

**FACTORS INFLUENCING FIRST YEAR  
RECRUITMENT OF STRIPED BASS  
IN LAKE TEXOMA**

**By**

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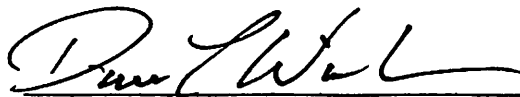
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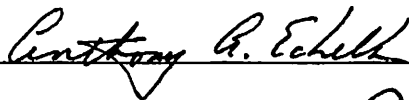
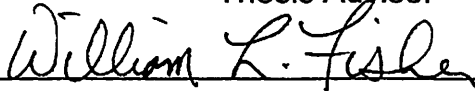
**Submitted to the Faculty of the Graduate College  
of the Oklahoma State University  
in partial fulfillment of the  
requirements for the Degree of  
MASTER OF SCIENCE  
December, 2004**

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IN LAKE TEXOMA

Thesis Approved:



Thesis Advisor



Dean of the Graduate College

## ACKNOWLEDGEMENTS

I'm greatly indebted to numerous individuals who have generously contributed to my graduate studies. I wish to express my sincere appreciation to my major advisor, Dr. Dana Winkelman, for his guidance and support. I also thank Dr. William Fisher and Dr. Tony Echelle for serving on my graduate committee.

I'm grateful to the staff of the Oklahoma Cooperative Fish and Wildlife Research Unit for their efforts in providing office assistance and travel logistics. Additionally, I thank Chris Novotny and Linda Guenther from the Meat Science Department for help during lipid extractions. This work would not have been possible without the help of my fellow students and technicians, namely Jason Schaffler, Greg Cummings, Derek York, Kyle Winters and Mark Nicholson. Data analysis and statistical procedures were simplified with the help of Dr. Carla Goad.

I thank the Oklahoma Cooperative Fish and Wildlife Research Unit and the Oklahoma Department of Wildlife Conservation (ODWC) for providing generous financial support for this project. ODWC employees, Jeff Boxrucker and Paul Mauck, also provided supplemental field data.

Finally, I would like to thank my friends and family for encouragement and motivation during my graduate work. Most of all, I'm grateful to my wife, Kim, for her continued motivation and patience while I was away many days in the field.

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## CHAPTER I.

### MANUSCRIPT INTRODUCTION

This thesis is composed of one manuscript written in the format for submission to the Transactions of the American Fisheries Society. Chapter I is an introduction to the rest of the thesis. The manuscript is as follows; Chapter II, "Factors influencing first year recruitment of striped bass in Lake Texoma."

CHAPTER II.

FACTORS INFLUENCING FIRST YEAR RECRUITMENT  
OF STRIPED BASS IN LAKE TEXOMA

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## **Abstract**

Overwinter survival and subsequent first year recruitment of temperate sportfishes is highly dependent on critical periods within the first growing season. We evaluated how diet shifts and condition of striped bass in a southern impoundment (Lake Texoma) influenced first year growth and overwinter mortality. We found no evidence of size-selective overwinter mortality of striped bass in 2002-2003. Size distributions of fish collected pre- and post-winter were similar without a detectable increase in median length or decrease in length range. During each sampling period, diet shifts were size-dependent with larger individuals consuming primarily fish. Size distributions rapidly diverged over the growing season, presumably due to the dietary switch to piscivory. Relative condition ( $K_r$ ) values were high throughout the growing and wintering periods. Lipid content was size-dependent and increased over the winter. Common winter constraints that limit recruitment of temperate sportfishes may not apply to Lake Texoma, a southern reservoir with relatively short, mild winters and an abundance of high quality food.

## **Introduction**

It has long been understood that year-class strength is set early in life; however, the factors underlying the recruitment of age-0 fishes is not as well understood. While year-class strength has traditionally been determined by sampling adult populations, several studies have demonstrated that larval (Uphoff 1989; Sammons and Bettoli 1998) and juvenile abundances (Schaefer 1972; Goodyear 1985) are probable indicators of cohort strength. However, these studies did not consider stresses associated with first winter survival and subsequent recruitment to the adult stock. Overwinter survival and subsequent first year recruitment of temperate sportfishes is highly dependent upon critical periods within the first growing season. Understanding how various factors influence overwinter survival of age-0 fish might help predict recruitment more accurately and allow better management of fish populations.

Critical periods during the first year of life include the time of hatching, the shift from an invertebrate diet to piscivory, fall lipid accumulation, and winter severity (Ludsin and DeVries 1997). Date of birth and piscivore size relative to available prey size may limit consumption, eventually leading to differential growth among cohorts (Hambright 1991; Ludsin and DeVries 1997). A dietary shift from invertebrates to fish is correlated with increased growth during early life stages (Shelton et al. 1979; Keast and Eadie 1985; Garvey and Stein 1998), presumably because predators derive greater net energy by consuming fish rather than invertebrates (Cummins and Wuycheck 1971; Aggus and Elliott 1975; Keast and Eadie 1985; Ludsin and DeVries 1997).

Reliance on energy reserves is important to overwinter survival because many temperate fish species experience decreased consumption due to limited food availability (Adams et al. 1982; Cunjak and Power 1987; Foy and Paul 1999) and reduced evacuation rates (Hurst and Conover 2001). Consequently, many species experience an energy deficit during cold winters and rely on lipid stores to fuel metabolism (Sogard 1997; Hurst et al. 2000). Smaller fish have lower relative energy reserves and maintain a higher metabolic rate, making larger individuals less likely to deplete their lipid reserves (Phillips 1969; Brett and Groves 1979). Therefore, size-selective overwinter mortality is common because smaller fish typically lose a higher percentage of their lipid reserve than larger individuals (Miranda and Hubbard 1994; Ludsin and DeVries 1997; Sutton and Ney 2001). Decreased condition during stressful winter months leaves individuals subject to mortality from low temperatures (Johnson and Evans 1991, 1996; Fullerton et al. 2000; McCollum et al. 2003), starvation (Post and Evans 1989; Thompson et al. 1991; Hurst and Conover 1998; Fullerton et al. 2000), and predation (Forney 1976; Nielsen 1979; Miranda and Hubbard 1994; Garvey and Stein 1998; Pratt and Fox 2002).

Striped bass *Morone saxatilis* have been stocked in over 100 freshwater reservoirs throughout the southern United States (Axon and Whitehurst 1985; Matthews et al. 1985). Previous field studies indicate that size-selective mortality of smaller individuals in winter months influences recruitment (Hurst and Conover 1998; Sutton and Ney 2001); however, these studies were conducted on

reservoirs and estuaries at northern latitudes. Southern reservoirs may differ in the severity of winter conditions.

