POPULATION DYNAMICS OF LARGEMOUTH BASS IN AN 808-HECTARE OKLAHOMA RESERVOIR

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RESERVOIR

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PREFACE

Several population parameters of Lake Carl Blackwell largemouth bass were estimated. Using several of these parameters, the net production of largemouth bass, a major tertiary consumer in reservoir ecosystems, was estimated and compared with production estimates in other artificial and natural environments.

Oklahoma State University Zoology Department provided a teaching assistantship (1967-69), the Oklahoma Department of Wildlife Conservation provided a Fish and Game Fellowship (1969-70), and equipment and supplies were provided by Oklahoma Cooperative Fishery Unit.

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CHAPTER I

INTRODUCTION

Largemouth bass, Micropterus salmoides (Lacépède) have been widely distributed in the contiguous 48 states of the United States and throughout the world. They have been managed because of their predaceous habits, desirable sporting qualities, and high food quality. Expanding human populations reduce per capita quantities of arable land and add to the importance of fresh-water fish as a major protein source for human populations (Holt, 1966). Fish production in fresh-water ponds, lakes, and reservoirs throughout the world can significantly supplement marine resources, provided observations on dynamics of natural populations are greatly expanded.

Dynamics of a largemouth bass population are described for Lake Carl Blackwell, a medium size reservoir (808 ha). Objectives of this study were to: (1) examine the feasibility of using shoreline electrofishing to obtain a representative sample of largemouth bass >176 mm (7 in) in a medium size reservoir, (2) estimate instantaneous rates of fishing, natural, and total mortality, (3) estimate age-distribution, (4) estimate growth rate, (5) estimate population biomass attributable to natural mortality, (6) compare fishing versus natural mortality, (7) determine aspects of homing, home range, and feeding habits and the effects of these factors on the success and selectivity of sampling, (8) estimate net production of largemouth bass, and (9) compare these parameter estimates with reported values for other impoundments.

CHAPTER II

DESCRIPTION OF STUDY AREA

Lake Carl Blackwell (Figure 1) is an impoundment of Stillwater Creek 12.8 km (8 mi) west of Stillwater, Oklahoma, and is owned and managed by Oklahoma State University. The reservoir was constructed as a Works Progress Administration Project beginning in 1936. The earth and rock dam, completed in 1938, is located in Section 3 Township 19 N, Range 1 W in Payne County. Only the north end of area 26 (Figure 1), in Noble County, is located outside of Payne County. Initially, the only use of the reservoir was recreation, but since March, 1950 it has also served as the domestic water source for the City of Stillwater.

Maximum surface area of approximately 1,214 ha (3,000 acres) was attained at spillway elevation (287.7, 944.0 ft, m.s.l.) in 1945 with an approximate capacity of 80 million cubic meters (65,000 acre-feet). The mean lake elevation during the study was 283.9 m, m.s.l. (Turner, 1971).

Water level of the reservoir has been receding since 1961 because of low rainfall and an expanding municipal demand. Reservoir level was approximately 4 m below spillway level on June 1, 1968 and fluctuation in 1968 was less than one meter. Due to spring rainfall in 1969, water level rose approximately 2 m, but the lake receded again during 1969 to about 283 m, m.s.l.

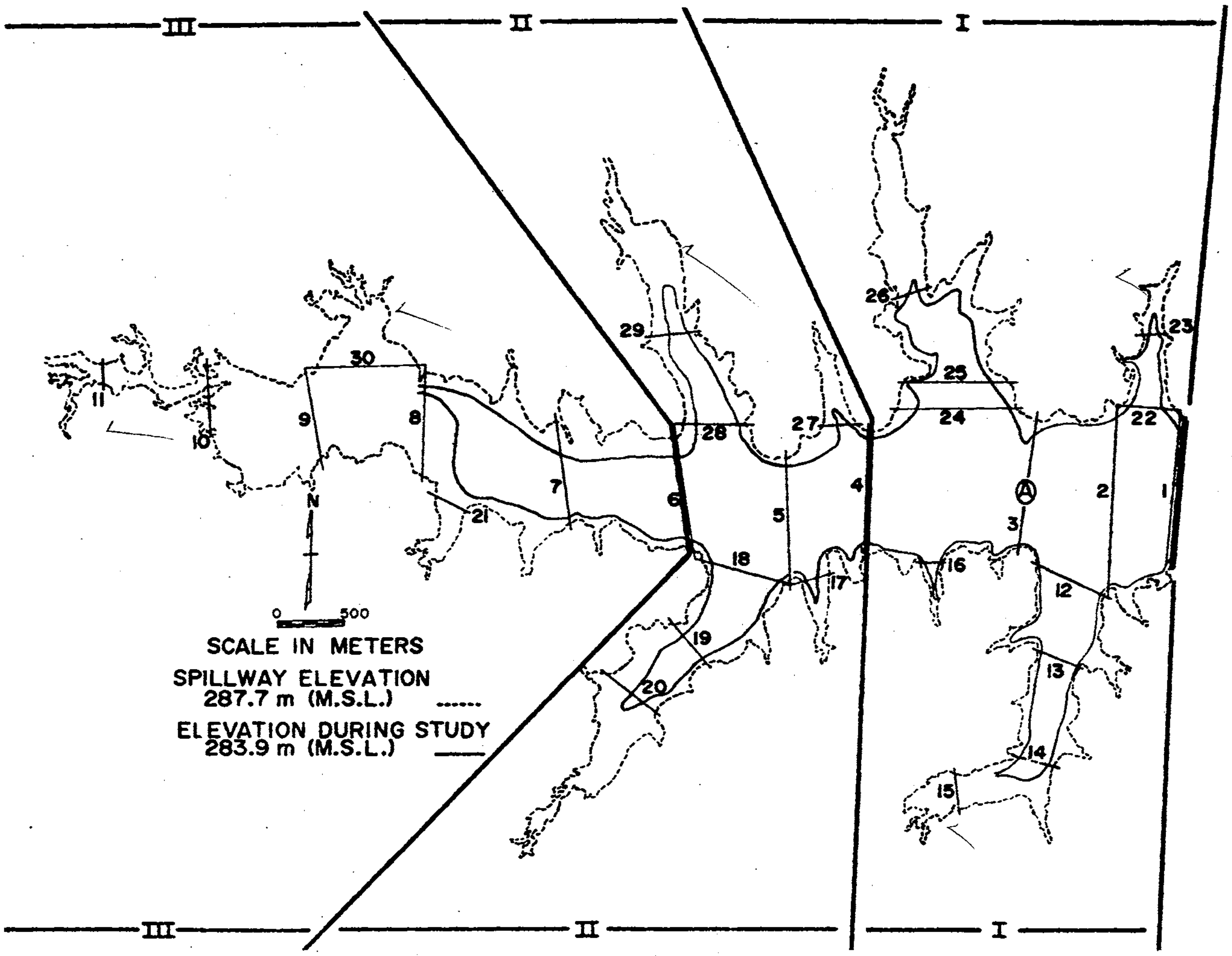


Figure 1. Map of Lake Carl Blackwell, Oklahoma Showing the Thirty Different Small Areas, Three Large Regions, and Release Point (A) of Displaced Bass, Used in the Study

Lake Carl Blackwell was stratified into three large regions and 30 areas to evaluate movement of largemouth bass between areas and regions, and to estimate population density per region (Figure 1). Region I has a surface area of 526 ha (1,302 acres) at spillway level (Table I), but during the study it was 392 ha (968 acres), 25.6% less than spillway elevation. Surface areas of Regions II and III were 33.7% and 45.1% less then their potential areas at spillway level, respectively. The reservoir had an over-all average surface area of 808 ha (1,996 acres) during 1968-69, 33.4% less than 1,214 ha (3,000 acres) at spillway level. Also, shoreline distances were 12.9%, 22.7%, and 22.0% less than at spillway level in Regions I, II, and III, respectively. Areas 11 and 15 were not included in the shoreline distance and surface area calculations, since they remained dry during most of 1968-69.

Terrestrial plants invaded the periphery of the lake following receding water level between 1961 and 1968. Then, with a 2 m increase in water level in the spring of 1969, terrestrial vegetation around the perimeter of the lake was flooded. Throughout 1969 the water receded and again terrestrial plants invaded the shoreline of the lake. A periodic sequence of natural drawdowns, succession, and flooding is a reoccurring phenomenon of the lake, as was noted in the first 12 years following initial impoundment in 1938 (Loomis, 1951).

The main body of water has an east-west orientation with several broad shallow arms extending north and south from the old creek bed. Maximum depth occurs near the dam, where during this study, water depth was as great as 10 m. Maximum depth in the major arms was 7.6 m (25 ft).

TABLE I

SURFACE AREA AND SHORELINE DISTANCE OF THREE STRATIFIED REGIONS OF LAKE CARL BLACKWELL AT SPILLWAY LEVEL AND DURING 1968-69

	Region I	Region II	Region III	Total
Surface area at spillway level (ha)	526	332	356	1214
Surface area at water level during 1968-69 (ha)	392	220	196	808
Percentage decrease of surface area during 1968-69 compared with spillway level	25.6	33.7	45.1	33.4
Shoreline distance at spillway level (km)	19.5	18.6	18.1	56.2
Shoreline distance at water level during 1968-69 (km)	17.0	14.4	14.1	45.5
Percentage decrease of shoreline distance during 1968-69 compared with spillway shoreline distance	12.9	22.7	22.0	19.0

The west shore of the lake was predominately mud flats resulting from low water levels in 1968-69. Turbidity, which was generally 25 to 80 Jackson turbidity units (Hysmith, personal communication), was caused by sediment inflow and wind action. There was generally an increase in turbidity from east to west in the main body of the reservoir. Surface currents have been observed to produce a conspicuous band of sediment-laden water (Norton, 1968). The east portion of the lake became turbid after heavy runoff or during strong winds, but cleared when runoff was zero and wind velocities low, conditions usually occurring in midwinter and midsummer.

High average wind velocity common on the southern Great Plains, combined with a generally rolling topography, relatively large fetch, and shallow water depth, creates a combination of circumstances which allows for nearly continuous mixing of the reservoir. Thermal stratification occurs sporadically for intervals of a few days in June, July, and August, when ambient temperature is very high and wind velocity relatively low. A weak thermocline may develop in summer, but is quickly destroyed by wind action. Complete exhaustion of hypolimnetic oxygen occurs quickly during thermal stratification of the lake (Loomis, 1951; Norton, 1968), but throughout the year, vertical oxygen and temperature profiles are generally orthograde.

Other ecological studies in Lake Carl Blackwell have included: sediment-benthos relationships (Norton, 1968); primary productivity as related to turbidity and light penetration (Claffy, 1955); distribution and occurrence of parasites in fishes (Spall, 1968); aspects of life histories of channel catfish (Jerald, 1970), carp (Mauck, 1970), and flathead catfish (Turner, 1971); and distribution of fishes (Loomis, 1951; Summerfelt, 1971).

CHAPTER III

METHODS AND MATERIALS

General

Largemouth bass were collected between June 1, 1968 and November 1, 1969, except during December, January, and February when electrofishing was ineffective. Electrical output was from a 180 cycle 230-volt, 3,000 watt AC generator mounted in a 16 ft flat-bottom boat powered by an outboard motor. Sampling operations required one man to dip fish and another man to operate the boat. Electrofishing was done by traversing the shoreline in water approximately 1 m deep.

Shorelines of all sampling areas, except 11, 15, 23, 29, and 30 (Figure 1) were easily sampled in 1968-69 with the electrofishing apparatus. Areas 11 and 15 were not sampled because they were basically mud flats and dry most of 1968-69. Areas 23, 29, and 30 were sampled but with difficulty because of submerged tree stumps.

A preliminary survey indicated bass were not uniformly distributed in the lake. The lake was stratified into three regions and sampling effort was proportioned to each region based on preliminary catch per unit of effort. Regions I, II, and III were allocated samples at a 6:3:1 ratio and actual distribution of the samples was 6.4:2.8:0.8:, respectively (Table II).

Bass >176 mm were tagged, weighed, and total length measured in the field. The same data were collected from bass <176 mm in the

TABLE II

CUMULATIVE NUMBER AND RATIO OF ELECTROFISHING TRIPS (APPROXIMATELY 3-HOURS/TRIP) IN REGIONS I, II, AND III IN LAKE CARL BLACKWELL, 1968-69

Year	Month	Regions I	Regions II	Regions III
1968	June	6	7	-
	July	12	12	1
	August	20	16	2
	September	28	18	3
	October	40	24	3
	November	46	25	4
1969	March	50	26	4
	April	59	30	6
	May	69	36	7
	June	74	37	7
	July	82	41	7
	August	87	42	8
	September	95	43	10
	October	104	45	13
	November	105	45	13
Ratio		6.4	2.8	0.8

laboratory. Weights were measured to the nearest ounce in the field, but in the laboratory to the nearest 0.1 g. Bass >176 mm were tagged with a spaghetti tag (T-bar Tag) below the anterior dorsal fin, with the "T" inserted between the pterygiophores. Each tag contained a code number and the letters O.C.F.U. (Oklahoma Cooperative Fishery Unit). Tags were orange with black numbers and letters. The upper lobe of the caudal fin was clipped at the time of tagging to estimate tag loss. Scale samples were taken on the left side below the lateral line where the margin of the pectoral fin meets the body as recommended by Lagler (1956).

Recaptured bass were weighed and measured to determine growth. Scale samples were taken posterior to the area of the first collection to make a comparison with scales taken at time of tagging. Recaptured bass without a tag were retagged. A few recaptured fish had regenerated the clipped caudal fin, which was then clipped again. Recaptured fish were released at the site of recapture.

Sex could not be reliably determined by external morphological features. Recognition of males by occurrence of worn caudal fins during spawning as observed by Snow (1963) was an inaccurate procedure for sex determination in the present study. In 1968, bass with worn caudal fins (assumed to have occurred while making and/or fanning a nest) were recorded as males; however, in 1969, ten bass with worn caudal fins were dissected and all determined to be females. Probing genital openings with a pointed object to determine sex was also unsatisfactory.

Sampling Gear

Hoop-nets, traps, and gill nets were frequently used in the course of several studies during 1968-69 in Lake Carl Blackwell for capturing channel catfish, Ictalurus punctatus (Rafinesque), flathead catfish, Pylodictis olivaris (Rafinesque), and bluegill sunfish, Lepomis macrochirus Rafinesque. These methods were inefficient for capturing largemouth bass. Seining, potentially effective for smaller bass, was not used because the amount of effort needed to obtain a representative sample exceeded available manpower. Electrofishing has been documented to be an effective method for capturing a representative sample of largemouth bass (Lewis, Summerfelt, and Bender, 1962; Witt and Campbell, 1959).

Homing and Movements

An enlarged map of the reservoir, showing areas and regions (Figure 1), was used on each of the 163 trips to the lake (Table II), to record on the map the tag number of each tagged bass at the site of capture. All but 100 non-recaptured bass were released at the capture site. One hundred non-recaptured bass were displaced to a central point (A in Figure 1) to evaluate homing. Displaced bass were classified as having homed if they were recaptured in the same area along the same shoreline where originally tagged. All recaptured bass were released at their capture site.

Distance displaced bass moved was measured on the map from point A (Figure 1) to point of recapture. Distances are based on the assumption that bass moved by the shortest possible water route. This was probably an underestimation of distance traveled, because displaced bass had a higher recapture rate than non-displaced bass, indicating that the displaced bass probably traveled the shoreline trying to find their "home" area rather than moving directly from the release site. The distance bass were displaced was assumed not to be so great that they could not physically home, a possibility discussed by Hasler and Wisby (1958).

Time for homing was measured between time of tagging and recapture. Since displaced fish were not continuously tracked, they may have returned to the original capture area some time prior to recapture.

Food Habits

Gastroscopes (Dubets, 1954) were used to determine largemouth bass stomach contents, because stomach contents could be examined in a live fish, and the fish tagged and released for other phases of the study. This technique (electrofishing and gastroscope) eliminated the problems of digestion which would have occurred in the use of a net or trap and the problem of bass gorging themselves on small fishes during sampling by poisoning (McLane, 1949). Time of feeding was effectively assessed because the degree of freshness of the forage could be ascertained. In some cases, the forage was still alive in the mouth or esophagus of the bass at time of collection.

Forage species, method of swallowing (head or tail-first and horizontally or vertically), time of capture, and average surface water temperature were recorded. Three different size gastroscopes were used to accommodate the size variation of bass. The smallest gastroscope was ineffective in examining bass <454 g (1 lb). Stomach and/or esophagus contents of some bass <454 g could be directly observed without a gastroscope by simply opening the bass' mouth.

Bass were stratified into 454 g size groups to determine whether different size bass utilize different forage species. Bass stomachs collected during different months of 1968-69 were combined to increase sample size in each size group. However, during the 1969 spawning season, three strata were formed (April 1-15, April 16-May 15, and May 16-May 31) to examine relationship between feeding and spawning. Also, fish with empty stomachs or fish with stomachs containing fresh crayfish or gizzard shad were stratified into morning and afternoon samples to compare relative feeding intensity during the morning (6 A.M. through 12 o'clock noon) with the afternoon (12:01 P.M. through 11 P.M.). Stomachs that contained partially digested fishes or crayfish were not included in these analyses, since time of feeding could not be determined.

Method of swallowing (capturing) the prey was recorded for bass stomachs that contained fresh crayfish or gizzard shad by noting orientation of prey species in the mouth, esophagus or stomach of the bass.

Population Estimates

Months were combined to represent period of tagging and period of recapture for Petersen estimates. Petersen population estimates were adjusted for an average tag loss of 22%, but not for mortality. Recaptured bass that had lost their tag could be identified by the fin clip and were retagged. Retagging recaptured bass which had lost their first tag reduced somewhat the extent of tag loss.

Separate Petersen estimates were made for several age groups to decrease bias in population estimates due to differential vulnerability of age groups to the electrofishing gear. These estimates were not adjusted for tag loss or mortality.

All Petersen estimates were calculated using the following formula: $N = \frac{M\ (C+1)}{R+1}$ (Bailey, 1951), where R = recaptures in subsequent sample; C = total subsequent sample, including recaptures; and M = total number originally marked. The 95% confidence interval for each estimate was made using a binomial distribution table (Snedecor and Cochran, 1967:6).

Fifty-nine Schnabel population estimates were made during 1968-69. Population estimates were not made in December 1968 and January and February 1969, because bass could not be captured by electrofishing during these months. They apparently abandon the shoreline for deeper water. In Schnabel estimates, recaptured bass missing a numerical tag were classified as a recapture because they could be recognized by their caudal fin clip. There were no tag losses using the Schnabel method, assuming all tags and fin clips were recorded. Schnabel estimates were adjusted for recruitment by aging all fish and not including the 1968 and 1969 year-classes. Displaced bass and their recaptures were not included in calculating Schnabel estimates because displaced bass had a significantly higher recapture rate. The number of bass displaced for the homing study were added to the Schnabel estimates.

Schnabel estimates were computed with and without adjustment for mortality. When adjusted for mortality, mortality was computed using a daily instantaneous mortality rate of 0.00174 for 1968 and 0.00144 for 1969. The daily instantaneous rates were derived from annual instantaneous mortality rates. Average number of days each tagged fish had been at large per month was determined by the formula:

$\overline{D} = \frac{(R)(30) + \left(\sum_{i=1}^{M} nd\right)}{N}$, where $\overline{D}$ = average number of days each tagged bass was at large during that month, R = total number of tagged bass that survived to the beginning of the month, 30 = the number of days taken for each month, N = total number of tagged fish having survived previous months and is present at the beginning of the month plus number of fish tagged during the month, d = number of days from time of tagging to end of month, n = number of fish tagged during one sampling period, and M = number of sampling periods during the month. The loss of tagged bass due to mortality was calculated by the formula: $A = (\overline{D})\ (i)\ (N)$, where A = number of tagged bass removed from the population because of mortality and i = daily instantaneous mortality rate. Mortality was assumed to be constant over time. Therefore, the number of bass removed per month (A) was subtracted at a constant rate for the month considered from Ricker's (1958) M_t value (marked fish at large).

Separate Schnabel population estimates were calculated for each of the three subdivisions (Regions I, II, and III) of the reservoir (Figure 1). Bass that had lost their T-bar tag were assumed to have been tagged in the region recaptured. Bass recaptured in a region other than where tagged were not classified as a recapture in that region unless they were recaptured in the same region again. The 1968 and 1969 year-classes and displaced bass were not included in these estimates. Schnabel estimates were not adjusted for mortality.

Schnabel population estimates were also made per age group. Age group estimates were not adjusted for mortality, but were adjusted for recruitment of 1968 and 1969 year-classes. Age of fish recaptured after over-wintering since tagging was recorded as the age when tagged.

Formulas used to calculate Schnabel population estimates and their variances were:

$\left(\frac{1}{N}\right) = \frac{\Sigma R}{\Sigma(CM)}$ and $V\left(\frac{1}{N}\right) = \frac{\Sigma R}{(\Sigma CM)^2}$, respectively (Ricker, 1958).

A DeLury population estimate was made by classifying each recaptured bass as having been removed from the population. As bass were tagged, the proportion of recaptures increased and the catch per unit of equal effort of untagged bass decreased. The unit of effort was 20 hours of actual electrofishing. Adjustment for recruitment was made by not including the 1968 and 1969 year-classes. Tag loss was not a problem because clipped caudal fins were used to identify marked bass.

Body-Scale Relationships

A body-scale relationship was calculated from a representative sample of 100 fish from ages I through VII, with a total length range of 190-560 mm. Linear and curvilinear regressions and reduction due to curvilinearity were calculated for the body-scale relationship.

