Comparative Ecology
of
Juvenile Striped Bass and
Juvenile Hybrid Striped Bass
in
Claytor Lake, Virginia

by

Jacob M. Rash

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Master of Science

in

Fisheries and Wildlife Sciences

APPROVED:

J. J. Ney, Chair

E. M. Hallerman   B. R. Murphy

J. R. Copeland

December 2003

Blacksburg, VA

Keywords: Striped bass, Hybrid striped bass, Recruitment, Growth, Survival

Comparative Ecology of Juvenile Striped Bass and Juvenile Hybrid Striped Bass in Claytor Lake, Virginia

By

Jacob Michael Rash

ABSTRACT

Since the introduction of hybrid striped bass *M. chrysops* x *M. saxatilis* to Claytor Lake, Virginia in 1993, relative abundance of striped bass *Morone saxatilis* has dropped disproportionately to stocking density. Potentially deleterious interactions between the two fishes that may limit recruitment to age 1 were considered in terms of trophic relationships, physiological indices of health, overwinter survival, and post-stocking predation.

Both fishes preferred habitat types characterized by structure-free sand or gravel substrates, but striped bass and hybrid striped bass did not exhibit significant diet overlap during the growing season. At a total length of approximately 120 mm, the juvenile moronids shifted from a mixed diet of zooplankton and invertebrates to a diet comprised primarily of age-0 fishes. However, after becoming piscivorous striped bass preyed primarily upon age-0 alewife *Alosa pseudoharengus,* while hybrid striped bass consumed age-0 sunfishes.

Striped bass achieved mean total lengths of 229 and 173 mm by the end of the growing season in 2001 and 2002, respectively. Stocked into the reservoir three months later than striped bass, mean hybrid striped bass total lengths reached 133 mm at the end of the 2002 growing season. Condition factor, relative weight, and lipid index values were low, but nearly equivalent for both striped bass and hybrid striped bass throughout this study. Overwinter starvation of smaller (< 150 mm total length) striped bass was observed for the 2001-2002 sampling season. Predation upon stocked fingerlings was not considered significant in limiting juvenile survival; only three fingerling moronids were found in the examination of stomach contents of 200 potential predators captured near stocking sites.

It does not appear that resource competition with hybrid striped bass during the growing season resulted in increased overwinter mortality of juvenile striped bass. Delayed stocking of hybrid striped bass lessens the potential for trophic competition between striped bass and hybrid striped bass at this early life-stage.

ACKNOWLEDGEMENTS

I thank Dr. John J. Ney for giving me the opportunity to become one of his students. His guidance, along with that of those who have served as graduate committee members (Dr. C. Andrew Dolloff, Dr. Eric R. Hallerman, Dr. Brian R. Murphy, and Mr. John R. Copeland), has piloted this study. During the experience there have been several memorable moments, and all of which are distinguished by the unique charms of Dr. Ney.

The long and odd hours of this study ensnared the help of many people. To those who helped along the way, Forest Allen, Marcy Anderson, Travis Brenden, Dennis Brown, Mike Clark, Tim Copeland, Jason Corrao, Josh Duty, Joe Grist, Whitney Grogan, John Harris, Justin Homan, Aaron Liberty, Todd Lenger, Jay McGhee, Josh Milam, Greg Murphy, Jason Persinger, Jamie Roberts, Larry Scarborough, Andy Strickland, Chris Williams, and Lora Zimmerman, I thank you. Also, I express gratitude to Kathy Finne and Dr. Eric Hallerman for their unselfishness in guiding me through the world of genetics. Last, but certainly not least, I thank John Kilpatrick. Going above and beyond the duties of a mentor and friend, John ensured that I completed whatever task was at hand.

I thank American Electric Power, the Virginia Department of Game and Inland Fisheries, and the Department of Fisheries and Wildlife Sciences at the Virginia Polytechnic Institute and State University for their financial support.

I am forever grateful to my family and my wife, Lauren, for their undying belief in me. Without their love and encouragement, this journey would not have been possible, much less, completed. Lauren, thank you for understanding.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The striped bass *Morone saxatilis* is a large, anadromous piscivore native to the Atlantic and Gulf coasts of North America (Matthews et al. 1988). Several inland states developed an intense interest in this fish after it became apparent that the species could complete its life cycle in freshwater, as first noted in the Santee-Cooper, South Carolina Reservoir system (Bailey 1975). The potential of striped bass to provide a trophy pelagic fishery and its ability to control prolific gizzard shad *Dorosoma cepedianum* populations (Harper and Jarman 1971), while not competing directly with native predators, such as largemouth bass *Micropterus salmoides*, is attractive to both anglers and biologists (Moss and Lawson 1982). Striped bass populations are generally maintained via annual stocking of fingerlings, or more rarely, by natural reproduction (Cheek et al. 1985).

Interest also has developed in hybrid striped bass *M. chrysops* x *M. saxatilis*. Due to their perceived advantages versus striped bass (higher temperature tolerance, supposedly sedentary nature, and high catchability), hybrid striped bass often are stocked as a substitute or, less frequently, as a supplement to striped bass in southeastern reservoirs to diversify fisheries for large open-water game fish and to exert additional predatory pressure on gizzard shad populations (Ott and Malvestuto 1981; Saul and Wilson 1981; Woiwode and Adelman 1991; Zhang et al. 1994; Rudacille and Kohler 2000). Axon and Whitehurst (1985) noted the increase in popularity of both striped bass and hybrid striped bass, reporting that 34 states have established fisheries for striped bass, hybrid striped bass, or a combination of both.

Sympatric stockings of striped bass and hybrid striped bass have led to concerns regarding the compatibility of the two fishes. Among Virginia systems, only Claytor

Lake supports a simultaneous fishery for both striped bass and hybrid striped bass. However, since the introduction of hybrid striped bass to Claytor Lake in 1993, catch-per-unit-effort for striped bass in Virginia Department of Game and Inland Fisheries (VDGIF) annual fall gillnet surveys has dropped precipitously, possibly due to competition with hybrid striped bass. Knowledge concerning the ecology of juvenile striped bass and juvenile hybrid striped bass following stocking is sparse. Investigation into the early-life histories of these two species in Claytor Lake may provide information about the apparent decline in striped bass numbers since the introduction of hybrid striped bass.

Bonds (2000) found that the diets of adult striped bass and hybrid striped bass in Claytor Lake overlapped significantly, with each being heavily dependent on the clupeid forage base. Juvenile *Morone* in other systems have been observed to shift food habits from zooplankton and aquatic insects to larval and juvenile fishes at approximately 100 mm total length (TL) (Stevens 1958; Markle and Grant 1970; Ware 1970; Axon 1979; Otto and Malvestuto 1981; Van Den Avyle et al. 1983; Saul and Wilson 1981; Kinman 1987; Matthews et al. 1992; Sutton 1997). Sutton and Ney (2001) reported that in Smith Mountain Lake, Virginia, smaller striped bass juveniles (<120 mm TL) maintained a mixed diet of invertebrates and age-0 cyprinids, while larger juveniles (>150 mm TL) were strictly piscivorous. Saul and Wilson (1981) reported similar results for juvenile hybrid striped bass in Cherokee Reservoir, Tennessee, with individuals less than 120 mm TL feeding primarily on invertebrates, while individuals greater than 120 mm TL were largely piscivorous.

For piscivorous fishes in temperate climates, rapid growth during the first months of life can be critical for overwinter survival (Chevalier 1973; Forney 1976; Nielsen 1980; Craig 1982; Minton and McLean 1982; Sutton 1997; Sutton and Ney 2001). Both striped bass and hybrid striped bass are characterized by rapid first-year growth. The hybrid striped bass does not reach the same ultimate size as the striped bass, but does grow more rapidly during the first two years of life than either white bass *Morone chrysops* or striped bass parent (Tuncer et al. 1990; Jenkins and Burkhead 1993). In controlled environments, hybrid striped bass fry can exhibit first-year growth rates of up to 1.8 g/day (Zhang et al. 1994), ultimately becoming 23.0% longer than striped bass fry over a 71-day period (Logan 1967). In natural systems, hybrid striped bass can achieve lengths greater than 200 mm TL during the first year of growth (Crandall 1978; Gilliland and Clady 1981; Layzer and Clady 1981; Saul and Wilson 1981; Austin and Hurley 1987).

Sutton and Ney (2001) described progressive increases in total length from time-of-stocking through the end of the growing season for age-0 striped bass in Smith Mountain Lake, Virginia. They reported that by December, the first-year total length of Smith Mountain Lake striped bass ranged from 97 to 268 mm in 1994 and 128 to 262 mm in 1995. Growth rates observed by Sutton and Ney (2001) are consistent with those observed in other inland waters, where first-year growth to sizes greater than 200 mm TL for striped bass is common (Stevens 1958; Mensinger 1970; Ware 1970; Erickson et al. 1971; Axon 1979; Van Den Avyle and Higginbotham 1979; Moss and Lawson 1982; Sutton 1997).

During the growing season, age-0 striped bass tend to frequent shallow, structure-free littoral areas over sand or gravel substrate (Mensinger 1970; Van Den Avyle and Higginbotham 1979; Van Den Avyle et al. 1983; Matthews et al. 1992; Sutton 1997), and in East Fork Lake, Ohio, Austin and Hurley (1987) found juvenile hybrid striped bass exhibiting preferences for these habitats types as well. Matthews et al. (1992) found a significant overlap in habitat use by juvenile white bass and juvenile striped bass in Lake Texoma, Oklahoma-Texas, but little information is available concerning the spatial distribution of sympatric juvenile striped bass and juvenile hybrid striped bass. From a thermal standpoint, age-0 hybrid striped bass exhibit optimal growth and peak conversion efficiency at 26.8ºC, while juvenile striped bass have a preferred thermal niche of 24-26°C (Coutant 1985; Woiwode and Adelman 1991). Thus, during the growing season, juvenile hybrid striped bass and juvenile striped bass would be expected to occupy similar thermal habitats within Claytor Lake. The cooler temperatures of late fall and early winter result in a loss of preferred water temperatures for these moronids within the littoral zone of the reservoir. The reduction in temperature may force juveniles of both species to move to deeper pelagic regions in search of suitable food sources and higher water temperatures.

The gradual movement of juvenile *Morone* from littoral habitats to pelagic regions of a system may coincide with the arrival of cooler temperatures, but the initial dispersal rates of *Morone* fingerlings from stocking sites can be rapid (Van Den Avyle and Higginbotham 1979; Sutton 1997). Sutton (1997) reported both rapid and gradual patterns of dispersal for juvenile striped bass in Smith Mountain Lake, Virginia. The rapid dispersal of age-0 individuals from stocking sites could make the identification of the mechanisms restricting juvenile survival difficult to determine because the monitoring of individuals is not immediate, but rather delayed until dispersed individuals return to littoral habitats where they can be monitored.

First-year survival of stocked striped bass fingerlings in inland water bodies is often less than 20% (Bailey 1975; Moore et al. 1991; Michaelson et al. 2001), but causes of this early mortality have received little attention until recently. Michaelson et al. (2001) quantified losses of stocked striped bass by predation to largemouth bass (the primary littoral piscivore) in Smith Mountain Lake, Virginia. Only 14 striped bass were recovered in 1,147 largemouth bass stomachs over the two-year study period, resulting in a 0.1-3.0% estimated loss of fingerlings to predation. McGovern and Olney (1988) noted similar results when the examination of 235 stomachs of 14 species of fishes collected in the Pamunkey River, Virginia provided no evidence of predation on striped bass eggs or larvae. Austin and Hurley (1987) reported predation by black basses and yearling striped bass on hybrid striped bass fingerlings in East Fork Lake, Ohio to be minimal. Thus, mortality of *Morone* fingerlings due to predation may also be insignificant in the regulation of first-year survival of juveniles within Claytor Lake, where the principal littoral piscivores are *Micropterus* spp.

Kilpatrick (2003) failed to document the presence of any juvenile moronids below Claytor Dam. Although emigration of *Morone* fingerlings from a reservoir has been reported (Austin and Hurley 1987), the overall contribution of emigration to the loss of individuals from a population should be minimal, given the small percentage of individuals that leave the reservoir. Low survival of juvenile *Morone* is perhaps more likely the result of size-dependent starvation (Austin and Hurley 1987; Sutton 1997).

Likelihood of overwinter survival for juvenile *Morone* is a function of the size of individual at the end of the growing season (Hurst and Conover 1998; Sutton and Ney 2001) and is not species-specific (Harrell et al. 1988). Larger individuals are able to accumulate greater lipid reserves than smaller individuals, and smaller individuals are more vulnerable to overwinter mortality (Post and Evans 1989; Johnson and Evans 1990; Hurst and Conover 1998; Sutton and Ney 2001).

The ability of an individual to obtain adequate energy reserves is critical for its survival. If both juvenile striped bass and juvenile hybrid striped bass eat similar food items and occupy the same habitat types, competition between the species could be limiting growth and ultimately, survival. The factors regulating first-year growth, survival, and recruitment to age 1 for stocked *Morone* fingerlings must be considered when establishing reservoir fishery management strategies (Sutton 1997). If results of this study indicate the presence of significant niche overlap between both fishes and the occurrence of overwinter starvation in striped bass, the compatibility of the *Morone* stocks within Claytor Lake should be questioned.

Justification

This study describes and compares the ecology of age-0 striped bass and age-0 hybrid striped bass in Claytor Lake, Virginia, to determine if age-0 striped bass and age-0 hybrid striped bass are compatible in the reservoir. Both striped bass and hybrid striped bass are prized gamefish, but their compatibility has received modest evaluation. Due to the decline in the catch-per-unit-effort of striped bass since the introduction of hybrid striped bass into the reservoir (Figure 1), an investigation into the early-life history characteristics of these fishes is warranted in Claytor Lake. There is a need to determine

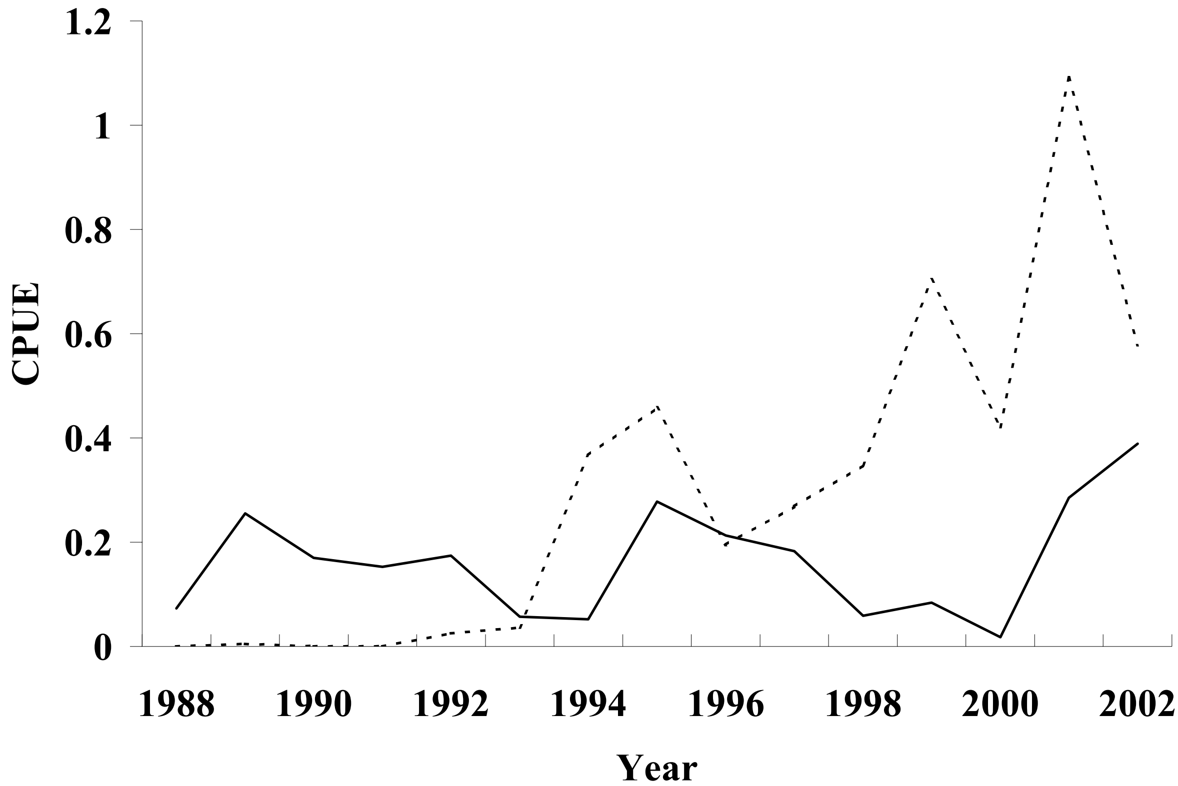

Figure 1. Catch-per-unit-effort for adult striped bass (solid line) and adult hybrid striped bass (dotted line) via Virginia Department of Game and Inland Fisheries annual gillnet sampling in Claytor Lake. Catch-per-unit-effort (CPUE) = number of fish caught per 9.29 m^2 of gillnet.

if the interactions of striped bass and hybrid striped bass at the juvenile life-stage are potentially resulting in competition and eventual mortality.