We explored how growth and size-dependent survival of age-0 striped bass are influenced by winter conditions in a southern reservoir. Specifically, we examined length distributions through the growing season and wintering months, related food habits to fish size, and assessed lipid content in pre- and post-winter periods.

## **Study Area**

Lake Texoma, formed by the impoundment of the Red and Washita Rivers on the Oklahoma-Texas border, is a nationally recognized striped bass fishery. Created in 1944 by the U.S. Army Corps of Engineers, this 36,000-ha lake provides hydroelectric power and flood control as well as serves as a multipurpose water supply source. Striped bass were first introduced to Lake Texoma in 1965 as a biological control for gizzard shad *Dorosoma cepedianum* and threadfin shad *D. petenense* and as an additional pelagic-zone sportfish (Harper and Namminga 1986). Since 1974, striped bass have naturally reproduced, making Lake Texoma one of about 10 self-sustaining reservoir populations of striped bass in the U.S. (Bailey 1974; Gustaveson et al. 1984; Axon and Whitehurst 1985). Generating in excess of \$25 million to the local economy, it has become the most valuable recreational fishery in Oklahoma (Schorr et al. 1995).

## **Methods**

### *Field collections*

Juvenile striped bass were collected in Lake Texoma from June 2002 to March 2003 using several gear types. Initially, juvenile fish were collected using a 12.2 m bag seine with 2 mm mesh. Later in the summer, we used a 12.2 m bag seine with 6 mm mesh to minimize escape of larger juveniles (>100 mm). Seining was conducted immediately after sunset when catch rates tend to increase (Mensing 1971; Hubbs 1984). By late summer, striped bass had moved into the pelagic zone and were sampled with monofilament experimental gillnets (107 m long x 2.4 m deep, consisting of 15.2 m panels with bar-mesh sizes of 10, 13, 16, 19, 22, 25, and 32 mm) from September to February. We also collected striped bass in March during annual gillnet surveys conducted by the Oklahoma Department of Wildlife Conservation (ODWC). ODWC nets were similar to ours except they did not have 22 mm bar-mesh panels. All striped bass were measured to the nearest mm (TL), blot dried, weighed to the nearest 0.01 g, and frozen for subsequent food habit and lipid analysis. To distinguish age-0 from age-1 striped bass, otoliths were removed and examined for annuli on all individuals >150 mm through November and >200 mm in subsequent months.

Range, median length, and 25<sup>th</sup>-75<sup>th</sup> percentiles were computed for each gillnet bar-mesh size to evaluate selectivity and help interpret length distributions. Size-selectivity of gillnets is well known for species of *Morone* and can influence length frequency distributions (Wilde 1991; Neumann et al. 1995). A bell-shaped distribution curve is common for each mesh size with numbers decreasing on either side of the maximum.

### *Growth patterns and winter survival*

Length-frequency distributions were compiled for each sampling period to evaluate first year growth patterns. Statistics for fish collected by seining and gillnetting were evaluated separately. Length distributions obtained from gillnetting were compared across all winter months (November-March) to evaluate possible length-dependent mortality. We assumed that an increase in median length with a corresponding decrease in length range would provide evidence for size-selective winter mortality of smaller individuals in the population. In addition, quantile-quantile plots were used to compare pre-winter (November) and post-winter (March) length frequency distributions for fish collected in gillnets (Post and Evans 1989; Braaten and Guy 2004). Quantiles 1, 5, 10, 25, 50, 75, 90, 95, and 99 were computed from each distribution and a positive slope, significantly less than 1.0, indicates size-selective mortality. Slopes that do not deviate from 1.0 indicate that distributions are similar. Fish collected with 22 mm bar-mesh in November sampling were omitted because this mesh panel was not used in the March sampling.

### *Food habits*

To determine critical diet shifts, prey items from frozen striped bass were quantified bi-monthly beginning in July and ending in March. Fish selected for diet analysis were thawed and their stomachs (esophagus to anterior end of the intestine) were removed and preserved in 10% buffered formalin. Where available, at least 10 striped bass per 20 mm length class were randomly chosen for analysis. Food items were categorized as zooplankton, insects, or fish and

weighed to the nearest 0.01 g. These prey categories were chosen to reflect major shifts in diet, in particular the shift from zooplankton and insects to piscivory. The gravimetric method was used to calculate the relative importance of these food categories and potential predator nutritional gain by direct comparison of similar mass units (Hyslop 1980).

We used the Plymouth Routines in Marine Environmental Research (PRIMER) program ANOSIM (Analysis of Similarity) to quantitatively assess length-dependent shifts in diet. This procedure is a non-parametric multivariate technique that has been used in other diet studies (Gillanders 1995; Crabtree 1998; Winkelman and Van Den Avyle 2002). ANOSIM first calculates all possible pairwise Bray-Curtis similarities that can range from 0 (no similarity) to 100 (identical). The similarities are then ranked from highest to lowest and Clarke's R statistic (Clarke 1993) is calculated using the mean ranks within and between groups. The data is then randomized and the statistic is recomputed. We used 10,000 permutations of the data. The actual R statistic is then compared to the distribution of R generated from the randomizations to determine the percentage of permutations that are as large or larger than the true R value (P value). If the true R value is unlikely to have come from the generated distribution then the null hypothesis ( $H_0$ : there are no differences between groups) is rejected.

#### *Condition Indices*

Condition indices, based on weight-length relationships, are commonly used to provide non-invasive indications of fish health (LeCren 1951; Wege and

Anderson 1978). We assessed body condition throughout the growing and wintering periods by computing relative condition as follows:

$$K_n = W/W' * 100,$$

where  $W$  is the weight of an individual and  $W'$  is its expected weight from the length-weight regression for the population (Anderson and Neumann 1996). A  $K_n$  value greater or less than 100 represents, respectively, better or worse than average condition. Other traditionally used indices of condition were not appropriate for analyzing our data. The Fulton-type condition factors ( $K$ ) are size-dependent and should be used only in comparing fish of similar lengths. Relative weight ( $W_r$ ) is a refinement of  $K_n$  allowing comparison of various sized individuals both within and among populations. However, rapid morphological changes during juvenile development makes  $W_r$  imprecise for striped bass <150 mm in length (Brown and Murphy 1991).