Age and Growth

Impressions were made with a roller press on plastic slides of at least three scales per tagged fish. A few scales from bass $\leq$176 mm were examined to verify the assumption that these fish were 1968 and 1969 young-of-the-year (0+). Plastic slides, 75 mm X 25 mm X 7.5 mm or 10.1 mm thick were preheated before scale impressions were made with a 100 watt light bulb beneath a metal surface. Both slide thicknesses gave satisfactory impressions. Scale impressions were examined at 40 magnifications using a scale projector with a 16 mm micro-tessar lens. All measurements were made in millimeters. Linear regression was used to describe the body-scale relationship and for back-calculation of growth rates.

Recaptured bass were placed into one of two strata depending on time of recapture. Bass recaptured before they had over-wintered were placed in one stratum and bass that were recaptured after they had over-wintered in the other stratum. Bass in each stratum were further stratified by age-class. Bass were weighed and total length measured at time of tagging and when recaptured. Change in weight and total length per day between time of tagging and recapture was determined for each age group.

Scales of tagged bass were compared with scales taken from the same bass after over-wintering to determine the morphology of the annulus and time of annulus formation. All bass were considered one year older on January 1.

Average back-calculated growth was computed separately for 1968 and 1969 collections to reduce bias from collecting different age groups during the two years.

Coefficient of Condition

Coefficient of condition (K_{TL}) was calculated by the formula: $K_{TL} = \frac{W\ 100,000}{L^3}$, where W = weight in grams, L = length in millimeters, and TL = total length. K_{TL} values of bass, stratified by age, captured during the spawning season were compared with K_{TL} values of bass captured in other months. Also, K_{TL} values of bass recaptured after over-wintering were compared with K_{TL} values of bass recaptured before over-wintering. Comparisons were made of K_{TL} values of each age stratum. Stratification by age was based on age at time tagged rather than age at recapture.

Total Mortality Rates

Mortality and survival were estimated from catch curves. Age 0+ bass were not included in 1968 and 1969 mortality estimates, and age I bass were omitted in 1969 estimates. Bass captured in 1968 were classified as one year older on January 1, 1969 and subject to the natural mortality rate of the older age group. Survival rates and their variances were estimated by Robson and Chapman's (1961) method using only known aged fish by:

$$(\hat{s}) = \frac{T}{n+T-1} \quad \text{and} \quad v(\hat{s}) = \frac{T}{n+T-1}\left(\frac{T}{n+T-1} - \frac{T-1}{n+T-2}\right),$$

respectively, where n = total sample size, $T = 1N_1 + 2N_2 + 3N_3 \ldots aN_a$ (sample size of the first group is not included in the T value, since it has a code of zero) and a = number of age groups included in the total sample. In addition, Jackson's and Heincke's methods (Ricker, 1958) were used to estimate survival for comparative purposes. Jackson's method of estimating survival was:

$$\hat{s} = \frac{N_2 + N_3 + N_4 \ldots N_a}{N_1 + N_2 + N_3 \ldots N_{a-1}},$$

where N_a = number in a^{th} age group. Heincke's method was:

$$\hat{s} = \frac{N - N_1}{N},$$

where N = total sample size and N_1 = number of fish in the youngest age group considered in the total.

The following formula given by Robson and Chapman (1961) was used to test if the discrepancy between the Robson and Chapman estimate and the Heincke estimate was due to sampling error or failure to satisfy one of the basic assumptions:

$$X^2 = \frac{(\text{Robson and Chapman's Est. - Heincke's Est.})^2}{\frac{T(T-1)}{n(n+T-1)^2} \quad \frac{(n-1)}{n+T-2)}} \ .$$

Total annual mortality rate, calculated for each estimate for 1968 and 1969, is the complement of the annual survival rate (a = 1-s). An instantaneous mortality rate (i) was calculated for each estimate by the following relationship: $s = 1 - e^{-i}$.

One hundred posters (Figure 2) were placed around the reservoir in 1968 offering $1.00 reward for return of tagged bass to the reservoir office and an additional 100 posters were placed around the reservoir in 1969. The reward for return of tagged largemouth bass was advertised in the local newspaper five times in 1968-69. Also, Lake Carl Blackwell fishing permits contained a statement about the return of tagged fishes. Fishermen were required to complete a questionnaire at the reservoir office before receiving a reward. Fishermen reports of tagged fish were used to estimate fishing mortality. Although supplemented with personal interviews of fishermen, estimates of fishing mortality were not complete; therefore, they are minimal estimates of harvest by fishermen.

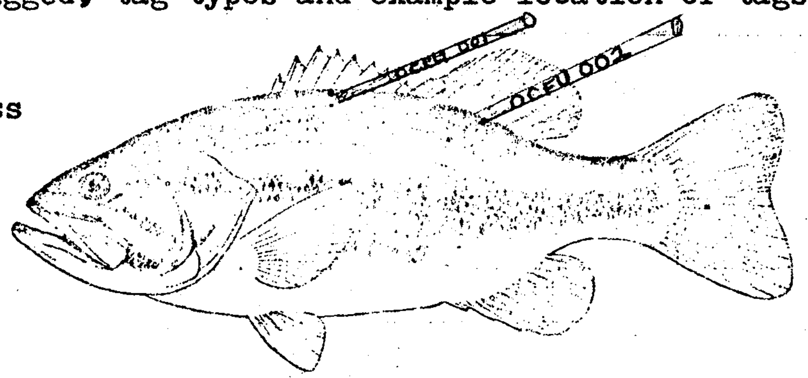
Number of bass reported by fishermen with numerical spaghetti tags was expected to be less than the number of marked bass removed by fishermen because of tag loss. The number of tagged bass recaptured by

$1.00 REWARD

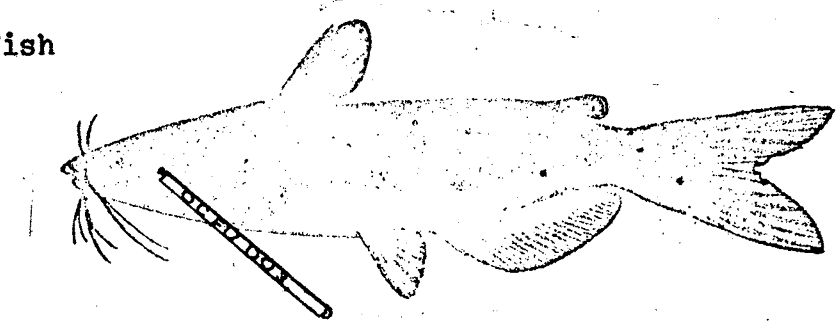
The Oklahoma Cooperative Fishery Unit at O.S.U. is undergoing an extensive study on the largemouth bass, channel catfish and flathead catfish of Lake Carl Blackwell. These species have been tagged and the return of these tags provides essential information needed to accomplish this study. A $1.00 reward will be given for the return of the tag at the Lakeshore Office. Some fish have two tags but the $1.00 reward will be paid for each fish only, not for each tag. The fish will be measured and weighed at the office, but the fisherman will keep the fish. Not all fish are tagged in the same place and some fish have only one tag.

The species tagged, tag types and example location of tags are shown.

Largemouth Bass



Channel Catfish



Flathead Catfish

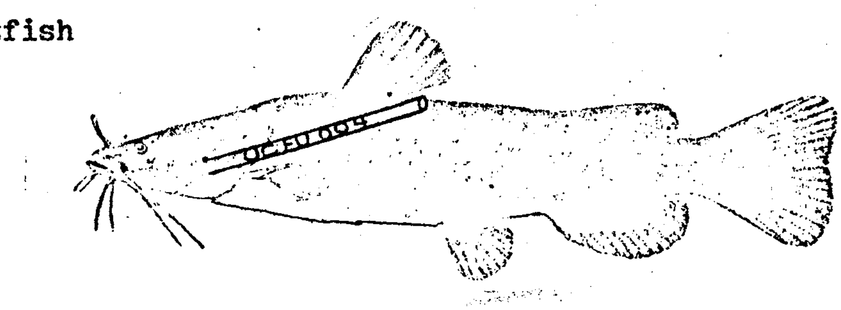


Figure 2. Example of a Poster Used to Solicit Return of Tagged Fish

fishermen was adjusted for tag loss to account for the expected number of tagged bass caught by fishermen for which tags were missing. Adjustments were based on the number of reported monthly captures.

Total annual instantaneous mortality rate (i) calculated by the Robson and Chapman method was used to adjust number of tagged bass at large for mortality.

The exploitation rate of bass by fishermen was calculated by the formula: $u = \frac{R}{C}$, where u = exploitation rate, R = number of tagged bass returned by fishermen, and C = total number of bass tagged in the population adjusted for tag loss, fishing mortality, and natural mortality. The instantaneous fishing rate (p) was calculated by: $P = \frac{i\ u}{a}$, where i = total annual instantaneous mortality rate, u = exploitation rate, and a = total annual mortality rate.

Eleven man-days of creel survey were made in 1969 to estimate fishermen characteristics of: place of residence (local, Oklahoma City, or other areas), percentage fishing for largemouth bass, catch rate of largemouth bass, and percentage of fishermen knowledgeable of the reward. These contacts also provided an opportunity to inform the fishermen of the tagged fish and reward. The entire catch was included in the creel survey for comparative purposes. Most interviews were on weekend days, when the largest number of interviews could be made per interview-day and an effort was made to interview all fishermen on the reservoir. Most interviews were of shoreline fishermen and only a few boat fishermen were included in the total sample. Traveling in an outboard motor boat and using binoculars, the reservoir was covered rapidly, allowing for complete census of fishermen on the reservoir on the day of the census.

Small children were not included in the sample since they usually caught only small sunfishes. Man-hours of fishing were based on number of fishing rods (e.g., man-hours x number of rods = total man-hours fishing).

If one rod was being used primarily to catch one species and another for a different species, the total time fished was equally proportioned between the two species. If a single fisherman was fishing for two different species with a single rod, then fishing time was proportioned between the species. Trotlines, snag-lines, and bank-lines were used extensively in Lake Carl Blackwell. However, these fishing methods were not included because bass are seldom captured by these methods. An exploitation rate for bass fishing was calculated for each age group to determine which age group contributed the greatest amount to the fishermen's creel.

Number of tagged bass remaining in the population at the end of each month was adjusted by subtracting the number removed by fishermen during the month and loss due to calculated natural mortality. Natural mortality was obtained by subtracting fishing mortality from the total instantaneous mortality rate for each age group estimated from the 1968 sample.

Some age 0+ bass were tagged in 1968, but they did not enter the fishermen's creel in 1968 or in 1969.

Standing Crop, Production, and Yield

Back-calculated growth rates of bass from scales were used in production analysis. Back-calculated growth in length, converted to weight, was used to estimate instantaneous growth rate (g) per age group by the formula: $\frac{W_t}{W_o} = e^{gt}$.

A length-weight relationship for each age group for 1968 and 1969 was calculated from a representative maximum sample of 50 fish. Age VI and VII bass were combined to increase sample size.

Total change in biomass per age group was calculated using an estimated population of 1,822 bass >176 mm. The estimated number per age group was based on age frequency of the 1968 sample. Estimated total biomass for an age group at the beginning of the year was calculated by multiplying the estimated number of bass in that age group by the estimated average weight of a bass in the age group.

Growth rate was calculated for age VI bass, but not for age VII bass because no age VIII bass were collected. Instantaneous growth rate calculated for age VI bass was assumed to be the growth rate for ages VI plus VII.

Mean weight ($\overline{W}$) per age group was calculated by the formulas:

$\overline{W} = \frac{W\ (e^{g-i}-1)}{g - i}$ or $\overline{w} \doteq \frac{W\ (1 - e^{-(i-g)})}{i - g}$ (Ricker, 1958).

CHAPTER IV

RESULTS AND DISCUSSION

Sampling Technique

Accuracy of estimated parameters is based on the assumption of representative sampling of the population. Hoop-nets, traps, and gill nets were frequently used during 1968-69 in the course of several other studies on Lake Carl Blackwell. In 1968-69, only five largemouth bass were captured with these gears, and these bass were captured in a single overnight gill-net-set on December 7, 1968. Loomis (1951) used gill nets, hoop-nets, and wire traps in Lake Carl Blackwell and found them to be ineffective for collecting largemouth bass. Similar findings have been reported in other waters for largemouth bass (Carter, 1967; Gerking, 1952).

Seining was considered impractical to adequately sample 45 km of shoreline, because too many man-days of effort would be needed; also there would be serious problems with deep water, irregular topography, aquatic vegetation, and tree stumps. Seines have been used to collect largemouth bass for making population estimates, but not in medium to large bodies of water (Threinen, 1956; Mraz and Threinen, 1955; Fredin, 1950).

In Lake Carl Blackwell, electrofishing seemed to sample bass of different sizes proportional to their abundance. Loeb (1957) reported electrofishing in New York waters yielded effective and representative samples of largemouth bass. Temperature, depth, salinity, barometric pressure, and turbidity of water have been reported to effect electrofishing efficiency (Lewis and Charles, 1958; Loeb, 1957; Witt and Campbell, 1959). Turbidity and water depth were limiting factors on electrofishing in Lake Carl Blackwell, with sampling being ineffective in water deeper than 2 m and in extremely turbid water, which occurred in the west end of the lake after heavy runoff. Largemouth bass are mainly littoral zone inhabitants and individuals alternate from sublittoral to littoral areas (Lewis and Flickinger, 1967). Thus, with repeated shoreline sampling, all bass should become vulnerable to capture.

Considering the complex action and interaction of the variables on electrofishing, this method was an effective technique for obtaining a representative sample of largemouth bass in Lake Carl Blackwell.

Homing and Movements

Preliminary data collected during June-July 1968 indicated largemouth bass in Lake Carl Blackwell were not uniformly distributed and were more abundant in Region I. Fishes are known to aggregate in different areas during winter, spawning, and feeding. Therefore, movements of largemouth bass were investigated to determine if bass remained nonuniformly distributed during 1968-69 and remained more abundant in Region I, justifying the preliminary allocation of sampling effort per region during the study. Movement data were also used to determine the degree of movement between regions in order to adjust for movement in or out of each region for which population estimates were made.

A total of 1,328 largemouth bass ≥176 mm was collected by electrofishing and only five by gill nets. The latter five fish were returned to the lake and not included in any of the calculations. Of the 1,328 bass captured, 312 (23.5%) were recaptures. Ten non-recaptured bass were taken to the laboratory for internal sex determination and five were placed in spawning ponds for future research. Therefore, 1,001 of the 1,328 captured largemouth bass were tagged and released.

Thirty of 100 bass displaced from site of capture to point A (Figure 1) were recaptured during 1968-69 (Table III). Each multiple recapture was counted only once. Seven of the 30 (23.3%) homed to their original site of capture. In a 3.2 ha (8 acres) pond, 68% of largemouth bass homed to their original site of capture and 77% were recaptured at their original site of capture after over-winter mixing in deeper water (Hasler and Wisby, 1958). Lewis and Flickinger (1967) found that of 96 recaptured largemouth bass in a 3.24 ha pond, 59% were recaptured 100 ft or less from original site of capture, 83% were within 200 ft or less, and 96% were within 300 ft or less.

The homing ability of males and females could not be compared because sex was not determined. Hasler and Wisby (1958) observed no sex differences in homing ability of largemouth bass, but did observe a higher percentage of homing in larger than smaller bass.

Mean distance traveled while homing was 1,756 m, ranging from 1,083 m for an age I bass to 3,208 m for an age VI bass (Table III). The time between displacement and recapture averaged 50 days, ranging from 5 days for an age I bass to 237 days for an age VI bass. The distance traveled per day averaged 98 m, ranging from 14 m for an age VI bass to 217 m for an age I bass.

TABLE III

NUMBER OF DISPLACED LARGEMOUTH BASS THAT HOMED TO THEIR ORIGINAL SITE OF CAPTURE, MINIMUM DISTANCE TRAVELED, TIME BETWEEN CAPTURE AND RECAPTURE, AND MINIMUM DISTANCE TRAVELED PER DAY

Age Group	Number Displaced	Number of Displaced Bass Homed[1]	Strayed	Minimum Distance Traveled Meters	Number of Days Between Capture and Recapture Per Fish	Minimum Distance Traveled M Per Day
O+	5	0	0	-[3]	-	-
I	50	3	11	1083	5	217
				1333	11	121
				1166	18	65
II	19	1	9	1500	21	71
III	6	1	1	1291	42	31
IV	9	0	1	-	-	-
V	6	1	1	2708	16	169
VI	5	1	0	3208	237	14
Total	100	7[2]	23	Mean 1756	50	98

[1]Multiple recaptures counted only once.

[2]Of the 30 recaptured displaced bass, 23.3% returned to their original site of capture.

[3]No recaptured bass homed.

Displaced bass were more prone to multiple recapture than bass returned to the site of capture, but both groups were equally vulnerable to single recapture. Of the 100 bass displaced, 16 (16.0%) were recaptured once (Table IV) and of the 901 bass released at site of tagging, 149 (16.5%) were recaptured only once. Thirteen per cent of the displaced bass were recaptured two times, but only 3.2% of the non-displaced bass were recaptured twice. Recapture rate for displaced bass recaptured at least two times was significantly different from the recapture rate of the non-displaced bass ($P < .05$, $X^2_{1d.f.} = 34.36$). When recaptures were totaled, regardless of whether it was first or fourth, 46.0% of the number of displaced bass were recaptured one or more times, compared with a recapture frequency of 23.2% for the fish released at site of capture. The percentage of multiple recaptured non-displaced bass was significantly different from the multiple recapture of displaced bass ($P < .05$, $X^2_{1d.f.} = 29.4$).

Observations in this study corroborates those by others, that bass displaced or disturbed from their original site of capture have a tendency to multiple recapture, especially if they have been displaced out of their home range. One Lake Carl Blackwell bass was collected five different times (counting time of tagging) with the electrofishing gear; it finally ended in a fishermen's creel. Ball (1947) collected one bass four different times in a net, Lewis and Flickinger (1967) collected one bass six times, and Fajen (1962) collected one smallmouth bass, Micropterus dolomieui Lacépède, in a stream ten different times. Multiple recapture also occurred in the nondisplaced bass, but not to the extent found in the displaced ones. Assuming the bass use the shoreline as a basis for orientation in homing, they would be subject

TABLE IV

COMPARISON OF PERCENTAGE RECAPTURE OF LARGEMOUTH BASS DISPLACED TO A CENTRAL RELEASE POINT WITH BASS RELEASED AT SITE OF CAPTURE

	Number	Percentage
Fish displaced to central release point	100	
Once Recaptured	16	16.0
Twice Recaptured[1]	13	13.0
Multiple Recaptured[2]	46	46.0
Fish released at site of capture	901	
Once Recaptured	149	16.5
Twice Recaptured	29	3.2
Multiple Recaptured	209	23.2

[1]Once recaptured bass are not included and if recaptured more than two times, only counted once.

[2]Bass counted each time recaptured.

to recapture in greater frequency than the bass which were returned to the original site of recapture. Parker and Hasler (1959) and Hasler and Wisby (1958) assumed bass would move randomly when displaced in waters with greatly reduced light penetration until the bass found a shoreline or other submerged landmarks useful for homing. The turbid waters in Lake Carl Blackwell should make visual homing difficult, which would place greater emphasis on use of topographic features as opposed to celestrial cues.

There may be a resident segment of the population that remains restricted in their movements and a mobile group which tends to move freely as found in bass population in St. John's River, Florida (Moody, 1960). Parker and Hasler (1959) reported that 27.7% to 46.1% of largemouth bass homed to the original site of capture in three Wisconsin lakes, but 53.9% to 72.3% wandered randomly. Bass recaptured several times in Lake Carl Blackwell may have been individuals belonging to a "mobile" portion of the population. Funk (1955) classifies largemouth bass in Missouri streams as a "semimobile" species. The higher proportion of recaptures of displaced fish produces an error in the population estimates, which would be an underestimation of the actual population. Thus, bass should not be displaced in estimating population size by the mark-recapture method.

One hundred and sixty three bass were recaptured in Region I, of which 95.7% were tagged in Region I, 3.7% in Region II, and 0.6% in Region III (Table V). Of the 37 recaptured in Region II, 89.2% were tagged in Region II, 10.8% in Region I, and none in Region III. Only six recaptures occurred in Region III and 83.3% were tagged in Region I, none in Region II, and 16.7% in Region III. The large percentage

(83.3%) that were recaptured in Region III but tagged in Region I represented a recapture of five fish. It is possible that fish did move into and out of Region III depending on degree of turbidity. However, a total of sixteen recaptured bass (7.8%) had moved out of the region in which they were originally tagged, compared with 190 (92.2%) recaptured in the region where tagged. This indicates little movement between regions. Some bass moved only a few meters but were classified as out of their tagging region, because they were tagged near an imaginary boundary between regions and moved a short distance into another region and were recaptured.

TABLE V

NUMBER OF NON-DISPLACED BASS RECAPTURED IN EACH REGION AND PERCENTAGE OF THE NUMBER TAGGED IN REGIONS I, II, AND III IN LAKE CARL BLACKWELL

Region Bass Were Recaptured	Number Recaptured	Percentage Tagged		
		Region I	Region II	Region III
I	163	95.7%	3.7%	0.6%
II	37	10.8%	89.2%	0.0%
III	6	83.3%	0.0%	16.7%
Total	206			

Cooper (1951) observed that largemouth bass captured on the shorelines of a 72.8 ha (180 acres) and a 232.8 ha (575 acres) lakes in Michigan, had a tendency to remain on the same shoreline. Restricted movements of smallmouth bass have also been verified in streams by Fajen (1962) and Gerking (1953).

Movements of largemouth bass between areas (Figure 1) during August 1968 and September 1969 (Figure 3) were limited. Even though sample sizes were relatively small, in August 1968 and in September 1969, 99% and 88%, respectively, were recaptured in the original tagging area. Lack of movement may have been due to high water temperatures and a decrease in feeding rate.