A great majority of stocked *Morone* mortality occurs within the first year of life, with survival often being less than 20% (Bailey 1975; Moore et al. 1991; Michaelson et al. 2001). The causes of this high early mortality have garnered little investigation. Predation does not appear to provide a substantial contribution to early mortality rates of stocked striped bass (Michaelson et al. 2001), but overwinter starvation of striped bass has been identified as a significant source of juvenile mortality (Hurst and Conover 1998; Sutton and Ney 2001). Starvation occurs in smaller individuals that are unable to accumulate sufficient energy reserves to survive the overwinter period. The appearance of a bimodal size distribution before the overwinter period would indicate that the growth of certain individuals is being limited. A potential source of this limitation could be trophic competition between striped bass and hybrid striped bass. If individuals are out-competed for available food sources during the growing season, then they may be unable to amass the energy reserves required to survive the overwinter period. Thus, if the potential for interspecific competition between juvenile striped bass and juvenile hybrid striped bass is found in this study, consideration should be given to alternate management strategies for the reservoir. By helping to identify possible limiting factors for *Morone* survival, this study will provide information to enable managers to design and implement stocking programs to enhance the recruitment of juvenile *Morone* into their fisheries.

Objectives

The goal of this research is to describe and compare the ecology of juvenile striped bass and juvenile hybrid striped bass in Claytor Lake, Virginia. Specific objectives are to:

1. Quantify and compare first-year growth of juvenile striped bass and juvenile hybrid striped bass;
2. Determine diet overlap of age-0 striped bass and age-0 hybrid striped bass;
3. Compare habitat associations of juvenile striped bass and juvenile hybrid striped bass; and
4. Assess the impacts of predation and starvation upon survival of stocked fingerlings of striped bass and hybrid striped bass.

STUDY AREA

Claytor Lake was created in 1939 by closure of a dam on the New River in Pulaski County, Virginia (Figure 2). Claytor Lake is a mainstream hydroelectric impoundment that maintains a riverine morphometry throughout its 26 km length (Kohler et al. 1986). The reservoir has a surface area of 1,820 ha at normal pool elevation of 663 m above mean sea level, with widths that range between 0.29 and 0.95 km. Claytor Lake has 161 km of shoreline, a 15-m average depth, and a maximum depth of 37.5 m (Kohler et al. 1986; Copeland 1999; Palmer 1999). The mean retention time of the reservoir has been estimated as 33 days (Copeland 1999; Palmer 1999). The moderately eutrophic reservoir is dimictic, experiencing spring and fall turnovers (Boaze 1972; Palmer 1999). The steep-gradient shape of the reservoir results in a limited littoral zone, best developed in a few bays and the major tributary, Peak Creek.

Since impoundment, fifteen species of fish have been stocked into Claytor Lake, making fish stocking the primary management activity on the reservoir (Kohler et al. 1986; Copeland 1999). Initial stocking programs featured centrarchid species and walleye *Stizostedion vitreum* (Kohler et al. 1986; Copeland 1999). Since 1960, stocking programs have been directed toward the development of a pelagic fishery (Copeland 1999). Preliminary attempts to establish threadfin shad *Dorsoma petenese*, rainbow trout *Oncorhynchus mykiss*, and brown trout *Salmo trutta* failed, and in 1968 striped bass fingerlings were introduced into the reservoir to help fill the pelagic niche (Kohler et al. 1986; Copeland 1999). To provide forage for the pelagic fishery, alewife *Alosa pseudoharengus* were introduced in the 1960s, and further expansion of the pelagic forage base was achieved via angler introduction of gizzard shad in the 1980s. As a

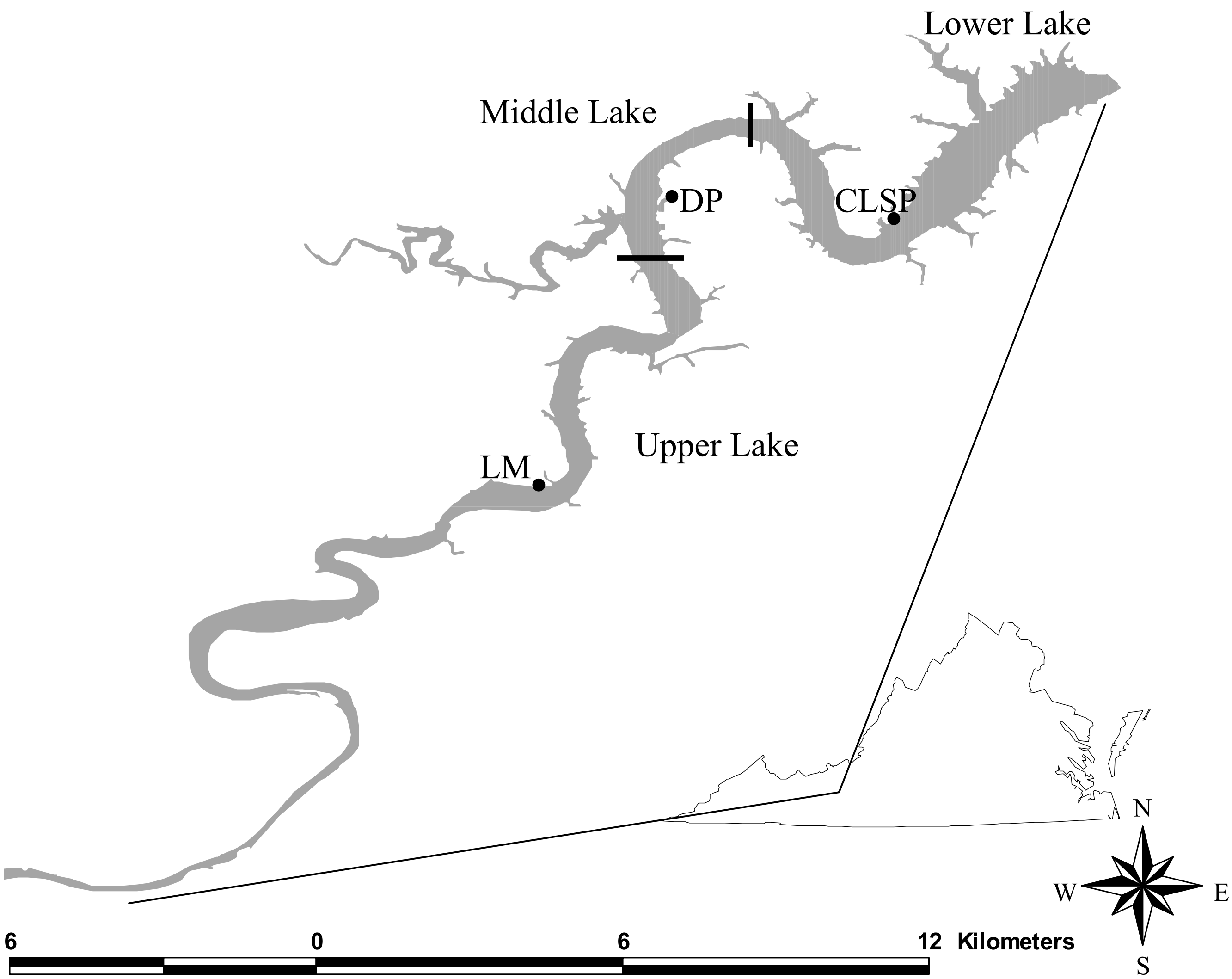

Figure 2. Map of Claytor Lake, Virginia, with sampling partitions and stocking sites. Partitions: Lower Lake = Claytor Dam to Twin Coves; Middle Lake = Twin Coves to Peak Creek; Upper Lake = Upstream of Peak Creek. Stocking sites: CLSP = Claytor Lake State Park; DP = Dehaven Park; LM = Lighthouse Marina.

result, alewife, gizzard shad, and sunfishes *Lepomis* spp. are the principal forage fishes (Bonds 2000).

Claytor Lake supports a fishery consisting of a mixture of warmwater and coolwater species. Warmwater species such as black bass *Micropterus* spp., flathead catfish *Pylodictis olivaris*, channel catfish *Ictalurus punctatus*, white bass, crappie *Pomoxis* spp., and other sunfishes have self-sustaining populations. Coolwater species such as walleye, muskellunge *Esox masquinongy*, striped bass, and hybrid striped bass have been maintained through periodic stocking programs of VDGIF.

Striped bass were stocked in Claytor Lake from 1968 through 1992 at a rate of approximately 70,000 fingerlings per year (John Copeland, VDGIF, pers. comm.). Stockings were reduced to approximately 33,500 fingerlings per year from 1993 through 1997, and in 1999 and 2000 to accommodate the addition of hybrid striped bass. However, stocking rates were again elevated back to approximately 70,000 individuals per year in 1998, 2001, and 2002. Hybrid striped bass have been stocked at a rate of 33,500 fingerlings per year from 1993 through 2002. The current stocking rates of each species result in density of approximately 38 fingerlings per hectare for striped bass and 18/ha for hybrid striped bass. The current striped bass stocking rate in Claytor Lake is higher than the density utilized in Lake Anna, Virginia, which currently has a striped bass stocking rate of approximately 20/ha (John Odenkirk, VDGIF, pers. comm.). However, the combined striped bass and hybrid striped bass fingerling density of Claytor Lake is similar to the stocking density of Smith Mountain Lake, Virginia, which currently receives striped bass at a density of approximately 54/ha.

In 2001, approximately 70,000 striped bass fingerlings and approximately 33,500 hybrid striped bass fingerlings were evenly distributed to three stocking sites: Claytor Lake State Park, Dehaven Park, and Lighthouse Marina (Table 1). In 2002, half of the approximately 70,000 striped bass fingerlings were stocked at Claytor Lake State Park and the other half at Lighthouse Marina, while roughly 33,500 hybrid striped bass were again equally distributed among the three stocking sites of Claytor Lake State Park, Dehaven Park, and Lighthouse Marina (Table 1). Striped bass fingerlings stocked on June 6, 2001, and June 14, 2002, averaged approximately 40 mm TL and less than 1.0 g (Table 1). Hybrid striped bass fingerlings, averaging more than 3.0 g, were stocked in September 2001, a stocking date three months later than striped bass. Hybrid striped bass stocked in August 2002 at an average weight of 11.0 g, were significantly larger than hybrid striped bass stocked in 2001 (Table 1). All striped bass fingerlings originated from the Brookneal, Virginia hatchery operated by VDGIF. Hybrid striped bass fingerlings were purchased for stocking by VDGIF from Keo Fish Farm in Arkansas (2001) and Southland Fisheries Corporation in South Carolina (2002).

Table 1. Summary of juvenile striped bass (STB) and juvenile hybrid striped bass (HSB) stockings during 2001 and 2002 at Claytor Lake, Virginia. Total lengths and wet weights are means; values in parentheses are the minimum and maximum total lengths and wet weights. CLSP = Claytor Lake State Park; DP = Dehaven Park; LM = Lighthouse Marina.

Year	Stock	Number Stocked	Stocking Sites	Rearing Site	Total Length (mm)	Wet Weight (g)
2001	STB	≈70,000	CLSP DP LM	Brookneal Fish Hatchery – VDGIF (Brookneal, VA)	41 (31 - 57)	0.86 (0.33 – 2.25)
	HSB	≈33,500	CLSP DP LM	Keo Fish Farm (Keo, AR)	68 (55 - 78)	3.22 (1.05 - 5.39)
2002	STB	≈70,000	CLSP LM	Brookneal Fish Hatchery – VDGIF (Brookneal, VA)	41 (33 - 49)	0.65 (0.35 – 1.04)
	HSB	≈33,500	CLSP DP LM	Southland Fisheries Corp. (Hopkins, SC)	94 (64 - 110)	10.77 (3.21 - 16.80)

METHODS

Field Collections

Age-0 striped bass and age-0 hybrid striped bass were sought weekly from stocking dates until the second week of December 2001 and 2002 (the approximate end of the growing season). In 2001, the littoral zone of the entire reservoir was searched intensively for the presence of juvenile striped bass and juvenile hybrid striped bass. With an increased understanding of the distribution of stocked juvenile *Morone* in the system, during the second field season, collection efforts were concentrated upon the areas where juvenile *Morone* were captured during the first year of sampling. However, in December of 2002, no specimens were collected. The failure to obtain juvenile *Morone* is probably due to the decline in water temperature (11.1ºC versus 5.5ºC, mean December 2001 and 2002, respectively) (Kilpatrick 2003). Thus, by December 2002, juveniles had likely moved from littoral to deep habitats to seek warmer water.

I partitioned the reservoir into three regions, lower lake (Claytor Dam to the Twin Coves), middle lake (the area between the Twin Coves and Peak Creek), and upper lake (area above Peak Creek) (Figure 2). I concentrated sampling efforts within each region upon areas where juveniles were consistently found (sand or gravel substrates without cover), during a single region each week. Habitats in each region found not to be consistently used by juvenile striped bass or juvenile hybrid striped bass (all areas with cover and all boulder substrates) also were monitored (see Habitat Usage), but in order to maximize capture success, sampling was concentrated upon suitable habitats. Fishes were again sought during the post-winter, pre-growing season period in March and April 2002 and 2003. However, I was unable to capture any juvenile moronids until April

2003 (one month later than first captures in the spring of 2002). March of 2003 was much colder and thus, winter was prolonged longer than in March of 2002, which may have affected distribution and activity of juvenile moronids.

To obtain representative samples of age-0 *Morone* over the size range present in the lake, a variety of sampling gears were utilized. Electrofishing was conducted weekly in each region to target fish in the littoral zone using a boom-type electrofisher with pulsed-DC current. A global positioning system (GPS) was used to record the location of each fish capture site. Horizontal gillnets were deployed each week from September through December of 2001 and 2002, and again in March and April of 2002 and 2003 to target fish not susceptible to electrofishing. Three bi-panel monofilament gillnets (30.5-m long and 1.8-m deep consisting of two 15.2-m long panels with bar mesh sizes of 25 and 19 mm, 19 and 13 mm, and 25 and 13 mm) were set perpendicular to the shoreline and anchored to the bottom to target fish that occupied waters deeper than those that could be sampled via electrofishing. One of each net type was set each week. Nets were set at dusk and retrieved at dawn the following day.

I sought to collect at least 30 juvenile striped bass and 30 hybrid striped bass in total using all gear types employed during each weekly sampling period. All striped bass and hybrid striped bass collected were immediately placed on ice. Upon return from field collection, all fish were blotted dry and weighed to the nearest 0.01 g, measured to the nearest 1 mm total length, and frozen for future stomach content analysis.

