IMPACTS OF SAUGEYE INTRODUCTIONS ON GROWTH AND POPULATION STRUCTURE OF LARGEMOUTH BASS AND WHITE CRAPPIE IN A TURBID RESERVOIR

By

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Bachelor of Science

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Springfield, Missouri

1996

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1999

IMPACTS OF SAUGEYE INTRODUCTIONS ON

GROWTH AND POPULATION STRUCTURE

OF LARGEMOUTH BASS AND WHITE

CRAPPIE IN A TURBID RESERVOIR

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PREFACE

The objectives of this study were to estimate changes in largemouth bass and white crappie populations following introductions of saugeye. Growth and population structures were used as measures of this change. Electrofishing and net gears were provided on loan from the OSU Cooperative Fisheries Unit as they became available.

I sincerely wish to express my appreciation to Dr. Dale Toetz, my major advisor, for his guidance, instruction, and constructive criticism throughout this project. I also thank Dr. Tony Echelle for serving on my committee and Dr. Bill Fisher who also served on my committee and enabled me to do this research with the use of the Oklahoma Cooperative Fish and Wildlife Research Unit's equipment.

I am indebted to my wife, brother, and parents who motivated and supported me throughout my research. The advice of Bill Anderson and assistance of Jim Long and Randy Hyler were invaluable to my study and I am grateful to them. Also, I thank the Oklahoma Department of Wildlife Conservation for funding this project and the Zoology Department at OSU for providing financial assistance.

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CHAPTER I

INTRODUCTION

The saugeye (*Stizostedion vitreum X S. canadense*) is a relatively new sport-fish that was first stocked in the 1980's throughout many states, including Oklahoma (Humphreys et al. 1984; Leeds and Summers 1987). Preliminary research from these introductions suggested that saugeye would survive in southern reservoirs where previous walleye introductions had failed (Smith and Carline 1983). As a result, numerous saugeye introductions have since occurred throughout Oklahoma, including Lake Carl Blackwell (LCB) (Boxrucker 1997). Successful introductions of saugeye, which have food preferences similar to the largemouth bass (*Micropterus salmoides*) at larger sizes (Horton and Gilliland 1990), could increase the predator-to-prey ratio and provide a viable tool for managers to reduce stunted prey species such as the white crappie (*Pomoxis annularis*). Such effects from saugeye introductions have been shown on Lake Thunderbird, OK (Summers et. al 1994).

Past solutions to the problem of stunted white and black crappie (*Pomoxis nigromaculatus*) populations have included prey management and harvest regulations (Mitzner 1984). Recently however, the advantages of predator management have gained popularity. The substantial use of crappie by predators such as the largemouth bass (LMB) and northern pike (*Esox lucius*) have been effective in creating quality crappie fisheries (Gabelhouse 1984; Willis et al. 1984). In several small Oklahoma impoundments, Gabelhouse (1984) found that the Proportional Stock Density (PSD) of white crappie was inversely proportional to the PSD of LMB, suggesting that quality crappie fisheries could occur if proper densities of large bass could be sustained. However, in reservoirs LMB often prey upon species other than centrarchids, such as shad species (Aggus 1972), and this often limits the extent to which managers can rely on LMB as a tool for crappie management.

Causes of stunting in white crappie populations have typically been attributed to erratic recruitment, which produces a single dominant year class leading to intraspecific competition for food (Goodson 1966). White crappie primarily feed on zooplankton and aquatic insects until they reach 150 mm total length (TL) (Burris 1956; Reid 1949). Beyond this size, white crappie are inefficient at consuming zooplankton due to the wide spacing between gill rakers (Wright et al. 1983). The energetic cost of obtaining larger amounts of small dietary items forces growth to slow down, unless another suitable forage can be utilized. White crappie that can switch to piscivory during this critical point generally have good growth rates (Burris 1956). However, Crawley (1954) found that invertebrate consumption was positively correlated with good growth rates, suggesting that a piscivorous switch would not be necessary if alternate forage were available in large enough quantities.

Factors other than food availability have also have been attributed to the crappie stunting. In Missouri, Colvin (1991) found that fishing pressure had caused high mortality of older fish, resulting in relatively large numbers of small fish. In a study of several Oklahoma impoundments, Hill (1984) found that physical factors such as size of lake and turbidity were more important in sustaining quality crappie populations. Turbidity however, is probably not the sole factor determining growth rates, since other slow-growing populations have been documented in relatively clear lakes (Martin 1952; Crawley 1954). Additionally, Hall et al. (1954) possibly found that growth rates declined as lakes aged. In addition to physical parameters, physiological factors and behavioral differences have also been cited as probable causes of high mortality and low growth rates in four other Oklahoma reservoirs (Schoch 1981).

In Lake Carl Blackwell, Muoneke et al. (1992) suggested that crappie were stunted and short-lived due to a lack of available food, namely gizzard shad, which were unavailable in small enough sizes to be eaten by average-sized white crappie. Many slow growth problems for fish are related to density-dependent factors; thus, reduction in numbers of crappie within a length group should alleviate direct and indirect factors causing slow growth and high mortality.

The degree to which saugeye will eat crappie appears to be a function of size of prey relative to length of saugeye. Saugeye will eat prey species that are approximately 25% of their total length (Horton and Gilliland 1990). Studies on Lake Thunderbird, OK suggest that saugeye in all length categories above 375 mm prefer shad species, with crappie becoming more important in the diet as saugeye become larger. Horton and Gilliland (1990) suggested that larger saugeye would feed more heavily on crappie, as indicated by the following data for percent of diet (by volume) consisting of crappie, mean length of crappie eaten (in parentheses) and total length of saugeye: 3% (85 mm), 350-374 mm; 7% (97 mm), 375-449 mm; 10% (146 mm), 450-524 mm; 24% (141 mm), 525-599 mm; and 27% (153 mm), 600-674 mm. Summers et al. (1994) and Boxrucker (1992) found that saugeye in this same population after reaching lengths of 457 mm (18 inches) could apparently alter white crappie populations and increase growth rates in ages 1-5. From the results for Lake Thunderbird, I made the assumption that saugeye would eat white crappie in Lake Carl Blackwell at 25% their body length starting when saugeye reached 457 mm. I hypothesized that white crappie would increase in growth as a result of increased saugeye predation in Lake Carl Blackwell and that length frequencies of intermediate white crappie would change compared to the population sampled in 1984-1985. More specifically, I predicted a larger percentage of crappie greater than 199 mm.