Bass exhibited a greater tendency to move in and out of areas during March, April, May, and June 1969. Percentage of bass recaptured in their tagged area ranged from 50% in March to 35% in April. Movements can be attributed to bass moving from deep water and seeking suitable spawning and feeding grounds. Lewis and Flickinger (1967) observed greatest bass movement during May, June, and July in a 3.2 ha (8 acres) lake in Illinois.

Movements of bass increased during or after September through November 1968-69 (Figure 3). Percentage of bass recaptured in the same area as originally tagged, ranged from 88% in September 1969 to 33% in November 1968. With decreasing water temperature, movements during October and November were probably related to bass seeking deeper water for winter.

Movement of bass was greatest in autumn (October and November) and spring (March, April, and May). Hasler and Wisby (1958) believe randomness of largemouth bass occurs in early spring and in autumn and

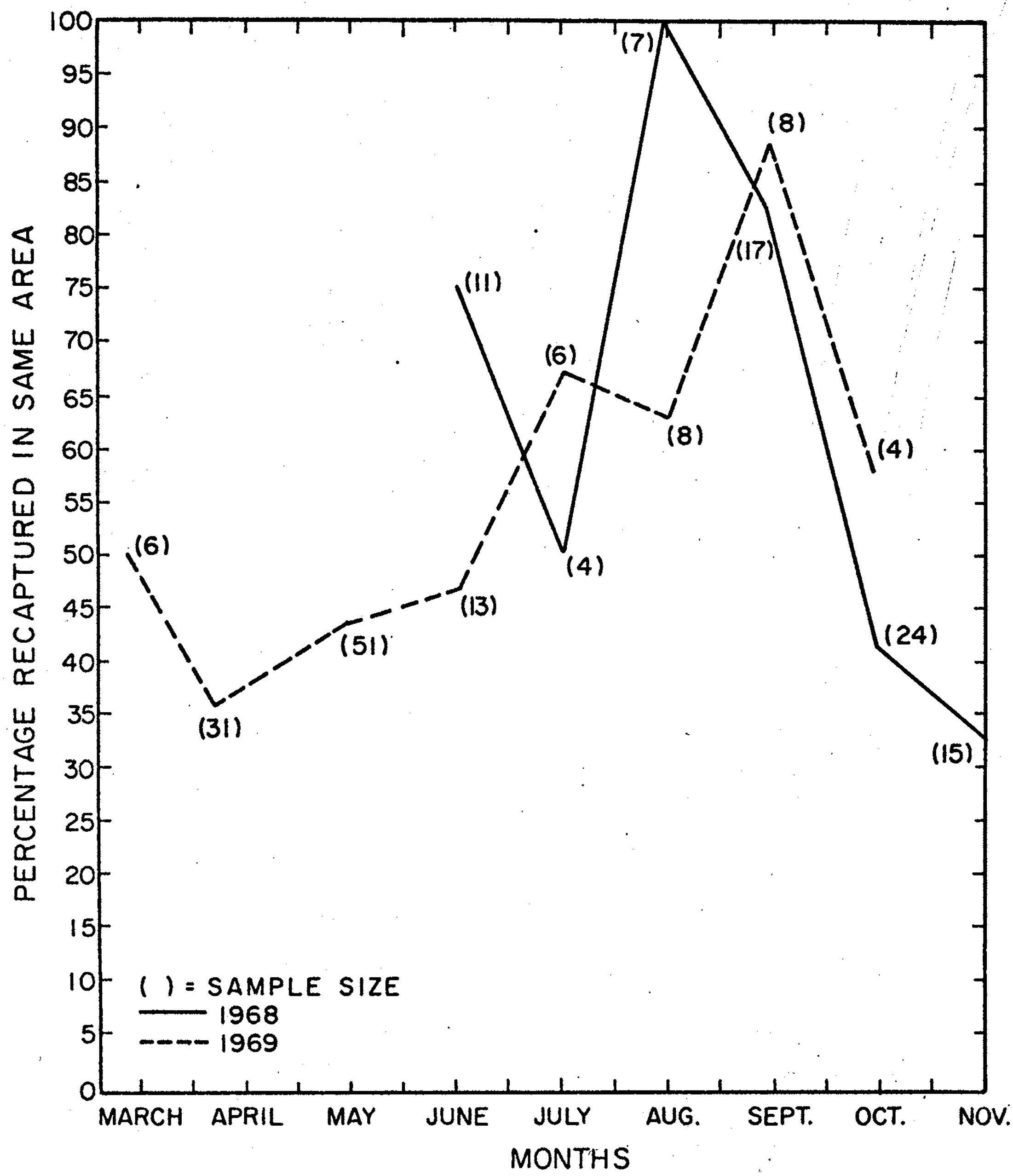


Figure 3. Seasonal Variation in Movements of Largemouth Bass Expressed as Percentage Recaptured in the Same Area as Tagged

they recommended population estimates be made during these periods. Cooper, Hidu, and Anderson (1963) recommended estimating largemouth bass population size only when the water temperature is <12.9 C. (55 F.). They assumed bass were apparently more randomly distributed, while seeking deeper water. However, only a few fish (tagged and untagged) were collected per trip when the water was <12.9 C. and not enough bass could be tagged or examined for tags to make an accurate population estimate. Therefore, data for population estimates were collected when water was >12.9 C.

Vertical distribution of largemouth bass can be affected by water temperatures and oxygen concentrations. Dendy (1945) found bass to be present only in waters of approximately 26 C. (80 F.) (epiliminion) and none in water 23.9 C. (75 F.) during July in Tennessee reservoirs, even where oxygen concentrations were not limiting in the hypoliminion. Ferguson (1958) reported a temperature preference for largemouth bass of 27 C. (81 F.). Lake Carl Blackwell apparently was thermally stratified for only short periods and largemouth bass would not have been vertically stratified.

Food Habits

Approximately 50% of the 819 stomachs examined were empty. A similar percentage of empty stomachs was observed in largemouth bass by Dubets (1954) and Schneidermeyer and Lewis (1956). However, because of intense feeding on incapacitated forage fish, only 8% of largemouth bass stomachs were empty when collected with rotenone (McLane, 1949). Lewis (1967) has emphasized the importance of vulnerability as a factor in feeding intensity of piscivorous fishes.

Food habits of largemouth bass during spawning were compared with food habits before and after spawning. The majority of bass in Lake Carl Blackwell spawned during the last week of April and the first week of May in 1969. The first female bass captured in 1969 (with a "bloody", frayed, lower lobe of the caudal fin) was on April 16, when surface temperature was 21 C. (70 F.). Feeding was apparently less during spawning, because in a 30-day period from mid-April to mid-May in 1969, the percentage of empty stomachs was generally higher than during other periods. The overall percentage of empty stomachs was 63.8% in April 16 - May 15, 1969, compared with 47.3% in October - November 1968 (Table VI and Figure 4). The highest percentage of empty stomachs was 75.5% in the April 1 - 15, 1969 interval, before spawning, compared with 51.8% and 49.1% of empty stomachs in June - July 1968 and June - July 1969, respectively (after spawning). An increase in feeding rate occurs after spawning as indicated by a lower percentage of empty stomachs compared with the percentage before and during spawning. Therefore, a decrease in feeding rate of largemouth bass during sexual development and spawning as reported by Lewis, Gunning, Lyles, and Bridges (1961) was verified. Dendy (1946) also, observed a decrease of bass feeding on gizzard shad, *Dorosoma cepedianum* (Le Sueur) during May and June in Norris Reservoir, Tennessee. However, Dendy observed an increase in the percentage of black crappie, *Pomoxis nigromaculatus* (Le Sueur) utilized by bass during the same time which may have accounted in part for the reduction of feeding on gizzard shad.

Percentage of empty stomachs remained about the same during June, July, August, and September 1968 and 1969. These were the months of highest surface temperature (Table VI and Figure 4), when feeding and

TABLE VI

PERCENTAGE OF LARGEMOUTH BASS STOMACHS THAT WERE EMPTY OR CONTAINED CERTAIN FRESH OR DIGESTED FOOD ITEMS, 1968-69

Date	Bass Group	No. Fish	Percentage Empty	Percentage Digested Fish	Percentage Gizzard Shad	Percentage Digested Crayfish	Percentage Fresh Crayfish
	91- 454	2	100.0	0.0	0.0	0.0	0.0
	499- 908	10	30.0	0.0	20.0	0.0	50.0
June	953-1362	13	53.9	30.9	7.6	0.0	7.6
+	1407-1816	12	66.7	25.0	8.3	0.0	0.0
July	1861-2270	14	42.8	7.1	28.5	0.0	21.4
1968	2315-2724	3	66.7	33.3	0.0	0.0	0.0
	Total = 54	Mean[1] =	51.8	16.6	14.8	0.0	16.6
	91- 454	11	9.0	18.2	27.3	0.0	45.5
	499- 908	36	44.4	11.1	0.0	8.3	36.1
August	953-1362	36	47.2	22.2	5.5	5.5	19.4
+	1407-1816	21	71.4	14.2	4.7	4.7	4.7
September	1861-2270	5	80.0	0.0	0.0	20.0	0.0
1968	2315-2724	6	83.3	16.6	0.0	0.0	0.0
	Total = 115	Mean[1] =	50.4	15.6	5.2	6.0	22.6
	91- 454	21	14.2	19.0	47.6	0.0	19.0
October	499- 908	33	51.6	6.4	19.3	6.4	16.1
+	953-1362	25	73.9	8.6	0.0	0.0	17.3
November	1407-1816	15	40.0	13.3	6.6	6.6	33.3
1968	1861-2270	5	60.0	20.0	0.0	0.0	20.0
	Total = 95	Mean[1] =	47.3	11.5	17.8	3.1	20.0

TABLE VI (Continued)

Date	Bass Group	No. Fish	Percentage Empty	Percentage Digested Fish	Percentage Gizzard Shad	Percentage	
						Digested Crayfish	Fresh Crayfish
	91- 454	4	100.0	0.0	0.0	0.0	0.0
	499- 908	3	33.3	0.0	66.7	0.0	0.0
March	953-1362	4	50.0	25.0	0.0	25.0	0.0
1969	1407-1816	1	0.0	0.0	0.0	100.0	0.0
	1861-2270	3	66.7	33.3	0.0	0.0	0.0
	Total = 15	Mean[1] =	74.1	29.2	66.7	62.5	0.0
	91- 454	3	0.0	0.0	0.0	33.3	66.7
April	499- 908	8	75.0	0.0	25.0	0.0	0.0
1-15,	953-1362	11	63.6	9.1	18.2	9.1	0.0
1969	1407-1816	3	100.0	0.0	0.0	0.0	0.0
	1861-2270	5	80.0	20.0	0.0	0.0	0.0
	Total = 30	Mean[1] =	75.5	16.4	21.6	21.2	66.7
	91- 454	27	7.4	0.0	85.2	0.0	7.4
April 16-	499- 908	21	76.2	9.5	14.3	0.0	0.0
May 15,	953-1362	44	50.0	20.5	29.5	0.0	0.0
1969	1407-1816	58	62.1	20.7	17.2	0.0	0.0
	1861-2270	35	62.9	20.0	17.1	0.0	0.0
	2315-2724	16	87.5	0.0	12.5	0.0	0.0
	2769-3178	4	50.0	50.0	0.0	0.0	0.0
	Total = 205	Mean[1] =	63.8	22.3	47.1	0.0	7.4

TABLE VI (Continued)

Date	Bass Group	No. Fish	Percentage Empty	Percentage Digested Fish	Percentage Gizzard Shad	Percentage Digested Crayfish	Percentage Fresh Crayfish
	91- 454	3	0.0	0.0	67.7	0.0	33.3
May 16-	499- 904	4	75.0	0.0	0.0	0.0	25.0
May 31,	953-1362	6	66.7	33.3	0.0	0.0	0.0
1969	1407-1816	8	62.5	37.5	0.0	0.0	0.0
	1861-2270	13	53.8	23.1	15.4	0.0	7.7
	2315-2724	2	50.0	50.0	0.0	0.0	0.0
	Total = 36	Mean[1] =	61.5	33.2	41.6	0.0	22.0
	91- 454	9	44.4	0.0	33.3	0.0	22.2
June	499- 908	13	46.2	7.6	46.2	0.0	0.0
+	953-1362	19	63.1	10.5	0.0	10.5	15.7
July	1407-1816	8	50.0	12.5	0.0	0.0	37.5
1969	1861-2270	9	33.3	33.3	11.1	0.0	22.2
	2315-2724	3	33.3	0.0	33.3	0.0	33.3
	Total = 61	Mean[1] =	49.1	11.4	18.0	3.2	18.0
	91- 454	39	51.2	2.5	38.4	0.0	7.6
August	499- 908	30	46.6	10.0	13.3	13.3	16.6
+	953-1362	13	69.2	7.6	15.3	7.6	0.0
September	1407-1816	7	71.4	14.2	0.0	0.0	4.2
1969	1861-2270	5	60.0	20.0	0.0	0.0	20.0
	2315-2724	1	100.0	0.0	0.0	0.0	0.0
	Total = 95	Mean[1] =	54.7	7.3	22.1	5.2	10.5

TABLE VI (Continued)

Date	Bass Group	No. Fish	Percentage Empty	Percentage Digested Fish	Percentage Gizzard Shad	Percentage Digested Crayfish	Percentage Fresh Crayfish
	91- 454	62	82.2	3.2	12.9	0.0	1.6
October	499- 908	25	48.0	8.0	24.0	4.0	16.0
+	953-1362	10	50.0	40.0	10.0	0.0	0.0
November	1407-1816	6	66.6	0.0	16.6	0.0	16.6
1969	1861-2270	4	25.0	25.0	0.0	25.0	25.0
	2315-2724	2.	0.0	50.0	0.0	50.0	0.0
	Total = 109	Mean[1] =	66.9	9.1	14.6	2.7	6.4

[1]Weighted Mean

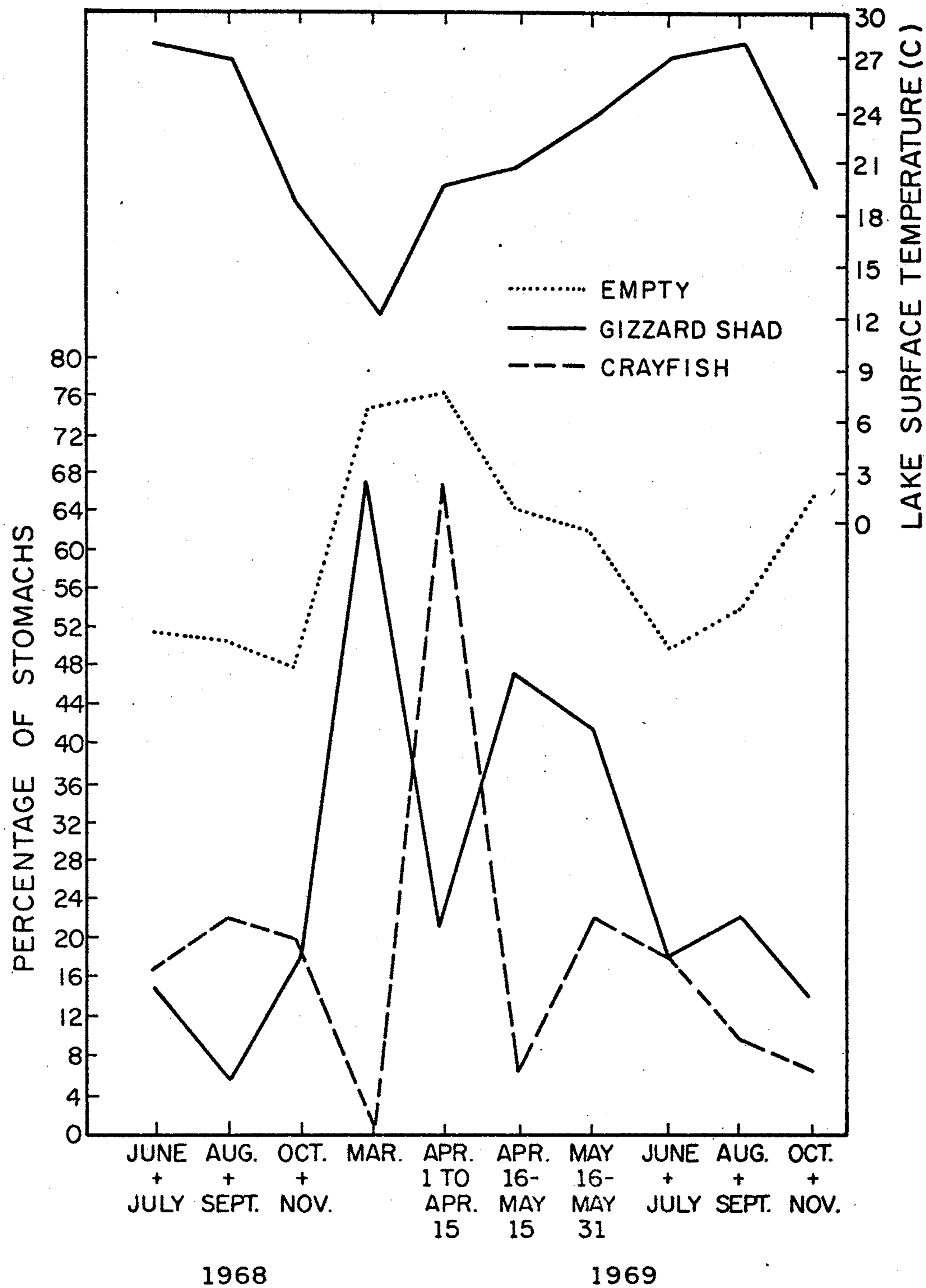


Figure 4. Percentage of Largemouth Bass Stomachs From Lake Carl Blackwell That Were Empty or Contained Gizzard Shad or Crayfish and Mean Surface Temperature Per Month, 1968-69

digestion rates were assumed to be the highest. Bass >453 g were observed in 0.61 m (2 ft) of water when the average surface temperature was 33 C. (90 F.). Therefore, the usual migration of largemouth bass to deeper and cooler waters and a reduction in feeding rate during the hot summer months in the south may not occur in a well-mixed reservoir (i.e., lacking stratification).

Percentage of stomachs containing undigested gizzard shad ranged from 5.2% in August-September 1968 to 66.7% (based only on three fish) in March 1969 (Table VI and Figure 4). The overall average of stomachs containing undigested gizzard shad was 12.6% in 1968 and 33.1% in 1969. The percentage of stomachs containing undigested crayfish ranged from 0.0% in March 1969 to 66.7% (based only on three fish) in April 1-15, 1969. The overall average of stomachs containing undigested crayfish was 19.7% in 1968 and 18.7% in 1969. Crayfish were utilized approximately at the same rate in 1968 (19.7%) and 1969 (18.7%), but gizzard shad were utilized more in 1969 (33.1%) than in 1968 (12.6%), suggesting a greater gizzard shad year-class strength in 1969 than in 1968.

Crayfish and gizzard shad were the major items occurring in largemouth bass stomachs in a 2,631 ha (6,500 acres) lake in southern Illinois (Schneidermeyer and Lewis, 1956). Dubets' (1954) also observed that bass fed largely on gizzard shad. Tadpoles and crayfish were used by bass in a pond where gizzard shad were not present (Lewis and Helms, 1964). Shad were utilized by bass in Norris Reservoir, Tennessee where crayfish were scarce (Dendy, 1946). Applegate and Mullan (1967) reported bass only 40 mm (1.6 in) feed on sac fry and fry of shad. Thus, the two forage species most utilized by largemouth bass in Lake Carl Blackwell, gizzard shad and crayfish, are the same forage species preferred by largemouth bass in other waters. Availability and vulnerability of the gizzard shad and crayfish are probably the reasons for their high incidence in bass stomachs.

Of the 819 stomachs examined, one contained a water beetle, two contained bluegills, two contained frogs, one contained a crappie, one contained a largemouth bass, and four contained other sunfishes. The remaining were either empty, contained gizzard shad, crayfish, different degrees of digested crayfish and gizzard shad, or unknown digested fish. Since only one largemouth bass was found in the stomachs examined, bass >453 g were basically noncannibalistic. However, scarcity of small bass due to weak year-classes in 1968 and 1969 may have been the reason for the low incidence of cannibalism. Stranahan (1906) observed cannibalism in smaller, but not in larger bass. Lack of cannibalism in bass >453 g in Lake Carl Blackwell seemed to be related to a greater availability of other forage species, e.g., gizzard shad and crayfish. Few bass stomachs contained more than one food item. Of bass stomachs examined with two or more items, the contents frequently consisted of a crayfish exoskeleton and a more recently swallowed prey. The observation that bass do not take food readily, unless their stomachs are empty (Markus, 1932), was generally verified by observations in the present study.

Channel catfish were not found in bass stomachs examined with gastroscopes. Six of ten bass ranging from 1,021 to 2,837 g, sacrificed to determine their sex, contained pectoral spines of channel catfish in their visera. As judged by size of their spines, age II to age VI bass occasionally consume channel catfish in the 0.2 to 0.4 kg size range.

Changing food habits of fry and fingerling bass have been previously reported. Henshall (1883 and 1885) stated that bass 25 mm (1 in) feed on minute crustaceans, 25 to 102 mm (4 in) feed on insects, and bass larger than 102 mm preferred crayfish. Murphy (1949) found largemouth bass in Clear Lake, California below 46 mm (1.8 in) fed on plankton, from 46 to 71 mm (2.8 in) fed on insects and over 71 mm fed chiefly on fishes. Changing of food habits by fingerling bass was observed in Arkansas (Applegate and Mullan, 1967; Hodson and Strawn, 1968) and in Alabama (Rogers, 1967). Hathaway (1927) observed small size bass eating more per body weight than large individuals.