Stock Identification

Juvenile striped bass and juvenile hybrid striped bass can be distinguished via investigation of meristic characters. Differentiating features include the number of lateral line scales (approximately 58 for striped bass and approximately 52 for hybrid striped bass) and the length of the second anal spine (shorter in relation to third anal spine for striped bass and longer in relation to third anal spine for hybrid striped bass) (Kerby 1979a; Kerby 1979b; Harrell and Dean 1988; Muoneke et al. 1991). While these characters were used successfully to distinguish between striped bass and hybrid striped bass stocked in 2002, over the course of the 2001-2002 season, I was unable to make a distinction between stocks by comparing meristic characters. Individuals collected in the late fall of 2001 (hybrids were stocked in late September) and the early spring of 2002 exhibited the diagnostic character of juvenile striped bass, but no individuals displayed the defining characteristics of juvenile hybrid striped bass. Thus, alternative methods were sought for species identification of age-0 moronids stocked in 2001.

Genetic markers were used to verify species type using amplification fragment size analysis at microsatellite loci. To provide tissue samples for comparative analysis, dorsal fin clips were removed from ten white bass (taken from Lake Norman and High Rock Lake, NC), ten hybrid striped bass (Southland Fisheries Corp., Hopkins, SC), ten striped bass (Brookneal Fish Hatchery, Brookneal, VA), two hybrid striped bass (Keo Fish Farm, Keo, AR), and ten fish of “questionable” phenotype (as determined from meristic analysis) from the 2001-2002 sampling season. Fin clips were frozen until subsequent DNA extraction, which was conducted under the guidance of Dr. Eric Hallerman and Kathy Finne of the Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University. The DNA was extracted from fin tissue using the Puregene DNA isolation kit (Gentra, Minneapolis, MN). Polymerase chain reaction (PCR) was used to amplify six potentially diagnostic microsatellite loci

SB6, *SB11*, *SB83* (Han et al. 2000), *SB91*, *SB113* (Roy et al. 2000), and *SB108* (C. Couch, North Carolina State University, pers. comm.). DNA was amplified with a PCR Express (Hybaid, Franklin, MA) thermocycler, with cycling conditions consisting of 30 amplification cycles of the following: 30 sec at 94°C; 30 sec at 49°C (SB6), 30 sec at 53°C (*SB11*, *SB83* and *SB91*), or 30 sec at 46°C (*SB108*); 40 sec at 72°C; and a final holding temperature of 4°C.

The amplification product was sent to the Virginia Bioinformatics Institute (Blacksburg, VA) to determine molecular weights, where an Applied Biosystems (Foster City, CA) 377 Genetic Analyzer was used for data collection, and Applied Biosystems Genescan and Genotyper Software were used for analysis. Output then was interpreted for species identification by Ms. Finne and Dr. Hallerman.

First-Year Growth

Subsamples of juvenile *Morone* fingerlings were obtained from hatchery vehicles at stocking sites or by the immediate sampling of stocked fingerlings to provide baseline size information on stocked *Morone* (Table 1). Temporal patterns in growth were described by calculating a monthly mean length and weight of juveniles, and then plotting means over the growing season (June through December 2001 and 2002) (Sutton 1997). Monthly length-frequency histograms for 2001-2002 and 2002-2003 were interpreted to describe patterns and size distribution in growth of juvenile striped bass and juvenile hybrid striped bass (Sutton and Ney 2001).

Total first-year growth in length was calculated for juvenile striped bass and juvenile hybrid striped bass during periods of linear growth via an absolute growth rate equation, which is defined as:

$$\text{absolute growth rate} = (Y_2 - Y_1) / (t_2 - t_1),$$

where Y_1 is the initial mean total length (mm) of juvenile *Morone*, Y_2 is the mean total length (mm) of juveniles for the final month of linear growth, t_1 is the initial day of stocking, and t_2 is the final day of fish collection during the final month of linear growth (Busacker et al. 1990).

Post-Winter Survival

Overwinter survival was evaluated by comparing length-frequency histograms from late fall and early spring. Juvenile striped bass have been reported to exhibit little to no growth over winter when water temperatures are below 10ºC (Cox and Coutant 1981; Kerby et al. 1987; Woiwade and Adelman 1991; Hurst and Conover 1998; Sutton and Ney 2001). Sutton and Ney (2001) noted that determination of size-dependent overwinter mortality from length-frequency data requires that: 1) mean length of fish increased over the winter while the variability in length decreased; and 2) the decrease in variability should be due to an upward shift in the minimum but not the maximum length. In addition, failure to attain some minimum size prior to the winter period may result in the inability of an individual to obtain the energy reserves required to survive the overwinter period (Sutton 1997). Therefore, lipid analysis was used as an indicator of overwinter health (see Indices of Health).

Food Habits

To assess diet composition, fish were thawed and stomachs, from the base of the esophagus to the anterior portion of the intestine, were removed and preserved in 10% formalin for subsequent analysis. Stomach contents were examined under a dissecting microscope and identified to the lowest possible taxon (order or family for invertebrates and genus or species for fish). Prey items were blotted dry and weighed to the nearest 0.01 g.

The percent contribution by weight of each prey type (Hylsop 1980) was calculated using the following equation:

$$\%WTP_i = \sum(WTP_i \,/\, WT) \,/\, N,$$

where $\%WTP_i$ is the average percent contribution by weight for prey type i, WTP_i is the weight of prey i consumed by an individual predator, WT is the total weight of all prey types consumed by that predator, and N is the total number of predators of that type sampled that contained food (Sutton 1997). Percent contribution by weight allows food types to be quantified in directly comparable mass units so that the relative importance of these diet items can be estimated in terms of approximate nutrition gained by the predator (Bowen 1996; Sutton 1997).

Diet Overlap

Diet overlap, as an index of interspecific trophic competition, was calculated between juvenile striped bass and hybrid striped bass by month and by 10 mm size class intervals during the 2001 and 2002 growing seasons and the 2002 and 2003 post-winter periods (Sutton 1997). Overlap was evaluated by using diet composition weight percentages and Schoener's (1970) overlap index, which is defined as:

$$C_{xy} = 1.0 - 0.5 \sum_{i=1}^{n} |p_{xi} - p_{yi}|,$$

where C_{xy} is the overlap index, p_{xi} is the proportion of food type i used by species x (striped bass), p_{yi} is the proportion of food type i used by species y (hybrid striped bass), and n is the total number of food categories (Crowder 1990). Overlap values of 0.6 or greater are considered indicative of potential trophic competition (Crowder 1990).

Indices of Health

Fulton condition factor (K), relative weight, and lipid index values were evaluated to assess the health of juvenile moronids within this study.

Condition Factor (K). - Body condition of each juvenile *Morone* was evaluated by the calculation of its Fulton condition factor (K), which is defined as:

$$K = (W / L^3) \times 100{,}000,$$

where W is the measured wet weight (nearest 0.01g) and L is the total length (nearest 1 mm) (Anderson and Neuman 1996).

Relative healthiness determined by condition factors only was compared within species. Comparison of condition factors between juvenile striped bass and juvenile hybrid striped bass would not be valid because of the different body shapes of these fishes (Anderson and Neuman 1996).

Relative Weight. - The relative weight index (W_r) represents a refinement of the K concept, via the ability to compare values between species and populations (Wege and Anderson 1978; Brown and Murphy 1991a; Anderson and Neuman 1996; Sutton 1997). However, due to the high variability in the length at which the growth form changes for both striped bass and hybrid striped bass, the relative weight index is not accurate for individuals less than 150 mm TL and 115 mm TL, respectively (Brown and Murphy 1991b; Anderson and Neuman 1996; Sutton 1997). Thus, relative weight index values for striped bass greater than 150 mm TL and hybrid striped bass greater than 115 mm TL were calculated for comparisons of fishes in Claytor Lake. Values calculated for individuals greater than the cutoff ranges were evaluated in comparison to other populations of *Morone*.

Relative weight was calculated using the following equation:

$$W_r = W / W_s \times 100,$$

where W_r is the relative weight of an individual, W is the wet weight of an individual, and W_s is the length-specific standard weight of an individual. The standard weight equations for striped bass and hybrid striped bass (Brown and Murphy 1991b) are:

for striped bass:

$$\log_{10}W_s = -4.924 + 3.007 \log_{10}TL,$$

for hybrid striped bass:

$$\log_{10}W_s = -5.201 + 3.139 \log_{10}TL.$$

Lipid Index. - During periods of low food availability or environmental stress, lipids provide an important source of energy, and their amount reflects the physiological capacity of the fish (Sutton and Ney 2001). Large fish typically accumulate greater lipid reserves (i.e., higher percentage of body composition in lipids) than smaller fish, suggesting that overwinter survival, a period when fish feed very little, could be a problem for juvenile fishes that do not attain some minimum size (and adequate lipid reserves) prior to their first overwintering period (Sutton and Ney 2001). Lipid index values were determined for juvenile *Morone* in Claytor Lake before and after winter, with lipid index defined as:

$$LI = (LPW / LFDW) \times 100,$$

where *LPW* is the weight of extracted lipid and *LFDW* is the lipid-free dry body weight (Sutton 1997).

After stomach removal for diet analysis, all individuals were frozen, dried to a constant weight (4-7 days) by heating at 55-60°C, and reweighed to the nearest 0.01 g. Weight loss (due to the heating process) provided an estimate of body water content, which was applied to the linear regression relationship between percent water and lipid index developed by Sutton (1997) for age-0 striped bass from Smith Mountain Lake, Virginia:

$$LI = 1.84 - 0.02(\%BW),\ r^2 = 0.98,\ P = 0.001,$$

where LI is the lipid index and $\%BW$ is the percent body water content for juvenile *Morone* collected from Claytor Lake.

This equation was used to estimate the lipid index for the juveniles based on their percent body water content as determined from the heating process. Temporal trends of lipid index for individuals were analyzed over the 2002 growing season and before and after winter in both the 2001-2002 and 2002-2003 seasons, to determine if a positive relationship existed between fish length and physiological health after the growing season.

Habitat Usage

During both sampling seasons, while collecting fish for growth and diet analysis, the habitat usage of the species in the littoral zone was documented. The dominant substrate, sand (particle size 0.06-1 mm), gravel (2-15 mm), cobble (64-256 mm), or boulder (> 256 mm) (Bain 1999) and percent and type of cover (woody debris and vegetation) over which each individual was captured were documented. Dominant substrate was determined by visual estimation of the largest percent of substrate type by area.

During the 2002 growing season, I searched for 100-m units of shoreline within the lower region of the reservoir that represented one of the possible habitat categories (four substrates, with and without cover). Due to the lack of "gravel with cover" habitat, this investigation resulted in a total of seven categories of 100-m units (four substrate types, with and without cover, exclusive of "gravel with cover"). Once per month, each habitat unit was electrofished for a continuous thirty-minute time interval to investigate for the presence of age-0 striped bass and age-0 hybrid striped bass. The division of the littoral zone into separate habitat units, coupled with standardization of sampling efforts, allowed comparison of catch-per-unit-effort data across habitat types.

Monthly habitat usage overlap by juvenile striped bass and juvenile hybrid striped bass then were calculated via Schoener's (1970) overlap index, which is defined as:

$$C_{xy} = 1.0 - 0.5 \sum_{i=1}^{n} |p_{xi} - p_{yi}|,$$

where C_{xy} is the overlap index, p_{xi} is the proportion of habitat type i used by species x (striped bass), p_{yi} is the proportion of habitat type i used by species y (hybrid striped bass), and n is the total number of habitat categories. Habitat electivity was calculated by using the Strauss linear selection index:

$$L_i = r_i - p_i,$$

where r_i is the usage proportion of habitat i by species, and p_i is the proportion of habitat i in the environment (14.3%) (Crowder 1990). Positive values indicate preference for a habitat type, and negative values indicate avoidance of a habitat type.

Predation

In 2002, electrofishing was conducted along the entire shorelines of the stocking coves (approximately 460 and 75 m at Claytor Lake State Park and Dehaven Park, respectively, and 410 m within the cove immediately downstream of Lighthouse Marina) and approximately 100 m above and below each stocking cove on the date of stocking, one day post-stocking, and three days post-stocking to capture potential predators (all omnivorous and piscivorous species). Electrofishing was then conducted weekly (100 m above and below and within stocking coves) for one month thereafter to target *Micropterus* spp., the primary littoral piscivores of Claytor Lake. To evaluate predation, predator stomach contents were evacuated with clear acrylic tubes and predators then were released (Michaelson et al. 2001). Stomach contents were bagged, preserved on ice and then returned to the lab.

Intensity of predation was assessed via frequency of occurrence of juvenile striped bass and juvenile hybrid striped bass in the diets of predators. When all specimens had been examined, the proportion of the potential predators that contained one or more juvenile striped bass or juvenile hybrid striped bass was calculated as the frequency of occurrence for that juvenile *Morone* as a food type (Bowen 1996).

Statistical Analysis

Statistical procedures used to analyze data are listed in Table 2. One-way analysis of variance (ANOVA) was used to test for differences in population means (total length and indices of health) (Ott and Longnecker 2001). To verify the accuracy of ANOVA results; a corresponding nonparametric statistical procedure (Kruskal-Wallis test) was used. Nonparametric procedures produced equivalent results, thus, only results of

ANOVAs are reported. Also, the Jonckheere-Terpstra trend test was applied to determine the presence of a size-dependent shift in lipid index over the growing season (Goodwin and Angermeier 2003). Statistical analysis were considered significant at $P < 0.05$ for Type I error.

Table 2. Statistical procedures used to analyze Claytor Lake data sets 2001-2003.

Data Set	Statistical Procedure
First-Year Growth	
Striped bass vs. hybrid striped bass total lengths	ANOVA
2001-2002 season vs. 2002-2003 season total lengths	ANOVA
Post-Winter Survival	
Fall vs. spring total lengths	ANOVA
Striped bass vs. hybrid striped bass total lengths	ANOVA
2001-2002 season vs. 2002-2003 season total lengths	ANOVA
Indices of Health	
Condition Factor (*K*)	
Month vs. month	ANOVA
2001-2002 season vs. 2002-2003 season	ANOVA
Relative Weight	
Month vs. month	ANOVA
2001-2002 season vs. 2002-2003 season	ANOVA
Striped bass vs. hybrid striped bass	ANOVA
Lipid Index	
Size-dependent increase in lipid index values	Jonckheere-Terpstra
Month vs. month	ANOVA
2001-2002 season vs. 2002-2003 season	ANOVA
Striped bass vs. hybrid striped bass	ANOVA

RESULTS

Field Collections

A total of 1,628 age-0 moronids (*N* = 1,507 for striped bass; *N* = 121 for hybrid striped bass) were collected from Claytor Lake during the 2001-2002 and 2002-2003 sampling seasons (Table 3). An additional 285 fingerlings (*N* = 153 for striped bass; *N* = 132 for hybrid striped bass) were obtained from hatchery trucks on the stocking date. More striped bass were collected during 2001-2002 (*N* = 842) than during 2002-2003 (*N* = 665) (Table 3). Significantly greater numbers of hybrid striped bass were collected in 2002-2003 (*N* = 119) than in 2001-2002 (*N* = 3). Both species were most commonly collected in shallow littoral areas with sand and gravel substrates lacking cover (Figure 3).

Stock Identification

The frequencies of alleles at the six microsatellite DNA loci examined in this study are displayed in Table 4. Although the allelic overlap occurs among stock categories, one can see the allele sizes at which white bass and striped bass tend to align, and the mosaic of frequencies (i.e., combinations of parental alleles) that hybrid striped bass exhibit. For example, at locus *SB6*, 88.0% of white bass alleles are between 201 and 207 base-pairs (bp), and 95.0% of striped bass alleles are between 185 and 201 bp (Table 4). Southland Fisheries, South Carolina hybrid striped bass alleles exhibit a broad range of alle1e sizes from 89 to 233 bp, which is similar to the distribution of alleles for Keo Fish Farm, Arkansas hybrid striped bass (from allele 185-235 bp), with both having 50.0% frequencies of the 199 bp allele. Individuals of questionable phenotype displayed

Table 3. Total number of juvenile striped bass (STB) and juvenile hybrid striped bass (HSB) collected by sampling season, sampling period, and collection method from Claytor Lake, Virginia.