For an independent measure of condition, striped bass from November and March sampling periods were selected to assess the relationship between body size and lipid content. We assumed that these months adequately represented fall and spring lipid levels. We selected striped bass from each 20 mm length class for both months. Individual striped bass were homogenized in a commercial Waring blender and 3-4 samples per fish were analyzed for lipid content following standard AOAC (2000) procedures. Samples (2.5-3.5 g wet weight) were placed on weighed filter paper and dried in an oven (100-102°C) for 24 h to achieve constant mass. After cooling in a desiccator, dry weights were recorded to the nearest 0.0001 g. The dried samples were placed in a Soxhlet



extraction apparatus for 24 h of continuous petroleum ether extraction. After extraction, samples were air dried for 30 min, oven dried for 1 h, cooled in a desiccator, and reweighed to the nearest 0.0001 g. Percent lipid content was computed as the difference in dry weight before and after extraction. All analyses were done using the SAS/MIXED procedure (Version 8, SAS Institute, 1999) that uses a model incorporating heterogeneity of variances for month/length combinations. All tests were considered significant at  $\alpha=0.05$ .

## **Results**

### *Growth patterns and winter survival*

Length distributions of striped bass collected early in the growing season indicate uninterrupted spawning over several days or weeks (Figure 1). Size variation was initially small but the range in length continued to increase throughout the growing season. Distributions appeared skewed, probably because larger individuals achieved rapid growth due to successful feeding events. Striped bass captured in late September ranged from 50 mm to 146 mm.

Fish collected with gillnets in November ranged from 81-247 mm (median = 197 mm; Table 1). Winter growth appeared minimal because fish collected in March (range = 93-264 mm, median = 176 mm; Table 1) had a similar range and median total length to those collected in November. Among months, median sizes differed by as much as 21 mm (Table 1); however, we feel that much of this variation was due to sampling variation rather than to actual changes in the population.

Length-frequency distributions for pre- and post-winter months (November and March) were similar (Figure 2) and showed no decrease in length range or change in median length. Furthermore, quantile-quantile analysis revealed no indication of size-selective mortality as the slope was not significantly different than 1.0 (Figure 3). These analyses indicate that size-selective overwinter mortality of smaller fish is not likely.

Evaluation of gillnet selectivity indicated that each bar-mesh size was selective for particular sized striped bass (Table 2). It appears that our experimental gillnets sufficiently sampled age-0 striped bass because there were no apparent gaps in sizes sampled between adjacent bar-mesh sizes. However, omission of a bar-mesh size may bias the resulting size distribution. The apparent decline of striped bass 190-200 mm in our March sample (Figure 2) can be explained by the lack of a 22 mm bar-mesh panel in the ODWC sampling nets. This particular bar-mesh size produced a catch distribution with a median of 196 mm and 25<sup>th</sup>-75<sup>th</sup> percentages of 187-203 mm. Therefore, discrepancies between March and earlier gillnet length distributions can be attributed to sampling artifact.

### *Food habits*

A total of 476 age-0 striped bass were examined for diet analysis. Length dependent diet shifts among zooplankton, insects, and fish were apparent across all sampled months (Figure 4). Zooplankton (primarily cladocerans and copepods) and insects (primarily dipterans) were important for smaller striped

bass whereas fish (atherinids, cyprinids, and clupeids) dominated the diets of larger individuals.

A diet shift was apparent as early as July, when striped bass  $\geq 80$  mm consumed almost exclusively fish and smaller individuals were consuming insects and small amounts of zooplankton. In September, larger striped bass ( $\geq 120$  mm) fed almost entirely on fish ( $>90\%$  composition by weight) whereas insects were most important for fish  $<120$  mm, representing 64% by weight of consumed prey. Zooplankton was important for striped bass  $<60$  mm; however, it decreased in importance with larger striped bass ( $\geq 120$  mm).

By November fish  $<100$  mm fed exclusively on zooplankton, whereas insects made a significant contribution for individuals 100-139 mm and fish averaged 99% of the diet of fish  $\geq 140$  mm. A similar trend was evident through winter (January) with food habits being size-dependent. Striped bass of all sizes were piscivorous; however, prey fishes were heavily utilized only for striped bass  $\geq 120$  mm. Smaller striped bass continued to consume smaller bodied prey items (i.e. zooplankton and insects). Diet data for fish  $<100$  mm was unattainable during this month of sampling due to the small sample size.

By March, zooplankton and insects reemerged as a significant food item for most striped bass. We found no evidence of piscivory in striped bass  $<160$  mm. Fish below this size consumed, on average, 37% zooplankton and 63% insects. Across all size classes of striped bass, zooplankton contributed on average 33% by weight of consumed prey items. Fish dominated (80% of weight) the diet of striped bass  $\geq 200$  mm during this month.

To further describe piscivorous food habits, fish weight consumed was divided into three discrete categories: shad, other fish (primarily atherinids and cyprinids), and digested fish remains. The category "digested fish remains" was used for unidentifiable fish tissue (skeletal or muscle fragments). We assume that the unidentifiable fish remains were in the same proportion as the shad and other fish categories. Weights of these categories, along with zooplankton, and insects were combined across all months for striped bass of discrete lengths (Figure 5). The stomach contents of fish <120 mm were dominated by zooplankton and insects with a small contribution of other fish and fish remains. Shad entered the diet by 120 mm and increased in proportion with length of striped bass. Other fish were present in the diets of striped bass 80-219 mm in length.

### *Condition Indices*

Age-0 striped bass collected from July to March were used to develop the following linear regression for determining  $K_n$  from weight-length equation:

$$\text{LogWT} = -5.13 + 3.05(\text{LogTL}), N=1541, r^2=0.99, P<0.0001,$$

where LogWT is the base ten logarithm of wet weight and LogTL is the base ten logarithm of total length. Median  $K_n$  values ranged from 106.8 in July to 91.3 in December (Figure 6). No clear trends in monthly median values existed. Based on these data, striped bass appeared in good physiological condition in all months.

Lipid percentages (Table 3) were length-dependent in both November and March with larger individuals having greater percentages than smaller individuals

( $F_{9,10}=56.11$ ,  $P<0.0001$ ). Contrary to our expectations, every length class had higher lipid percentages in March than in November, producing a significant month effect ( $F_{1,86.4}=231.80$ ,  $P<0.0001$ ; Figure 7). Striped bass of all sizes had accumulated fat reserves during the wintering period and were in excellent condition.

## Discussion

We found no evidence of size-selective overwinter mortality of striped bass in Lake Texoma during the winter of 2002-2003. This contradicts many published studies on overwinter survival in other fishes. Usually, larger individuals have higher survival rates as has been shown in striped bass (Sutton and Ney 2001; Hurst and Conover 1998) white perch *Morone americana* and yellow perch *Perca flavescens* (Post and Evans 1989; Johnson and Evans 1991), largemouth bass *Micropterus salmoides* (Ludsin and DeVries 1997; Garvey et al. 1998; Fullerton et al. 2000), smallmouth bass *Micropterus dolomieu* (Oliver et al. 1979), walleye *Stizostedion vitreum* (Forney 1976), freshwater drum *Aplodinotus grunniens* (Bodensteiner and Lewis 1992; Braaten and Guy 2004), coho salmon *Oncorhynchus kisutch* (Quinn and Peterson 1996) tiger muskellunge *Esox lucius* X *E. masquinongy* (Carline et al. 1986), bluegill sunfish *Lepomis macrochirus* (Cargnelli and Gross 1996) pumpkinseed *Lepomis gibbosus* (Bernard and Fox 1997) and Atlantic silversides *Menidia menidia* (Schultz et al. 1998). Other studies found limited, mixed, or no evidence of asymmetric overwinter mortality among different fish species (Toneys and Coble 1979; Garvey et al. 1998; Jackson and Noble 1999).