Studies on Lake Thunderbird since the introduction of saugeye have allowed managers to establish a protocol for selecting new lakes for introductions of saugeye (Gilliland and Boxrucker 1995). One of the major concerns of managers for selecting new lakes is how saugeye will affect LMB populations (Horton and Gilliland 1990). Using a diet overlap index (Wallace 1981) with values above 0.6 considered as significant, Horton and Gilliland (1990) found that 93% of the forage overlap values among saugeye and LMB for all seasons were ≥ 0.8 in Lake Thunderbird. They concluded that although no apparent harmful effects on the LMB had occurred, potential competition could occur if forage became limited.

Age and growth for LMB in Lake Carl Blackwell were last measured in 1983 during a study to evaluate effects of hybrid striped bass (*Morone saxatilis* X *chrysops*) introduction. Results from that study suggested that competition could occur between LMB, white bass (*Morone chrysops*), and hybrid striped bass when shad populations were low (Kleinholtz 1985). Since that time there have been multiple stockings of hybrid striped bass, and since 1993, saugeye and hybrid striped bass have been stocked annually at a rate of about 68,000 fingerlings per year.

Leeds (1988) suggested that a diet overlap existed between adult LMB and saugeye during the summer months when both species selected shad. Both saugeye and hybrid striped bass use mostly gizzard shad (*Dorosoma cepedianum*) and centrarchids as forage. It is possible that continuous stockings of two competitors (saugeye and hybrid striped bass), would cause a decline in growth of LMB.

Assumptions based on the Lotka - Voltera competition model, suggest that in order for the LMB and saugeye populations to coexist successfully, each species should inhibit its own growth before it inhibits that of the other (Pianka 1994). Requirements for this outcome are based on the use and partitioning of available forage. The extent of change in white crappie and LMB populations in Lake Carl Blackwell should reflect the impact of the saugeye introductions.

My purpose was to determine if age and growth and length frequencies of white crappie in Lake Carl Blackwell have changed since the introduction of saugeye in 1993. I also compared growth of white crappie in 1996-1998 to that in 1984-1985 (Muoneke et al., 1992 and 1993). Finally, I evaluated population structure, growth and mortality of saugeye and LMB to determine whether competition with saugeye is affecting growth of LMB.

CHAPTER II

DESCRIPTION OF THE STUDY AREA

Lake Carl Blackwell is a shallow, turbid, windswept impoundment on Stillwater Creek in north-central Oklahoma, USA. The reservoir began filling and reached spillway elevation in 1945. At spillway elevation the reservoir has nearly 100 miles of shoreline and a surface area of approximately 1400 ha. Maximum depth is 11 m and mean depth is 4.8 m (Orth 1977). The watershed is composed of gently rolling and partially wooded land used primarily for grazing, although some sections are planted with small-grain crops.

Wind-generated wave action results in turbulent conditions and an absence of stratification except when temperatures are high and wind speeds low. Turbidities normally range from about 17.0 to 109.7 ppm SiO_2 and average about 42.5 ppm (Hysmith 1975). The western end of the lake is composed primarily of mud flats and scattered standing timber, with some littoral aquatic vegetation in the creek area. The north and south shores are principally mud flats with some rock outcroppings.

CHAPTER III

METHODS

Study Design

Fish populations in Lake Carl Blackwell were studied from May 1998 through December 1998. The study design chosen was similar to that used by Muoneke et al. (1992, 1993) in 1984-1985 when the lake was last sampled for white crappie. Regions were selected, each representing a different habitat type, on the basis of turbidity and underwater structure (dead tree stumps) (Figure 1). The north region (=N in Fig. 1) had the lowest turbidity and highest structural diversity; the south region (S) had moderate turbidity and moderate structural diversity; and the west region (W) had high turbidity and low structural diversity.

Three coves (each containing 2 sampling sites) were randomly selected to set nets in for the first night and the remaining coves were sampled the next night. Sampling was performed each month from June through December 1998. A combination of one collapsible cylindrical hoop-net and one trap-net were simultaneously set at each of six sites and soaked for one night. The nets were then all picked up and re-deployed to the remaining six sites for another night. One site was near the mouth of the cove and one was within the cove. Nets were deployed in 2-8 m of water within 15-20 m of each other. Nets were not set in exactly the same location from month to month, but they were in the general area. A total of 12 sites were sampled each month.

Hoop nets were made of 13 mm-bar-mesh multifilament with 12 cm funnels at both ends supported by five metal or composite hoops 0.9 m in diameter and held in place by two wooden supports. Trap nets were made of 13 mm-bar-mesh and had three rectangular (1.3 X 0.9 m) frames, four 0.9 m diameter frames, and a 15 m center lead (Houser 1960).

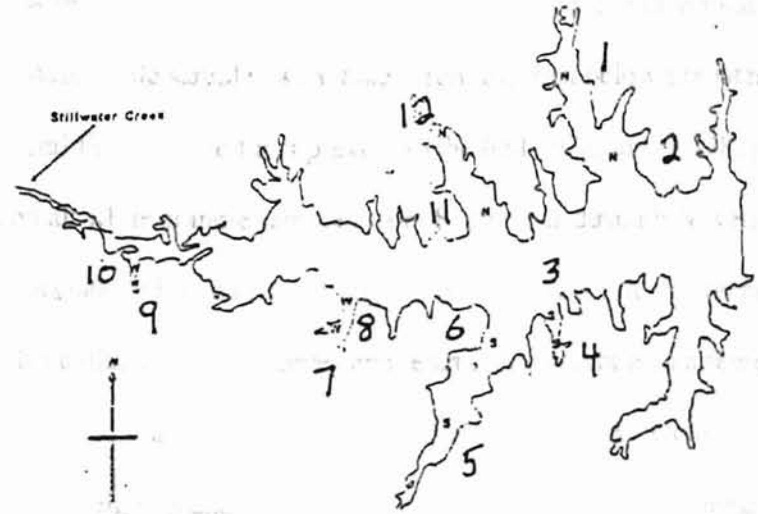

Figure 1. Sampling sites for white crappie collected with frame nets and hoop nets in Lake Carl Blackwell, OK, June-December 1998. The letters (N), (S), and (W) denote sites in the north, south, and west regions of the lake respectively (from Muoneke et al. 1993).

Catch per unit effort (CPUE) was measured by number of white crappie captured per net night. Only white crappie data were used, although a few black crappie were captured. Net nights were counted only if at least one fish was captured (since nets sometimes collapse or acquire large escape holes upon deployment).

