			
	20		5	3		6	9	0.00441
21 May		174			71			
	11		3	2		3	4	0.00376
1 June		177			74			

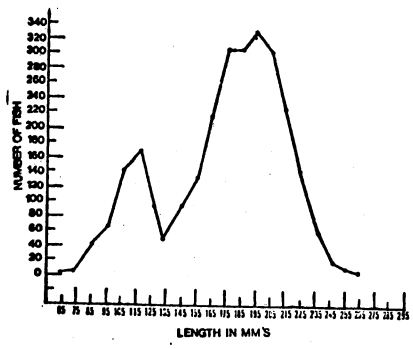
Table 16 (Continued)

Date	Days[1]	$\bar{L}$	Increment mm	Increment %	$\bar{w}$	Increment grams	Increment %	g[2]
26 June		-			1.27			
	96					75.81	5,969	0.04277
30 Sept.		174.58			77.08			
	224					04.31	-6	-0.00026
12 May		175.96			72.77			
26 June		-			1.27			
	320					71.50	5,630	0.01265
12 May		175.90			72.77			

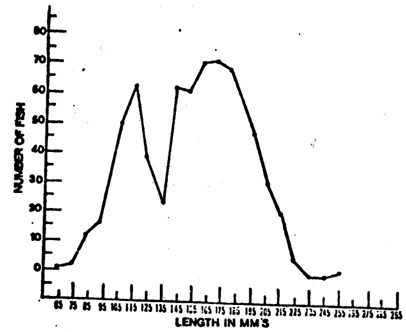
[1]The number of days between estimates of length and weight.

[2]The instantaneous rate of growth.

Figure 5. Number of YOY largemouth bass per 10 mm length class during fall 1973: (a) fall 1973-entire interval; (b) 4 September - 7 September; (c) 10 September - 17 September; (d) 17 September - 25 September; (e) 26 September - 5 October; (f) 5 October - 8 October; (g) 9 October - 20 October; (h) 20 October - 25 October.



5A



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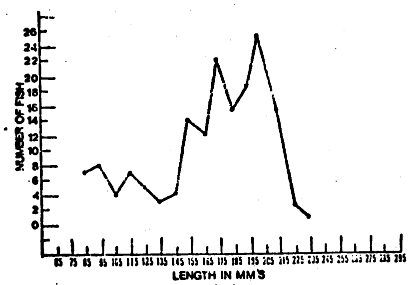

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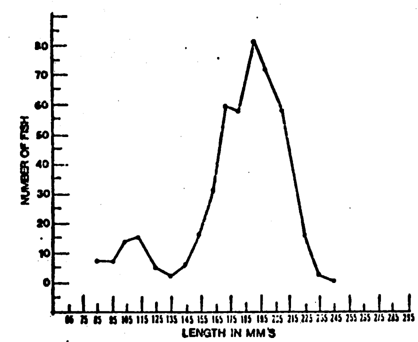

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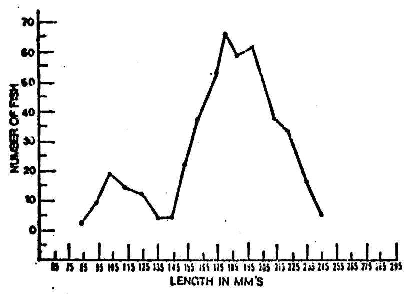

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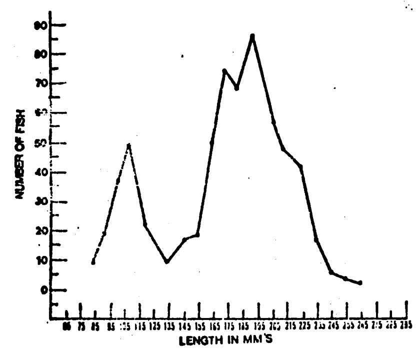