Most studies showing size-dependent winter mortality were done in mid-high latitudes where winters are typically more severe than those on Lake Texoma. Winter temperature may not be correlated with mortality in lower latitudes, resulting in increased survival (Summerfelt and Shirley 1978; Fullerton et al. 2000). We believe that common mechanisms causing overwinter mortality, such as starvation, energy depletion, predation, and harsh winter temperatures are not as critical in Lake Texoma.

High condition values throughout the winter most likely explain the ability of smaller individuals to persist during winter months. Although relative condition ( $K_n$ ) of fish collected from December to February was slightly below the average condition, the values for March were above average. Furthermore, fat content increased during winter months as fish of all sizes collected in March contained higher percentages of lipids by weight than did the same cohort of fish collected four months prior. While lipid content was size-dependent during both sampling months, even small fish had higher lipid levels in March. In contrast, previous studies demonstrated diminished lipid content during winter months in a variety of fishes (Miranda and Hubbard 1994; Hurst et al. 2000; Sutton and Ney 2001). Smaller individuals tend to utilize their lipid reserves during this time due to higher relative metabolic rates than larger individuals (Brett and Groves 1979). Diminished energy supply coupled with low water temperature leave individuals at a greater risk of starvation, osmoregulatory failure, and predation.

Larger striped bass were consuming fish rather than insects and zooplankton, possibly explaining their high lipid content relative to smaller

individuals. The switch to piscivory may allow higher growth rates and subsequent surplus energy reserves than a continued diet of lower quality food types, such as zooplankton and insects. Matthews et al. (1988) found that in some years, condition coefficients of striped bass in Lake Texoma declined during late spring months when shad were scarce and insects were heavily consumed. Nutritional quality can vary among prey fishes consumed (Cummins and Wuycheck 1971; Davis and Boyd 1978; Miranda and Muncy 1989). Our data supported this because the largest striped bass, which ate shad exclusively, had higher lipid content than slightly smaller individuals consuming a mixed diet of shad and silversides.

Our food habitat study revealed size-dependent diet switches. Smaller individuals in every sample consumed copepods, cladocerans, and various insect larvae, while larger individuals consumed fish. Diet shifts have been observed in both hatchery ponds (Harper et al. 1968; Humphries and Cumming 1971; Harper and Jarman 1971) and the natural environment (Gomez 1970; Saul 1983; Matthews et al. 1988, 1992; Hurst and Conover 2001; Sutton and Ney 2001). Copepods are generally the first prey item utilized followed by cladocerans and insect larvae. Fish typically enter the diet as striped bass approach 60 mm TL and become increasingly important until about 100 mm TL when they dominate the diet; however, fish have been found in stomachs of 30 mm striped bass (Sutton and Ney 2001). Juveniles appear to be opportunistic feeders (Setzler et al. 1980; Saul 1981; Crance 1984) whereas adults are selective for soft-rayed fish (Setzler et al. 1980; Matthews et al. 1988).

The dietary switch to piscivory is crucial for rapid growth (Shelton et al. 1979; Keast and Eadie 1985; Ludsin and DeVries 1997; Garvey and Stein 1998) due to the high caloric value of fish (Cummins and Wuycheck 1971; Aggus and Elliott 1975). Furthermore, the supply and consumption of age-0 clupeid prey is considered a requirement for rapid growth of striped bass in several southern impoundments (Saul 1981; Van Den Avyle et al. 1983; Sutton and Ney 2001). The transition to piscivory observed in our study was abrupt and probably reflects gape limitations of smaller striped bass. Predators display selection towards fish prey of specific body depths within their gape limitations (Dennerline 1987; Hambright 1991; Sutton and Ney 2001) and larger striped bass have a greater proportion of the age-0 shad biomass available for consumption. This fish diet probably enabled larger striped bass to grow faster and store more lipids both before and after winter. However, smaller striped bass were able to maintain and increase their lipid content overwinter despite continuing to feed on zooplankton and insects. Small striped bass (80-99 mm) were in favorable physiological condition even with a 100% diet of zooplankton but were still at a disadvantage compared to the larger members of that year-class.

Important forage fish species found in Lake Texoma are inland silversides *Menidia beryllina*, gizzard and threadfin shad, freshwater drum, blacktail shiner *Notropis venustus*, and bluegill sunfish, with inland silversides dominating the seined catch (Echelle and Mense 1967; Mauck 1991). Matthews et al. (1992) reported that in Lake Texoma, juvenile striped bass less than 150 mm primarily ate copepods and chironomids and some inland silversides. Echelle and Mense



(1967) further documented that inland silversides were the most important forage fish for several predators utilizing littoral areas in the lake. It is widely documented that small age-0 striped bass prefer shallow shorelines devoid of physical habitat structure over rock-gravel or sand substrates (Setzler et al. 1980; Crance 1984; Matthews et al. 1992). Inland silversides utilize these same habitats and are probably vulnerable to feeding striped bass. While adult striped bass prefer cooler temperatures (Matthews 1985; Schaffler et al. 2002), juvenile striped bass typically are more temperature tolerant and select warmer environments, i.e. shoreline habitats, where they experience optimal growth (Cox and Coutant 1981). Optimal temperature along with available prey may cause small striped bass to remain in these near-shore habitats. As striped bass grow they become highly selective for shad species (Matthews et al. 1988), which may be one reason they move to the pelagic zone in winter (Saul 1981; Sutton et al. 2000). This selection towards shad is reflected in our food habit data as shad consumption steadily increased with increased size of striped bass. Although inland silversides were common in the stomachs of smaller striped bass throughout the winter, shad represented a larger percent of diet by weight.

March sampling showed an interesting trend of increasing proportions of zooplankton and insects in striped bass diet. Matthews et al. (1988) previously documented this marked "switching" among prey items of striped bass in Lake Texoma during the spring and early summer months when shad forage decreased. They speculated that despite the availability of silversides, small minnow species, and small sunfish species in the littoral zone, striped bass

preferred a diet of shad and insects. It seems that after striped bass have switched to eating shad they either avoid other fish prey species or those species are unavailable. Stevens (1979) reported similar results in Santee-Cooper Reservoir, South Carolina where approximately 40% of the striped bass in the lake starved to death rather than switching to an alternate fish source (i.e. crappie) However, we did not collect prey availability data and cannot address the mechanisms behind striped bass prey selection, relative to the availability of other fish prey types in Lake Texoma during our study.