White crappie collected in the traps were put on ice and taken to the laboratory to be processed within 3 hours after sampling. Data collected included total length and weight of each fish. Also, scale samples were taken from the area below the lateral line, near the point of the pectoral fin when the fin is pressed to the body (Carlander 1982). Scales were collected on all white crappie sampled from September through November. Scales were pressed on acetate slides and read using an Eberbach 32X microfiche projector.

I also collected scale samples and length and weight measurements from LMB obtained from bass tournaments on the lake from May, 1998 - October, 1999. Fish were sampled at the weigh–in and released immediately afterwards. Tournaments occurred on the lake every Wednesday night three times each month from March through October and club tournaments occurred about 3 times each year. Additionally, LMB and saugeye samples were collected using electrofishing methods. I used pulsed DC current at a 5-40 Hz rate (Novotny and Priegel 1974) from a Coffelt variable voltage pulsating unit attached to an 8-hp 240 volt generator mounted to a 4.9-m, aluminum flat – bottom boat and powered by a 40-hp outboard. Electrofishing areas were randomly selected by using a map of Lake Carl Blackwell overlaid with one-half inch grid squares, which represent 610 m quadrants on the lake (Figure 2). Five sampling quadrants were predetermined for each trip by randomly selecting a number from to A1-A9 and a number from B1-B15. The grid-square representing the two numbers together had all of its available shoreline electrofished. Electrofishing CPUE was measured by, the number of fish captured for each hour of effort.

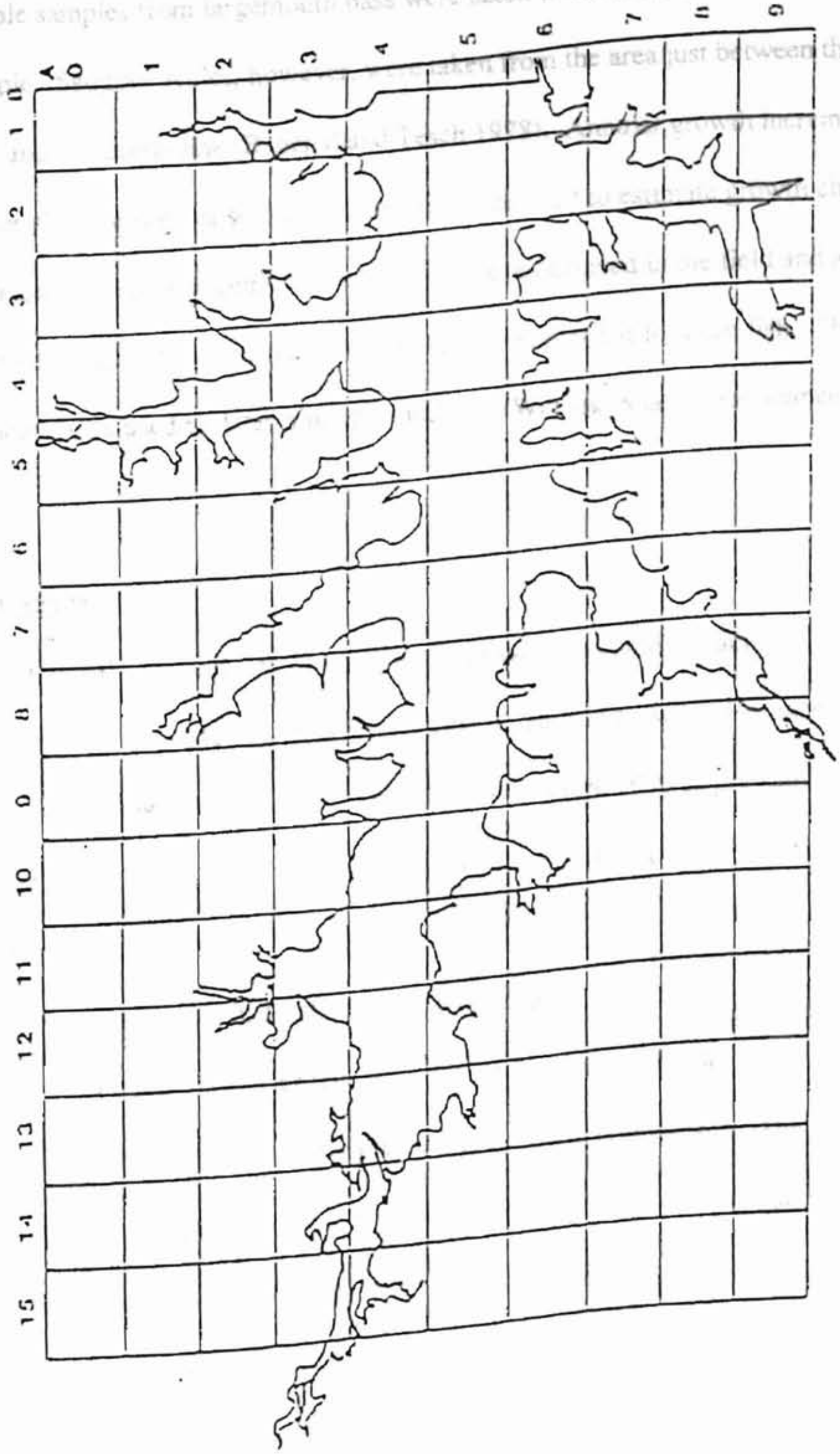

Figure 2. Lake Carl Blackwell random sampling design for electrofishing (from Kleinholtz 1985).

Scale samples from largemouth bass were taken in the same manner described for white crappie. Saugeye scales, however, were taken from the area just between the two dorsal fins and the lateral line (Bagenal and Tesch 1978). Annular growth increments were digitized for all three species so that raw data could be used to estimate growth changes.

Measurements of largemouth bass and saugeye occurred in the field and all fish were released alive. Total length (mm) and weight (g) were recorded for each fish. These measurements were used to determine the condition (W*r*) and relative abundance of both species.

Statistical Analysis

Horton and Gilliland (1990) suggested that saugeye could impact crappie growth upon reaching 18 inches (457 mm), typically after 3 years of growth. Because initial stocking of saugeye was in 1993, I designated growth before 1996 as pre-saugeye and any growth after 1996 as post-saugeye years. All statistical tests were performed using Microsoft Excel (Dodge et al. 1995).