		STB			HSB		
Sampling Season	Sampling Period	Electro-fishing	Gillnetting	Total	Electro-fishing	Gillnetting	Total
2001-02	June	-----	-----	-----	-----	-----	-----
	July	30	-----	30	-----	-----	-----
	August	110	-----	110	-----	-----	-----
	September	127	19	146	-----	-----	-----
	October	173	38	211	-----	-----	-----
	November	143	12	155	3	-----	3
	December	25	15	40	-----	-----	-----
	March	5	5	10	-----	-----	-----
	April	138	2	140	-----	-----	-----
	May	-----	-----	-----	-----	-----	-----
	Total			842			3
2002-03	June	22	-----	22	-----	-----	
	July	90	-----	90	-----	-----	
	August	103	-----	103	7	-----	7
	September	151	9	160	26	-----	26
	October	138	21	159	40	1	41
	November	42	3	45	5	-----	5
	December	-----	-----	-----	-----	-----	-----
	March	-----	-----	-----	-----	-----	-----
	April	33	2	35	10	-----	10
	May	51	-----	51	30	-----	30
	Total			665			119

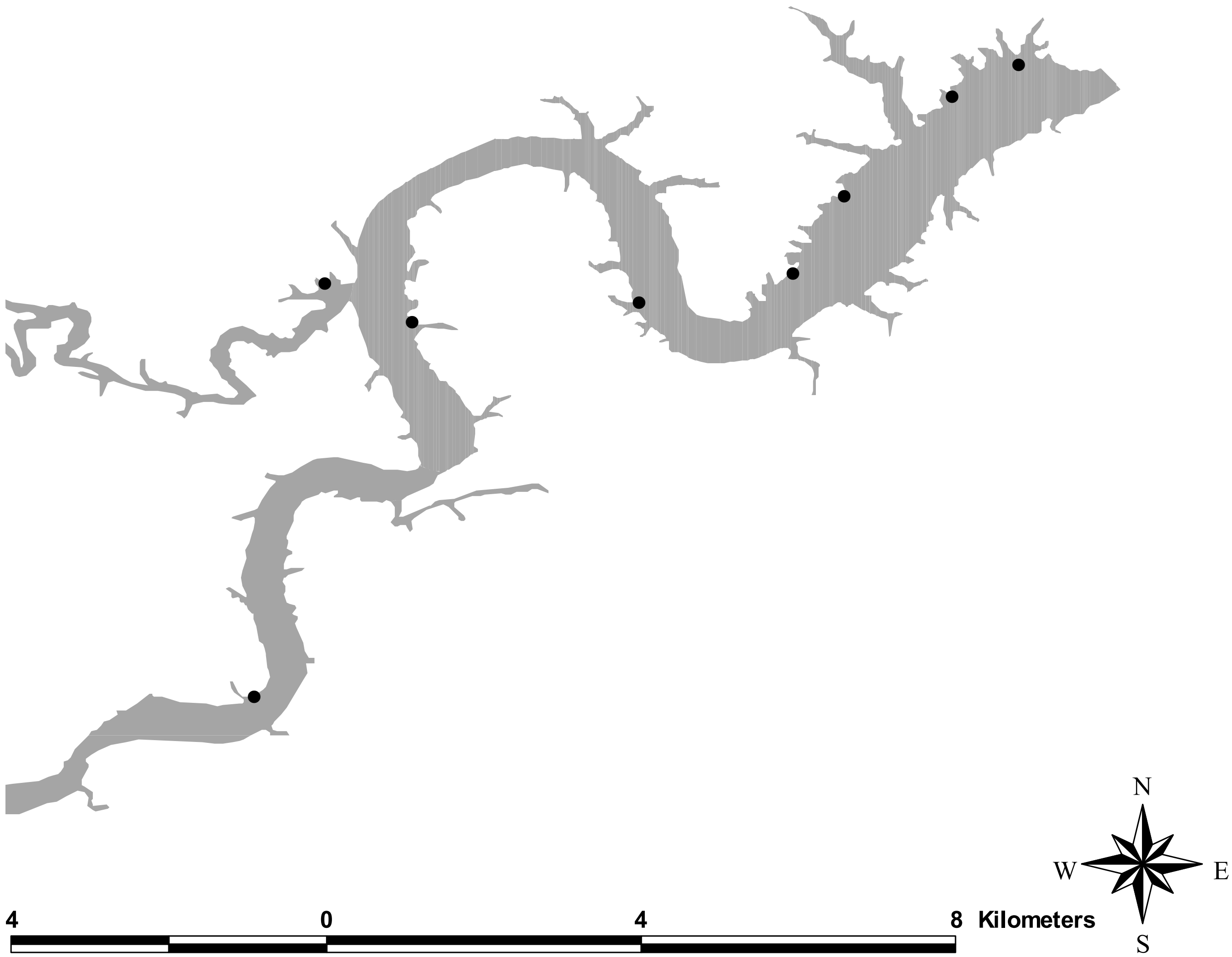

Figure 3. Most effective sampling sites for juvenile striped bass and juvenile hybrid striped bass in Claytor Lake, Virginia (2001-2003).

Table 4. Allele frequencies for given *Morone* stocks at six microsatellite DNA loci. bp = base pairs.

Locus	Alleles (bp)	Stock				
		White Bass	Striped Bass	Southland Fisheries Hybrid Striped Bass	Keo Fish Farm Hybrid Striped Bass	Questionable Individuals
N		10	10	10	2	10
SB6	185	----	0.30	----	0.05	0.28
	187	----	0.15	----	0.05	0.44
	189	----	----	0.25	0.05	----
	193	0.06	----	----	----	----
	199	----	0.05	0.50	0.50	----
	201	0.25	0.45	----	0.05	0.22
	203	0.13	----	----	----	----
	205	0.19	----	----	----	----
	207	0.31	----	----	----	----
	211	----	0.05	----	----	0.06
	219	0.06	----	----	0.20	----
	231	----	----	----	0.05	----
	233	----	----	0.25	----	----
	235	----	----	----	0.05	----
SB11	113	----	0.17	0.13	0.50	0.20
	127	----	----	0.13	----	----
	137	----	0.61	----	----	0.80
	177	----	0.17	----	----	----
	179	----	----	0.25	----	----
	183	----	----	----	0.50	----
	185	----	0.05	----	----	----
	191	----	----	0.06	----	----
	193	----	----	0.06	----	----
	197	----	----	0.37	----	----

Table 4 continued. Allele frequencies for given *Morone* stocks at six microsatellite DNA loci. bp = base pairs.

Locus	Alleles (bp)	Stock: White Bass	Striped Bass	Southland Fisheries Hybrid Striped Bass	Keo Fish Farm Hybrid Striped Bass	Questionable Individuals
N		10	10	10	2	10
SB83	163	----	----	0.05	----	0.38
	165	----	0.17	0.10	0.25	0.38
	167	----	0.05	----	0.25	----
	169	----	0.23	----	0.25	----
	171	----	0.17	0.25	----	----
	173	----	0.05	----	----	0.12
	175	0.07	0.28	----	----	----
	177	----	----	----	----	0.12
	179	0.12	----	0.05	----	----
	181	0.12	----	0.05	----	----
	183	----	0.05	0.15	0.25	----
	185	----	----	0.10	----	----
	189	0.12	----	----	----	----
	191	0.31	----	----	----	----
	193	----	----	0.05	----	----
	195	----	----	0.05	----	----
	197	0.07	----	0.10	----	----
	207	----	----	0.05	----	----
	209	0.19	----	----	----	----

Table 4. continued. Allele frequencies for given *Morone* stocks at six microsatellite DNA loci. bp = base pairs.

Loci	Alleles (bp)	Stock: White Bass	Striped Bass	Southland Fisheries Hybrid Striped Bass	Keo Fish Farm Hybrid Striped Bass	Questionable Individuals
N		10	10	10	2	10
SB91	117	0.19	----	----	----	----
	119	0.44	----	----	----	----
	121	0.06	----	----	----	----
	125	----	----	----	0.25	----
	131	----	0.13	----	----	----
	133	----	0.06	----	----	----
	135	----	0.06	----	----	0.17
	141	----	0.06	----	----	----
	143	----	0.06	----	----	----
	149	----	0.06	----	----	0.17
	151	----	0.13	0.10	0.25	0.17
	153	0.13	0.44	0.20	0.50	0.50
	155	----	----	0.20	----	----
	159	----	----	0.05	----	----
	161	----	----	0.40	----	----
	163	----	----	0.05	----	----
	179	0.06	----	----	----	----
	191	0.06	----	----	----	----
	193	0.06	----	----	----	----
SB108	166	0.67	----	----	----	----
	178	0.22	----	0.50	0.75	----
	180	----	0.05	0.05	----	0.17
	182	----	0.05	----	----	----
	184	----	0.17	0.05	----	0.29
	188	----	----	0.05	----	0.05
	190	----	0.05	----	----	0.05
	192	----	0.05	0.15	0.25	----
	196	----	----	0.05	----	0.05
	198	----	0.17	0.1	----	0.17
	200	----	0.28	0.05	----	0.11
	206	----	0.11	----	----	0.11
	212	0.11	----	----	----	----

Table 4 continued. Allele frequencies for given *Morone* stocks at six microsatellite DNA loci. bp = base pairs.

		Stock				
Locus	Alleles (bp)	White Bass	Striped Bass	Southland Fisheries Hybrid Striped Bass	Keo Fish Farm Hybrid Striped Bass	Questionable Individuals
N		10	10	10	2	10
SB113	181	0.28	----	----	----	----
	183	----	----	----	----	0.10
	185	0.21	----	----	----	----
	187	----	----	----	0.25	----
	193	0.15	----	----	----	----
	195	0.07	----	----	----	----
	197	----	0.20	----	----	----
	199	----	0.30	0.05	----	0.50
	201	----	0.50	----	----	0.30
	203	----	----	----	----	0.10
	213	----	----	0.22	0.25	----
	215	----	----	0.17	----	----
	217	----	----	----	0.50	----
	219	----	----	0.40	----	----
	221	0.15	----	0.11	----	----
	233	0.07	----	----	----	----
	235	0.07	----	----	----	----
	239	----	----	0.05	----	----

allele frequencies similar to those of striped bass, with 94.0% of their alleles between 185 and 201 bp in size.

Observations of allele frequencies led to several inferences key to the objective of this study. First, comparisons of allele frequencies failed to indicate that 2001 hybrid striped bass fingerlings provided by Keo Fish Farm were anything other than F1 hybrid striped bass. Second, individuals of "questionable" phenotype were most probably juvenile striped bass exhibiting poor condition.

Subsequent reexamination (via meristic characters) of all juvenile *Morone* collected during the 2001-2002 sampling season revealed the presence of only three juvenile hybrid striped bass. The original difficulty associated with correctly differentiating between juvenile striped bass and hybrid striped bass appears to have been a consequence of low capture success for hybrid striped bass fingerlings of the 2001 stocking. As a result, due to the lack of hybrid striped bass specimens, I did not compare hybrid striped bass versus striped bass for the 2001-2002 sampling season.

First-Year Growth

2001. – Age-0 striped bass increased consistently in length and weight over the 2001 growing season (Figure 4). Length and weight distributions were relatively uniform at the time of stocking, with ranges of 31-57 mm TL (mean = 41 mm TL and SE ± 0.47) and 0.33-2.25 g (mean = 0.86 g and SE ± 0.03) (Table 5). Length distributions remained fairly uniform in July, with lengths ranging from 37-94 mm TL (mean = 120 mm TL and SE ± 1.73). However, by August, total lengths began to become more variable (range of 119 mm TL, mean = 146 mm TL, and SE ± 2.49) and ranges in total length distribution remained highly uneven throughout the growing season (September: range = 117 mm,

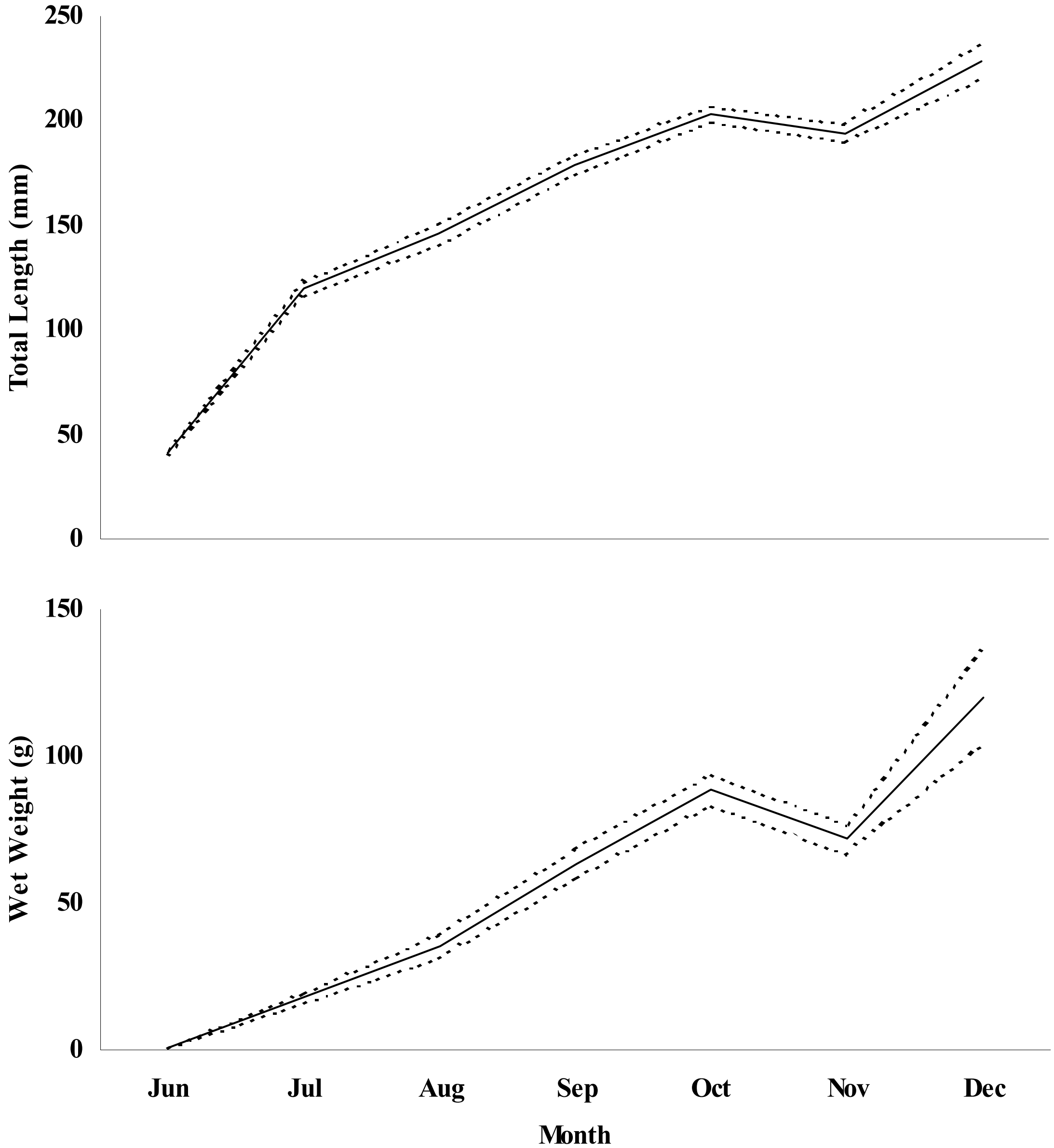

Figure 4. Temporal patterns of first-year increase in total length (mm) and wet weight (g) for juvenile striped bass over the 2001 growing season in Claytor Lake. Mean total length and mean body weight are represented by solid lines, and 95% confidence intervals are represented by dashed lines.