Comparing the size ranges of fish collected before and after winter indicated that growth of striped bass during the winter was negligible. Other studies have indicated that age-0 striped bass discontinue feeding as water temperatures drop below 10°C (Hartman and Brandt 1995; Hurst and Conover 1998). Water temperatures in Lake Texoma were at or below this threshold during much of the winter (average surface temperature: December = 10.9°C, January = 6.9°C, February = 8.9°C, March = 12°C) indicating that growth should be minimal regardless of fish size. However, we found striped bass of all sizes were feeding during this time.

Although historic water temperature data for our study site was unavailable, we were able to obtain monthly air temperature averages for November through March from the National Oceanic and Atmospheric Administration Center to determine if we experienced an unusually mild or cold winter. Monthly departures from normal ranged from +0.9°C in December to -2.4°C in February; therefore, our study year represented a typical winter.

However, cold temperatures may indirectly affect striped bass recruitment by reducing the amount of shad. Threadfin shad are very sensitive to harsh winter conditions, and Mauck (1986) reported that environmental factors such as discharge of flood waters and severe cold weather had an impact on densities of threadfin shad in Lake Texoma. Therefore, in years of extremely low temperatures, loss of forage and subsequent loss of striped bass may be expected.

#### *Implications for Lake Texoma striped bass recruitment*

Our results indicate that winter conditions that hinder recruitment of fishes in northerly temperate reservoirs may not be as important in Lake Texoma, a southern reservoir. All sizes of age-0 striped bass in Lake Texoma were successful at surviving the winter. This was most likely due to the relatively short, mild winter experienced at this latitude and the abundance of highly profitable food items during this critical period. We conclude that overwinter mortality will not effect striped bass recruitment in Lake Texoma during years of similar climatic patterns that we observed during this study.

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Table 1. Sampling statistics for age-0 striped bass collected from Lake Texoma using experimental gillnets.

Sampling Month	N	Median Total Length (mm)	Total Length Range (mm)	Total Length 25th-75th Percentile Range (mm)
Sep	81	157	70-228	119-182
Oct	116	184	82-247	150-205
Nov	189	197	81-247	173-212
Dec	92	193	111-266	172-210
Jan	108	191	104-258	167-224
Feb	70	176	101-243	154-197
Mar	343	176	93-264	146-219

Table 2. Size structure of age-0 striped bass caught in seven sizes (bar-mesh) of gillnets fished in Lake Texoma.

Bar-mesh (mm)	Number	Striped Bass Length (mm)		
		Range	Median	25-75%
10	30	70-240	85	80-89
13	64	96-247	110	105-116
16	49	125-226	149	141-154
19	211	135-266	173	165-186
22	158	153-243	196	187-203
25	113	185-250	216	209-230
32	26	216-258	240	231-248

Table 3. Sampling statistics for age-0 striped bass evaluated for lipid content in pre- and post-winter periods. Length groups that are statistically different within months are denoted by differing letters ( $\alpha=0.05$ ).

Total Length (mm)	November				March			
	N	% Lipid	S.E.		N	% Lipid	S.E.	
80-99	8	7.9	0.4	B	6	12.0	1.0	C
100-119	9	4.0	0.7	C	14	9.3	0.7	CD
120-139	2	2.6	1.0	BCD	10	8.0	1.1	D
140-159	10	3.4	0.8	CD	13	9.2	0.9	CD
160-179	13	2.0	0.3	D	15	6.7	1.1	D
180-199	15	4.2	0.6	C	8	12.7	1.4	C
200-219	9	6.6	0.8	B	10	18.5	1.6	B
220-239	17	11.9	1.1	A	15	18.1	1.0	B
240-259	6	13.9	1.0	A	16	24.3	0.9	A
260-269	*	*	*	*	4	27.0	1.6	A

Figure 1. Length-frequency distributions of age-0 striped bass collected by seining in Lake Texoma.

Figure 2. Pre- and post-winter length distributions for young-of-the-year striped bass collected through gillnetting in Lake Texoma. Fish collected with 22 mm bar-mesh in November sampling were omitted because this bar-mesh size was not used in the March sampling.

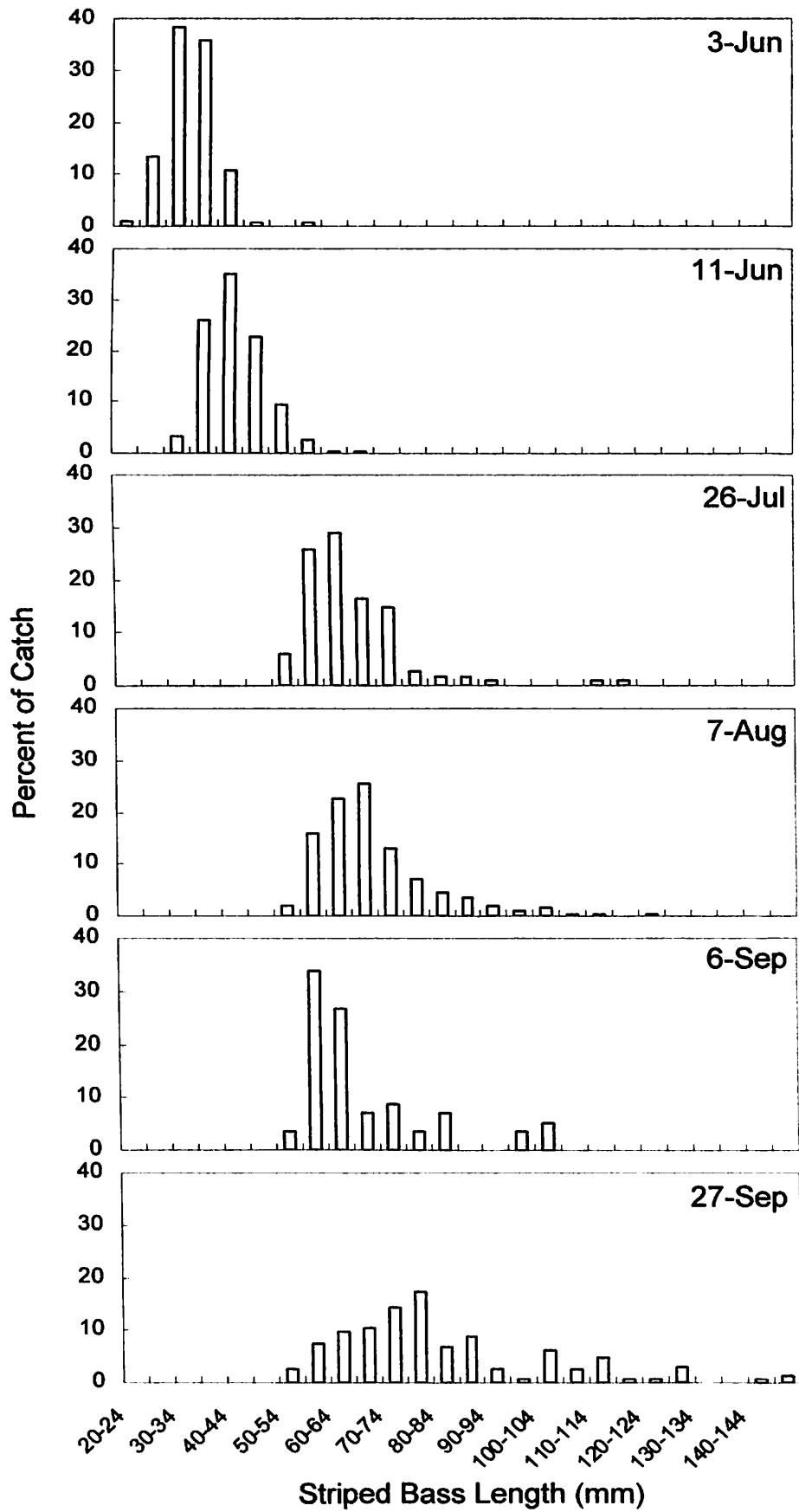
Figure 3. Pre-winter (November 2002) and post-winter (March 2003) quantile-quantile plots for age-0 striped bass collected in Lake Texoma. The dashed line corresponds to a 1:1 slope. Fish collected with 22 mm bar-mesh in November sampling were omitted because this bar-mesh size was not used in the March sampling.