Since white crappie had not been sampled in pre-saugeye years and pre-saugeye data could only be obtained from older fish, which were few in my sample, I partially relied on the data collected in 1984-1985 as my pre-saugeye growth comparison. The 1984-85 and 1994-95 data were compared using a paired t-test to test the assumption that growth rates had not significantly increased in the interim time-period. If growth rates were not significantly higher in 1994-1995, I used the 1984-1985 data as my pre-saugeye treatment.
Data used for paired-t-tests were taken from increments of back-calculated lengths (Appendix, Tables 4 and 5).

Large sample sizes of smaller fish provided sufficient data to make a growth comparison for white crappie ages 1 and 2 and bass ages 1-3. In these instances, scale annulus measurements from digitized entries were used to test pre- and post-saugeye growth with a single-factor ANOVA (Weisberg 1993). Analyses were performed on the white crappie and largemouth bass samples taken in September, October, and November. I obtained an incremental length by subtracting the annulus measurements in consecutive years. The mean was then determined by combining all increments from either pre- or post-saugeye age groups. The pre- and post-saugeye incremental length means were tested for statistical differences and then back-calculated to give mean growth in mm, using the equation:

$$L = a + bS$$

where L=total length, S= scale annulus, a = y-intercept (determined from regression analysis), and b = slope (Carlander 1982). Since different groups of fish were used in each ANOVA, slopes for each fish were determined and used to back-calculate the individual length of the increment separately using the equation:

$$(Lt-a)/S * Li + a$$

where Lt = total length and Li = incremental length. Each back-calculated length was then averaged for the group being tested. An alpha value of 0.05 was used for all statistical tests.

Back-calculated growth estimates were made for all three species using the Fraser-Lee back-calculation method. Intercepts of 36 white crappie ($R^2 = 0.89$), 30 largemouth bass ($R^2 = 0.86$), and 32 saugeye ($R^2 = 0.85$) were calculated by least squares regression.

Instantaneous total annual mortality, Z, was determined for the recruited segment of the population for all three species by regressing natural log of catch-per-unit-effort against age (Ricker, 1975).

Relative weight (W_r) indices were determined for all three species by using the formula:

$$W_r = W / W_s * 100$$

where W = weight (g) and (W_s) = standard weight. I used the following standard weight equations proposed by Wege & Anderson (1978) for white crappie and largemouth bass and Flamming et al. (1993) for saugeye.

$$\text{Crappie: } \text{Log}_{10} W_s = -5.102 + 3.112 \log_{10} TL$$

$$\text{LMB: } \text{Log}_{10} W_s = -5.316 + 3.191 \log_{10} TL$$

$$\text{Saugeye: } \text{Log}_{10} W_s = -5.692 + 3.266 \log_{10} TL$$

The population size structures were determined using PSD (Anderson and Gutreuter, 1983) and relative stock density (RSD; Gablehouse, 1984) for standard length classes (Table 1). All white crappie collected were used for these analyses, and compared to similar indices calculated for white crappie collected in 1984-1985 (Muoneke et al. 1992), because these data most closely represented a pre–saugeye population. LMB collected by electrofishing gear were used in the PSD and RSD analyses, and additional tournament samples were included for the relative weight (W_r) calculations. All saugeye collected by trap nets and electrofishing gear were used in population and (W_r) analyses.

Table 1. Lengths (mm) for five categories used for RSD and W_r comparisons on largemouth bass, saugeye, and crappie.

Species	Stock	Quality	Preferred	Memorable	Trophy
	Category				
Crappie	130-199	200-249	250-299	300-379	≥380
LMB	200-299	200-379	380-509	510-629	≥630
Saugeye	230-349	350-459	460-559	560-689	≥690

CHAPTER IV

RESULTS

Population Structure

There was a higher frequency of large white crappie in 1998 than in 1984-1985 samples (Figure 3). The mean length of fish, from the length frequency distribution, changed from approximately 145 mm TL in 1984-1985 to about 170 mm in 1998. In 1984-1985, almost all fish were under 180 mm, and individual cohorts were undetectable from the length frequency distribution. In 1998, only about half of the population was below 180 mm, and a cohort was distinguishable between 130 mm and 170 mm (Figure 4).

Compared with Muoneke's (1992) results, PSD dramatically shifted from 2 in 1984-1985 to 21 in 1998 (Table 2). RSD's showed a distinguishable shift in stock and quality length groups, but numbers of white crappie above the preferred length (250 mm) were still low.

Largemouth bass length frequencies appeared to show well-defined cohorts throughout the population (Figure 5). A PSD of 49 was calculated, along with relative stock densities (RSD) of 52 (stock), 21 (quality), 25 (preferred), 3 (memorable), and 0 (trophy) (Table 3). With the exception of the quality class, these values fit within the values suggested by Gablehouse (1984), for a moderate density of LMB in a balanced community.

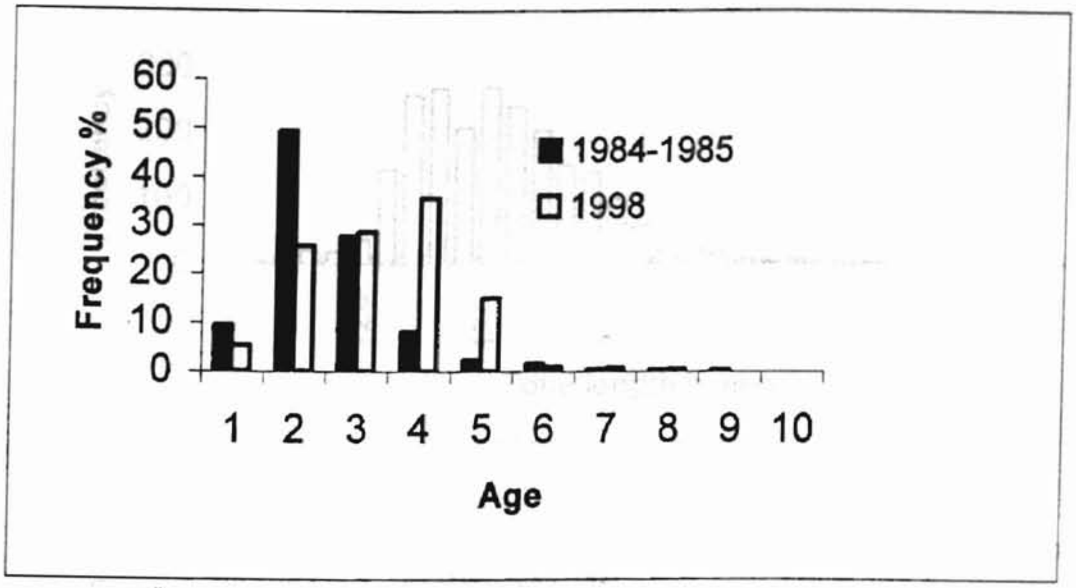

Figure 3. Comparison of white crappie age distributions in Lake Carl Blackwell, OK sampled at two different times with hoop and trap nets. Saugeye were introduced in 1993.