However, it seems that observations have not been made on whether changes occur in the food habits of bass >453 g with increase in size. Food items or percentage of different items utilized by different size groups of bass in Lake Carl Blackwell were similar (Table VI). All size groups utilized gizzard shad and crayfish and there was no increase in percentage of empty stomachs as bass became larger.

Samples were stratified to determine if bass in Lake Carl Blackwell feed more intensively during the morning or during the afternoon. Percentage of the 672 stomachs examined in 1968-69 that was classified as empty, or containing fresh crayfish or gizzard shad were tabulated for fish collected in the morning and compared with percentages of the same categories for fish collected in the afternoon. Stomachs that contained digested fish or digested crayfish were not included, because time of ingestion could not be determined for partially digested food.

In 1968, 75.0% of the fish collected in the morning had empty stomachs, compared with 56.0% of the fish collected in the afternoon (Table VII). This difference was significant ($P < .05, X^2_{1d.f.} = 9.2$).

TABLE VII

PERCENTAGE OF LARGEMOUTH BASS STOMACHS THAT CONTAINED GIZZARD SHAD, CRAYFISH, OR WERE EMPTY IN THE MORNING AND EVENING IN LAKE CARL BLACKWELL, 1968-69

Month	Sample Size	Percentage: Empty	Percentage: Gizzard Shad	Percentage: Crayfish	Sample Size	Percentage: Empty	Percentage: Gizzard Shad	Percentage: Crayfish
1968								
	Morning				Afternoon			
June + July	15	73.3	13.3	13.3	30	63.3	13.3	23.3
Aug. + Sept.	38	78.9	5.2	15.7	50	54.0	8.0	38.0
Oct. + Nov.	11	63.6	0.0	36.3	68	54.4	22.0	23.5
Weighted Mean		75.0	6.2	18.7		56.0	15.6	28.3
Total	64				148			
1969								
	Morning				Afternoon			
Mar., Apr. + May	9	55.5	33.3	11.1	220	72.2	25.0	2.7
June + July	4	50.0	0.0	50.0	48	58.3	22.9	18.7
Aug. + Sept.	36	72.2	11.1	16.6	47	55.3	36.1	8.5
Oct. + Nov.	31	83.8	3.2	12.9	65	72.3	23.0	4.6
Weighted Mean		73.7	10.0	16.2		68.4	25.7	5.7
Total	80				380			

In 1969, 73.7% of largemouth bass collected in the morning had empty stomachs, compared with 68.4% in the afternoon. This difference was not significant ($P > .05$, $X^2_{1d.f.} = 1.03$), but the difference corroborates the findings of the previous year. These findings suggest that bass feed from mid-morning through the afternoon, which results in a lower percentage of empty stomachs in the afternoon than in the morning. The high percentage of empty stomachs in the morning indicates that feeding decreases at night, especially between 12 midnight and 6 A.M. Dubets (1954), however, in studying feeding activity through the 24-hour cycle, could not establish a specific feeding period for largemouth bass.

Method of swallowing (capturing) prey, based on position of prey species in mouth, esophagus, or stomach was recorded for 230 bass stomachs containing freshly captured crayfish or gizzard shad. Crayfish were swallowed tail-first in 96.8% of 93 bass stomachs containing fresh crayfish (Table VIII). The small percentage of crayfish which seemed to have been swallowed head-first may have rotated during digestion, as has been previously observed in largemouth bass (Molnar and Tolg, 1962). Large bass utilizing small crayfish could swallow them head or tail-first, but large bass usually utilized larger forage.[1] Orientation of the crayfish in swallowing tail-first was apparently to induce folding of the large chelipeds, whereas a head-first orientation would cause a spreading of the chelipeds, inhibiting swallowing.

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[1]By inspection, there seemed to be a direct relationship between size of bass and size of forage species utilized. This has been reported for bass feeding on green sunfish (Tarrant, 1960).

TABLE VIII

ORIENTATION OF PREY (CRAYFISH AND GIZZARD SHAD) SWALLOWED BY LARGEMOUTH BASS IN LAKE CARL BLACKWELL, 1968-69

		Crayfish			Gizzard Shad	
Bass Group	No. of Stomachs	% Head-first	% Tail-first	No. of Stomachs	% Head-first	% Tail-first
91- 454	25	0.0	100.0	63	69.8	30.2
499- 908	33	9.0	91.0	32	68.7	31.3
953-1362	15	0.0	100.0	18	61.1	38.9
1407-1816	11	0.0	100.0	9	33.3	66.7
1861-2270	8	0.0	100.0	13	69.2	30.8
2315-2724	1	0.0	100.0	2	100.0	0.0
Weighted Mean		3.2	96.8		66.4	33.6
Total	93			137		

Gizzard shad were swallowed head-first in 66.4% of 137 bass stomachs containing fresh shad. Orientation of shad did not vary greatly in bass of different sizes, except in the 1,407-1,816 g group, which usually swallowed gizzard shad tail-first. The higher percentage of forage fish swallowed head-first probably facilitated swallowing because this prey orientation compresses the median fins, which if spiny, would injure the predator. All 137 gizzard shad were apparently in a horizontal position in the esophagus and/or stomach in reference to orientation of largemouth bass. This horizontal position of forage was probably due to the turning of prey by largemouth bass before swallowing, as reported by Lawrence (1958).

Evaluation of Assumptions for Population Estimates

Population estimates using mark-recapture data, are based on the following assumptions (Ricker, 1958):

(a) Marked fish suffer the same natural mortality as unmarked fish.

(b) Marked fish are as vulnerable to the fishing gear as unmarked fish.

(c) Marked fish do not lose their mark.

(d) Marked fish become randomly mixed with unmarked fish; 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.

(e) All marks are recognized and reported on recovery.

(f) Recruitment to the catchable population during the collections is negligible.

Mortality of Marked Fish

Marked fish were assumed to have the same rates of natural mortality as unmarked fish. Differential mortality of marked and unmarked fish is difficult to evaluate in nature, but the 312 recaptured bass appeared to have no detrimental effects from being tagged. Careful handling during tagging and rapid return to the lake after tagging should have reduced occurrence of higher mortality among marked fish. The large percentage of multiple recaptures indicates that mortality of the tagged bass probably was not different from mortality of untagged bass. The calculated K_{TL} values for tagged bass was not significantly different from the untagged bass (Table XXIII), indicating that the process of tagging had no effect on condition or "well being".

Vulnerability of Marked Fish

Vulnerability of tagged bass to electrofishing was discussed in the section on homing and movements of bass. It is apparent from the high frequency of multiple recaptures that displaced bass were exceptionally vulnerable to the electrofishing gear. It was assumed that the non-displaced tagged bass were as vulnerable as the untagged bass. If tagged fish are more vulnerable to capture than unmarked fish, an underestimation of the population size may result. Buck and Thoits (1965) attributed underestimation of certain largemouth bass populations in Illinois farm ponds to higher vulnerability of certain bass to recapture. An underestimated bass population in a Pennsylvania farm pond was also attributed to bass behavior (Cooper, Hidu, and Anderson, 1963). Swingle, Smitherman, and Spencer (1965) underestimated a bass population in a 1.4 ha (3.5 acres) pond using electrofishing and Petersen and Schnabel methods. They concluded that electrofishing was an effective sampling gear for bass, but showed greater vulnerability of marked bass to electrofishing. Unequal vulnerability may have caused the large percentage of returns of bass in two T.V.A. reservoirs by hook-and-line (Chance, 1955). Kimsey (1956) reported that largemouth bass in the open water of a 16,194 ha (40,000 acres) California lake moved randomly, but that bass in shallow regions may have been more sedentary. If tagged bass in Lake Carl Blackwell were basically sedentary in shallow water, they would have had a greater probability of being recaptured, causing an underestimation of population size. Observations on bass movement in Lake Carl Blackwell indicates that little inter-region movement occurred, but the shoreline sedentary behavior hypothesized by Kimsey could not be tested. However, bass <250 mm generally school along the shoreline but larger bass of spawning age are less often found in schools and are not limited to a sedentary shoreline existence.

Tag Loss

Bass were marked with a T-bar spaghetti tag and the upper lobe of the caudal fin clipped. Average percentage tag loss was 22% for 1968-69. This percentage tag loss was used to adjust data used in making population estimates. Clipped caudal fins regenerated rapidly, but since regenerated fin rays were slightly deformed, they were easily recognized even after complete lobe regeneration.

Random Distribution of Marked and Unmarked Fish

Bass were not uniformly distributed and were more abundant in certain areas than others. Sampling was allocated to Regions I, II, and III on a 6:3:1 ratio, respectively, based on preliminary catch data, and the actual sampling ratio was 6.4:2.8:0.8 (Table II). Buck and Thoits (1965) reported that displaced tagged bass may not redistribute themselves in a random manner after tagging and home to their original living areas where they were again highly vulnerable to capture. Hasler and Wisby (1958) and Cooper, Hidu, and Anderson (1963) proposed making population estimates only in early spring and autumn when bass were more randomly distributed.

Recognition of Marked Fish

Recognizing marked bass collected by electrofishing was not a problem, because if a tag was lost, the caudal fin clip was used to identify marked fish. Fishermen would not recognize and report fish with a clipped fin. Reports of fishermen's catch were used for estimates of fishing mortality after adjustment for tag loss.

Recruitment to Population

Emigration and immigration were not considered important variables because Lake Carl Blackwell was basically a "closed" system. During most of 1968-69, Stillwater Creek, entering Lake Carl Blackwell in area 10, was dry and immigration and emigration were impossible. Emigration could not occur because no water flowed over the spillway during 1968-69. Loss of adult bass moving upstream to farm ponds was not measured but was assumed to be small and probably compensated by bass moving out of farm ponds. Movement of bass from small ponds on the watershed would have been possible only during periods of heavy rains in spring of 1969. Age of all bass >176 mm was determined by the scale method and this enabled the population estimates to be adjusted for recruitment by the 1968 and 1969 year-classes (growth).

Because population estimates were made by regions, movement of bass between the three regions would be important; however, movement between regions was low, except in Region III (Table V). Bass recaptured in one region, but tagged in another region were not classified as a recapture until they were recaptured in the region again. This enabled a population estimate to be made for each region without bias due to movements between regions.

Summary

Multiple recaptures and K_{TL} values indicate that tagging had no detrimental effect on the bass and tagging mortality was assumed to be identical to estimates of mortality rates of untagged bass. Non-displaced tagged bass were assumed to be as vulnerable to electrofishing as untagged bass. Displaced bass were more vulnerable to recapture, so they were not included as marked or recaptured fish. Population estimates were adjusted for tag loss. Bass were not uniformly distributed and sampling effort was allocated per region, based on preliminary observations of population distribution. Recognition of marked fish was not a problem because clipped caudal lobes were used to recognize fish which had lost their tag. Recruitment to the population was adjusted for the 1968 and 1969 year-classes and emigration and immigration did not occur because the population was closed and movement between regions was low.

Population Estimates

Petersen Estimates

An average of 10.1 bass (marked and unmarked) was captured per trip, or 3 hours of electrofishing[2]. Insufficient numbers of fish were captured per day to make daily estimates by the Petersen procedure. Petersen estimates were made using the combined total number of fish tagged during one, two, or three months to represent one tagging interval, and all recaptures during the next one or two months to represent the interval of recapture (Table IX). Total number of bass marked in June-July 1968 equals M; C and R were derived from total catch and recapture, respectively, made in August-September 1968 (Table IX). The population estimate was 1,771, and the 95% confidence limits were 1,647 to 2,019. For the second estimate, the total number of bass marked in August-September 1968, not including June-July marked fish, was used as a new M value and new C and R values were derived from total catch and recapture, respectively, made in October-November 1968. This process of combining months was continued for 1968 and 1969 to obtain eight successive Petersen estimates. Tagged bass collected during the period of each subsequent sample, but not tagged during the appropriate period, were recorded as an untagged bass. Population estimates were adjusted for an average 22% tag loss for each subsequent sample but not for

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[2]Bennett and Brown (1968) collected from 16 to 23 bass per hour by electrofishing in Lake Raymond Gary, Oklahoma.

TABLE IX

PETERSEN ESTIMATES OF NUMBERS OF LARGEMOUTH BASS PER MONTH AND PER AGE GROUP WITH 95% CONFIDENCE LIMITS FOR 1968-69

Time Period: Tagged	Time Period: Recapture	Population Estimate + 95% C. I.	Population Estimates Per Age Group + 95% Confidence Limits: I + II	III + IV	V, VI + VII	Total
June + July, 68	Aug. + Sept., 68	1771[1] (1647-2019)	579 (568- 648)	952 (952-1056)	100 (95-145)	1631 (1517-1859)
Aug. + Sept., 68	Oct. + Nov., 68	1528 (1100-2139)	1008 (777-1360)	261 (246- 347)	72 (70-115)	1341 (953-1890)
Oct. + Nov., 68	Mar., Apr., + May, 69	2034 (1424-2888)	1204 (1012-1601)	292 (278- 347)	176 (176-214)	1672 (1171-2374)
Mar., Apr., + May, 69	June + July, 69	1595[2] (1435-2137)	967 (958-1257)	268 (231- 412)	429 (417-690)	1664 (1498-2229)
June + July, 69	Aug. + Sept., 69	301[2] (292- 367)	117 (113- 159)	70 (70- 98)	45 (45-126)	232 (230- 271)
"	"	455[3] (437- 523)	229 (218- 329)	70 (70- 98)	45 (45-126)	344 (331- 395)
Aug. + Sept., 69	Oct., 69	384[2] (380- 464)	170 (170- 209)	27 (27- 37)	0	197 (196- 238)
"	"	1388[3] (1375-1526)	1150 (1138-1240)	27 (27- 37)	0	1177 (1166-1294)

[1]Point estimate with all ages combined and confidence limits given in parenthesis.

[2]1968 year-class not included.

[3]1968 year-class included.

mortality, which was assumed to be non-significant during the three to five month interval of tagging and recapture.

A population estimate was calculated using combined June-July 1969 tagging data and combined August-September 1969 recapture data, with the 1968 year-class included and another estimate omitting the 1968 year-class (Table IX). Few 1969 year-class (young-of-the-year) fish were large enough to be tagged during August-September 1969, excluding them from all population estimates. An estimated 1,388 bass were present in August-September 1969 when the 1968 year-class was included and 384 bass were estimated excluding the 1968 year-class. The estimated population of 1,388 present in August-September 1969 was about 400 bass less than the estimated number present in June-July 1968.

Sum of the separate age class estimates was basically the same as the estimate for the same period not stratified by age (Table IX). This indicates equal vulnerability of ages I-VII to electrofishing. The slight difference between the single (non-stratified) estimates and the sum of the age stratified estimates was probably due to lack of adjustment in the latter for tag loss. This adjustment was not made because the tag loss could not be proportioned by age groups.

The Petersen estimates of largemouth bass >176 mm in Lake Carl Blackwell during 1968-69 varied from 1,300 and 2,000. The sharp reduction in the estimate of 1,595 in March-May 1969 and the estimate of 301 in June-July 1969 suggests very heavy mortality or significantly higher vulnerability of tagged bass to capture than untagged fish. Comparing Petersen estimates with those made by the Schnabel method (Table X) suggests that sampling in June-August was selective for shoreline inhabitants which were highly vulnerable to multiple

TABLE X

SCHNABEL ESTIMATES, NOT ADJUSTED FOR MORTALITY, AND CONFIDENCE LIMITS ($\alpha = .05$) OF THE NUMBER OF LARGEMOUTH BASS AT THE END OF EACH MONTH IN LAKE CARL BLACKWELL, 1968-69

		Population			
Year	Month	Mean	Lower Limit	Upper Limit	Cumulative Sampling Trips[1]
1968	June	229	105	α	8
	July	527	309	1796	17
	August	1266	836	2605	27
	September	1301	978	1939	36
	October	1447	1187	1853	49
	November	1411	1182	1751	54
1969	March	1455	1254	1732	58
	April	1693	1462	2009	68
	May	1864	1641	2157	80
	June	1824	1614	2097	86
	July	1845	1639	2111	94
	August	1824	1627	2075	101
	September	1803	1613	2045	111
	October	1815	1627	2052	121
	November	1808	1622	2042	122

[1]Each trip equals 3 hours of electrofishing.

recapture. This bias reduced the estimates made by the Petersen method and made these estimates less accurate than Schnabel estimates.

Schnabel Estimates

The Schnabel multiple census estimate uses continuous mark-recapture during a time period to estimate a population. The Schnabel estimate is the population size occurring at some time during the sampling period, not on the day tagging began as in the Petersen method. Bass were tagged and recaptured in the Schnabel estimates throughout 1968-69. A larger sample size was obtained with the Schnabel method than with the Petersen method, giving more confidence in the accuracy of the Schnabel estimates.

Schnabel estimates were made during 1968-69, except during December 1968 and January-February 1969. In Lake Carl Blackwell bass were not vulnerable to electrofishing from December through February. Poor catch rate by electrofishing in these methods was apparently related to scarcity of bass in the shallow water rather than variation in vulnerability to capture related to water temperature. In Minnesota, fingerling bass leave the shoreline in August and are scarce in October (Kramer and Smith, 1960). In Lake Carl Blackwell, bass abandon the shoreline and move to deeper water later in the year than in Minnesota.

A Schnabel population estimate of approximately 1,800 bass >176 mm was calculated when unadjusted for mortality, and 1,900 with the 100 displaced bass included (Table X and Figure 5). Approximately 1,850 bass >176 mm were calculated when unadjusted for mortality, but stratified by age group, and 1,950 including displaced bass (Table XI).

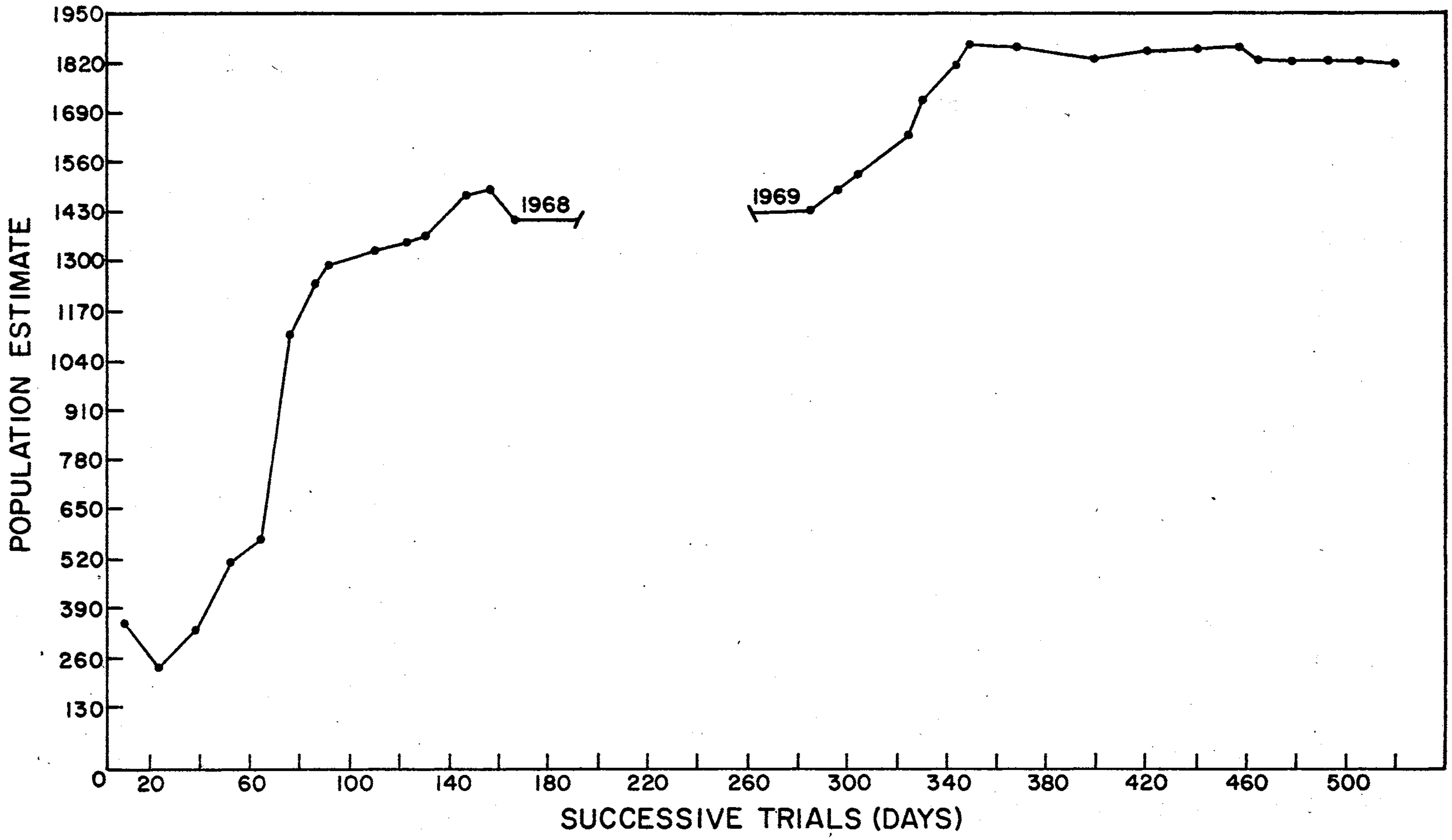

Figure 5. Schnabel Estimates of Largemouth Bass (>176 mm) in Lake Carl Blackwell on Successive Days, 1968-69. Estimates Were Not Adjusted for Mortality

TABLE XI

SCHNABEL ESTIMATES, NOT ADJUSTED FOR MORTALITY, AND CONFIDENCE LIMITS ($\alpha \doteq .05$) OF THE NUMBER OF LARGEMOUTH BASS OF DIFFERENT AGE GROUPS AT THE END OF EACH MONTH IN LAKE CARL BLACKWELL, 1968-69

		Population Estimates Per Age Group Plus 95% Confidence Limits			
Year	Month	I + II	III + IV	V, VI + VIII	Total
1968	June	-[1] (-)	34 (14-α)	96 (27-α)	130
	July	- (-)	120 (57-2371)	84 (19-α)	204
	August	2992 (978- α)	264 (148-1198)	89 (49-403)	3345
	September	606 (397-1278)	322 (191-1005)	93 (52-408)	1021
	October	1007 (748-1540)	361 (231- 820)	112 (65-393)	1480
	November	969 (735-1420)	323 (215- 644)	122 (71-417)	1414
1969	March	1038 (812-1437)	293 (201- 526)	133 (77-452)	1464
	April	1123 (910-1464)	407 (295- 654)	227 (148-488)	1757
	May	1173 (970-1481)	408 (314- 579)	294 (221-437)	1875
	June	1271 (957-1453)	386 (303- 529)	294 (223-426)	1951
	July	1188 (982-1502)	391 (311- 525)	288 (222-408)	1867
	August	1203 (1004-1499)	368 (296- 483)	284 (221-396)	1855
	September	1129 (1055-1212)	376 (303- 494)	293 (228-408)	1798
	October	1152 (1075-1239)	376 (303- 491)	301 (237-411)	1829
	November	1040 (977-1110)	378 (306- 494)	301 (237-411)	1719

[1]No recaptures.