Table 5. Descriptive statistics for juvenile striped bass length and weight distributions over the 2001 growing season and 2002 post-winter period in Claytor Lake.

Month	*N*	Mean Total Length (mm)	Range (mm)	Mean Wet Weight (g)	Range (g)
June	153	41	31-57	0.86	0.33-2.25
July	30	120	94-137	17.74	8.33-27.27
August	110	146	81-200	35.50	4.70-92.49
September	146	179	114-231	69.49	13.25-148.80
October	211	204	138-261	88.78	22.79-196.66
November	155	194	118-278	71.69	20.92-179.49
December	40	229	174-272	120.23	43.60-220.00
March & April	150	219	139-278	102.59	117.22-252.22

mean = 179 mm TL, and SE ± 2.26; October: range =123 mm, mean = 204 mm TL, and SE ± 1.92; and November: range = 160 mm, mean = 194 mm TL, and SE ± 2.30). Weight varied more widely, but also increased in range over the growing season (August: range = 87 g, mean = 35.51 g, and SE ± 1.92; September: range = 136 g, mean = 63.49 g, and SE ± 2.47; October: range = 174 g, mean = 88.78 g, and SE ± 2.65; and November: 159 g, mean = 71.69, and SE ± 2.49). Although distributions were variable, juvenile striped bass displayed a linear growth rate from the date of stocking until October, when the growth rate became asymptotic (Figure 4). During the period of linear growth (June to October) juvenile striped bass total lengths increased by 1.10 mm/day. By the final month of the growing season, juvenile striped bass ranged from 174-278 mm TL (mean = 229 mm TL and SE ± 4.31) and 43.60-220.00 g (mean = 120.23 g and SE ± 7.93).

However, unlike the juvenile striped bass observed in Smith Mountain Lake, Virginia, by Sutton (1997), age-0 striped bass in Claytor Lake did not demonstrate significant divergence in size through the progression of the growing season (Figure 5). By the end of the growing season, Sutton (1997) observed two distinct size modes of fish, with mean total lengths of the small and large modes to be approximately 100 and 226 mm TL, respectively.

2002. – Both juvenile moronids experienced growth patterns during the 2002 growing season similar to those for striped bass in the 2001growing season (Figure 6). The initial ranges of distributions for fingerling striped bass and fingerling hybrid striped bass at the time of stocking were, 33-49 mm TL (mean = 41 mm TL and SE ± 1.06) and 0.35-1.04 g (mean = 0.65 and SE ± 0.05) and 64-125 mm TL (mean = 96 mm TL and SE ± 1.47) and 3.21-16.80 g (mean = 10.77 g and SE ± 0.45), respectively (Table 6).

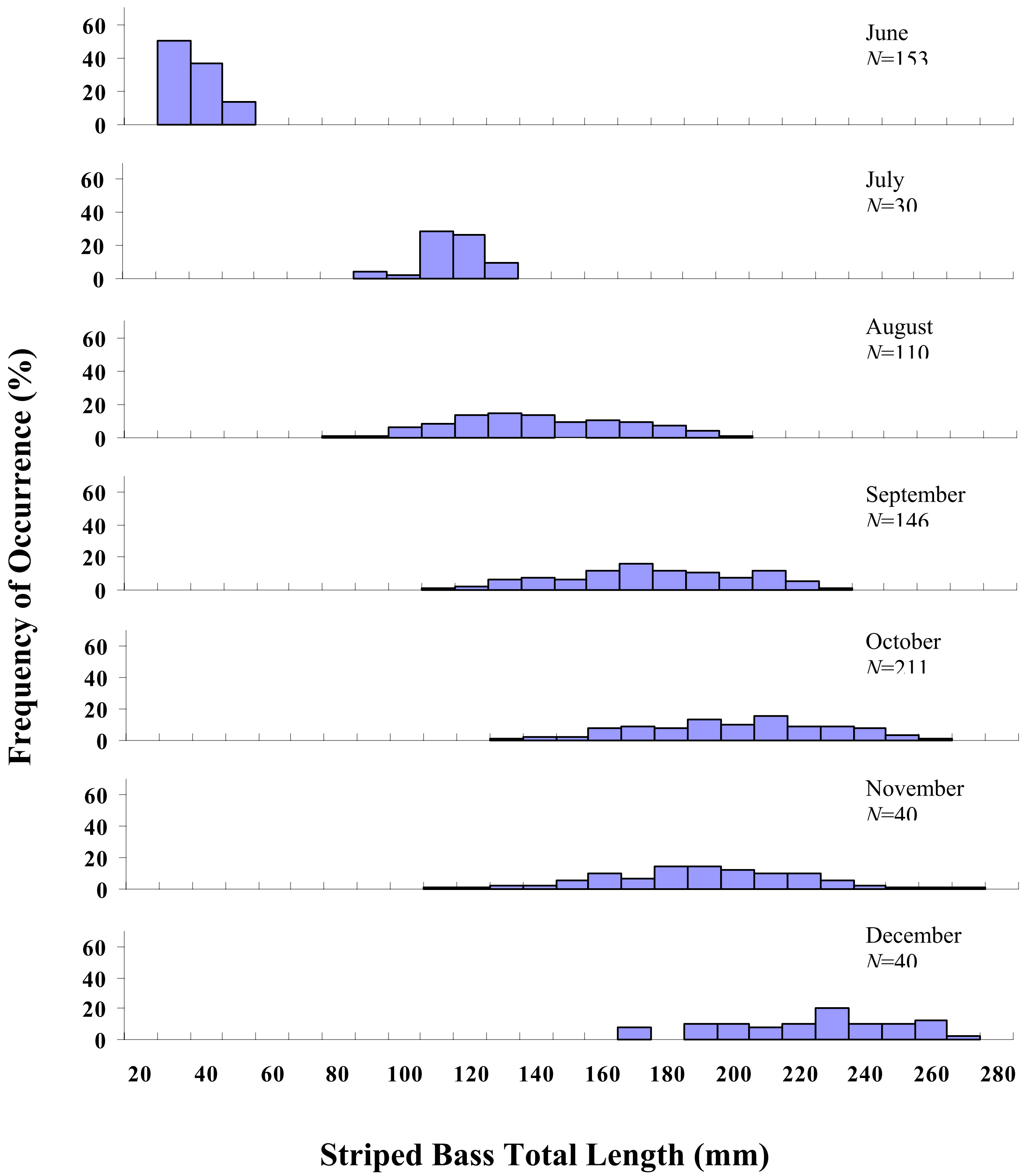

Figure 5. Monthly length-frequency distributions of juvenile striped bass in Claytor Lake over the 2001growing season.

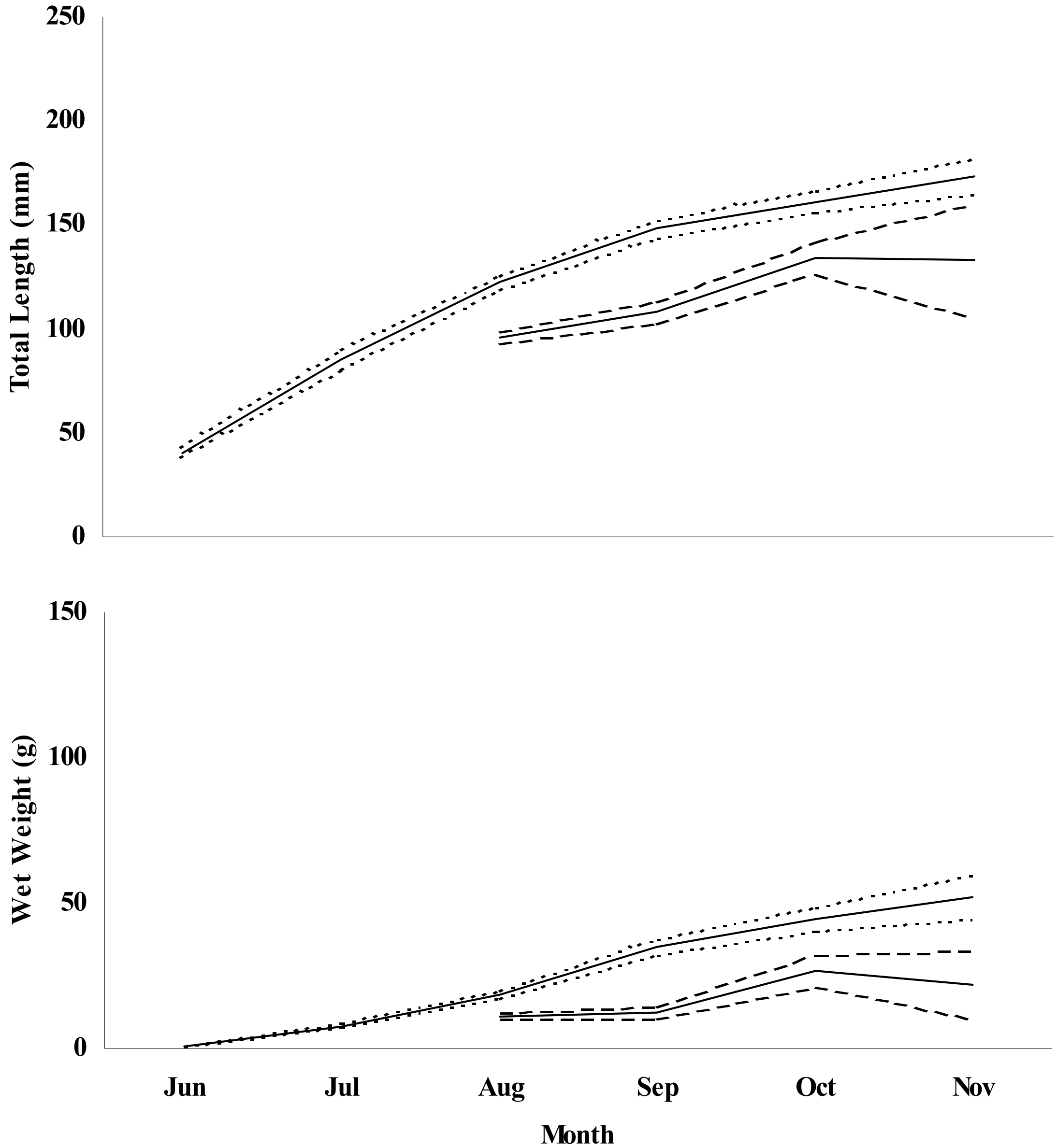

Figure 6. Temporal patterns of first-year increase in total length (mm) and wet weight (g) for juvenile striped bass (June-November) and juvenile hybrid striped bass (August-November) over the 2002 growing season in Claytor Lake. Mean total length and mean body weight are represented by solid lines, and 95% confidence intervals are represented by dashed lines.

Table 6. Descriptive statistics for juvenile striped bass (STB) and juvenile hybrid striped bass (HSB) length and weight distributions over the 2002 growing season and 2003 post-winter period in Claytor Lake.

Stock	Month	*N*	Mean Total Length (mm)	Range (mm)	Mean Wet Weight (g)	Range (g)
STB	June	22	401	33-49	0.65	0.35-1.04
	July	90	86	52-127	7.23	1.33-22.74
	August	103	123	78-167	18.40	3.97-44.95
	September	160	148	79-203	33.95	4.48-84.14
	October	159	161	92-247	44.61	6.89-166.50
	November	45	173	112-227	52.10	12.55-123.91
	April & May	86	238	136-332	150.56	20.94-436.02
HSB	August	55	96	64-125	10.77	3.21-16.80
	September	26	108	86-140	12.12	5.87-28.61
	October	41	135	86-192	27.00	5.59-74.23
	November	5	133	98-157	21.98	7.85-34.40
	April & May	40	264	119-335	227.95	15.31-458.16

Variability in monthly length and weight distributions increased throughout the growing season for both striped bass and hybrid striped bass. By October, striped bass and hybrid striped bass lengths exhibited a range of 155 (mean = 162 mm TL and SE ± 2.57) and 106 mm TL (mean = 135 mm TL and SE ± 3.79), respectively, and the range in weight was 160 (mean = 45 g and SE ± 2.17) and 69 g (mean = 27 g and SE ± 2.74), for striped bass and hybrid striped bass, respectively.

Also, as seen in 2001, juvenile *Morone* exhibited a linear growth rate from the month of stocking until October, at which time the growth rate began to plateau (Figure 6). For striped bass, the linear growth from June to October was characterized by a growth rate of 0.81 mm/day, and by November, juvenile striped bass length and weight exhibited a range of 155 mm (mean = 173 mm TL and SE ± 4.45) and 111 g (mean = 52.10 g and SE ± 3.88), respectively. Juvenile hybrid striped bass during the period of linear growth (August to October) grew at a rate of approximately 0.52 mm/day, and by November, juvenile hybrid striped bass displayed a range of 59 mm (mean = 133 mm TL SE ± 13.49) and 27 g (mean = 21.98 g and SE ± 5.96), respectively. Juvenile striped bass and juvenile hybrid striped bass did not present a clear bimodal size distribution late in the 2002 growing season (Figures 7 and 8, respectively).

There was no significant difference between total lengths of striped bass fingerlings stocked in 2001 and 2002 (ANOVA, $F = 0.18$, df = 173, $P = 0.673$). However, the mean total length of 2002 hybrid striped bass fingerlings at stocking was significantly greater (40%) than mean total lengths of 2001 hybrid striped bass fingerlings (ANOVA, $F = 426.24$, df = 128, $P < 0.001$).

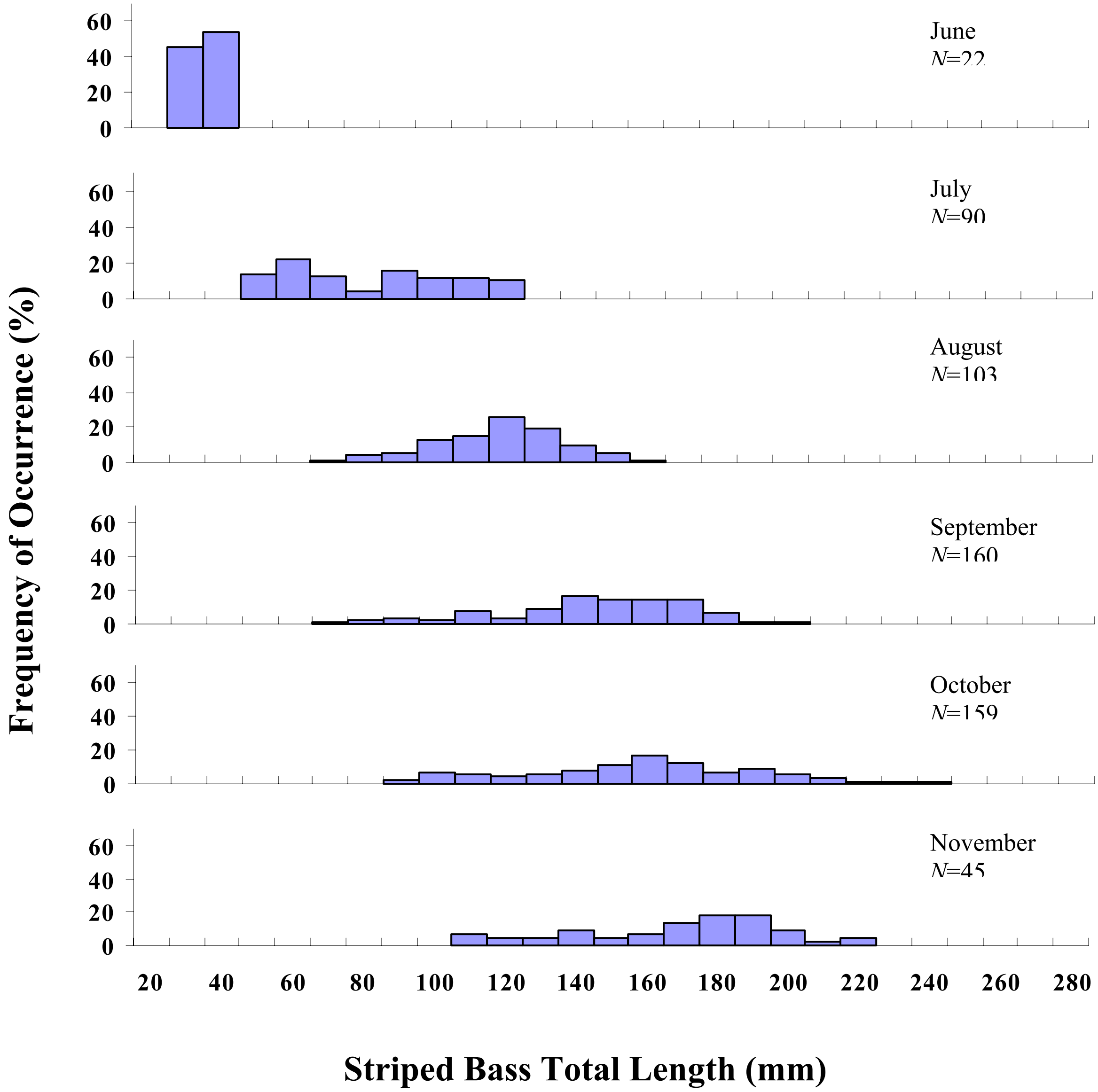

Figure 7. Monthly length-frequency distributions of juvenile striped bass in Claytor Lake over the 2002 growing season.