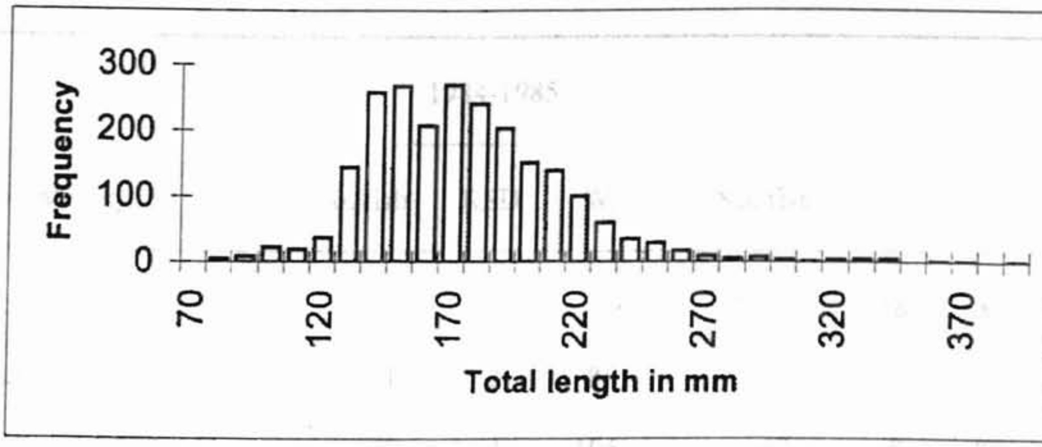

Figure 4. Length frequencies of white crappie collected with trap and hoop nets from June – December 1998 in Lake Carl Blackwell, Oklahoma.

Table 2. RSD and W_r comparisons for crappie collected in 1998 to crappie collected in 1984-1985 (Muoneke et al. 1992).

	1984-1985			1998		
Size Category	No. fish	RSD	W_r	No. fish	RSD	W_r
Stock-Quality	6571	96	79	1597	78	81
Quality-Preferred	161	2	86	387	18	78
Preferred-Memorable	62	1	106	47	2	86
Memorable-Trophy	42	1	109	14	1	105
Trophy	5	0	123	1	0	109

[a] PSD is 2 (1984-1985) and 21 (1998)

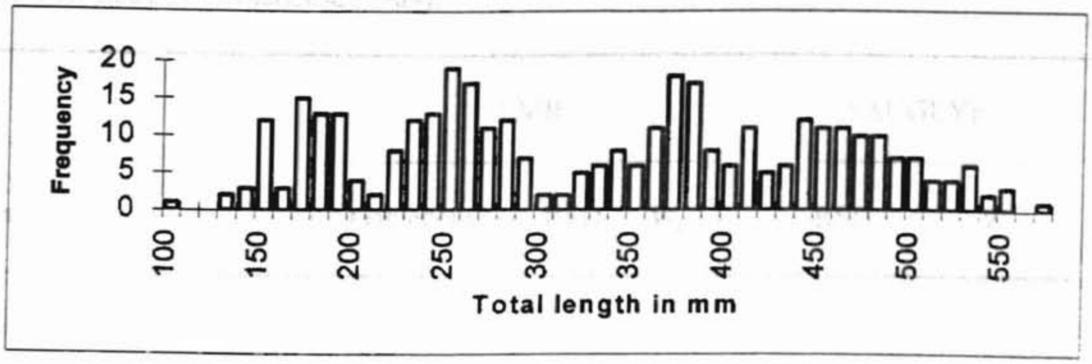

Figure 5. Length frequencies for largemouth bass collected by electrofishing during the spring and fall of 1998 in Lake Carl Blackwell, Oklahoma.

Table 3. RSD and W_r values for largemouth bass and saugeye in 1998, and values recommended by Gablehouse (1984).

	LMB			SAUGEYE	
Category	Gablehouse	RSD	W_r	RSD	W_r
Stock-Quality	30-60mm	52	89	83	87
Quality-Preferred	30-60mm	21	90	10	79
Preferred-Memorable	10-30mm	25	97	4	81
Memorable-Trophy	0-10mm	3	100	4	87
Trophy	0-5mm	0	0	0	0

*PSD =49 for LMB (40-70 Gablehouse), and 17 for saugeye

Saugeye length frequencies showed that very few fish were caught at lengths exceeding 350 mm (Figure 6). A relatively low PSD of 17 was observed for this population; RSD's were 83 (stock), 10 (quality), 4 (preferred), 4 (memorable), and 0 (trophy) (Table 3).

Relative Weight (W_r)

Relative weights, which represent the suitability of the environment for growth shortly before capture, were low for white crappie below 300 mm (Table 2). Relative weights did not increase in the size categories where RSD's had declined, suggesting that there was still inadequate forage for those lengths of white crappie (Muoneke 1992). Relative weights remained high (>100) for fish over 300 mm.

Relative weights were good for LMB above the preferred length (380 mm); however, lower length classes were slightly sub-standard (Table 3). Relative weights of saugeye were poor (<90) for all length classes, suggesting forage availability problems, which could lead to increased interspecific competition.

Mortality

The total annual mortality estimate for white crappie age 4 and older in 1998 was 47% ($Z = 0.64$; $r^2 = 0.85$) (the regression was insignificant for ages 2 and 3 fish). Compared to estimates from 1984-1985, when total annual mortality was estimated at 52% for age-2 and older fish, mortality has decreased to 48%. Thus, the population is outside the mortality range (50-80%) postulated by Colvin & Vasey (1986) for white crappie with inadequate population structure and overall poor condition. This slight decrease in mortality probably reflects the 12% increase in frequency of age-5 fish in the 1998 population compared to 1984-1985 (Figure 3).