Mortality was assumed to be insignificant during the short time period for the Petersen estimates. Schnabel estimates were made over a longer period of time and if mortality of tagged and untagged fish was different, an over or underestimation results.

A Schnabel estimate, adjusted for mortality, was approximately 1,400 bass, 400 lower than the Schnabel estimate not adjusted for mortality (Table XII). The estimate was approximately the same value calculated by the Petersen method for the August-September 1969 marking period with the 1968 year-class included.

Bass were not uniformly distributed in the reservoir, but were more abundant in Region I than II or III. Schnabel estimates were made for each region separately. Approximately 1,800 bass were estimated to be present in Regions I and II (Table XIII). The 1,800 bass plus the 231 estimated to be present in Region III and the 100 displaced bass gave a population estimate of 2,131 in the reservoir. If the estimates had been adjusted for mortality, it is possible the estimates would have been approximately 450 lower. This adjustment would have given an estimate of 1,681 bass which would be similar to the Petersen estimate of June-July 1968, the DeLury estimate, discussed next, and between the Schnabel estimates adjusted and unadjusted for mortality.

DeLury Estimate

The DeLury method estimates population number by relating a decreasing catch rate with cumulative catch. As fish are removed from the population, catch per equal unit of effort (Y axis) decreases and the extrapolated least squares regression line to the cumulative catch (X axis), is the estimated population (Figure 6).

TABLE XII

SCHNABEL ESTIMATES AND CONFIDENCE LIMITS (α = .05) OF THE NUMBER OF LARGEMOUTH BASS AT THE END OF EACH MONTH IN LAKE CARL BLACKWELL, 1968-69. ESTIMATES WERE ADJUSTED FOR DAILY INSTANTANEOUS MORTALITY RATES, WHICH WERE 0.00174 AND 0.00144 IN 1968 AND 1969, RESPECTIVELY

Year	Month	Population			Cumulative Sampling Trips[1]
		Mean	Lower Limit	Upper Limit	
1968	June	229	105	α	8
	July	512	300	1482	17
	August	1143	753	2370	27
	September	1211	911	1806	36
	October	1340	1100	1713	49
	November	1304	1103	1597	54
1969	March	1312	1108	1609	58
	April	1397	1211	1650	68
	May	1494	1321	1718	80
	June	1455	1291	1668	86
	July	1461	1296	1675	94
	August	1432	1273	1636	101
	September	1405	1252	1601	111
	October	1398	1253	1583	121

[1]Each trip equals 3 hours of electrofishing.

TABLE XIII

SCHNABEL ESTIMATES, NOT ADJUSTED FOR MORTALITY, AND CONFIDENCE LIMITS (α = .05) OF THE NUMBER OF LARGEMOUTH BASS AT THE END OF EACH MONTH IN THREE REGIONS IN LAKE CARL BLACKWELL

	Region I				Region II[1]				
	Population			Cumulative	Population			Cumulative	Total
Year-Month	Mean	Lower Limit	Upper Limit	Sampling Trips	Mean	Lower Limit	Upper Limit	Sampling Trips	Population Mean[2]
1968									
June	46	19	α	6	89	37	α	7	135
July	295	143	α	12	154	77	α	12	449
August	1763	1032	6018	20	205	117	841	16	1968
Sept.	1068	753	1831	28	192	112	656	18	1260
Oct.	1251	971	1759	40	285	171	854	24	1536
Nov.	1195	957	1589	46	263	161	716	25	1458
1969									
Mar.	1196	969	1562	50	311	190	845	26	1507
April	1301	1084	1627	59	623	389	869	30	1924
May	1353	1149	1643	69	549	398	882	36	1902
June	1315	1126	1580	74	506	374	782	37	1821
July	1300	1119	1552	82	519	389	779	41	1819
August	1282	1109	1519	87	481	367	700	42	1763
Sept.	1258	1092	1482	95	490	373	713	43	1748

TABLE XIII (Continued)

Year-Month	Region I Population Mean	Region I Population Lower Limit	Region I Population Upper Limit	Region I Cumulative Sampling Trips	Region II[1] Population Mean	Region II[1] Population Lower Limit	Region II[1] Population Upper Limit	Region II[1] Cumulative Sampling Trips	Total Population Mean[2]
Oct.	1254	1095	1469	104	507	387	738	45	1761
Nov.	1246	1089	1457	105	507	387	738	45	1753

[1]Region III - All months combined =

Population Mean	Population Lower Limit	Population Upper Limit	Cumulative Sampling Trips
231	107	α	13

[2]Sum of population means for Regions I and II.

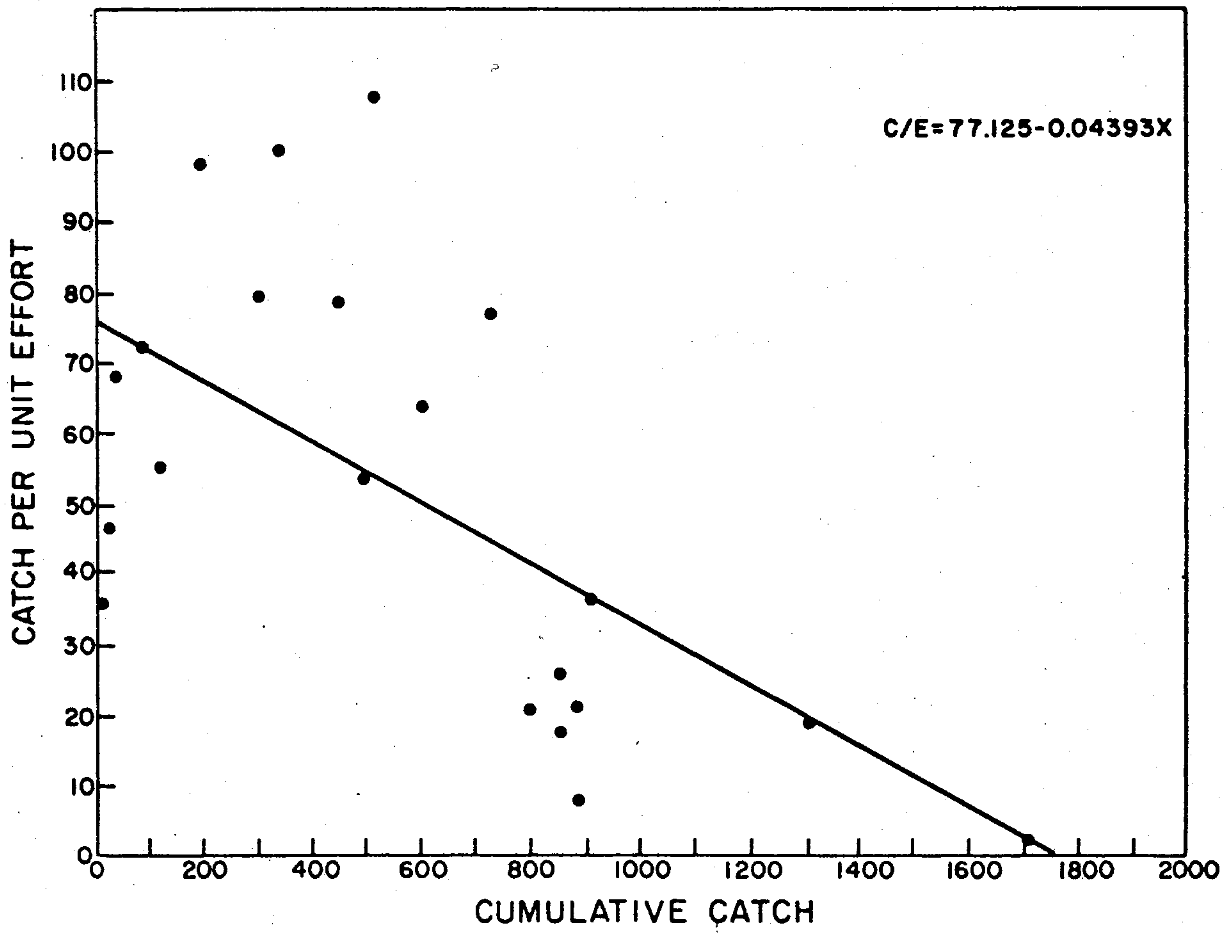

Figure 6. DeLury Regression Estimate of Largemouth Bass in Lake Carl Blackwell. The Unit of Effort Was Twenty Hours of Electrofishing

An estimate of 1,756 bass >176 mm (95% C.I., Ricker, 1958, 0-6859) was obtained by the DeLury method. The point value (1,756) corroborates those obtained from the mark-recapture studies, but the procedure seems unreliable because of the extremely wide confidence limits.

Comparisons of Population Estimates

Petersen estimates made during 1968-69 ranged from approximately 1,300 to 2,000 bass >176 mm. The DeLury estimate was 1,756 bass >176 mm. The Petersen and DeLury estimates were assumed less accurate than the Schnabel estimates, because of the small sample size and wide confidence limit, respectively. The overall average of the Schnabel estimates at the end of each month from April to November 1969 (Tables X, XI, XII, and XIII) was 1,822 (Table XIV), and taken as the population estimate of bass >176 mm in Lake Carl Blackwell and used in the production analysis.

Body-Scale Relationship

The linear and curvilinear regressions calculated for body-scale relationship were significant ($P < .005$) (Table XV). The linear regression of the total body length in mm (Y) on the total scale radius in mm (X) was: $Y = 36.67 + 1.29X$ with a correlation coefficient (r) of 0.97; the curvilinear regression was $Y = 18.6 + 1.4X - 0.0004X^2$. Since the reduction due to curvilinearity was non-significant ($P > .10$), the linear relationship between total body length and scale radius was used (Figure 7).

Mraz and Threinen (1955) in Brown's Lake, Wisconsin calculated a body-scale relationship of $S = 0.1813L^{1.3613}$ with total length (L) and

TABLE XIV

AVERAGE OF SCHNABEL ESTIMATES FROM APRIL-NOVEMBER 1969 OF THE NUMBER OF LARGEMOUTH BASS AT THE END OF THESE MONTHS IN LAKE CARL BLACKWELL

Schnabel Estimates	Population Mean[1]
Unadjusted for mortality	1910
Adjusted for mortality	1535
Stratified by age group	1931
Stratified by region	1911
Overall mean	1822

[1]Average of monthly estimates from April-November 1969 plus the 100 displaced bass.

TABLE XV

REDUCTION IN VARIANCE OBTAINED BY USE OF LINEAR VERSUS CURVILINEAR RELATIONSHIPS BETWEEN TOTAL LENGTH (MM) AND SCALE RADIUS (MM) FOR LARGEMOUTH BASS FROM LAKE CARL BLACKWELL

Source of Variation	Degrees of Freedom	F	Probability
Total	100		
Linear Regression	1	2031.40	$P < .005$
Residual	99		
Curvilinear Regression	2	1021.75	$P < .005$
Reduction due to Curvilinearity	1	1.51	$P > .100$
Residual	96		

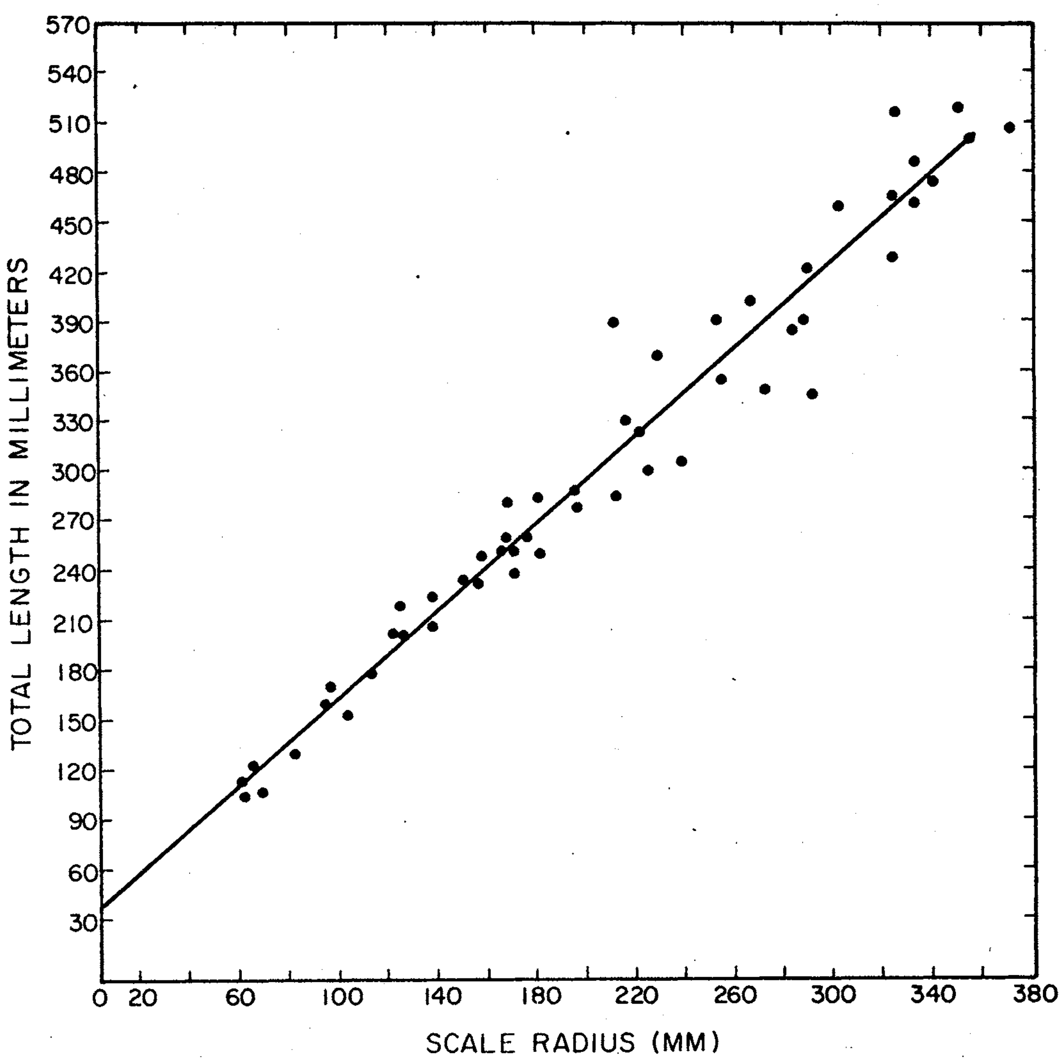

Figure 7. Relationship of Scale Radius to Total Body Length of Largemouth Bass in Lake Carl Blackwell

scale radius (S) measured in inches. A body-scale relationship calculated for bass in a California reservoir was Y = 0.89 + 0.0599X with fork length (Y) and scale radius (X) measured in inches (Tharratt, 1966). LaFaunce, Kimsey, and Chadwick (1964) also measured fork length and scale radius in inches to calculate the relationship: Y = 0.62 + 0.062X for largemouth bass in Sutherland Reservoir, California. Thompson (1964) calculated for bass in Clear Lake, Iowa a body-scale relationship of Y = 1.00 + 1.496X (r = 0.969) with total length and scale radius measured in inches.

Age and Growth

Age and Growth of Recaptured Bass

Age I bass recaptured before they over-wintered gained an average of 27 g (0.7 g/day) and increased an average of 11 mm (0.3 mm/day) during an average of 39 days (Table XVI). Weight change ranged from -85 g (-2.2 g/day) to +170 g (4.4 g/day). Change in total length varied from 0.0 mm to 60 mm (1.5 mm/day). These changes occurred in bass during the summer months of 1968-69. No bass were included in this stratum that had over-wintered after tagging. Age II tagged bass gained an average of 79 g (1.7 g/day) and increased an average of 13 mm (0.3 mm/day) during an average of 46 days. Age II bass had a greater increase in weight and length than any other age group. Some bass in all age groups lost weight between tagging and recapture, but only age IV-VI bass had a net weight loss. Age VII bass did not lose weight but sample size was small. Greatest variation occurred in age V bass, ranging from a 340 g loss (9.4 g/day) to a 738 g gain (20.5 g/day).

TABLE XVI

CHANGE IN TOTAL LENGTH (MM) AND WEIGHT (G) DURING TIME BETWEEN TAGGING AND RECAPTURE OF LARGEMOUTH BASS RECAPTURED BEFORE OVER-WINTERING

Age	Sample Size	Change in Total Length (mm)		Relative[1] Change mm/day	Change in Weight (g)		Relative[2] Change g/day	Mean Days Between Tagging and Recapture
		Mean	Range		Mean	Range		
I	27	+11	0 - +60	+0.3	+27	-85 - +170	+0.7	39
II	23	+13	0 - +83	+0.3	+79	-85 - +369	+1.7	46
III	9	+03	0 - +19	+0.1	+34	-85 - +198	+0.8	42
IV	15	+02	-4 - +20	+0.1	-100	-199 - +113	-2.9	34
V	14	+00	-4 - +2	-	-28	-340 - +738	-0.8	36
VI	9	+02	0 - +11	+0.0	-91	-313 - +113	-2.0	46
VII	1	+02	+2	+0.1	00			16
Total	98							

[1]Average change in total length per day, based on average time between tagging and recapture.

[2]Average change in weight per day, based on average time between tagging and recapture.

Measuring error (maximum 4 mm) is assumed to account for the observed decrease in total length of some age IV and age V bass, where the mean growth in total length for the year-classes was positive. Since bass in Lake Carl Blackwell usually spawn at the beginning of their third summer (age II), the observed decrease in weight may have been caused by maturation and release of gametes or by variation in stomach fullness and tagging. Sample sizes were too small to conclude that all bass >III years old in Lake Carl Blackwell lost weight. Tag loss decreased the sample size in this stratum because weight change could not be determined from a recaptured bass lacking its numerical tag.

Weight loss also occurred in recaptured bass >III years old after they had over-wintered (Table XVII). Weight gain by age VI bass is based on one fish. Age VI bass that over-wintered after tagging had the greatest weight increase (312 g, 1.0 g/day) during 310 days. Age I bass that over-wintered had the second greatest weight increase (53 g, 0.3 g/day) during an average of 204 days. Net loss in weight of 40 g (0.1 g/day) and 151 g (0.6 g/day) occurred in age IV and age V bass, respectively. No age VII bass were recaptured after they had over-wintered.

Little growth occurred during winter months (Tables XVI and XVII). Strawn (1961) observed that the maximum growth rate of bass fry occurred in water temperatures from 27.5 C. (81.5 F.) to 30 C. (86 F.) and decreased above and below this range. In Lake Carl Blackwell, 27.5-30 C. occurs in June, July, August, and September (Figure 4). Observed slow growth of over-wintering bass (October-May) supports the expected correlation between growth rate and water temperature. Lambow (1958)

TABLE XVII

CHANGE IN TOTAL LENGTH (MM) AND WEIGHT (G) DURING AVERAGE TIME BETWEEN TAGGING AND RECAPTURE OF LARGEMOUTH BASS RECAPTURED AFTER OVER-WINTERING

Age	Sample Size	Change in Total Length (mm) Mean	Range	Relative Change[1] mm/day	Change in Weight (g) Mean	Range	Relative Change[2] g/day	Mean Days Between Tagging and Recapture
I	31	+13	-2 - +88	+0.1	+53	-085 - +454	+0.3	204
II	7	+06	+1 - +14	0.0	+16	-114 - +113	+0.1	226
III	9	+04	+1 - +20	0.0	+22	-199 - +198	+0.1	220
IV	5	00	00	-	-40	-199 - +085	-0.1	270
V	6	00	00	-	-151	-710 - +085	-0.6	240
VI	1	+05	+ 5	0.0	+312	000	+1.0	310
Total	60							

[1]Average change in total length per day, based on average time between tagging and recapture.

[2]Average change in weight per day, based on average time between tagging and recapture.

observed no growth in young bass after October in Louisiana lakes. Kramer and Smith (1960) reported that temperature was the most important parameter affecting growth rate of bass during their first summer, with no differences in the growth rate of males and females. Pardue and Hester (1966) observed that male bass grew at a faster rate than females during the first year and attained sexual maturity at a smaller size. Sex may have contributed to the variability of growth rates, but temperature was assumed the most important variable in Lake Carl Blackwell.

Age and Growth of All Bass

Time of annulus formation was determined from scales of recaptured bass that had over-wintered since tagging. In most bass, the annulus was formed by May.