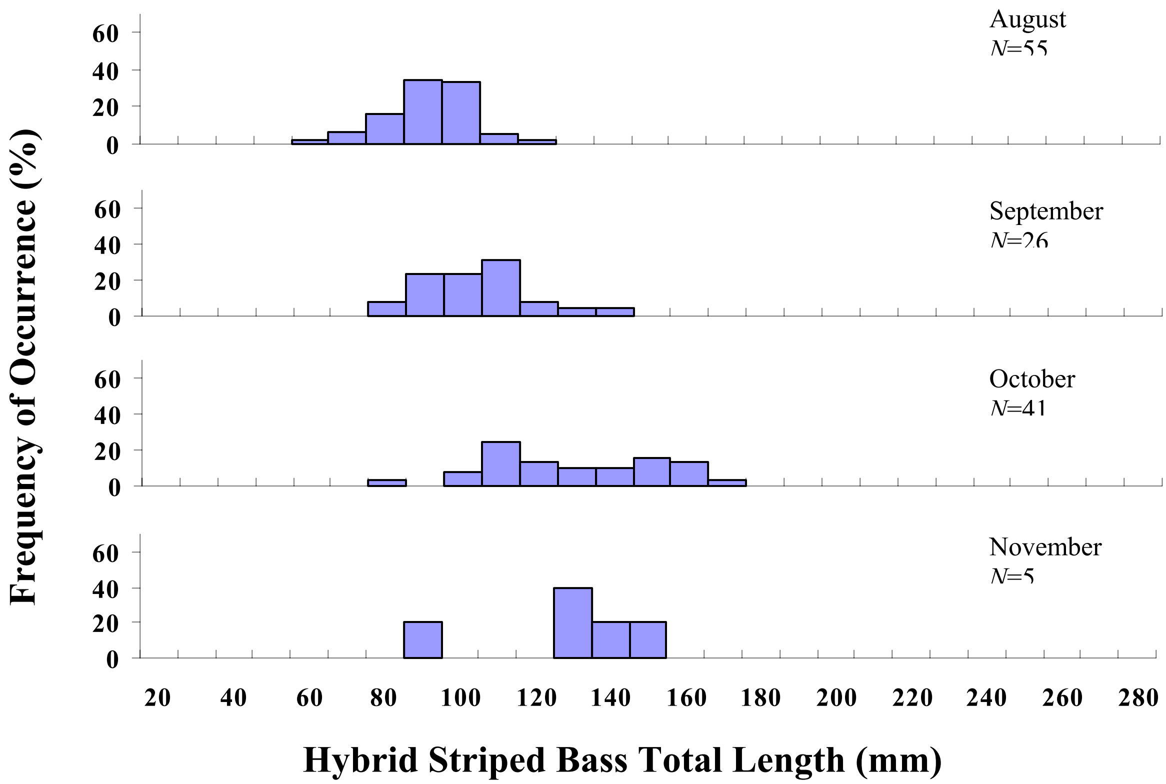

Figure 8. Monthly length-frequency distributions of juvenile hybrid striped bass in Claytor Lake over the 2002 growing season.

Although there was not a significant difference between initial total lengths of striped bass in 2001 and 2002, and fish exhibited the same growth pattern (linear until October), mean total lengths of 2001 striped bass were significantly greater than mean total lengths of 2002 fingerlings at the same times during the growing season (July 40%: ANOVA, $F = 62.16$, df = 118, $P < 0.001$; August 18%: ANOVA, $F = 57.47$, df = 211, $P < 0.001$; September 21%: ANOVA, $F = 99.23$, df = 304, $P < 0.001$; October 26%: ANOVA, $F = 177.73$, df = 368, $P < 0.001$; November 12%: ANOVA, $F = 18.02$, df = 198, $P < 0.001$).

To compare total lengths attained by the end of the growing season, individuals in the final months of the growing season (October and November) were pooled for both striped bass and hybrid striped bass. At the end of the growing season striped bass mean total lengths were 22% greater than hybrid striped bass mean total lengths (ANOVA, $F = 34.11$, df = 248, $P < 0.001$). Total lengths of individuals captured in spring are reviewed in the following section (see Post-Winter Survival).

Post-Winter Survival

2001-2002. – Mean juvenile striped bass total lengths differed significantly between fall (November and December) 2001 and spring (March and April) 2002 (Table 5), with spring individuals being 9% larger (ANOVA, $F = 28.69$, df = 343, $P < 0.001$). The length-frequency distributions before and after winter do not present clear bimodality (Figure 9). However, attention must be given to the overall shift in the population mean and the resulting loss of smaller (< 150 mm TL) individuals (5% < 150 mm TL in the fall versus 1% < 150 mm TL in the spring), and no increase in the maximum total length. No juvenile hybrid striped bass were collected in the 2002 post-winter period.

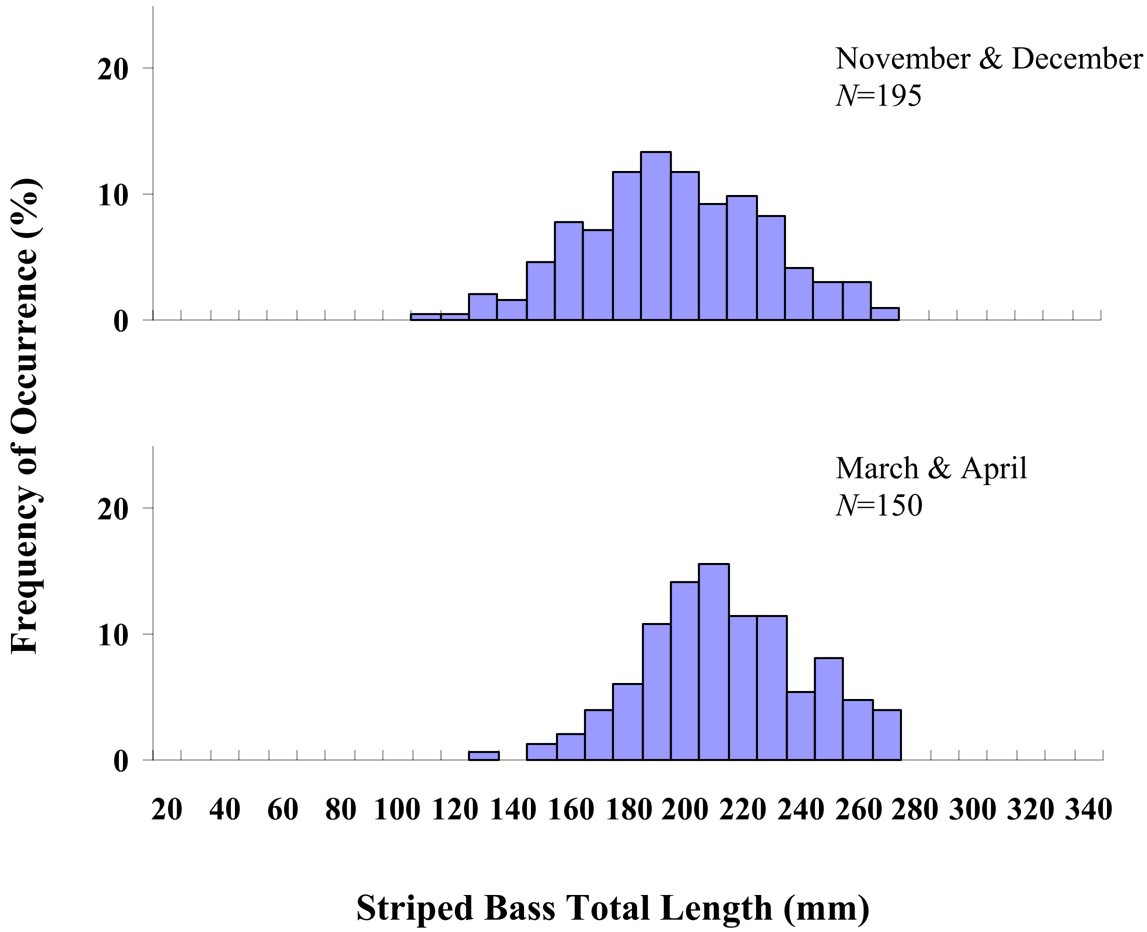

Figure 9. Length-frequency distributions of juvenile striped bass before and after overwintering in Claytor Lake during the 2001-2002 sampling season.

2002-2003. – Age-0 striped bass mean total lengths differed significantly between fall (October and November) 2002 and spring (Table 6), with striped bass mean total lengths being 45% larger in spring (ANOVA, $F = 263.87$, df = 288, $P < 0.001$), coupled with an 105 mm increase in the maximum length. Juvenile striped bass failed to display a bimodal size distribution before the winter (Figure 10), but once more, striped bass did exhibit a shift to larger-mode individuals in the spring distribution (32% < 150 mm TL in the fall versus 1% < 150 mm TL in the spring).

Juvenile hybrid striped bass also had significantly different mean total lengths between fall 2002 and spring 2003 periods (Table 6), with mean total length of spring individuals being 97% larger (ANOVA, $F = 236.78$, df = 84, $P < 0.001$). Again, it is difficult to detect the presence of bimodality upon visual observation of the length-frequency distribution for hybrid striped bass (Figure 11). In late fall, 70% of hybrid striped bass collected were less than 150 mm TL versus only 5% in the spring (Figure 11). Thus, I observed a substantial upward shift in size distribution for hybrid striped bass following the overwinter period.

Given the violation of Sutton's (1997) method for inferring overwinter mortality (an increase in the mean, but not the maximum length), the increases in total length for both striped bass and hybrid striped bass in the spring of 2003 are likely due to factors other than the overwinter mortality of small individuals. First, consideration should be given to the inefficiency of sampling techniques to representatively capture larger individuals that may have been present in the fall. Second, individuals could have grown over the winter months. Finally, individuals may have grown during the spring period before becoming susceptible to capture. I consider these possible explanations in the

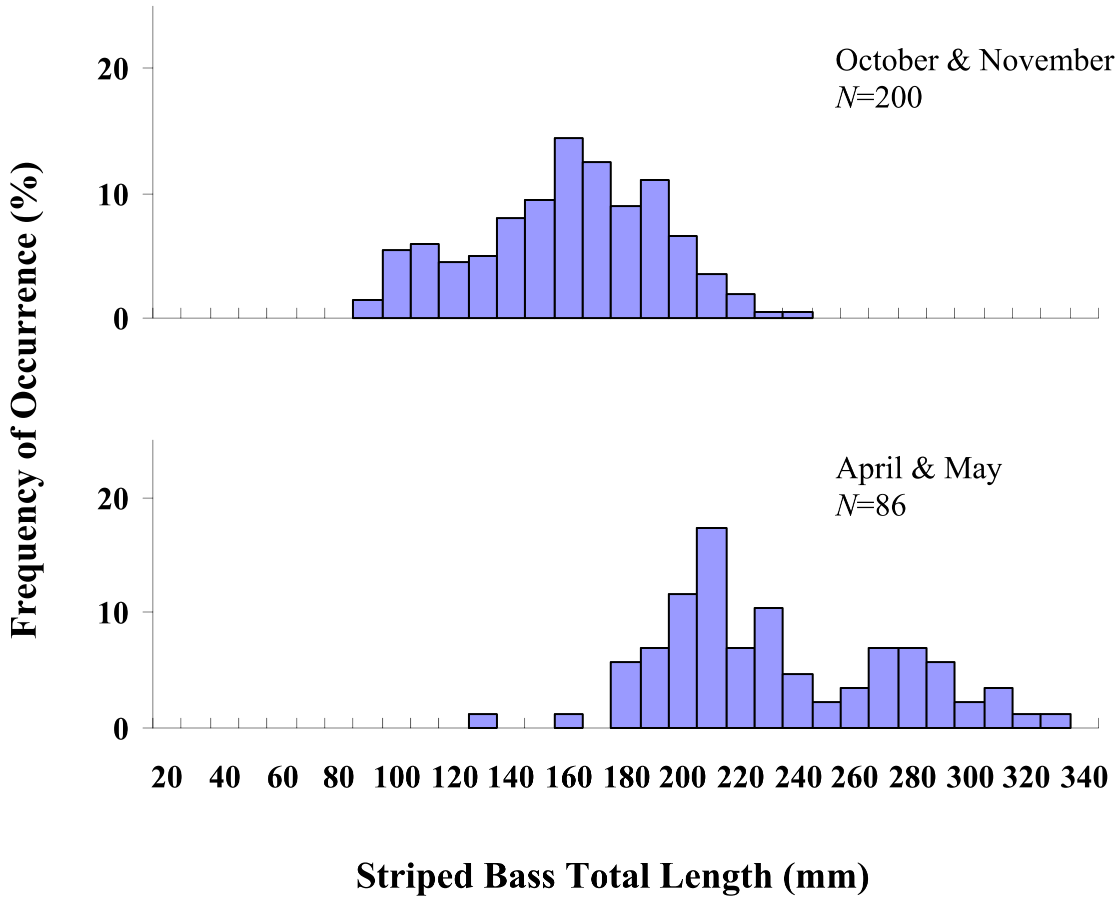

Figure 10. Length-frequency distributions of juvenile striped bass before and after overwintering in Claytor Lake during the 2002-2003 sampling season.