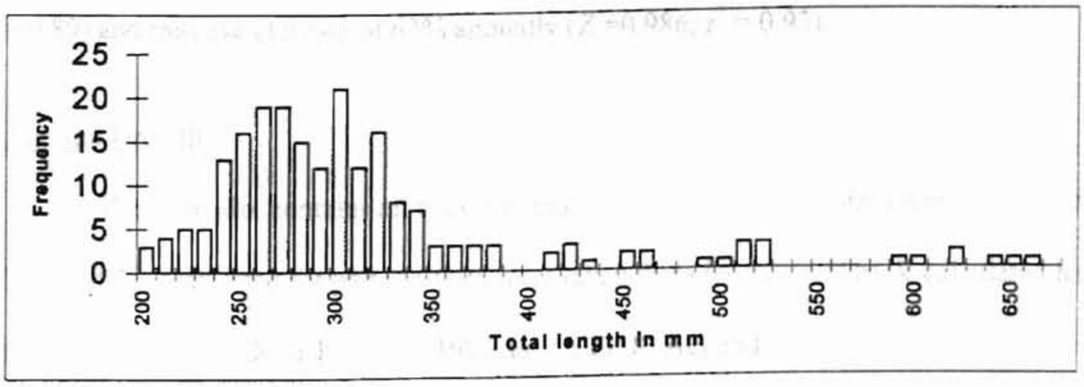

Figure 6. Length frequencies for saugeye collected by electrofishing and trap-nets during the spring and fall of 1998 in Lake Carl Blackwell, OK.

Total annual mortality rates were also calculated for largemouth bass and saugeye in 1998 for age 2 and older fish. Largemouth bass died at a rate of 32% annually ($Z = 0.384$; $r^2 = 0.89$) and saugeye at a rate of 63% annually ($Z = 0.986$; $r^2 = 0.93$).

Age and Growth

The appendix contains all back-calculated lengths for all species (Appendix, Tables 1, 2, and 3). Data used for paired t-tests were taken from incremental back-calculated lengths for white crappie collected in 1984-1985 and in 1998 (Appendix, Tables 4 and 5)

White Crappie

Paired t-test comparisons of back-calculated lengths at age in 1984-1985 to back-calculations in 1994-1995 showed that growth had not increased in the 10 year period in age 1 ($df = 1$; $t = 1.5$; $P = 0.19$) or age-3 ($df = 1$; $t = 5.0$; $P = 0.06$) (Table 4). Therefore, the data could be reasonably used to test incremental growth change from 1984-1985 to 1996-1998 for those ages, but not age-2 where it increased ($df = 1$; $t = 12.0$; $P = 0.03$). Age-4 growth could not be tested due to insufficient sample size.

Table 4. Results from paired t-tests to examine the hypothesis that incremental growth in white crappie had not increased from back-calculated length-at-age data collected in 1984-1985 to "pre-saugeye" (1994-1995) data. Lengths in the 1984-1985 column are averages of the first two length increments for the appropriate age class. Lengths in the pre-saugeye column are averages from 1994-1995 back-calculated increments.

Age	1984-1985 Length (mm)	1994-1995 Length (mm)	P value
1	86	83	0.19
2	42	54	0.03
3	35	32	0.06

Since it appeared that white crappie growth rates had not increased in the 10-year period, another series of t-tests were used to compare back-calculated mean lengths from 1984-1985 data to my post-saugeye (1996-1998) back-calculated lengths (Table 5). The test showed that growth of age-1 white crappie increased, suggesting the saugeye possibly impacted this size class (df = 2; t = 8.7; P = 0.006). Conversely, growth of age-3 white crappie was not significantly different in post-saugeye years (df = 2; t = 1.2; P = 0.17). Growth of age-4 fish apparently decreased in 1996-1998 post-saugeye years (df = 1; t = 23.0; P = 0.01).

To confirm the paired t-test results and to compare age 2 growth, I used only the data collected in 1998 and compared growth from 1994-1995 to growth after 1996 using an ANOVA. I again found that Age 1 white crappie grew significantly less in pre-saugeye years than in post-saugeye years (82 vs 96 mm; N_{pre} =369; N_{post} = 377; F = 362.7; P < 0.000); where N = number of fish in test for pre- and post-saugeye comparisons. I found that age-2 white crappie grew from 53 mm in a pre-saugeye year to 54 mm in post- saugeye years (N_{pre} = 475; N_{post} = 112; F = 6.5; P = 0.01) (Table 6).

Largemouth bass

Incremental growth increased in two of the three LMB age classes (Table 7). In pre-saugeye years, age 1-growth was 141 mm compared to post-saugeye years where growth was 144 mm (N_{pre} = 149; N_{post} = 97; F = 5.04; P=0.03). Incremental growth at age 2 did not change significantly between pre- and post-saugeye years (N_{pre} = 147; N_{post} = 56; F = 0.4; P = 0.5). Incremental growth of pre-saugeye and post-saugeye age 3-fish was 81 mm and 66 mm respectively. Apparently, LMB grew less in the post-saugeye years (N_{pre} = 97; N_{post} = 27; F = 7.3; P = 0.007). The standard error of the age estimates were relatively high for age class 3, which might have complicated the analysis (Table 8).

Table 5. Paired t–test results for white crappie incremental growth comparison of pre- and post-saugeye growth effects using 1984-1985 back-calculations as pre-saugeye data. Post-saugeye represents years 1996-1998, except age 4 (1997-1998). Age represents all growth occurring in the year given. Lengths in the 1984-1985 column are averages of the first two (age-4) or three (ages 1 and 3) increments. Lengths in the post-saugeye column are averages from 1996-1998 increments. Age-2 was not used in this comparison because it increased between 1984-1985 and 1994-1995 (Table 4).

Age	1984-1985 Length (mm)	1996-1998 Length (mm)	P-value
1	85	98	0.006
3	37	33	0.172
4	38	27	0.014

Table 6. Mean back-calculated incremental growth (mm) from ANOVA's for white crappie in pre- and post-saugeye years. Post-saugeye start at three growing seasons past the first introduction in 1993 (or after 1995). Pre-saugeye are the year(s) before 1996.

Age	Pre-saug (yrs.)	Pre-saug (length)	Post-saug (yrs.)	Post-saug (length)	P-value
1	1994-1995	82	1996-1998	96	< 0.000
2	1995	53	1996-1998	54	0.010

Table 7. Mean back-calculated incremental growth (mm) from ANOVA's for LMB in pre- and post-saugeye years. Post-saugeye start at three growing seasons past the first introduction in 1993 (or after 1995). Pre-saugeye are the years before 1996.