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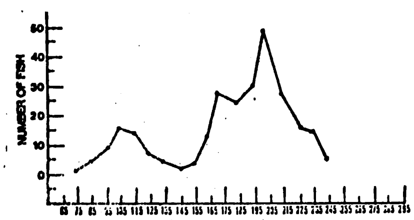
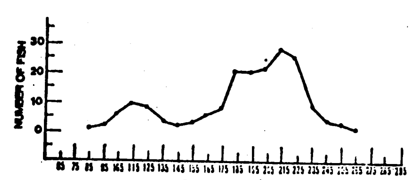
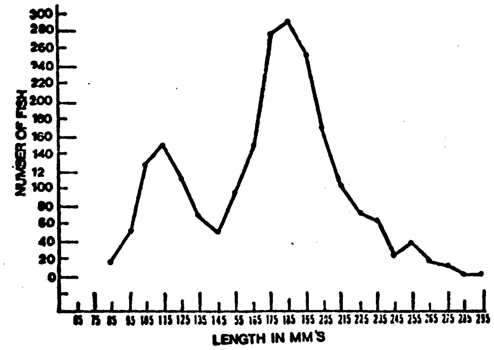


5G

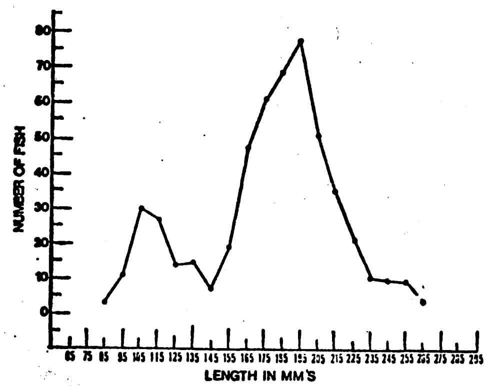


5H

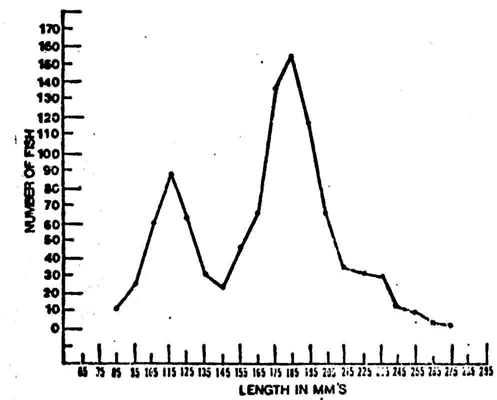
Figure 6. Number of YOY largemouth bass per 10 mm length class during spring 1974: (a) entire interval; (b) 5 April - 23 April; (c) 22 April - 8 May; (d) 10 May - 3 June; (e) 23 May - 11 June.


NUMBER OF FISH
LENGTH IN MM'S

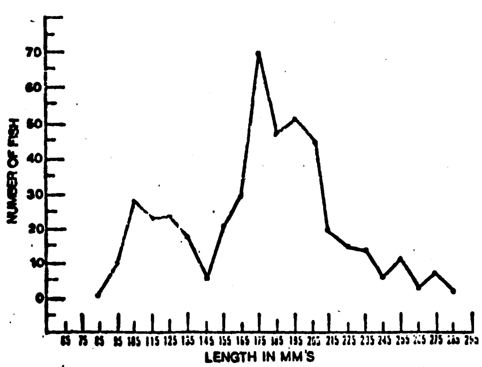
6A


NUMBER OF FISH
LENGTH IN MM'S

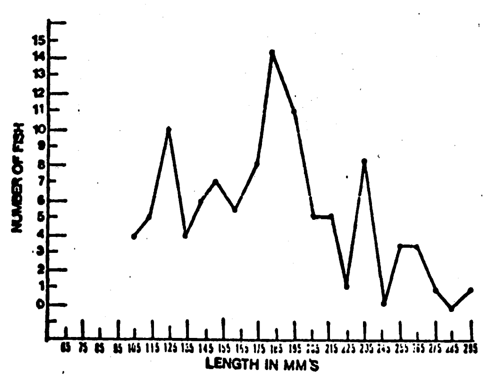
6B


NUMBER OF FISH
LENGTH IN MM'S

6C


NUMBER OF FISH
LENGTH IN MM'S

6D


NUMBER OF FISH
LENGTH IN MM'S

6E

lations of YOY would be produced which could be distinguished by size. Aggus and Elliot (1975) observed bimodal growth in Bull Shoals Reservoir, Missouri and attributed it to the large size group being piscivorous while the small size group was not. However, they did not explain why the large size group began to feed on fish while the small size group did not. Summerfelt (1975) attributed this pattern to frontal systems which reduced water temperatures and interrupted spawning resulting in several size classes. At Bull Shoals Reservoir, this pattern was found only in years of high water level and large year-classes, precisely the same set of circumstances that were present at Lake Carl Blackwell. Unlike the population at Bull Shoals Reservoir, the small size group at Lake Carl Blackwell did not disappear overwinter due to predation or other factors. In fact, the relative percent of the small size group increased overwinter probably because of fishing pressure on the large size group.