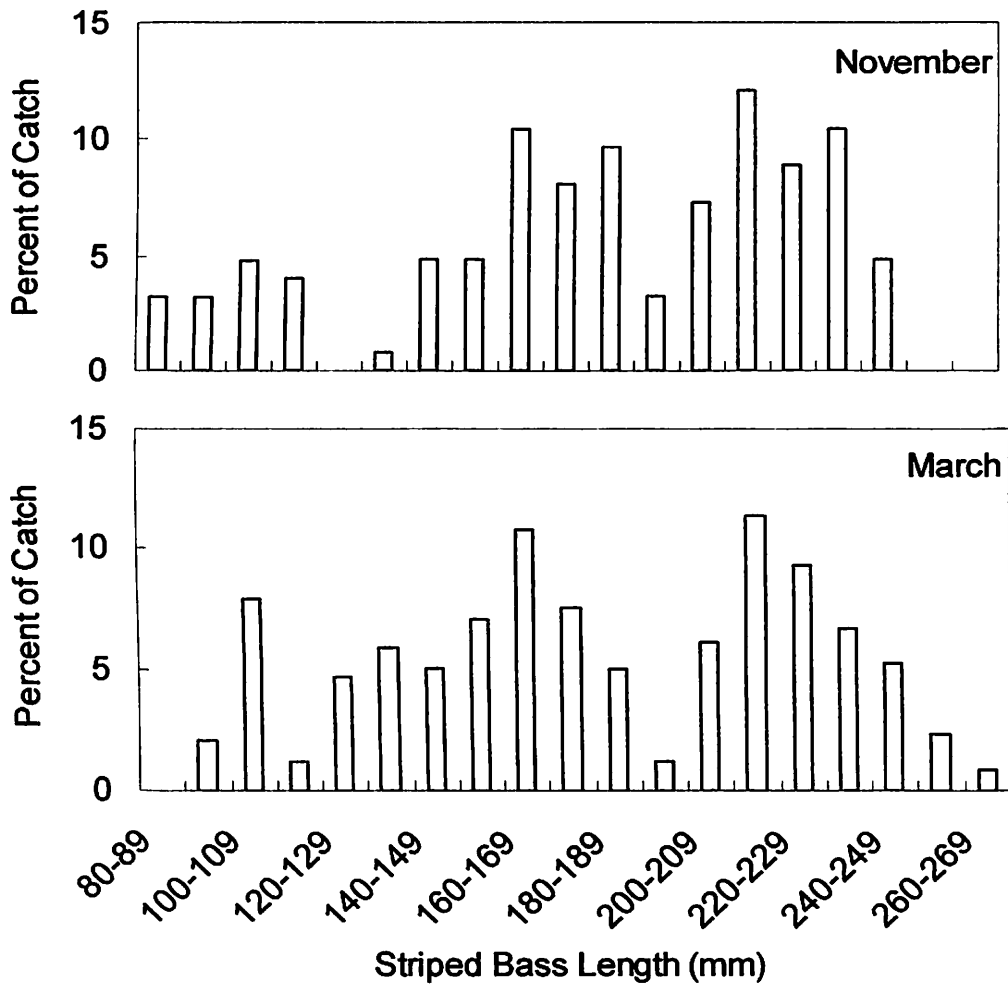
Figure 4. Bi-monthly length-dependent food habits of age-0 striped bass collected from Lake Texoma from July to March. Results are expressed in percent of diet by weight for each 20 mm size class. Length groups that are statistically different within months are denoted by differing letters ( $\alpha=0.05$ ).