Age	Pre-saug (yrs.)	Pre-saug (length)	Post-saug (yrs.)	Post-saug (length)	P-value
1	1992-1995	141	1996-1998	144	0.025
2	1993-1995	105	1996-1998	98	0.542
3	1994-1995	81	1996-1998	66	0.007

Table 8. Mean length (mm) at age at capture for largemouth bass, crappie, and saugeye in Lake Carl Blackwell during the fall of 1998. The standard error for aging by scale method is denoted in parentheses. Fish hatched in 1998 are considered to be age-1.

Species	Age	No. fish	Mean Length (SE)
Crappie	1	39	102 (1.69)
	2	190	151 (0.99)
	3	140	181 (2.12)
	4	265	195 (1.47)
	5	112	217 (3.41)
	6	7	258 (16.1)
	7	5	302 (20.7)
	8	3	357 (14.7)
	9	1	325 (0.0)
LMB			
	1	43	165 (3.20)
	2	79	231 (3.85)
	3	27	289 (11.1)
	4	40	361 (6.16)
	5	29	418 (8.10)
	6	20	475 (9.19)
	7	7	503 (9.22)
Saugeye			
	1	47	246 (3.03)
	2	101	293 (2.93)
	3	12	397 (18.7)
	4	8	469 (34.2)
	5	4	605 (34.3)

Saugeye

Saugeye growth was relatively poor compared to other estimates from saugeye populations in Thunderbird Reservoir, OK and in other states (Table 9). Age-1 fish sampled in the fall had achieved a mean length of 293 mm (SE = 2.9) and age-2 fish were estimated at 397 mm (SE = 18.7). These estimates may be suspect however. Using otoliths the Oklahoma Department of Wildlife Conservation estimated saugeye growth in Lake Carl Blackwell in 1997 to be 357 mm, and 472 mm for ages 1 and 2 fish, respectively (Hicks 1997).

Table 9. Mean total lengths (mm), by October, of age-1 and age-2 saugeye from several reservoirs compared to Lake Carl Blackwell (B.L Johnson, D.L. Smith, and R.F. Carline, unpubl. data) (Leeds 1988).

	Age	
Location	1	2
Pleasant Hill Reservoir, Ohio	385	392
Charles Mill Reservoir, Ohio	340	439
Deer Creek Lake, Ohio	361	454
Morris Reservoir, Tenn.	389	465
Thunderbird Reservoir, Okla.	445	543
Lake Carl Blackwell, Okla.	293	397

CHAPTER V

DISCUSSION

Data from growth rate comparisons of the white crappie population in 1998 suggest that saugeye have affected the growth of the age-1 portion of the population by causing average growth rates to increase from 82 mm to 96 mm in the 1990's (Table 6). Although growth rates of age-2 white crappie were significantly different, the change from 53 to 54 mm is not one that would be practically significant.

Except for the second year of growth in white crappie, statistical tests show no essential differences between 1983-1984 fish and those representative of a later, pre-saugeye population (1994-1995) (Table 4). Possibly, the change in length frequencies between 1980's and 1990's was caused by increased growth of age-2 crappie in 1994-1995. However, the degree to which this might have happened can not be determined. It is evident however, that the larger age-1 fish have caused a shift of the length frequencies. I found lower RSD values for stock-quality white crappie in 1998 compared to 1984-1985 (78 vs 96), suggesting that numbers of intermediate (130-200 mm) crappie have declined since 1984-1985. Correspondingly, white crappie greater than 200 mm were less abundant in 1984-1985 (RSD = 2 vs 18). The dramatic shift in PSD's from 2 in 1984-1985 to 21 in 1998 also supports this conclusion.

Low relative weights (W_r) for the 1998 population suggest that white crappie are still experiencing effects of intraspecific competition. Although fish are reaching larger sizes in the population, it appears that competition is severe enough between smaller length groups to keep fish in poor condition. Only fish >250 mm (where competition is probably negligible (RSD $\leq$ 2)) had good or robust W_r values.

Muoneke (1992) suggested that increased growth would occur if crappie could shift to piscivory at 150 mm. Although my study did not include an analysis of stomachs, it is possible to speculate on the probability that a switch to piscivory after 1984 caused the shift in average length of white crappie from 145 mm in 1984-1985 to 170 mm in 1998. More white crappie were observed in the (200-249 mm) class, which could be attributed to increased piscivory. However the W_r for this group was very low ($W_r = 78$), suggesting that intraspecific competition was still high. As Crawly (1954) found in a similar study, white crappie grew to a larger length (i.e. 249 mm) without piscivory by using the more available zooplankton and insects once the density of the previous length class (130-199 mm) had been reduced. If a piscivorous food base were more abundant in Lake Carl Blackwell, an increased RSD of white crappie would be expected in the 250-299 mm length group, but this did not occur. Instead, the RSD was 2 and W_r was still low at 86. Additionally, it appears that age-4 fish in this length class are experiencing decreased growth rates.

Research on Thunderbird Reservoir found that age-1 white crappie made up a small proportion of the saugeye diet (Leeds 1988). However, it appears that in Lake Carl Blackwell, saugeye are eating age-1 white crappie in sufficient quantities to decrease their density and increase their growth. Low densities of the preferred food of saugeye, shad, may cause saugeye to shift to white crappie. Another possible reason might be found in the relatively high abundance of saugeye less than 300 mm TL (Figure 6). Higher densities of saugeye at 300 mm would likely affect preferable sized prey (i.e. 90 mm). Additionally, it should be noted that hybrid white X striped bass may be more effective at catching shad, and continual stockings of both saugeye and hybrid bass may force the saugeye to switch to a less preferred forage (i.e. white crappie).

Growth rates of largemouth bass changed in an inconsistent pattern between age groups in my pre- and post-saugeye comparisons. Age-1 growth increased by 3 mm;

however, this appeared to be due to the 1998-year class which was approximately 25 mm longer than previous years' estimates (Table 5).

Age-3 growth of LMB had significantly declined by 15 mm. This could be attributed to a relatively high standard error in aging for this group (SE = 11.096) (Table 7). One possibility for error may have been a false annulus that was not always read correctly for that group of fish. Alternatively, it is possible that the decline in growth is due to interspecific competition with saugeye. Attention should be given to the possibility that this trend could continue.