Production

Because no instantaneous mortality and growth rates could be calculated for the 1972 year-class, no gross production estimates could be made for that year-class. The estimate of the population during fall 1972 was 29 and the mean weight of YOY largemouth bass in that sample was 28.9 g which gave a biomass estimate of 0.838 kg (0.001665 kg/ha, Table 17). This was considered the net production of the 1973 year-class during the first growing season.

The 1973 year-class, including stocked bass, had an estimated population of 119,436 and an average weight of 77.08 g during the fall sample for an estimated net production of 9,206.13 kg (7.662 kg/ha)

Table 17. Net and gross production of YOY largemouth bass in Lake Carl Blackwell.

Period	Elapsed time (days)	Gross production (kg)		Net production		
		Production in period	Cumulative production	Production in period	Cumulative production	Cumulative P_n/ha
			Indigenous bass			
5-15-72[1] to 10- 6-72	144	-	-	0.84	0.84	0.001665[2]
5-15-73 to 6-26-73	42	-	-	184.40	184.40	0.171058
6-26-73 to 9-30-73	96	8,374.14	8,374.14	8,353.59	8,353.80	7.106117
9-30-73 to 5-12-73	224	-2,771.13	5,603.01	-2,782.04	5,755.96	4.109639
			Indigenous bass plus stocked bass			
5-15-73 to 6-26-73	42	-	-	198.83	198.83	0.184397
6-26-73 to 9-30-73	96	9,024.42	9,024.41	9,007.29	9,206.13	7.662197
9-30-73 to 5-12-74	224	-2,988.04	6,036.38	-2,999.79	6,206.33	4.431193

[1]The mid-point of the spawning season at Lake Carl Blackwell is approximately 15 May.

[2]This production estimate is the 1972 year-class.

during the first growing season. Although the net production was approximately 11,000 times greater than in 1972, the net production per surface ha increased by only 4,600 times due to the large increase in surface area. The estimated total population of the 1973 year-class was 156,562 on 26 June 1973 (when the bass were about 50 mm) and the mean weight was 1.27 g. This gave a biomass and net production from spawning to 26 June of 198.83 (0.1843 kg/ha, Table 17). The spring 1974 population estimate was 85,287 with an average weight of 72.77 g. This gave an estimated biomass and annual net production of 6,206.33 kg (4.4312 kg/ha). The net production from the summer estimate to the fall estimate (B_2 - B_1) was 9,007.29 kg (7.4967 kg/ha) and from fall 1973 to spring 1974 was -2,999.79 kg (-2.1418 kg/ha). The estimated gross production of the total population between summer and fall estimates was 9,024.42 kg and between fall and spring estimates was -2,988.04 kg. The production lost to mortality between summer 1973 and fall 1973 (P_g - P_n) was 17.13 kg and between fall 1973 and spring 1974 was 11.75 kg.

The estimated indigenous population of the 1973 year-class was 145, 200 and the mean weight was 1.27 g on 26 June; therefore, the estimated net production from spawning to 26 June was 184.4 kg (0.1711 kg/ha). The population during fall 1973 was 110,768 and the mean weight was 77.08 g resulting in a net production estimate of 8,538.00 kg (7.1061 kg/ha) during the first growing season, and the spring 1974 population estimate was 79,098 and the mean weight was 72.77 g. Therefore the estimated net production during the first year of life was 5,755.96 kg (4.1096 kg/ha). Gross production of the indigenous population was 8,374.14 kg between the summer and fall estimates and -2,771.13

kg between the fall and spring estimates. The production loss due to mortality was 20.55 kg between summer and fall and 10.91 kg between fall and spring.