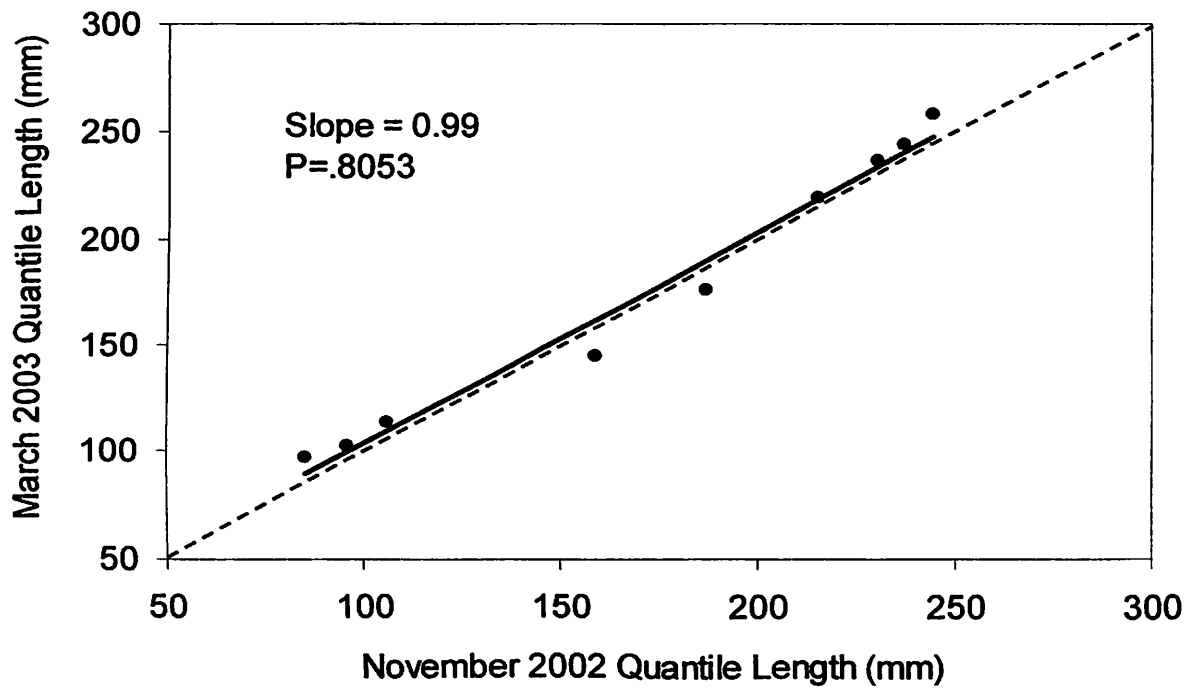
Figure 5. Length-dependent food habits of age-0 striped bass collected in Lake Texoma from July to March. The other fish category is primarily composed of atherinides and cyprinids. Results are expressed in percent of diet by weight for each 20 mm size class.

Figure 6. Temporal patterns in relative condition ( $K_n$ ) for age-0 striped bass in Lake Texoma. Median and 25<sup>th</sup>-75<sup>th</sup> percentage values are represented for each month of sampling. The line at 100  $K_n$  reflects expected condition of fish at a given size.

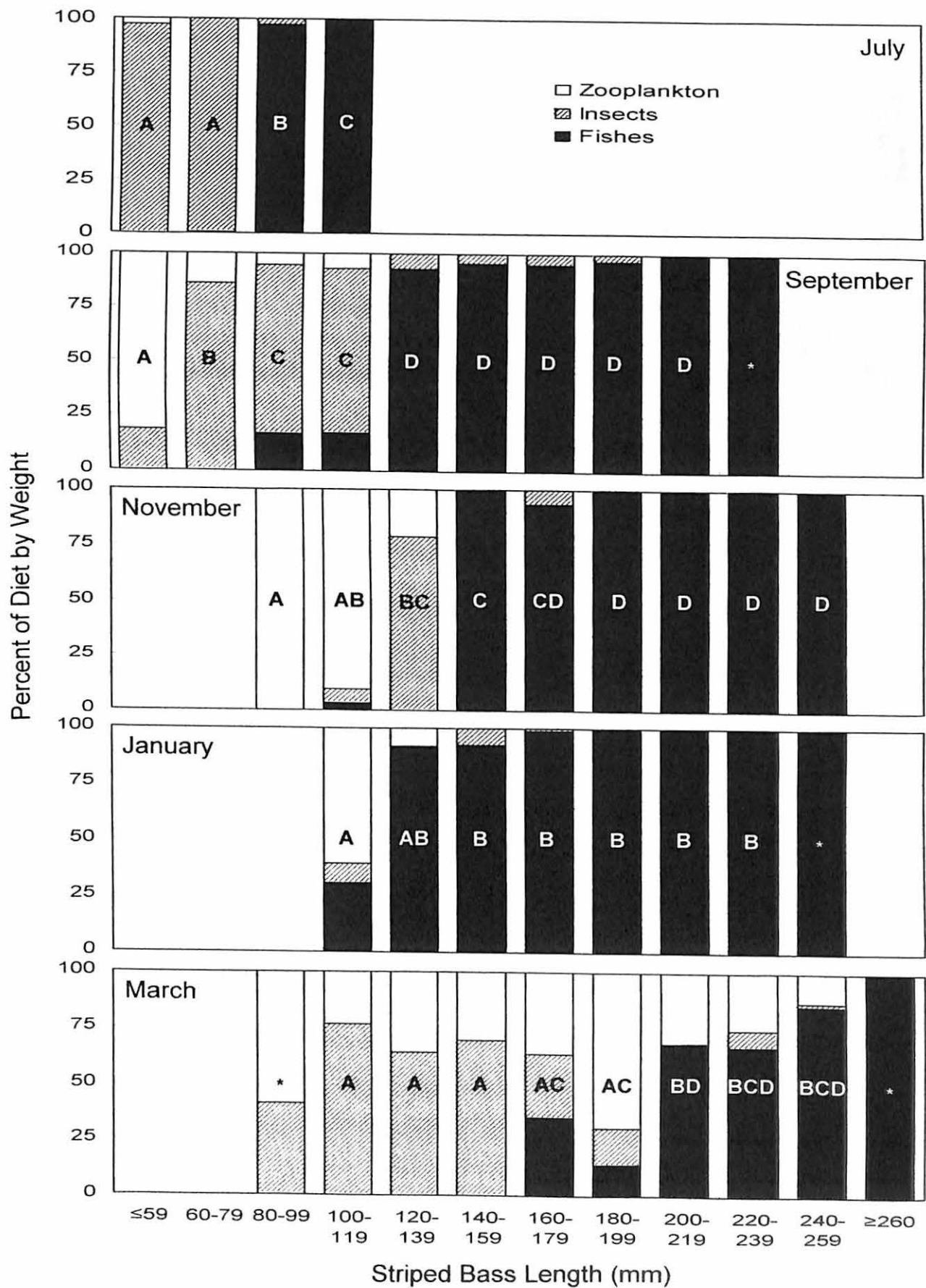
Figure 7. Comparison of mean ( $\pm 1$  SE) percent lipid content for age-0 striped bass at pre- and post-wintering months.