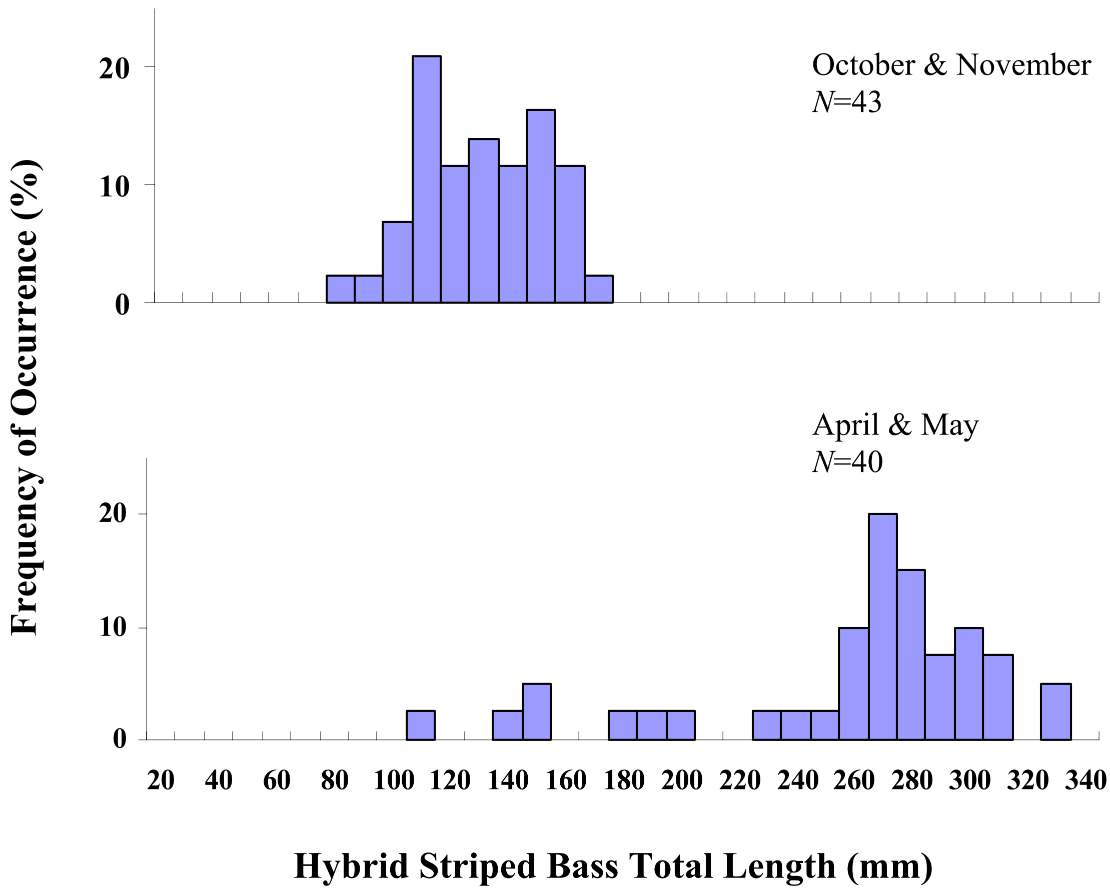

Figure 11. Length-frequency distributions of juvenile hybrid striped bass before and after overwintering in Claytor Lake during the 2002-2003 sampling season.

Discussion section. Also, comparing my data to length-frequency distributions observed for juvenile striped bass in Smith Mountain Lake, Virginia, my study did not show the quantity (up to 60%) of smaller individuals (< 150 mm TL) in the fall that was reported by Sutton (1997). The lack of a high percentage of small individuals in the fall, may have contributed to the failure to observe distinct bimodal size distributions in the fall that were expected in this study and reported by Sutton (1997).

With both hybrid striped bass and striped bass having experienced an upward shift in length-frequency distributions of the winter, spring hybrid striped bass mean total lengths were in fact 11% greater than mean striped bass total lengths (ANOVA, $F = 9.62$, df = 124, $P = 0.002$).

Food Habits

2001-2002. – Diet composition of age-0 striped bass changed through the growing season. The rapid dispersal of juvenile *Morone* from stocking locations in Claytor Lake did not allow for diet analysis of fingerlings during their first month in the reservoir, as I was unable to locate them. However, in July 2001 (one month post-stocking) juvenile striped bass fed primarily upon age-0 cyprinids (mainly spottail shiner *Notropis hudsonius*) and age-0 alewife, with these age-0 prey items comprising approximately 88% of stomach contents by weight, while aquatic insects (Ephemeroptera) comprised the remaining 12% of diet items (Figure 12). Age-0 alewife comprised the majority of the diet by weight until October, and age-0 sunfishes and age-0 cyprinids were the dominant food item consumed by juvenile striped bass during the remainder of the fall months (Figure 12). Zooplankton (cladoceran and copepods), aquatic insects (Chironomidae, Ephemeroptera, and other Diptera), and age-0 gizzard shad were

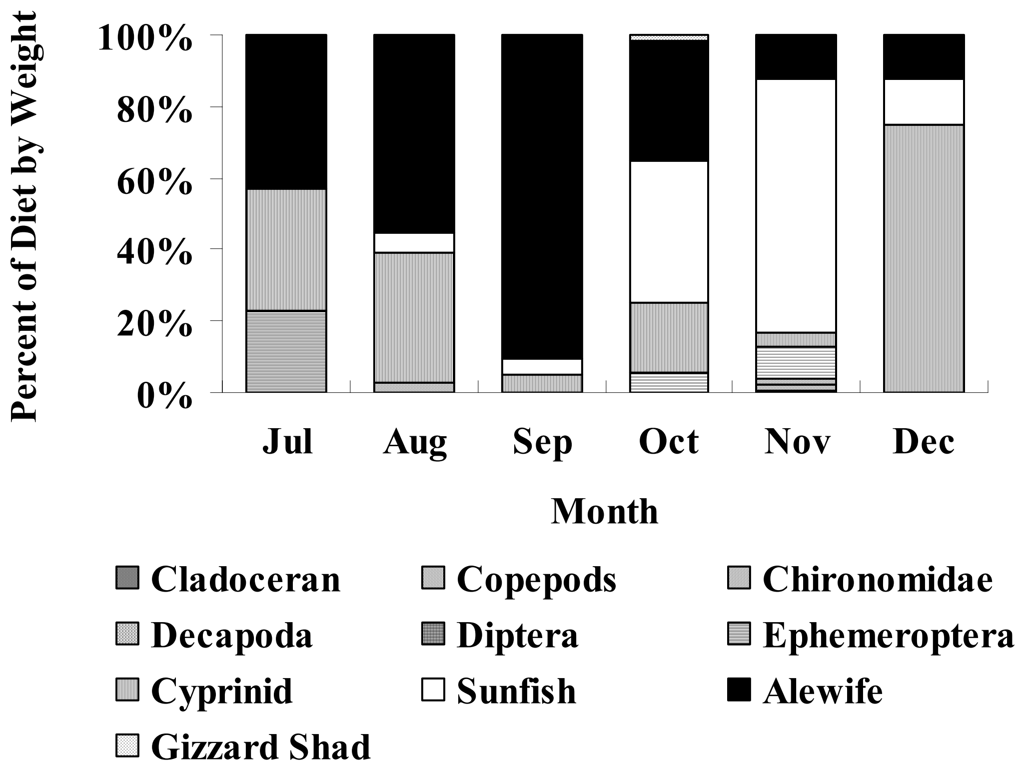

Figure 12. Temporal patterns in juvenile striped bass diet composition over the 2001 growing season in Claytor Lake.

infrequently consumed by juvenile striped bass during the 2001 growing season (Table 7). Also, 37% of juvenile striped bass collected had empty stomachs (Table 7).

Juvenile striped bass exhibited a size-dependent shift in food habits over the 2001 growing season, but were piscivorous at all sizes, from 110 to 260 mm TL (Figure 13). Stomach contents of individuals greater than 120 mm TL contained progressively increasing percentages of age-0 fishes, mainly cyprinids, sunfishes, and alewife (Figure 13). Individuals greater than 240 mm TL relied on diets composed almost entirely of age-0 alewife (Figure 13).

During the 2002 post-winter period individuals less than 180 mm TL maintained a mixed diet composed of approximately 50% age-0 fishes and 50% zooplankton and aquatic insects (Figure 14). Individuals up to 220 mm TL had small percentages of zooplankton and aquatic insects as well, and individuals 230 mm TL and greater were 100% piscivorous, with age-0 alewife serving as the dominant food item.

2002-2003. – As in the 2001-2002 sampling season, the rapid dispersal of fingerling *Morone* from stocking locations did not allow for the analysis of striped bass diets immediately following stocking. However, in July 2001 (one month post-stocking) juvenile striped bass (95 to 127 mm TL) fed primarily upon age-0 alewife (approximately 69% of diet content by weight), with the remaining diet items consisting of a mixture of age-0 sunfishes, age-0 cyprinids, cladocerans and chironomids (Figure 15). During the course of the growing season, Ephemeroptera and other Diptera larvae were infrequently consumed by juvenile striped bass (Table 7). Approximately one-third of striped bass and hybrid striped bass lacked stomach contents, respectively (Table 7).

Table 7. Frequency of occurrence (%) of food items in the diets of juvenile striped bass (STB) and juvenile hybrid striped bass (HSB) in all 2001-2002 and 2002-2003 season samples in Claytor Lake.

Item	STB 2001-2002 (N = 842)	STB 2002-2003 (N = 643)	HSB 2002-2003 (N = 157)
Zooplankton			
Cladoceran	1.33	1.16	14.42
Copepods	-----	0.17	0.96
Aquatic Invertebrates			
Chironomidae	2.15	1.32	2.88
Ephemeroptera	3.34	1.32	1.92
Other Diptera	1.33	0.83	1.92
Decapoda	-----	0.33	2.88
Fish			
Alosa pseudoharengus	16.29	23.68	11.54
Dorosoma cepedianum	0.53	-----	-----
Centrarchidae	12.15	6.13	2.88
Notropis hudsonius	4.00	2.32	-----
PDUF	21.63	32.12	20.19
Empty	37.25	30.63	40.41

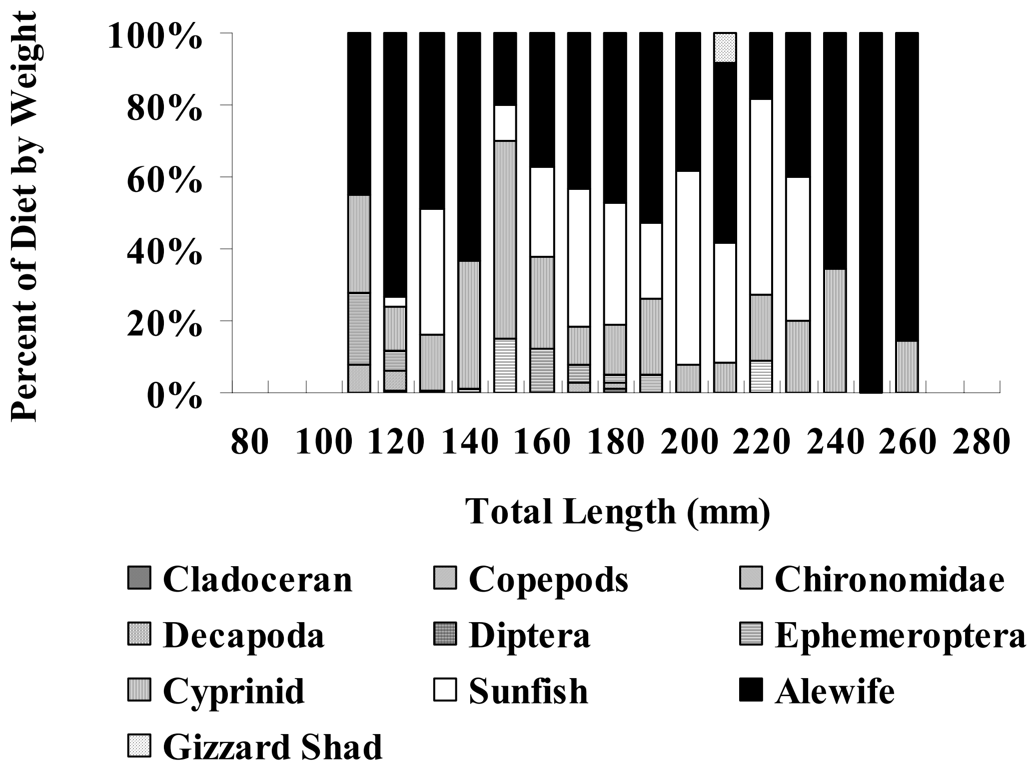

Figure 13. Size-dependent patterns in juvenile striped bass diet composition over the 2001 growing season in Claytor Lake.

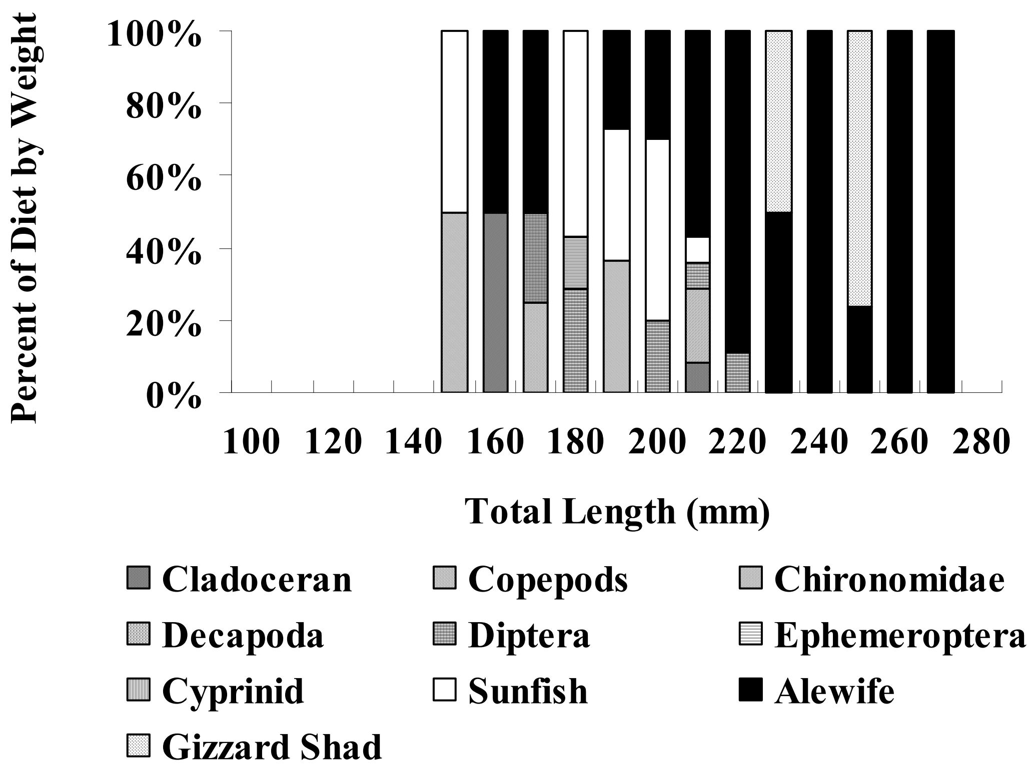

Figure 14. Size-dependent patterns in juvenile striped bass diet composition during the 2002 post-winter period in Claytor Lake.