Back calculated growth of largemouth bass for Oklahoma reservoirs has been validated in several studies, including the report by Jenkins and Hall (1953). Annuli on scales of bass in Louisiana were observed to correspond well to known age bass (Muncy, 1965). Prather (1966) observed that 83.8% of annuli on bass scales in Alabama corresponded to known age of the fish. Caldwell, Odum, Hellier, and Berry (1955) observed annuli formed in winter on Florida bass, even without a change in water temperature. They attributed this to a change in photoperiod.

Back-calculated lengths of age I bass captured in 1968 averaged 151 mm (Table XVIII). Average annual increment was 132 mm from I to II years, 81 mm between years II and III, 53 mm between years III and IV, 34 mm between years IV and V, 23 mm between years V and VI, and 7 mm between years VI and VII.

TABLE XVIII

MEAN CALCULATED TOTAL LENGTH (MM) AT END OF EACH YEAR OF LIFE AND 95% CONFIDENCE LIMITS OF LARGEMOUTH BASS IN LAKE CARL BLACKWELL CAPTURED IN 1968

Year Class	Age Group	Number of Fish	I	II	III	IV	V	VI	VII
1967	I	267	128 ± 3						
1966	II	68	150 ± 5	283 ± 7					
1965	III	64	148 ± 10	287 ± 8	374 ± 7				
1964	IV	54	156 ± 12	287 ± 9	373 ± 8	431 ± 7			
1963	V	35	153 ± 19	277 ± 18	370 ± 12	429 ± 11	465 ± 10		
1962	VI	10	176 ± 58	296 ± 36	373 ± 26	431 ± 24	469 ± 21	493 ± 18	
1961	VII	2	145 ±276	267 ±468	329 ±148	375 ±103	420 ±205	455 ± 64	481 ± 96
Unweighted Means			151	283	364	417	451	474	481
Mean Annual Increment			151	132	81	53	34	23	7
Number of Fish			500	233	165	101	47	12	2

Growth increments for bass captured in 1969 were basically the same as the ones captured in 1968, except for age VI and VII bass (Table XIX). The increment between these two age groups was 22 mm in 1969 (n = 10) compared with 7 mm in 1968 (n = 2).

Growth in the first year of life for bass in Lake Carl Blackwell was 151 mm in 1968 and 148 mm in 1969. These growth rates were greater than those calculated for age I bass in some Oklahoma waters (Jenkins and Hall, 1953; Jenkins, 1949; Jenkins, Leonard, and Hall, 1952; and Finnell, 1954) (Table XX), but were less than the average total length of age I bass in Grand Lake, Lake Eucha, and Spavinaw Lake, Oklahoma (Thompson, 1950; Jackson, 1965). The average total length of 151 and 148 mm was also less than that calculated for I year olds in Bull Shoals Reservoir, Missouri (Hanson, 1962), but was approximately the same calculated by Applegate, Mullan, and Morais (1966) for the same reservoir several years later. Norris Reservoir in Tennessee, Louisiana waters, and Sutherland Reservoir, California, also had greater growth in the first year than calculated for Lake Carl Blackwell bass (Calhoun, 1966; Muncy, 1965). Total length averages for age I bass were less for waters in Montana, Iowa, Minnesota, Wisconsin, Michigan, Ohio, Connecticut, and Massachusetts than those calculated in the present study (Table XX). Bass in Montana ponds did not reach 454 g until the sixth or seventh year (Brown and Logan, 1960).

Total length at the end of second year of life for bass in Lake Carl Blackwell was 283 mm in 1968 and 286 mm in 1969. Total lengths of 283 and 286 mm by the end of the second year of life in Lake Carl Blackwell were greater than most reported in other waters (Table XX), except in Lake Eucha and Spavinaw Lake, Oklahoma (Jackson, 1965); Norris

TABLE XIX

MEAN CALCULATED TOTAL LENGTH (MM) AT END OF EACH YEAR OF LIFE AND 95% CONFIDENCE LIMITS OF LARGEMOUTH BASS IN LAKE CARL BLACKWELL CAPTURED IN 1969

Year Class	Age Group	Number of Fish	I	II	III	IV	V	VI	VII
1968	I	102	129 ± 6						
1967	II	219	131 ± 3	269 ± 4					
1966	III	52	148 ± 9	290 ± 8	368 ± 15				
1965	IV	101	156 ± 9	291 ± 7	375 ± 5	425 ± 5			
1964	V	94	162 ± 11	286 ± 9	366 ± 7	425 ± 6	460 ± 5		
1963	VI	46	153 ± 16	285 ± 13	368 ± 12	422 ± 10	466 ± 8	485 ± 21	
1962	VII	10	160 ± 33	292 ± 26	379 ± 17	429 ± 18	463 ± 17	487 ± 16	508 ± 15
Unweighted Means			148	286	371	425	463	486	508
Mean Annual Increment			148	138	85	54	38	23	22
Number of Fish			624	522	303	251	150	56	10

TABLE XX

CALCULATED TOTAL LENGTH IN MILLIMETERS OF LARGEMOUTH BASS AT EACH ANNULUS IN DIFFERENT AREAS OF THE UNITED STATES

Authors	Location	Age (Years)												
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Jenkins & Hall, 1953	Oklahoma	139	246	317	378	434	472	505	531	574				
Jenkins, 1949	Oklahoma	114	216	323	378	442	467	505						
Jenkins, Leonard & Hall, 1952	Oklahoma	117	198	264	333	401	503							
Jenkins, Leonard & Hall, 1952	Oklahoma	94	198	264	335	378	472	526						
Jenkins, Leonard & Hall, 1952	Oklahoma	127	203	282	315	355	381	406	424					
Jenkins, Leonard & Hall, 1952	Oklahoma	-	201	351	391	455	498							
Thompson, 1950	Oklahoma	160	269	358	411	467	498							
Jackson, 1965	Oklahoma	163	302	386	424	480	508	546	574					
Jackson, 1965	Oklahoma	155	295	355	416	495	528	544	561	574				
Finnell, 1954	Oklahoma	124	193	282	351	404								
Applegate, Mullan & Morais, 1966	Missouri	152	211											
Hanson, 1962	Missouri	165	282	361	388	409	426	439	449					
Stroud, 1959	Tennessee	142	259	328	328	363	386							
Calhoun, 1966	Tennessee	175	309	373	409	444	490	528						
Schoffman, 1962	Tennessee	-	239	278	309	340	367	397	463	475	508	536	-	565
Muncy, 1965	Louisiana	208	264	292	355	388	498							
Calhoun, 1966	California	170	299	376	479	477								
Calhoun, 1966	California	107	206	295	261	449	462	469						
Tharratt, 1966	California	147	274	338	381	416	447							
Brown & Logan, 1960	Montana	48	96	145	195	201	292	328	351	373	351			

TABLE XX (Continued)

Authors	Location	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Thompson, 1964	Iowa	104	242	327	376	405	431	453	480	469				
Calhoun, 1966	Minnesota	89	170	236	292	333	383	414	447	459				
Calhoun, 1966	Minnesota	94	178	266	317	371	414	444	455	511				
Calhoun, 1966	Wisconsin	86	168	231	282	317	353	396						
Threinen & Mraz, 1954	Wisconsin	91	168	231	277	302	335	404	457	-	-	-	549	
Mraz & Threinen, 1955	Wisconsin	91	170	228	272	304	345	411	452	467	477	498	521	511
Bennett, 1937	Wisconsin	71	165	246	297	335	353	386	424	449	469	490	485	490
Bennett, 1937	Wisconsin	94	221	302	343	378	411	439	464	485	500	490	508	
Lagler & DeRoth, 1952	Michigan	84	162	239	295	330	356	378	442					
Calhoun, 1966	Michigan	-	168	241	297	333	366	391	419	455	457	477		
Calhoun, 1966	Ohio	89	178	249	297	356	391	416	457					
Calhoun, 1966	Connecticut	129	211	272	328	373	411	444						
Calhoun, 1966	Massachusetts	102	233	325	381	416	444	467	477	439				
Grice, 1959	Massachusetts	94	152	206	351									

Fork Length measurements were converted to total length by: TL = 1.04 F.L.

Reservoir, Tennessee, and Sutherland Reservoir, California (Calhoun, 1966). Total length at the end of the third year of life was 364 mm in 1968 and 371 mm in 1969 in Lake Carl Blackwell. These were less than those for Lake Eucha, Oklahoma (Jackson, 1965); Norris Reservoir, Tennessee, and Sutherland Reservoir, California (Calhoun, 1966). Total length at the end of the fourth year of life was 425 mm in 1969 in Lake Carl Blackwell. This size was greater than growth of bass in all waters but Sutherland Reservoir, California (Calhoun, 1966). The 463 mm length for age V bass in 1969 in Lake Carl Blackwell was less than those reported for Grand Lake, Oklahoma (Thompson, 1950); Lake Eucha and Spavinaw Lake, Oklahoma (Jackson, 1965), and Sutherland Reservoir, California (Calhoun, 1966). The 486 mm length for age VI bass in 1969 in Lake Carl Blackwell was less than those reported for Illinois River, Oklahoma (Jenkins, Leonard, and Hall, 1952); Grand Lake, Oklahoma (Thompson, 1950); Lake Eucha and Spavinaw Lake, Oklahoma (Jackson, 1965); Norris Reservoir, Tennessee (Calhoun, 1966), and Louisiana (Muncy, 1965). The total length for age VII bass in 1969 in Lake Carl Blackwell was 508 mm. This was less than those reported for Claremore Lake, Oklahoma (Jenkins, Leonard, and Hall, 1952); Lake Eucha and Spavinaw Lake, Oklahoma (Jackson, 1965), and Norris Reservoir, Tennessee (Calhoun, 1966).

Largemouth bass growth rates in Lake Carl Blackwell were generally as good or better than the growth rates in Missouri, Tennessee, Louisiana, California, and other Oklahoma waters and better than growth rates in the north and northeastern part of the United States (Table XX).

Number of bass represented in each age group varied between the 1968 and 1969 samples (Tables XVIII and XIX). A larger percentage of bass was >III years old in the 1969 sample (40.2%) than in the 1968 samples (20.2%).

Coefficient of Condition

Coefficient of condition (K_{TL}), condition factor or ponderal index, is a length/weight relationship which expresses for comparative purposes the degree of "well-being", relative robustness, plumpness or fatness in numerical terms.

Average K_{TL} calculated for age I + II bass for June, July, August, September, October, and November were not significantly different ($P > .05$, $t_{12d.f.} = 1.586$) from those calculated for the same group for March, April, and May (during spawning season) (Table XXI). The same comparison for V, VI + VII year old bass was not significantly different ($P > .05$, $t_{8d.f.} = 1.831$). Average K_{TL} for ages III + IV bass during the non-spawning months was significantly different ($P < .05$, $t_{11d.f.} = 2.536$) from those during the spawning season. A significant difference between K_{TL} during the spawning season compared with those for the rest of the year probably would have occurred for sexually mature female bass. However, no significant seasonal change in the K_{TL} could be determined for males and females combined.

The two largest K_{TL} values (1.72 and 1.68) were for V, VI + VII year old bass during the spawning season, April and May 1969. Increase in K_{TL} values during April and May for ages III + IV bass was not as great as the increases in K_{TL} for ages V, VI, and VII. The K_{TL} of the ages III + IV bass during April and May were significantly larger than

TABLE XXI

SEASONAL CHANGES IN MEAN CONDITION FACTOR AND CONFIDENCE LIMITS (α = .05) FOR LARGEMOUTH BASS IN LAKE CARL BLACKWELL, 1968-69

	K-Factor/Age Groups[2]			
Date	0+	I + II	III + IV	V, VI + VII
June 68	-[1]	1.30±.19 (4)	1.63±.11 (14)	1.59±.09 (15)
July 68	-	1.54±.12 (23)	1.53±.06 (19)	1.58±.10 (12)
Aug. 68	1.67±.37 (5)	1.45±.06 (53)	1.54±.05 (30)	1.63±.12 (10)
Sept. 68	1.19±.19 (6)	1.37±.05 (73)	1.46±.05 (17)	-
Oct. 68	-	1.35±.03 (121)	1.55±.04 (21)	1.48±.09 (6)
Nov. 68	1.22±.14 (3)	1.34±.06 (34)	-	-
March 69	-	1.35±.06 (26)	1.60±.28 (5)	-
April 69	-	1.28±.04 (81)	1.60±.03 (49)	1.72±.05 (40)
May 69	-	1.42±.07 (40)	1.60±.05 (46)	1.68±.04 (72)
June 69	-	1.42±.15 (10)	1.54±.09 (15)	1.54±.10 (9)
July 69	1.25±.09 (5)	1.47±.07 (21)	1.52±.08 (13)	1.52±.10 (4)
Aug. 69	1.15±.11 (16)	1.48±.09 (23)	1.46±.09 (10)	1.55±.14 (8)
Sept. 69	1.11±.03 (57)	1.53±.04 (43)	1.61±.14 (4)	-
Oct. 69	1.20±.04 (92)	1.49±.04 (72)	1.50±.22 (4)	1.60±.13 (12)
Nov. 69	1.12±.19 (5)	-	-	-
Grand Average	1.24	1.41	1.55	1.59

[1]Dash indicates no bass of the particular age group was collected during the month.

[2]Number in parenthesis is sample size.

overall average for all months. The lowest K_{TL} value for ages I + II bass was in April 1969 (1.28). Some age II bass did spawn during 1969, but average K_{TL} for age II fish did not increase in April as did K_{TL} in III + IV and V + VI + VII year old bass, which may indicate that older bass were responsible for the greatest portion of spawning in 1969.

Age 0+ bass, with a grand K_{TL} average of 1.24, were significantly different ($P < .01$, $t_{20d.f.} = 3.121$) from the grand K_{TL} average of 1.41 for ages I + II bass (Table XXI and Figure 8). The grand K_{TL} average of 1.41 for ages I + II bass was also significantly different ($P < .001$, $t_{25d.f.} = 4.922$) from the grand K_{TL} average of 1.55 for ages III + IV. The grand K_{TL} average of 1.55 for ages III + IV was not significantly different ($P > .05$, $t_{21d.f.} = 1.549$) from the grand K_{TL} average of 1.59 for the combined ages V + VI + VII. Muncy (1965) observed that the C-factor (weight measured in pounds and total length in inches) for largemouth bass in Louisiana increased with fish age. I, II, and III year old bass had C-factors of 42, 46, and 58, respectively, in one lake and 44, 56, and 61 for I, II, and III year old bass, respectively, in a second lake. These differences probably would not have been as great had he sampled bass in age groups IV and older.

K_{TL} values were compared for bass recaptured before and after over-wintering. K_{TL} values were less in the over-wintered recaptures for all three age strata, but were not significantly different ($P > .0001$, $t_{4d.f.} = 0.8572$) from K_{TL} values for bass that did not over-winter (Table XXII). Slight decreases in the K_{TL} values may have been caused by loss of weight during the winter, since bass are known to lose weight during periods of low temperatures. K_{TL} values may have been influenced by the time relationship between tagging and recapture. Recaptured bass

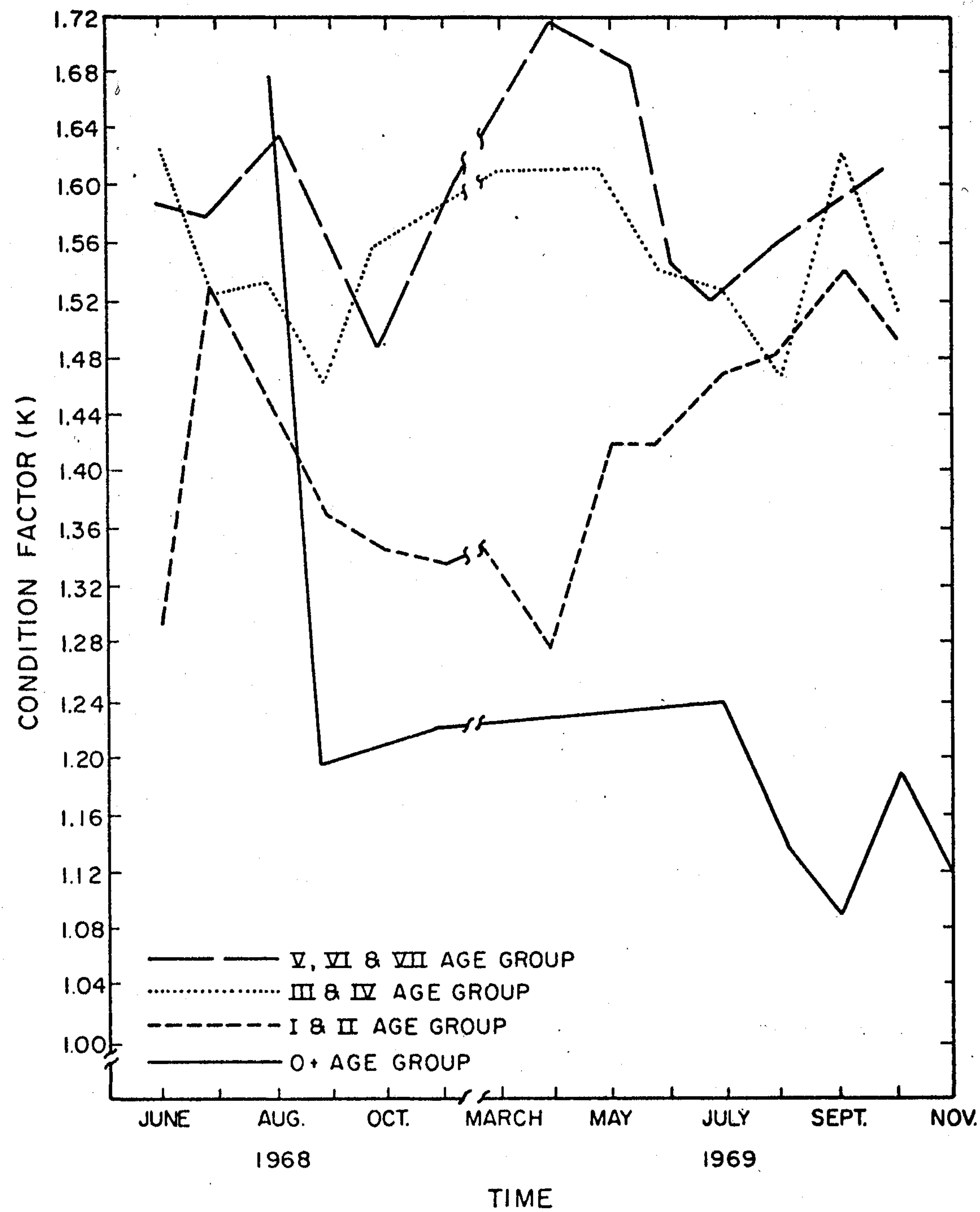

Figure 8. Seasonal Variation of Mean Condition Factor for Largemouth Bass in Lake Carl Blackwell, 1968-69

of ages I + II did have a lower K_{TL} than bass at time of tagging, 1.34 and 1.44, respectively (Table XXIII). K_{TL} values of the recaptured bass of the other two age strata (III + IV, and V + VI + VII) were larger, 1.67 and 1.65, respectively, but were not significantly different ($P > .001$, $t_{4d.f.} = 0.4334$). Therefore, the loss of weight (decrease in K_{TL}) in the over-wintered bass was assumed to have been caused by natural conditions (cold temperatures) and not due to the tagging procedure. The process of tagging and handling was assumed to have no affect on the K_{TL} of the bass in Lake Carl Blackwell.

TABLE XXII

MEAN CONDITION FACTOR AND CONFIDENCE LIMITS ($\alpha = .05$) OF RECAPTURED BASS THAT OVER-WINTERED COMPARED WITH BASS RECAPTURED BEFORE OVER-WINTERING

Months Combined for Recaptures	Age Groups	Over-Wintered	Not Over-Wintered
April, May, June & July	I + II	1.30±.06 (16)[1]	1.41±.05 (24)
March, April, May, June & July	III + IV	1.46±.08 (16)	1.50±.06 (24)
March, April, May, Aug. & Sept.	V, VI + VII	1.54±.14 (12)	1.64±.07 (24)

[1]Numbers in parenthesis are sample sizes.

TABLE XXIII

MEAN CONDITION FACTOR AND CONFIDENCE LIMITS ($\alpha = .05$) OF TAGGED AND UNTAGGED BASS

Months Combined	Age Groups	K-Factor of Tagged Bass	K-Factor of Untagged Bass
March, April, May, June & July	I + II[1]	1.34±.08 (29)[2]	1.44±.05 (50)
March, April, May, June & July	III + IV	1.67±.12 (16)	1.56±.07 (24)
March, April, May, Aug. & Sept.	V, VI + VII	1.65±.12 (12)	1.62±.07 (24)

[1]Only II year olds were included to calculate the K-Factor for the recaptured bass.

[2]Numbers in parenthesis are sample sizes.

The range in K_{TL} values for bass in Lake Carl Blackwell was generally lower than reported in the literature. Beckman (1945) calculated K_{SL} values of 2.31 for 46 mm bass and 2.27 for 392 mm bass in Michigan waters. K_{TL} values for largemouth bass in Florida ranged from 1.29 to 1.83, with weight measured in grams and length in millimeters (Clugston, 1964). These compare favorably with K_{TL} values calculated for bass in this study. Jenkins (1955) measuring length in inches and weight in pounds, calculated C_{TL} values of 39, 40, 43, 45, 46, 47, 49, and 50 for bass in the 4, 5, 6, 7, 8, 9, 10, and 11 inch groups, respectively. The C_{TL} values for bass in Iowa ranged from 50.2 to 69.2 (Thompson, 1964).