My aging of saugeye was particularly suspect. Using otoliths, the Oklahoma Department of Wildlife Conservation obtained projected estimates of length at ages 1 and 2 that were 70 mm larger than my estimates. Saugeye scales were difficult to read in some instances due to the closeness of the annuli. Also, scales taken from a single fish varied in size, making it difficult to regress an accurate y-intercept for back-calculations

Boxrucker (1997) proposed that 10 hours of electrofishing would be sufficient to estimate a mean abundance of large saugeye with a 75% confidence interval. He also suggested that fall night electrofishing and spring diel electrofishing methods should be used to obtain large saugeye 457 mm (>18 inches). I electrofished at night for a total of 14.27 hours and only captured 6 fish (CPUE = 0.42f/h). From those results, it was not apparent that there would be enough large saugeye to affect intermediate and larger sized white crappie. However, a diel sampling bias could have affected my results. Boxrucker (1997) showed that CPUE was greater in the day vs. the night in fall sampling. CPUE may have been increased if day samples had been used. Even with the possible bias, catch rates were still much lower for fall night electrofishing in Lake Carl Blackwell (0.42 f/h) than in Lake Thunderbird (8.67; Boxrucker 1997).

Other methods of sampling may have produced different length frequencies. When sampling for crappie with trap nets in the fall I captured 10 saugeye over 457 mm (18 inches), suggesting that large saugeye in the lake were not efficiently sampled by electrofishing. However, the Oklahoma Department of Wildlife Conservation used gill nets to sample saugeye in 1997 in Lake Carl Blackwell and found 62% of the fish sampled were over 457 mm (18 inches) (N = 83) whereas no fish sampled by electrofishing were above 400 mm (Hicks 1997). Gill nets were not used in my study because mortality associated with saugeye in gill nets can be high and sacrificing the fish is usually necessary.

Anecdotal information may also suggest a reason for the low CPUE of large fish. In the spring of 1998 and 1999, water flowed over the spillway, and anglers caught large numbers of saugeye > 457 mm (18 inches) and up to 4.08 kg (9 pounds). Such events may ultimately decrease the number of large saugeye in the population and thus the effectiveness of using saugeye to manage crappie in Lake Carl Blackwell.

Summary

Introductions of saugeye appear to have caused an increase in age-1 white crappie growth from 82 mm in pre-saugeye years (1994-1995) to 96 mm in post-saugeye years (1996-1998). Also, the RSD shift in stock-quality fish from 96 in 1984-1985 to 78 in 1998 suggests the saugeye introduction reduced the abundance of small white crappie in the lake following saugeye introductions. A change in PSD from 2 to 21 suggests that more quality fish are now in the population as a result of saugeye interactions. However, these crappie did not represent larger length classes and appear to be only in the quality-preferred group. A preferred-memorable RSD of 1 and 2 for pre- and post-saugeye periods respectively, shows that white crappie are still not surviving to large lengths. Relative weights show that although white crappie are reaching sizes (150 mm) where a piscivorous switch should allow enhanced growth, their condition still remains low. A W_r of 78 for quality-preferred fish suggests that white crappie growth will probably not continue to increase unless forage density increases through reduced intraspecific competition by white crappie.

Minimal growth changes for ages 2 and 3 white crappie suggests that saugeye are not affecting larger white crappie in the population. Few white crappie are growing to sizes exceeding 250 mm and probably will not do so, unless the number of mid-sized crappie (150-200 mm) declines.

The size of largemouth bass may determine how they are affected by saugeye introductions. LMB growth rates for age-3 fish decreased in post-saugeye years and age-0 growth rates increased. The RSD and PSD values suggest that the population is within the range for a quality fishery consisting of several predator species. Also, the LMB population appears to have good relative weights, except for stock-quality fish.

The number of saugeye surviving to a minimum harvest length of 457 mm (18 inches) is small relative to the number of fish being stocked each year. Sampling efforts show very few fish above the length of 350 mm, the size where saugeye should begin to feed on white crappie. This suggests high mortality or inefficient sampling techniques for large fish. Additionally, the condition of the saugeye is poor for all length classes. If condition is an indicator of available forage, then the saugeye in Lake Carl Blackwell may be showing effects of competition with largemouth bass and other predator species.

Management Recommendations

A creel census on this lake would help to evaluate the use of the saugeye fishery by anglers, and to determine whether survival to sizes exceeding 457 mm (18 inches) is sufficient to warrant the current minimum length limit. Continuous efforts should be made to evaluate natural mortality of saugeye, effectiveness of sampling techniques, and losses due to spillway overflow.

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APPENDIX

MEAN BACK-CALCULATED LENGTHS FOR WHITE CRAPPIE, LARGEMOUTH BASS AND SAUGEYE

Table 1. Average back-calculated total lengths (mm) for each age class of white crappie collected in the fall of 1998 in Lake Carl Blackwell.

Age	Year	N	1	2	3	4	5	6	7	8	9
1	1998	39	102								
2	1997	190	97	151							
3	1996	140	95	147	181						
4	1995	265	82	137	171	195					
5	1994	112	83	136	166	195	217				
6	1993	7	98	152	184	210	239	258			
7	1992	5	84	134	168	196	229	270	302		
8	1991	3	82	142	197	218	248	284	323	357	
9	1990	1	81	135	157	195	224	250	291	314	325

Table 2. Average back-calculated total lengths (mm) for each age class of LMB collected in the fall of 1998 in Lake Carl Blackwell.

Age	Year	N	1	2	3	4	5	6	7
1	1998	43	165						
2	1997	79	138	231					
3	1996	27	127	238	289				
4	1995	40	145	243	312	361			
5	1994	29	142	247	322	380	419		
6	1993	20	127	236	321	388	437	476	
7	1992	7	142	242	312	365	421	475	503

Table 3. Average back-calculated total lengths (mm) for each age class of saugeye collected in the fall of 1998 in Lake Carl Blackwell.

Age	Year	N	1	2	3	4	5
1	1998	47	246				
2	1997	101	221	293			
3	1996	12	252	329	397		
4	1995	8	259	359	424	469	
5	1994	4	259	354	471	554	606

Table 4. Average annual increments of back-calculated lengths (mm) for each age class of white crappie collected in 1998. Underlined values were used in t-tests between 1984-1985 and 1994-1995. Values with an asterisk are for 1996-1998 comparisons.

Age	Year	N	1	2	3	4	5	6	7	8	
1	1998	39	102*								
2	1997	190	97*	54							
3	1996	140	95*	52	34*						
4	1995	265	82	55	34*	24*					
5	1994	112	83	53	30*	29*	22				
6	1993	7	98	54	32	26	29	19			
7	1992	5	84	50	34	28	33	41	32		
8	1991	3	82	60	55	21	30	34	39	34	
9	1990	1	81	54	22	38	29	26	41	23	11

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