Because of the difficulty of making true production estimates, the most common approximation of production reported in the literature is standing crop (biomass) at one point in time. The standing crop of YOY bass would be equal to the net production from spawning to the time of the standing crop estimate. Zweiacker (1972) estimated the biomass of the 1968 year-class at Lake Carl Blackwell to be 41.8 kg (0.052 kg/ha) at the start of the second year of life. This is 50 times greater than the fall estimate of the 1972 year-class but 150 times smaller than the spring 1974 estimate of the 1973 year-class, the estimate closest to the time of Zweiacker's estimate. The 1973 year-class had an estimated net production of 4.43 kg/ha in spring 1974 and that value is considered the best estimate of net production during the first year of life since it is closest to the end of the first year. This is higher than any previous value for all ages combined in Lake Carl Blackwell as well as for Age 0 bass alone. Zweiacker and Brown (1971) estimated the total net production of largemouth bass in Lake Carl Blackwell to be 1.35 kg/ha and Zweiacker (1972) estimated it at 0.97 kg/ha. Although high for Lake Carl Blackwell this is not unusually high. Cooper et al. (1963) found a standing crop of 94.2 kg/ha at the start of the second year of life in a small pond and Sheddan (1972) found a standing crop of 5.6 kg/ha in a reservoir. Although they did not report standing crops in biomass, several authors obtained higher population densities (Bennett 1950, Patriarche 1953, Aggus and Elliot 1975, Table 11) and therefore probably had higher standing crops.

The dramatic difference in population, growth and production between the 1972 and 1973 year-classes seem to be the direct result of an increase in lake level. Water level manipulation has been recognized as a potential management tool because of its effect on survival and growth of YOY fishes (Wood 1951). Bross (1969) traced ten-fold differences in year-class strength of largemouth bass to water level fluctuations during and after spawning. Aggus and Elliot (1975) found a significant positive correlation between the amount and duration of flooded vegetation during and after spawning and the number of YOY largemouth bass collected in fall rotenone samples. They also found a correlation between water level and growth rate as did Zweiacker et al. (1973) in Lake Carl Blackwell.

The water level at Lake Carl Blackwell had declined almost continuously from 1961 through 1972. This prolonged period of decreasing level allowed terrestrial vegetation to gradually follow the receding lake level and this vegetation was flooded when the lake level rose during winter 1972 and spring 1973. This pattern of low water level and subsequent flooding of vegetation is a recurring phenomenon at Lake Carl Blackwell (DeGruchy 1952, Johnson 1974) but never to the extent that occurred in 1972-1973.

It would appear that the increase in water level and the flooded vegetation improved the environment for YOY bass in four ways: 1) it provided cover for nest sites reducing the effects of wave action on the nests, 2) it provided cover for the fry and juvenile largemouth bass reducing predation by other fishes, 3) it provided a source of terrestrial invertebrates for food as they were trapped by the increasing water level, and 4) the flooded terrestrial vegetation acted as a food source for aquatic invertebrates and as a nutrient source increasing the primary productivity and therefore the food supply for the YOY bass. In contrast, there was little cover present during the 1972 spawning season and the nests were more susceptible to wave action, the YOY bass were more susceptible to predation and without the added nutrients and invertebrates, the growth of the 1972 year-class was slower than the 1973 year-class even though the population was low and little competition for food would be expected.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this project was to estimate population, growth, mortality rates and production of the 1972 and 1973 year-classes of largemouth bass during their first year of life in Lake Carl Blackwell. The population of the 1972 year-class was estimated in fall 1972 and spring 1973 while the 1973 year-class was estimated in summer 1973, fall 1973 and spring 1974 using mark-recapture methods. Mortality rates were calculated for each interval delineated by a pair of population estimates of the same year-class and growth rates were calculated for each interval delineated by a pair of mean length and weight estimates. Net production was estimated by the formula $B_2 - B_1$ (B is biomass) and gross production was estimated using the exponential formula of Chapman (1971).

The population estimate of the 1972 year-class was 29 in fall 1972 and 34 in spring 1973 and the total growth during the first growing season was estimated at 143 mm and 29 g. Net production of YOY bass during 1972 growing season was 0.838 kg. Because the estimated population was higher in spring 1973 than fall 1972, no mortality rate or gross production estimate could be calculated.

The estimated population of the 1973 year-class was 145,200 during summer 1973, 110,768 during fall 1973 and 79,098 during spring 1974. The daily instantaneous mortality rate was 0.00282 between the summer and fall estimates and 0.00150 between the fall and spring estimates. The total growth during the first growing season was 189 mm and 99 g. The net production of the 1973 year-class from spawning to fall 1973 was 8,538 kg. Differences in growth, population and production between the 1972 and 1973 year-classes was attributed to an increase in water level.

The null hypothesis that the previous low population of adult bass was not caused by high mortality from the time the YOY bass reached 50 mm to the end of their first year of life was not disproven. In fact, the mortality rates calculated in this project were lower than most literature values for the corresponding period of time.

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