Total Mortality Rates

Mortality rate is the sum of fishing and natural mortality. It is complementary to survival rate and was estimated using catch curves. Assumptions made in using catch curves were: (a) survival rate was uniform with age calculated over the range of age-groups in question, (b) fishing and natural mortality, individually, were uniform or varied compensatorily, (c) there had been no change in the mortality rate with time, (d) the sample was taken randomly from the age-groups involved, and (e) the age-groups in question were equal in numbers at the time each was being recruited to the fisher (Ricker, 1958).

Monthly variation in rate of natural mortality was not determined. Therefore, uniformity of natural mortality during the six months (April-September) when sampling was most intense, was not measured, but was assumed to be constant with time. Fishing mortality, discussed in a later section, was greatest during April and May.

Only 58 young-of-the-year bass were collected in 1968 and 126 young-of-the-year in 1969 (Figure 9). There may have been a larger number of young-of-the-year in the summer of 1969 than in 1968. Young bass were difficult to see in turbid water and when observed, were usually found entangled in aquatic vegetation, consequently they were less likely to be collected than larger bass. Human bias of netting larger before smaller bass also probably contributed to a lower percentage capture of small bass than their actual abundance. The 1967 year-class (age I) was more abundant in 1968 sample than the 1968 year-class (age O+), suggesting that young-of-the-year bass are not as vulnerable to capture by electrofishing as older fish or the 1967 year-class was more numerous than the 1968 year-class.

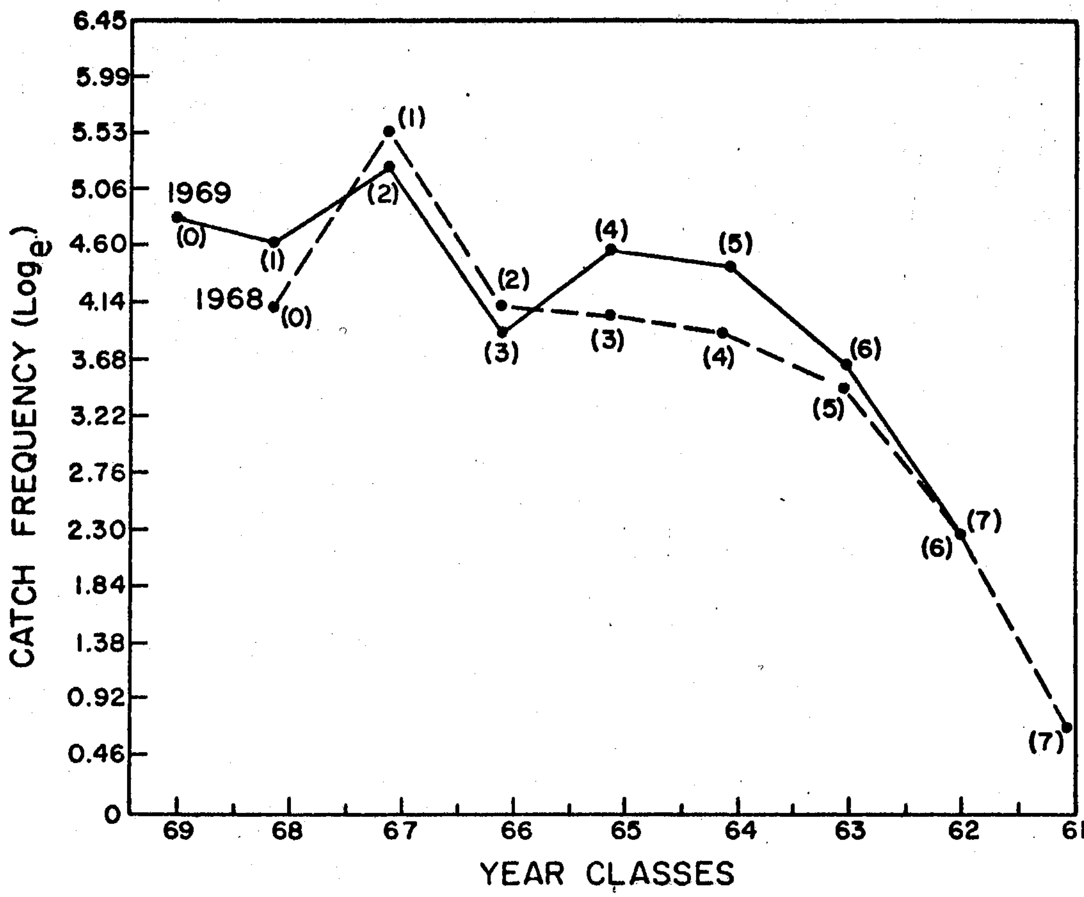

Figure 9. Number of Largemouth Bass in Successive Year-Classes in Lake Carl Blackwell, 1968-69

Assuming recruitment remains constant from year to year, year-class numbers should decrease with increase in age. However, the 1967 year-class (age II) was more abundant in 1969 than either the 1968 (age I) or 1969 (age 0+) year-classes (Figure 9). Even with two years of mortality acting on the 1967 year-class, they were more abundant than the 1968 year-class which was subjected to one year of mortality and the 1969 year-class which was subjected to a few months of mortality. This indicates that a strong year-class of bass may have occurred in 1967 or that age dependent vulnerability to the collecting device accounts for the apparent increase in number of the 1967 year-class.

Kramer and Smith (1962) observed that year-class strength of largemouth bass in Minnesota waters is determined during egg deposition and two week old fingerlings. They found that wind action had the greatest effect on year-class strength, and that illumination, dissolved oxygen, total alkalinity, hydrogen ion concentration, cannibalism, predation, food habits, growth rate, and condition of bass were not as important in determining year-class strength. Jurgens and Brown (1954) also observed that wind action was detrimental to the development of bass spawns. With wind action being prevalent in Lake Carl Blackwell, year-class strength may have varied during 1967 through 1969.

There was an increase in the number of IV, V, and VI year old bass in the 1969 sample compared with their density in 1968 sample when they were III, IV, and V years old, respectively. This increase was assumed to have been caused by a disproportioned catch of older, sexually mature fish during the spawning season in 1969 and not in 1968 when samples were not collected during the spawning season. There was no increase in age II and age III bass in the 1969 sample, which were I and II years old in 1968 sample, respectively. Some age II and age III bass were sexually mature and spawned in 1969, but the majority of the spawning population was probably composed of older bass. This supplements data obtained from the K_{TL} values, which indicated IV, V, and VI year old bass were responsible for the majority of spawning in Lake Carl Blackwell.

Annual survival rates were estimated to be 0.5288 in 1968 and 0.5964 in 1969 by Robson-Chapman's method (Table XXIV); 0.4678 for 1968 and 0.5918 for 1969 by Jackson's method; and 0.4660 for 1968 and 0.5804 for 1969 by Heincke's method.

Including age I bass in the estimate for 1969, a survival rate of 0.8502 was obtained by Jackson's method, compared with 0.5918 when age I bass were omitted. A survival rate of 0.8365 was obtained by Heincke's method with age I bass included, compared with 0.5804 with age I fish omitted.

Total instantaneous mortality rate (i) ranged from 0.5175 for Robson-Chapman's estimate in 1969 to 0.7636 for Heincke's estimate in 1968 (Table XXIV). Total instantaneous mortality rate for bass II years old and older in a California lake ranged from 1.51 to 0.80 (LaFaunce, Kimsey and Chadwick, 1964).

Robson-Chapman regarded their estimator of survival as better than the Heincke's estimator. Since the estimate of survival by Heincke's estimator was different from the estimate by Robson-Chapman, the discrepancy may lie in sampling error or in failure to satisfy one of the basic assumptions (Ricker, 1958). The survival estimate calculated for 1968 with Heincke's formula was significantly different

TABLE XXIV

ANNUAL SURVIVAL RATE, ANNUAL MORTALITY RATE, AND TOTAL INSTANTANEOUS MORTALITY RATE OF LARGEMOUTH BASS BASED ON THE I, II, III, IV, V, VI, AND VII AGE GROUPS SAMPLED, 1968-69, USING THREE DIFFERENT ESTIMATORS

Method	Date	Annual Survival Rate (s)	95% Upper Limit	95% Lower Limit	Annual Mortality Rate (a)	Total Instantaneous Mortality (i)
Robson-Chapman	1968	0.5288	0.5578	0.4998	0.4712	0.6368
Robson-Chapman	1969	0.5964	0.6232	0.5696	0.4036	0.5175
Jackson	1968	0.4678	-[1]	-	0.5322	0.7593
Jackson	1969	0.5918	-	-	0.4082	0.5243
Heincke	1968	0.4660	-	-	0.5449	0.7636
Heincke	1969	0.5804	-	-	0.4196	0.5447

[1]No confidence limits were calculated for the Jackson and Heincke estimates.

($P < .05$, $X^2_{1d.f.} = 14.99$) from the survival estimate made with Robson-Chapman's formula (Table XXV). Heincke's estimator produced a smaller survival rate than Robson-Chapman's estimator, and the discrepancy between the two estimates seems to lie in the disproportioned collection of younger age bass. When comparing only age groups V, VI, and VII, the difference between the two estimates was non-significant ($P > .05$, $X^2_{1d.f.} = 0.57$). The difference between the two estimates in 1969 was non-significant ($P > .05$, $X^2_{1d.f.} = 0.80$).

Based on the 1968 collections, the highest instantaneous mortality rates were for the I, V, and VI year olds and the smallest for age II fish (Table XXVI). Fry mortality was not calculated. Mortality rate increases continuously for fish II years and older. At age VI, the mortality was greater than age I fish. Because of the increase in older bass in samples during 1969, the 1968 mortality rates are assumed to be more accurate and were used in the production analysis.

Because estimated number of age I and III bass was greater in 1969 than estimates of 0+ and age II fish in 1968, no mortality rates could be computed for these age classes.

Robson-Chapman's estimates of total annual mortality were 47.0% in 1968 and 40.0% in 1969. Total annual mortality in Lake Carl Blackwell was lower than most other mortality estimates reported for largemouth bass (Table XXVII). Total annual mortality ranged from 83.0% for a California lake (LaFaunce, Kimsey, and Chadwick, 1964) to 24.0% for a Wisconsin lake (Mraz and Threinen, 1955). The average of the total annual mortality estimates cited in Table XVII is 63.2%.

TABLE XXV

CHI-SQUARE TEST OF DIFFERENCE BETWEEN HEINCKE'S AND ROBINSON & CHAPMAN'S METHODS OF CALCULATING SURVIVAL RATE

D.F.	Date	Ages Omitted	Robson & Chapman Survival Estimate	Heincke Survival Estimate	Calculated Chi-Square Values
1	1968	none	0.5288	0.4660	14.99[1]
1	1968	I	0.5849	0.7081	24.96[1]
1	1968	I, II	0.4969	0.6121	17.55[1]
1	1968	I, II, III	0.3788	0.4653	8.57[1]
1	1968	I, II, III, IV	0.2333	0.2553	0.57
1	1969	none	0.5964	0.5804	0.80

[1]Statistically significant at the .05 level.

TABLE XXVI

ANNUAL SURVIVAL RATE (s), ANNUAL MORTALITY RATE (a), AND TOTAL INSTANTANEOUS MORTALITY RATE PER AGE GROUP (i) BASED ON SAMPLES TAKEN DURING 1968-69. THE 1968 SAMPLE WAS COLLECTED FROM JUNE 1968 THROUGH NOVEMBER 1968 AND THE 1969 SAMPLE FROM MARCH 1969 THROUGH NOVEMBER 1969.

	1968			1969		
Age	Annual Survival Rate (s)	Annual Mortality Rate (a)	Total Instantaneous Mortality (i)	Annual Survival Rate (s)	Annual Mortality Rate (a)	Total Instantaneous Mortality (i)
I	0.2546	0.7454	1.3665	-[1]	-	-
II	0.9411	0.0589	0.0608	0.2374	0.7626	1.4397
III	0.8437	0.1563	0.1696	-[1]	-	-
IV	0.6481	0.3519	0.4339	0.9307	0.0693	0.0715
V	0.2857	0.7143	1.2518	0.4894	0.5106	0.7154
VI	0.2000	0.8000	1.6095	0.2174	0.7826	1.5279

[1]There was an increase in number of bass for the I and III year olds in 1969 compared with the 0+ and II year olds in 1968.

TABLE XXVII

FISHING, NATURAL, AND TOTAL ANNUAL MORTALITY (PERCENTAGE) OF LARGEMOUTH BASS IN OTHER LENTIC ECOSYSTEMS

Authors	Locality and Water Type	Mortality		
		Fishing	Natural	Total
Chance, 1955	Tennessee (Res.)	41.6[1]	-	-
Kimsey, 1956	California (Lake)	20.0	36.0	56.0
LaFaunce, Kimsey & Chadwick, 1964[2]	California (Lake)	20.0	48.0	68.0
		40.0	38.0	78.0
		47.0	26.0	73.0
		35.0	20.0	55.0
		48.0	35.0	83.0
Bennett, Adkins & Childers, 1969	Illinois (Lake)	1.5[3]	38.0[4]	-
		63.0	-	-
Cole, 1966	Arkansas (Lake)	32.0	38.0	70.0
Gerking, 1952	Indiana (Lake)	35.7	24.3	60.0
Threinen & Mraz, 1954	Wisconsin (Lake)	11.7	-	-
Mraz & Threinen, 1955	Wisconsin (Lake)	12.1	11.9	24.0
Maloney, Shupp & Scidmore, 1962	Minnesota (Lake)	15.0	54.9[5]	69.9
Cooper & Latta, 1954	Michigan (Lake)	26.0	44.0	70.0
Mraz & Cooper, 1957	Wisconsin (Pond)	-	-	51.5[6]
Present study[8]	Oklahoma (Res.)	1.2[7]	45.8	47.0
Present study[9]	Oklahoma (Res.)	1.2	38.8	40.0

[1]Percentage of tagged bass recaptured by hook-and-line.

[2]Estimates for 5 consecutive years.

[3]Range from 1941 through 1963.

[4]Average of Bennett's stratified natural mortality based on size strata.

[5]Bass IV years old.

[6]Average total mortality of stocked adult bass.

[7]Estimated from Table XXVIII.

[8]Based on 1968 data.

[9]Based on 1969 data.

Fishing Mortality

The first tagged bass returned by a fisherman was during August 1968, after 178 bass had been tagged in the population (Table XXVIII). Number of tagged bass in the population was adjusted for an average total, monthly, instantaneous, mortality rate of 0.0531 for 1968 and 0.0431 for 1969. These rates assume constant mortality during the year. Average total monthly instantaneous mortality rate was adjusted for a 22% tag loss.

Exploitation rate (u) ranged from 0.0018 for June and July 1969 to 0.0728 for April 1969. Only 13 tagged bass were returned during 1968, resulting in an instantaneous fishing rate (p) of only 0.00496 for August, September, and October 1968. No tagged bass were returned during November through March 1968-69 by fishermen.

The greatest number (33) of tagged bass captured by fishermen was during April 1969 (Table XXVIII), with instantaneous fishing mortality of 0.00777. The month of second greatest instantaneous fishing mortality (0.0326) was May 1969. Total instantaneous fishing mortality for April, May, June, and July was 0.01141. Total instantaneous fishing mortality was 0.01637 for seven months of 1968-69. Average monthly instantaneous fishing mortality for the seven months was 0.00234.

Fishing mortality may have been underestimated if the $1.00 reward was not sufficient incentive to obtain fishermen returns of tagged bass. Number of tagged bass returned may have increased with an increase reward and/or a more intensive creel census. Unawareness of the tagging study by the high percentage of non-local fishermen (43.3%) may have caused a low return of tagged bass. An average of 63.2% of the fishermen interviewed knew about the reward for tagged bass, in spite of

TABLE XXVIII

RATE OF EXPLOITATION (u) AND INSTANTANEOUS FISHING MORTALITY (p) PER MONTH, ALL AGES COMBINED, BASED ON TAG RETURNS BY FISHERMEN, 1968-69, PLUS ADJUSTMENT FOR TAG LOSS

Date	Number of[1] Tagged Fish Caught by Fishermen	Estimated[2] Number of Tagged Fish in Population	Rate of Exploitation (u)	Instantaneous Fishing Mortality (p)
1968				
Aug.	1	178	0.0056	0.00063
Sept.	7	268	0.0061	0.00294
Oct.	5	401	0.0124	0.00139
1969				
April	33	453	0.0728	0.00777
May	17	557	0.0305	0.00326
June	1	547	0.0018	0.00019
July	1	549	0.0018	0.00019
Total	65[3]			0.01637

[1]Adjusted for return of bass with lost tag.

[2]Adjusted for natural mortality and removal by fishermen.

[3]No bass were returned during the winter months (November-March).

posters, fishing licenses, local newspaper, and personal interviews acquainting fishermen with the reward. Of the 171 fishermen, 56.7%, 32.3%, and 11.1% were local, from Oklahoma City, or other areas, respectively.

Of the 171 fishermen interviewed, 13.8% were fishing for largemouth bass and 61.8% for channel catfish (Table XXIX). More fishermen fished for channel catfish than any other species. Local fishermen often said that Lake Carl Blackwell is good fishing for catfish but not largemouth bass.

Catch rate was highest for crappie (0.76 fish/hr) and lowest for largemouth bass (0.05 fish/hr). Catch rate for largemouth bass in Lake Carl Blackwell was slightly greater than the lowest recorded catch rate (0.04 fish/hr) for largemouth bass during fall fishing in a Missouri reservoir (Hanson, 1962), and greater than the lowest recorded for a California reservoir and a Michigan lake (LaFaunce, Kimsey, and Chadwick, 1964; Lagler and DeRoth, 1952) (Table XXX). A low catch rate would be expected from the calculated instantaneous fishing mortality estimate of 0.01637.

In a local bass contest held on 4 May 1969 at Lake Carl Blackwell, 30 men fishing from boats with artificial lures for 10 hours caught two largemouth bass. This was a catch rate of approximately 0.007 bass per hr assuming each fishermen fished during the entire contest. This catch rate, although a sample for only one day, does substantiate the apparent low catch rate for largemouth bass determined from the other creel surveys.

Exploitation rate for age I bass ranged from 0.017 to 0.050 for the 3 months in which age I bass were captured by fishermen (Table XXXI).

TABLE XXIX

PERCENTAGE OF FISHERMEN FISHING FOR THE FOUR MOST UTILIZED SPORT SPECIES IN LAKE CARL BLACKWELL, CATCH RATE (NO./HOUR), AND TOTAL FISHING PRESSURE (HOURS), BASED ON INTERVIEWS IN 1969

Date	Number of Fishermen Interviewed	Percentage of Fishermen Fishing for These Species				Catch Rate, No./Hour, for Species Shown				Total Fishing Pressure (Hours)
		Largemouth Bass	White Bass	Crappie	Channel Catfish	Largemouth Bass	White Bass	Crappie	Channel Catfish	
April 27	2	100.0	0.0	0.0	0.0	0.20	-[1]	-	-	5.0
May 4	19	0.0	15.8	57.9	21.0	-	1.50	1.70	0(9.)[2]	37.0
May 27	3	0.0	0.0	100.0	0.0	-	-	1.70	-	4.0
June 8	8	0.0	0.0	0.0	100.0	-	-	-	0.09	21.0
July 19	12	0.0	16.7	0.0	83.3	-	0.00	-	0.08	15.0
July 26	12	12.5	16.7	0.0	70.8	0(.5)	0.95	-	0.31	113.0
July 27	15	13.3	13.3	0.0	73.4	0(3.)	0.50	-	1.29	31.5
Aug. 23	20	0.0	12.5	0.0	67.5	-	0.80	0.23[3]	0.20	132.5
Aug. 24	10	10.0	70.0	0.0	20.0	0(.5)	0.64	-	6.00	18.0
Aug. 30	29	39.7	0.0	0.0	60.3	0(1.)	0.59(3)	0.24[3]	1.21	112.0
Sept. 1	41	13.4	2.4	12.2	72.0	0(14)	0.25	0.32	0.64	102.5
Total	171									591.5
Weighted Mean		13.8	10.9	11.1	61.8	0.05	0.73	0.76	0.50	53.8

[1]Species was not fished for.

[2]0 indicates zero catch and number in parenthesis indicates time of fishing in hours.

[3]Caught coincidental while fishing for other species.