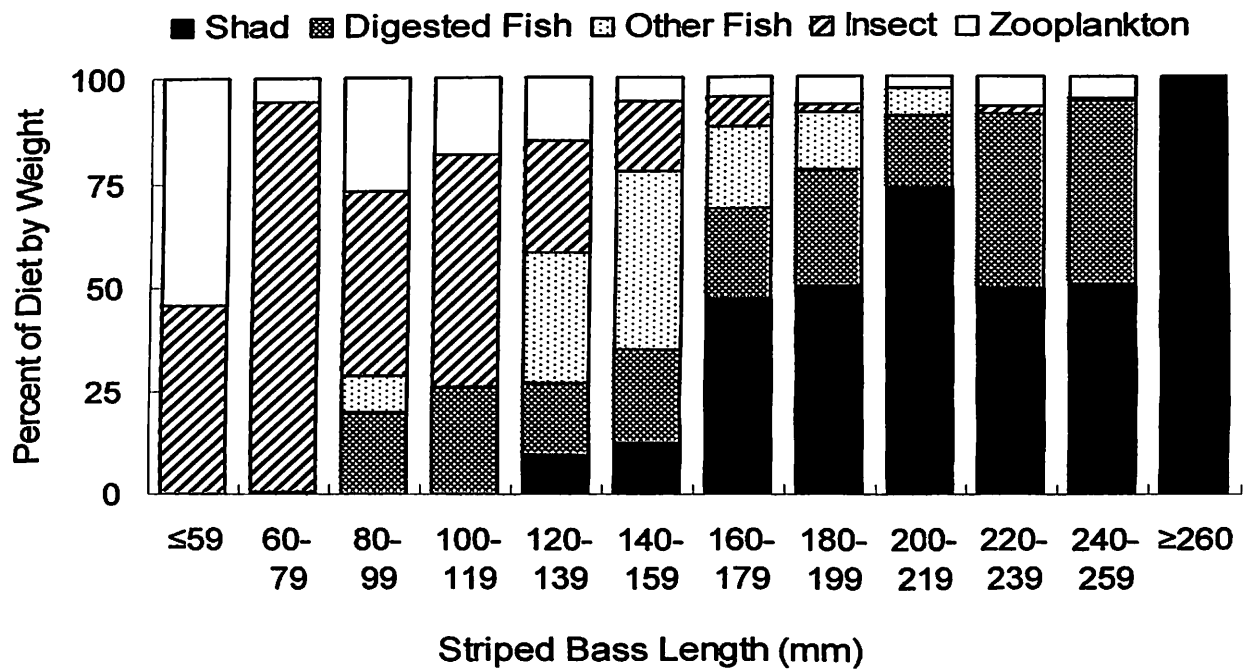


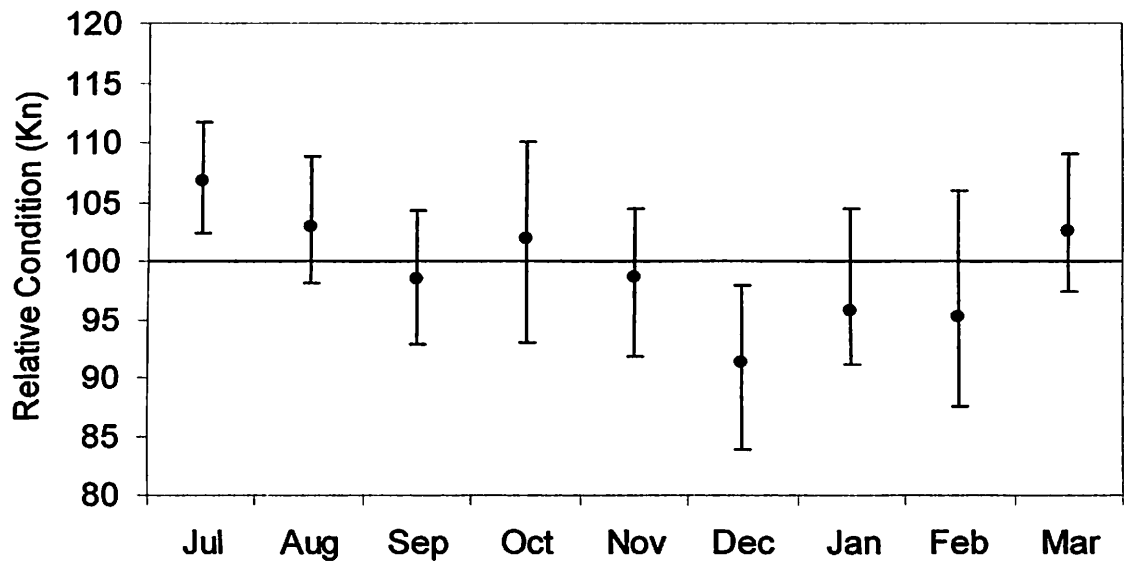


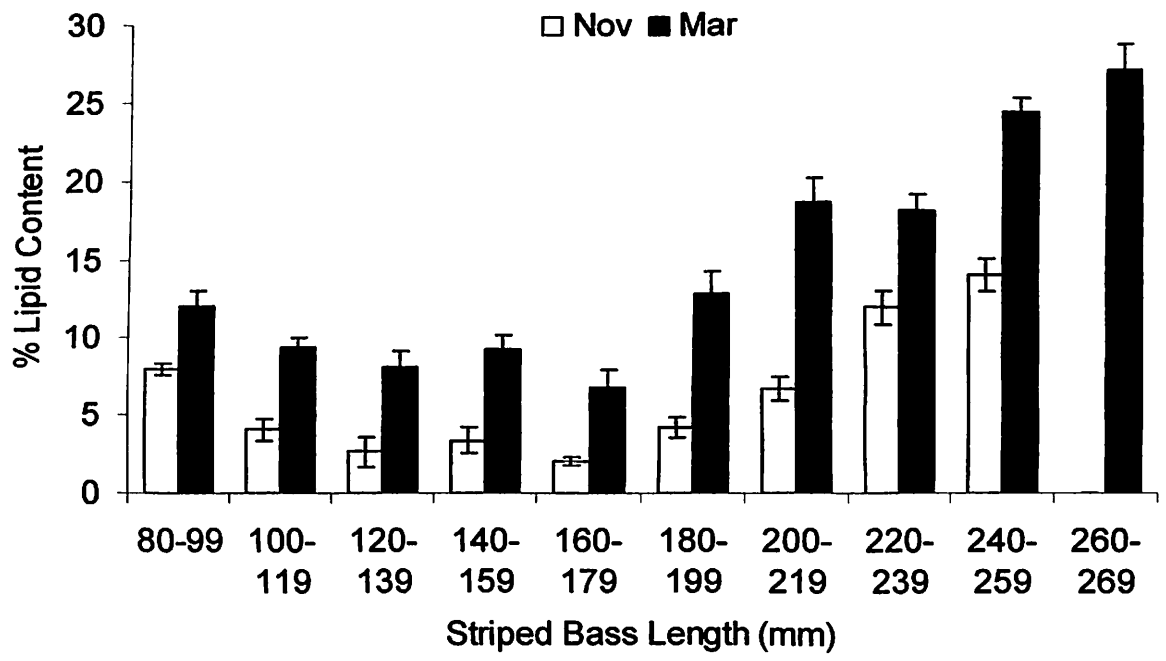












VITA



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**Thesis Title: FACTORS INFLUENCING FIRST YEAR RECRUITMENT OF STRIPED BASS IN LAKE TEXOMA**

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