TABLE XXX

FISHING PRESSURE, YIELD PER ACRE, AND YIELD PER HOUR FOR LARGEMOUTH BASS IN OTHER LENTIC ECOSYSTEMS

Authors	Location and Water Type[1]	Annual Fishing Pressure Per Acre	Annual Yield Per Acre		Annual Yield Per Hour	
			Numbers	Pounds	Numbers	Pounds
Jackson, 1965	Okla. (2)	-	9.0	15	0.23	.41[2]
	Okla. (2)	-	1.7	3	0.08	.17[2]
Hanson, 1962	Mo. (1)	-	-	-	.04-0.10[3]	-
Byrd & Crance, 1965	Ala. (2)	-	8.0-104.0[3]	11- 62[4]	-	-
Dendy, 1956	Ala. (3)	-	-	42	-	-
McConnell, 1963	Ariz. (2)	400[5]	-	71-188	-	-
LaFaunce et al., 1964	Calif. (1)	-	-	-	.04-0.26[6]	-
					.06-1.21	.03-.72[7]
Hansen et al., 1960	Ill. (3)	-	-	-	.09-0.56	.05-.48[8]
Bennett, 1950	Ill. (3)	-	-	30-109	-	-
Bennett et al., 1969	Ill. (3)	296[9]	76.0	22	-	-
Threinen & Mraz, 1954	Wis. (2)	100[9]	6.7	4	0.06	.04
Mraz & Threinen, 1955	Wis. (2)	75[9]	6.7	4	-	-
Lagler & DeRoth, 1952	Mich. (2)	-	-	-	.04-0.25	-
Present study	Okla. (1)	-	-	-	0.05	-

[1] 1 = reservoirs, 2 = lakes, and 3 = ponds

[2] catch rates included spotted bass

[3] fall fishing rate only

[4] range of 20 lakes in Alabama

[5] angler days per acre

[6] during first 10 days of open season

[7] fertilized ponds

[8] unfertilized ponds

[9] man hours per acre per year

TABLE XXXI

RATE OF EXPLOITATION OF LARGEMOUTH BASS PER MONTH PER AGE GROUP, BASED ON TAG RETURNS BY FISHERMEN IN LAKE CARL BLACKWELL, 1968-69

Date	Number of Tagged Bass[1]							Number of Bass Caught[2]						Rate of Exploitation					
	0+	I	II	III	IV	V	VI+ VII	I	II	III	IV	V	VI+ VII	I	II	III	IV	V	VI+ VII
August 1968	5	57	21	27	35	24	8	1	-	-	-	-	-	.017	-	-	-	-	-
September 1968	7	101	40	40	40	26	10	5	-	1	-	-	-	.050	-	.025	-	-	-
October 1968	9	201	58	52	47	30	16	4	1	-	-	-	-	.020	.017	-	-	-	-
April 1969	0	43	291	73	73	65	46	-	23	4	3	3	2	-	.079	.055	.041	.046	.043
May 1969	0	43	313	80	100	99	64	-	14	-	1	1	-	-	.045	-	.010	.010	-
June 1969	0	43	315	82	104	101	68	-	1	-	-	-	-	-	.003	-	-	-	-
July 1969	0	47	330	83	110	102	69	-	-	1	-	-	-	-	-	.012	-	-	-
Total	0	47	330	83	110	102	69	10	39	6	4	4	2						

[1]Adjusted for natural and fishing mortality per age group.

[2]Adjusted for tag loss per age group per month.

Exploitation rate with all age strata considered, was lowest for age II bass during June 1969 (0.003) and highest for age II bass during April 1969 (0.079). For age III bass, exploitation ranged from 0.012 to 0.055, 0.010 to 0.041 for age IV bass, 0.010 to 0.046 for age V bass, and 0.043 for age VI + VII bass. Highest exploitation for all ages, except age I, was during April 1969.

Rate of exploitation decreased with age. Ten age I bass were returned from a total of 47 tagged, giving an exploitation rate of 0.213 (Table XXXI). A total of 39 age II bass were returned from a total of 330 tagged, giving an exploitation rate of 0.118. An exploitation rate of 0.072, 0.036, 0.039, and 0.029 was calculated for the III, IV, V, and VI + VII year olds, respectively. McConnell (1963) reported that the majority of largemouth bass harvested in an Arizona lake was in their second year of life.

Total instantaneous fishing mortality during the seven months for age I bass contributed only 1.7% ($p = 0.0133$) to the total instantaneous mortality rate compared with 98.3% ($q = 0.7833$) contributed by natural mortality (Table XXXII). For age II bass, fishing mortality contributed 33.1% ($p = 0.0123$) compared with 66.9% ($q = 0.0249$) contributed by natural mortality. Percentage of the total mortality contributed by fishing for the III, IV, V, and VI + VII year olds was 8.3%, 2.1%, 1.5%, and 0.8%, respectively. The greatest fishing mortality of largemouth bass in the reservoir was experienced by age II bass, yet a greater percentage of age II bass was removed by natural causes than by fishing.

TABLE XXXII

INSTANTANEOUS FISHING MORTALITY (p) AND INSTANTANEOUS NATURAL MORTALITY (q) BY AGE GROUP PER MONTH OF LARGEMOUTH BASS IN LAKE CARL BLACKWELL

Date		Instantaneous Fishing Mortality (p)[a] Per Age Group Per Month						Instantaneous Natural Mortality (q)[b] Per Age Group Per Month					
		I	II	III	IV	V	VI+VII	I	II	III	IV	V	VI+VII
August	1968	.0026	-	-	-	-	-	.1112	.0051	.0141	.0361	.1043	.1341
September	1968	.0076	-	.0022	-	-	-	.1062	.0051	.0119	.0361	.1043	.1341
October	1968	.0031	.0015	-	-	-	-	.1107	.0036	.0141	.0361	.1043	.1341
April	1969	-	.0067	.0049	.0042	.0067	.0072	.1138	c	.0092	.0319	.0976	.1269
May	1969	-	.0038	-	.0010	.0039	-	.1138	.0012	.0141	.0351	.1004	.1341
June	1969	-	.0003	-	-	-	-	.1138	.0048	.0141	.0361	.1043	.1341
July	1969	-	-	.0011	-	-	-	.1138	.0051	.0130	.0361	.1043	.1341
Total		.0133	.0123	.0082	.0052	.0106	.0072	.7833	.0249	.0905	.2475	.7195	.9315

[a] Based on the following relationship: $p = \frac{i\ u}{a}$

[b] Based on the relationship ($q = i-p$), with i per age group derived from the catch curve.

[c] Is a negative value, because the fishing mortality (p) for this particular month for the II year olds was greater than the total monthly instantaneous mortality rate (i).

Standing Crop, Production, and Yield

Calculated length-weight relationships for each age group were used to convert total length to weight for each age group for 1968 and 1969 samples (Table XXXIII).

Mean weight (g) of bass based on 1968 samples was 43, 309, 787, 1,205, 1,603, and 2,014 for age groups I, II, III, IV, V, and VI + VII, respectively. Weight per age group for 1969 samples was calculated by the same method and was similar to 1968 samples.

Jenkins (1955) calculated a length-weight relationship for bass in Oklahoma waters to be $\log W = -2.6979 + 3.3327 \log L$, with W = pounds and L = inches. In Michigan waters a length-weight relationship of $\log W = -4.6252 + 2.9927 \log L$ was calculated, where W = grams and L = standard length in millimeters (Beckman, 1945). Tharratt (1966) calculated a length-weight relationship of $\log W = -3.43716 + 3.163 \log L$, with W = pounds and L = fork length in inches for bass in a California lake. Also, a length-weight relationship of $\log W = -3.530 + 3.308 \log L$, with W = pounds and L = fork length in inches for bass was calculated in California by LaFaunce, Kimsey, and Chadwick (1964). Thompson (1964) calculated the length-weight relationship of $\log W = -1.13124 + 3.0910 \log L$, with W = pounds and L = inches for bass in an Iowa lake.

Total biomass at the beginning of the year for age I, II, III, IV, V, and VI + VII fish was 41.80, 76.63, 183.37, 237.39, 205.18, and 88.62 kg, respectively (Table XXXIV). Net change in biomass per age group was based on annual instantaneous growth and annual total instantaneous mortality rates. Annual instantaneous growth rates ranged from 1.9713 for age I to 0.1600 for ages VI + VII. Annual total instantaneous mortality rate ranged from 1.3665 for age I bass to 0.0608 for

TABLE XXXIII

LENGTH-WEIGHT RELATIONSHIP OF LARGEMOUTH BASS BY AGE GROUP IN 1968 AND 1969 COLLECTIONS, WEIGHTS (g) CALCULATED FROM THE LENGTH-WEIGHT RELATIONSHIPS, AND TOTAL LENGTH (mm) OBTAINED FROM BACK-CALCULATED DATA

Length-Weight Relationship	Age	Sample Size	Average Length (mm)	Average Weight (g)
1968				
Log W = -3.32 + 2.35 Log L	I	100	128	43
Log W = -5.55 + 3.28 Log L	II	65	283	309
Log W = -4.41 + 2.84 Log L	III	55	374	787
Log W = -5.06 + 3.09 Log L	IV	50	431	1205
Log W = -4.05 + 2.72 Log L	V	35	465	1603
Log W = -3.28 + 2.45 Log L	VI+VII[1]	12	487	2014
1969				
Log W = -4.81 + 2.99 Log L	I	90	129	31
Log W = -5.85 + 3.41 Log L	II	100	269	253
Log W = -5.06 + 3.10 Log L	III	35	368	786
Log W = -5.44 + 3.24 Log L	IV	70	425	1191
Log W = -5.17 + 3.15 Log L	V	75	460	1656
Log W = -4.10 + 2.75 Log L	VI+VII[1]	40	497	2060

[1]Ages VI and VII were combined to increase sample size.

TABLE XXXIV

NET CHANGE IN BIOMASS PER AGE GROUP OF LARGEMOUTH BASS IN LAKE CARL BLACKWELL, BASED ON A POPULATION SIZE OF 1,822 BASS

Age	Estimated Population Size	Estimated Total Biomass (W) (kilograms)	Instantaneous Growth Rate (g)	Total Instantaneous Mortality Rate (i)	Annual Mean Weight ($\overline{W}$) (kilograms)	Net Change in Biomass ($\overline{W}$(g-i))
0+		00.00				+ 41.80
I	972	41.80	1.9713	1.3665	57.43	+ 34.73
II	248	76.63	0.9322	0.0608	122.81	+107.02
III	233	183.37	0.4253	0.1696	208.97	+ 53.43
IV	197	237.39	0.2852	0.4339	220.44	- 32.78
V	128	205.18	0.2231	1.2518	128.09	-131.77
VI+VII	44	88.62	0.1600[1]	1.6095[2]	46.78	- 67.81
Total	1822	832.99			784.52	+ 4.62

[1]Instantaneous growth rate could not be determined (no VII year olds) and was taken to be 0.1600, the rate calculated for the VI year olds.

[2]Instantaneous mortality rate of the VII year olds could not be determined, so the mortality rate of the VI year olds was taken as the estimate of the combined VI+VII year olds.

age II bass. Biomass gain was greater than biomass lost for age 0+, I, II, and III fish. This is corroborated by a weight gain of recaptured age I, II, and III bass. Biomass lost was greater than biomass gained for bass >III years old (Table XXXIV). Mean biomass ($\overline{W}$) present was greatest for age IV bass (220.44 kg), but net production was a negative 32.78 kg. Age group III bass had a net production and a mean biomass of 208.97 kg. Greatest net gain was 107.02 kg for age II bass, accounting for 45.1% of the total net production. Comparison of production of the Lake Carl Blackwell bass with other fish populations indicates a general case of greater net production with younger age groups. Age I and age II brook trout, Salvelinus fontinalis (Mitchill) in a creek in Wisconsin accounted for 81-95% of annual production (Hunt, 1966). Gerking (1962) estimated that 58% of total production occurred in the two youngest age groups of bluegills.

Overall change in biomass of the reservoir was a net gain of 4.62 kg (.0057 g/m^2/year). Cooper, Hidu, and Anderson (1963) estimated gross production of 5 to 8 g/m^2/year of largemouth bass in a pond, but net production was not given because natural mortality was not estimated. Production estimates for other fish species have ranged from 54.7 g/m^2/year to negative values (Chapman, 1967).

Mean standing crop of largemouth bass > 176 mm was estimated to be 1.67 bass per ha (0.68 bass per acre) and 0.97 kg per ha (0.86 lb per acre) (Table XXXV). These are based on a mean population estimate ($\overline{N}$) of 1,348 bass. These standing crop estimates are lower than most published estimates (Table XXXVI). The lowest standing crop of large-mouth bass reported prior to this study for an Oklahoma lake was 1.1 kg/ha (Jenkins, 1955). The low end of the range for reservoirs from

TABLE XXXV

ESTIMATED NUMBER AND BIOMASS PER HECTARE OF LARGEMOUTH BASS IN LAKE CARL BLACKWELL, 1968

	Lake Carl Blackwell
Total surface area during 1968 (hectares)	807.77
Total surface area during 1968 (acres)	1996.00
Mean number of bass during 1968 ($\overline{N}$)[1]	1348.00
Mean number of bass per hectare	1.67
Mean number of bass per acre	0.68
Mean weight of bass during 1968 ($\overline{W}$) in kg	784.52
Mean weight of bass during 1968 ($\overline{W}$) in lbs	1729.54
Kg of bass per hectare	0.97
Lbs of bass per acre	0.86

[1] $\overline{N} = \frac{Na}{i}$ a = 0.4712 i = 0.6368. These values are taken from Table XXIV, Robson-Chapman estimates of 1968. N = 1822 bass.

TABLE XXXVI

STANDING CROP (KG/HA) OF LARGEMOUTH BASS IN OTHER LENTIC ECOSYSTEMS OF THE UNITED STATES

Authors	Location	Water[1] Type	Standing Crop (kg/ha)
Jenkins, 1955	Oklahoma	2	1.1 - 17.9
Swingle, 1950	Alabama	3	38.1 - 197.3[2]
Parsons, 1954	Tennessee	1	3.8
Patriarche, 1952	Missouri	1	7.4[3]
Carlander, 1955	Texas to Mass.	1	0.1 - 66.1
" "	Florida to Wis.	2	0.2 - 23.2
Meehean, 1941	Florida	2	7.4 - 18.0
Isaac & Bond, 1963	Oregon	3	17.3 - 409.9[4]
Carlander, 1951	Iowa	2	18.9
Speaker, 1948	Iowa	2	2.9
Fessler, 1950	Iowa	3	0.0 - 37.6
Bennett et al., 1969	Illinois	3	34.7 - 80.7
Hansen et al., 1960	Illinois	3	80.7
Gerking, 1962	Indiana	2	4.1 - 9.8
Moyle et al., 1949	Minnesota	2[9]	0.0 - 34.2
		2[10]	0.0 - 74.5
Mraz & Threinen, 1955	Wisconsin	2	37.3
Threinen, 1956	Wisconsin	2	4.3 - 20.0[5]
Threinen & Mraz, 1954	Wisconsin	2	33.6[6]
Ball, 1948	Michigan	2	1.1 - 173.8[7]
Lagler & DeRoth, 1952	Michigan	3	13.7 - 33.9
Taylor, 1950	West Virginia	2	10.3
Surber, 1947	West Virginia	3	88.1[8]
Present study	Oklahoma	1	1.4

[1] 1 = reservoirs, 2 = lakes, and 3 = ponds

[2] bass-bluegill combination

[3] catchable size bass only

[4] >101 mm bass

[5] >126 mm bass

[6] >151 mm bass

[7] includes smallmouth bass

[8] adult bass only

[9] game-fish lakes

[10] rough-fish lakes

Texas to Massachusetts was 0.1 kg/ha, and 0.2 kg/ha for lakes from Florida to Wisconsin (Carlander, 1955). Ball (1948) reported 1.1 kg/ha in some Michigan lakes. Low standing crop biomass in Lake Carl Blackwell was caused by a small number of bass and not by their growth rate, as their growth was average or above average for this geographical area (Tables XVIII, XIX, and XX).

Based on mean weight ($\overline{W}$) of 57.43 kg for age I bass (Table XXXIV) and an annual instantaneous fishing mortality rate of 0.0133 (Table XXXII), a total of 0.76 kg was lost to fishing (Table XXXVII). Age I bass lost 77.12 kg to natural mortality ($q = 1.3428$). Fishing contributed 1.51 kg and natural mortality 5.31 kg to the total biomass lost of age II bass. Age III bass lost 1.71 kg to fishing and 32.35 kg to natural mortality. Of gross production, 6.83 kg were removed by fishing and 441.15 kg eliminated through natural mortality. Fishing accounted for 1.5% of the total biomass loss.

Yield from fishing ranged from 0.34 kg, age VI + VII, to 1.71 kg, age III. The 0.34 kg harvested of age VI + VII bass was 0.5% of the total biomass loss in that age group. Percentage biomass harvested relative to total biomass lost was 22.1%, 5.0%, 1.2%, 0.9%, and 0.5% of age groups II, III, IV, V, and VI + VII, respectively. Percentage biomass harvested by fishing, compared with total biomass removed, decreased with increased age, for age groups >II.

TABLE XXXVII

AVERAGE WEIGHT ($\overline{W}$) (kg) OF LARGEMOUTH BASS, BIOMASS GAINED ($\overline{W}g$), LOST BY FISHING MORTALITY ($\overline{W}p$), LOST BY NATURAL MORTALITY ($\overline{W}q$), AND TOTAL MORTALITY ($\overline{W}i$) IN LAKE CARL BLACKWELL, 1968

Age	($\overline{W}$)	($\overline{W}g$)	($\overline{W}p$)	($\overline{W}q$)	($\overline{W}i$)
I	57.43	113.21	0.76	77.12	77.88
II	122.81	114.48	1.51	5.31	6.82
III	208.97	88.87	1.71	32.35	34.06
IV	220.44	62.87	1.15	93.64	94.79
V	128.09	28.58	1.36	158.01	159.37
VI+VII	46.78	7.48	0.34	74.72	75.06
Total	784.52	415.49	6.83	441.15	447.98

CHAPTER V

SUMMARY

Objectives of the study were to estimate density, mortality, movement, growth, and net production of largemouth bass in Lake Carl Blackwell, Oklahoma. Estimates of these population parameters give a better understanding of natural fish production and a base line for evaluating the production possible with a management program.

Largemouth bass were collected from June 1968 through November 1969, except during the winter months of 1968-69. An electrofishing apparatus was efficient for collecting bass from relatively shallow water up to one meter in depth. Gill nets and fish traps were used extensively during the study, but accounted for capturing only five of 1,333 bass collected in the study.

Lake Carl Blackwell has a surface area of 1,214.2 ha and a shoreline of 56.2 km at spillway level. Average surface area and shoreline distance during the study were estimated at 807.8 ha and 45.5 km, respectively, a reduction of 33.4% and 19.0%, respectively, of the dimensions at spillway.

A total of 1,001 bass was tagged during 163 electrofishing trips in Regions I, II, and III which were allocated samples at a 6:3:1 ratio. Actual distribution of samples was 6.4:2.8:0.8, respectively. One hundred of 1,001 bass were displaced to central release point to evaluate homing ability; the balance was released at the site of capture. Total number of recaptures of displaced bass was 46% of which 16.0% were recaptured once and 13.0% were recaptured at least twice. Multiple recaptures of non-displaced bass was 23.2% of 901 bass released at site of capture. Distance traveled between time of tagging and recapture of the displaced bass ranged from 1,083 to 3,208 m. Time between tagging and recapture ranged from 5 to 237 days. Distance traveled per day ranged from 14 to 217 m. Twenty-three per cent of the displaced bass returned ("homed") to the original capture site. Percentage of bass that were recaptured in the same area as tagged was greatest during August and September 1968-69. Only 16 of 206 tagged bass were recaptured out of the region in which they were originally tagged.

Gizzard shad and crayfish were the major food items utilized by largemouth bass. No differences were observed in food habits of bass of various sizes. Stomachs of 819 bass were examined by gastroscopes of which approximately 50% were empty. Percentage of empty stomachs increased during the 1969 spawning season. No increase in percentage of empty stomachs was observed as water temperature decreased from summer to winter. A larger percentage of bass contained crayfish in 1968 compared with 1969, but a larger percentage of bass contained gizzard shad in 1969 compared with 1968. Feeding was apparently more intense in the morning than in the afternoon. Bass usually swallowed crayfish tail-first, but 66% of the gizzard shad were swallowed head-first. All gizzard shad were orientated horizontally in the esophagus or stomach of the bass. Cannibalism was negligible for bass in Lake Carl Blackwell.

After comparing population estimates obtained by the Petersen, Schnabel, and DeLury methods, a point estimate of 1,822 bass $\geq$176 mm was taken as the most accurate estimate.

Linear and curvilinear regressions of body length on scale radius were computed for the body-scale relationship of 100 representative bass. Linear and curvilinear regressions proved to be significantly different ($P < .005$), but reduction in variance with the curvilinear relationship was not significant ($P > .100$). The linear relationship, used for back-calculation of growth was: $Y = 36.67 + 1.29X$, where Y = total length in millimeters and X = scale radius in millimeters.

Average weight gained by recaptured bass that over-wintered and those that did not over-winter was positive for age groups I, II, and III. Recaptures of the remaining age groups, both those that over-wintered and those that did not over-winter, lost weight. Mean change in total length for both over-wintering and nonover-wintering groups (all ages) was zero or positive.

Mean total length at annulus formation for ages I, II, III, IV, V, VI, and VII, based on back-calculation of lengths in 1968, was 151, 283, 364, 417, 451, 474, and 481 mm, respectively. The 1969 back-calculated lengths at the end of each year of life were 148, 286, 371, 425, 463, 486, and 508 mm for ages I, II, III, IV, V, VI, and VII, respectively.

Condition factor (K_{TL}) increased with fish age, but did not vary between seasons. Calculated K_{TL} values were not different between the tagged and untagged bass.

Total instantaneous mortality rate (i) for age I, II, III, IV, V, and VI bass was estimated to be 1.3665, 0.0608, 0.1696, 0.4339, 1.2518, and 1.6095, respectively. Annual mortality rate (a), annual survival rate (s), and total instantaneous mortality rate (i) for all ages combined from 1968 sample and based on Robson-Chapman's method was 0.4712, 0.5288, and 0.6368, respectively. Exploitation rate by fishing was greatest during April 1969 and the instantaneous fishing mortality (p) was greatest for age I bass.

Length-weight relationships were calculated separately for each age group and for 1968 and 1969 samples. These relationships were used to convert back-calculated total length to weight in the production analysis.

Net positive change in biomass occurred for ages 0+, I, II, and III and a negative net change occurred for bass >age III. Net positive gain of biomass in age groups I, II, and III and net loss in the other age groups is corroborated by the positive gain in mean weight of age groups I, II, and III and mean loss in weight of the other age groups of recaptured bass. An overall net gain of 4.62 kg was calculated for the reservoir, based on the population estimate of 1,822 bass. Mean total weight of bass >176 mm was 0.97 kg per ha (0.86 lbs/acre). Annual weight gained ($\overline{W}g$), lost by fishing ($\overline{W}p$), lost by natural mortality ($\overline{W}q$), and total mortality ($\overline{W}i$) for all ages combined was 415.49, 6.83, 441.15, and 447.98 kg, respectively.

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