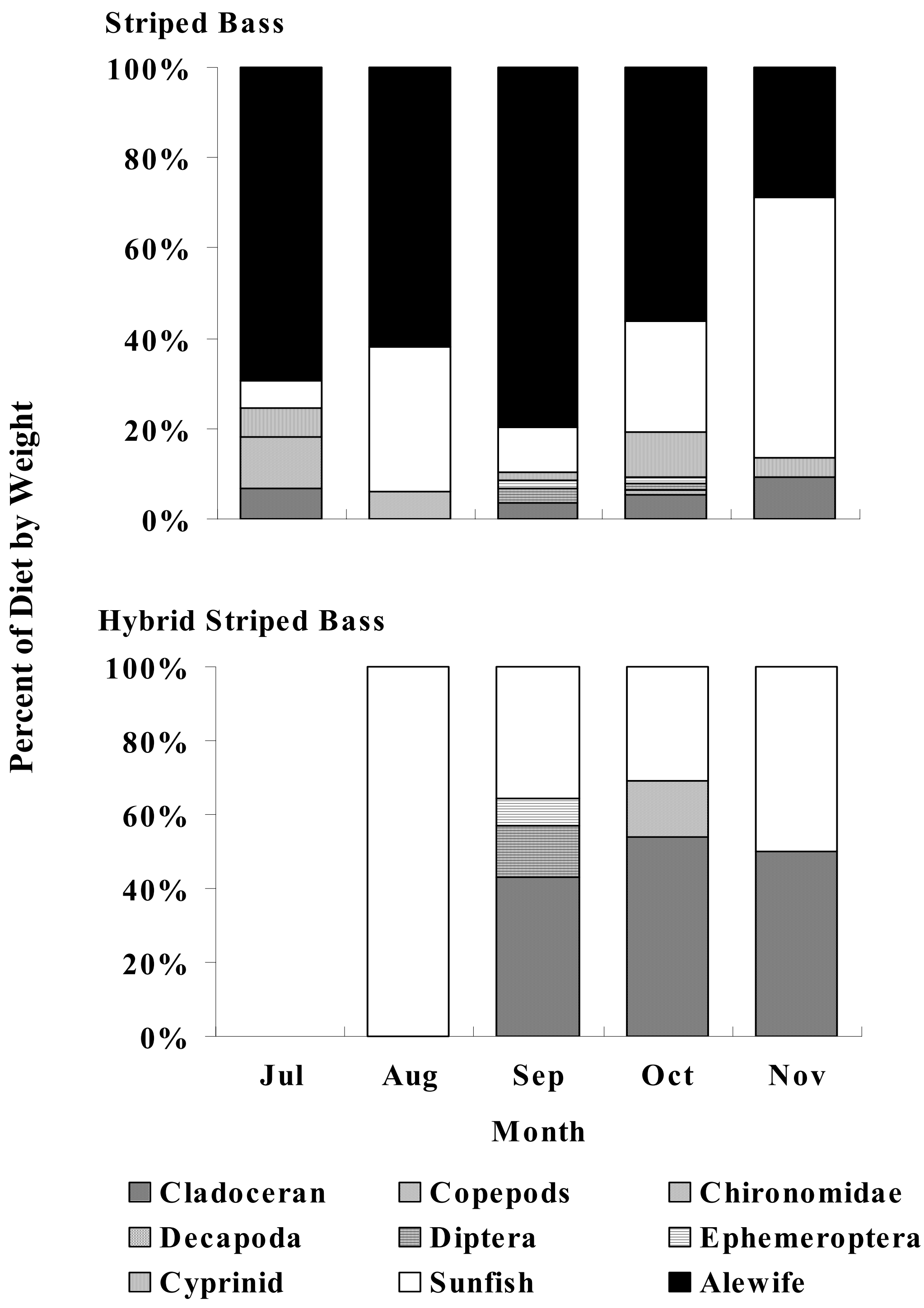

Figure 15. Temporal patterns in juvenile striped bass and juvenile hybrid striped bass diet composition over the 2002 growing season in Claytor Lake.

As in 2001, striped bass during the 2002 growing season exhibited a size-dependent shift in food habits (Figure 16). Individuals in the 80-mm TL size class consumed 100.0% cladocerans, while all size classes 90 mm TL or greater were at leastpartially piscivorous (Figure 16). At approximately 120 mm TL and greater, age-0 fishes became the principal diet item for juvenile striped bass, with age-0 alewife comprising the largest percentage of stomach contents (Figure 16).

Unlike juvenile striped bass during the 2001 and 2002 growing seasons, hybrid striped bass in 2002 contained no alewives (Figure 15). During the fall months, hybrid striped bass consumed a mixture of cladocerans, Chironomidae, Ephemeroptera, and other Diptera, as well as age-0 sunfish (Figure 15). It should be noted that the high percentage (100%) of age-0 sunfish in the hybrid striped bass diet in August might be an artifact of small sample size; only one specimen (125 mm TL) of the five captured in August had food in its stomach.

Juvenile hybrid striped bass exhibited a size-dependent shift in food habits over the growing season (Figure 16) similar to that of striped bass in 2001 and 2002. Hybrid striped shifted from a diet composed mainly of cladocerans, with infrequent amounts of Chironomidae and Ephemeroptera, to piscivory at approximately 120 mm TL (Figure 16). Following the shift to piscivory, individuals greater than 120 mm TL had 100% of stomach content by weight comprised of age-0 sunfish (Figure 16).

During spring 2003, age-0 alewife, age-0 sunfish, and decapoda comprised 100% of the diet by weight for juvenile striped bass (Figure 17). While 140 mm TL hybrid striped bass ate cladocerans, the larger size classes consumed age-0 alewife and/or crayfish (Figure 17). Age-0 alewife constituted the largest percent contribution by

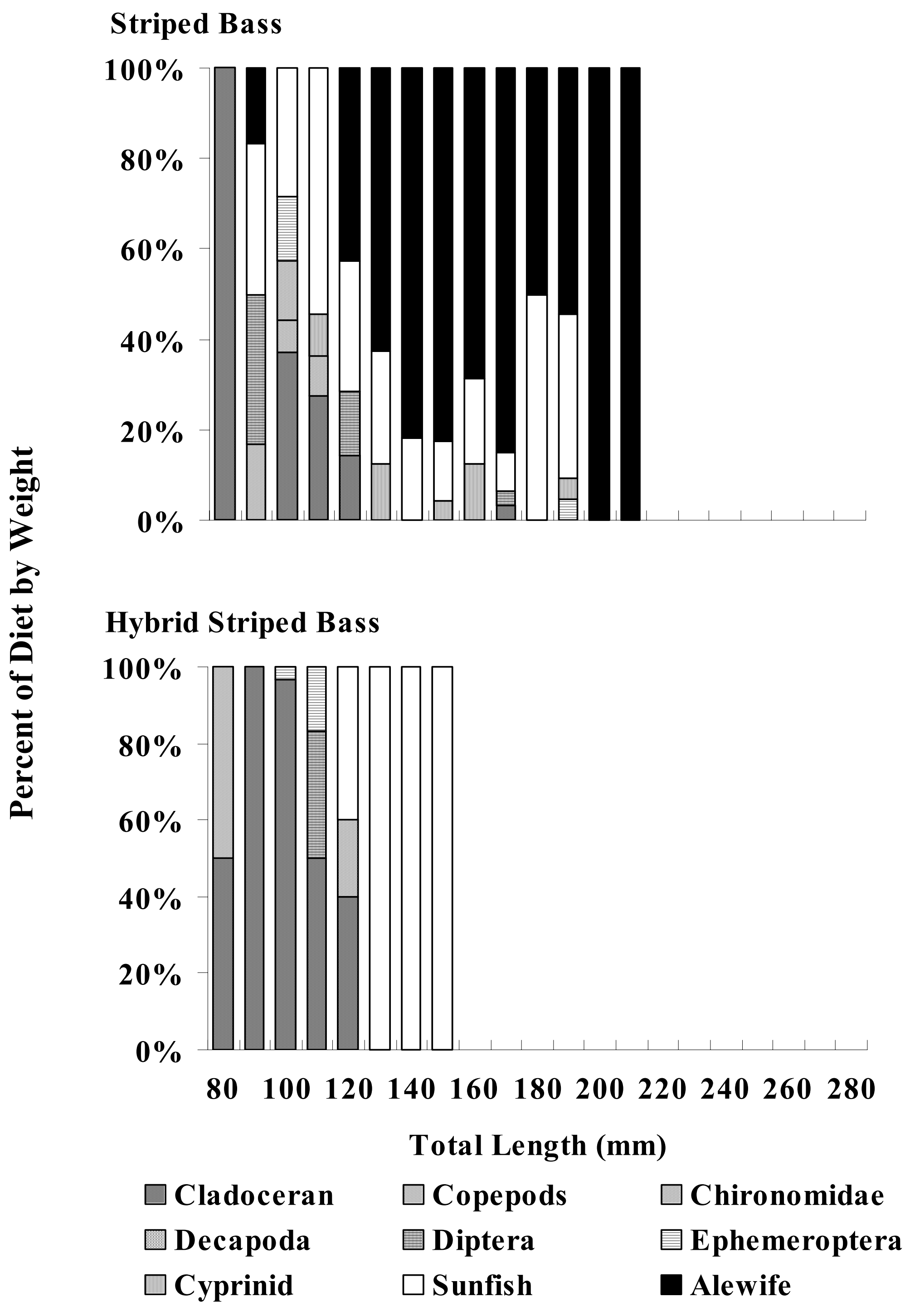

Figure 16. Size-dependent patterns in juvenile striped bass and juvenile hybrid striped bass diet composition over the 2002 growing season in Claytor Lake.

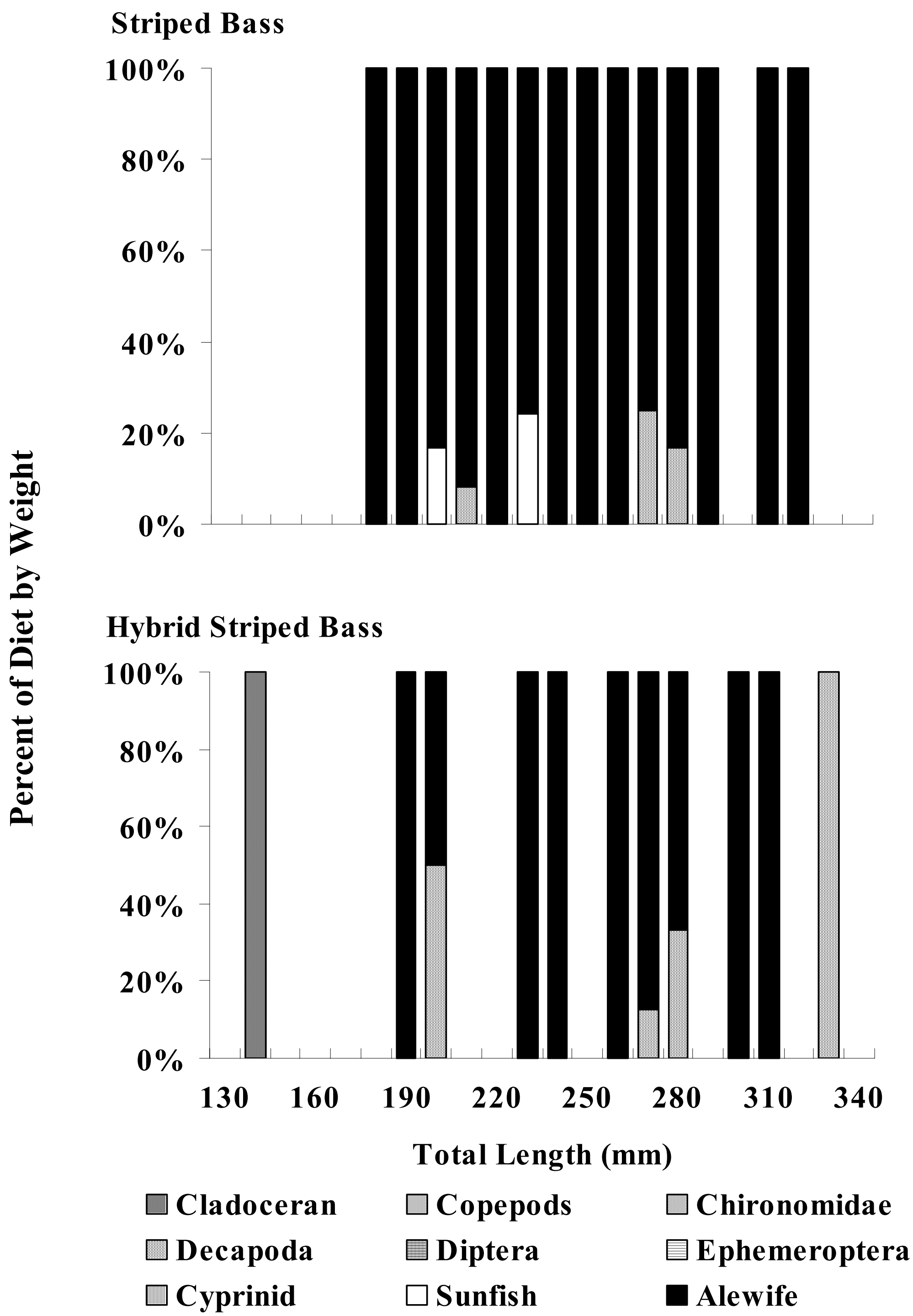

Figure 17. Size-dependent patterns in juvenile striped bass and juvenile hybrid striped bass diet composition during the 2003 post-winter period in Claytor Lake.

weight for both striped bass and hybrid striped bass during the 2003 post-winter period (Figure 17).

Diet Overlap

During the 2002 growing season, juvenile striped bass and juvenile hybrid striped bass did not exhibit diet overlap values greater than 0.6 for any month (Table 8). However, juvenile striped bass and juvenile hybrid striped bass did exhibit an overlap value of 0.80 for the spring of 2003, when diets were predominately comprised of age-0 alewife (Table 8).

Diet overlap was calculated for age-0 striped bass and age-0 hybrid striped bass over 10-mm TL size ranges by month of the growing season (Table 9). Although sample sizes in these analyses were small, overlap values greater than 0.6 were calculated for 81-90-mm TL and 91-100-mm TL classes for the month of September (Table 9). During this period, a large portion of the diet was cladocerans, Chironomidae, and other Diptera. Also, an overlap value of 1.00 was obtained for the 101-110-mm TL size class in the month of October. Both striped bass and hybrid striped bass individuals within this size range fed exclusively on cladocerans. During spring 2003, overlap values greater than 0.6 were obtained for all size classes present, except 281-290-mm TL. Age-0 alewife were the principal food item for juvenile striped bass in the spring of 2003, but juvenile hybrid striped bass in the 281-290-mm TL size range utilized more crayfish as prey (Figure 17).

Table 8. Temporal patterns in diet overlap values for juvenile striped bass (STB) and juvenile hybrid striped bass (HSB) over the 2002 growing season and 2003 post-winter period in Claytor Lake. The total overlap value reflects the pooling of all individuals from each month.

Month	*N* STB	*N* HSB	Schoener's Index of Overlap
August	85	1	0.30
September	115	15	0.03
October	109	13	0.15
November	24	2	0.27
April & May	60	26	0.80

Table 9. Temporal patterns in diet overlap values for 10-mm total length size classes of juvenile striped bass (STB) and juvenile hybrid striped bass (HSB) over the 2002 growing season and 2003 post-winter period in Claytor Lake.

Month	Length Class (mm)	*N*		Overlap Value
		STB	HSB	
August	121-130	6	1	0.51
September	81-90	2	1	1.00
	91-100	8	1	0.89
	101-110	5	1	0.00
	111-120	8	1	0.10
	121-130	6	1	0.00
October	101-110	3	3	1.00
	111-120	5	2	0.01
	141-150	4	1	0.39
April & May	191-200	4	1	1.00
	201-210	12	1	0.72
	231-240	4	1	0.91
	241-250	3	1	1.00
	261-270	2	3	1.00
	271-280	8	7	0.91
	281-290	5	2	0.54
	311-320	3	2	1.00

Indices of Health

2001-2002. – During the 2001 growing season condition factor (*K*) (range 0.67-1.40) and relative weight (range 54-103) for striped bass displayed similar patterns, with both health index values indicating generally poor condition of age-0 striped bass. Other researchers have reported juvenile moronid *K* values to range from 1.31-2.79 (Ware 1970; Burkuloo 1975; Kinman 1987; Austin and Hurley 1987). With, individuals with relative weight values less than the benchmark of 100 considered to be in less than "desirable" condition (Anderson and Neuman 1996). During the 2001-2002 season, juvenile striped bass mean condition values (excluding the month of stocking) were below 1.00, and monthly mean relative weight values did not to exceed 86.

Mean condition factor values for juvenile striped bass (all individuals) declined over the growing season (from 1.17 in June to 0.94 in December) (Figure 18). Condition factor values declined 14.6% from June (month of stocking) to July (ANOVA, $F = 61.05$, df = 112, $P < 0.001$). Following the initial rapid decline from June to July, mean age-0 striped bass *K* values then declined 8.9% over the growing season (July to December) (ANOVA, $F = 25.79$, df = 62, $P < 0.001$).

Declining trends were observed for relative weight values of age-0 striped bass individuals above the 150 mm TL cutoff range (Figure 19). Juvenile striped bass did not attain total lengths greater than 150 mm until the month of August. From August until December, mean relative weight values decreased 14%, from 86 to 76 (ANOVA, $F = 64.79$, df = 78, $P < 0.001$). There was not a significant difference between fall and spring mean condition factor values (0.92 and 0.90, respectively) (ANOVA, $F = 3.21$, df = 333,

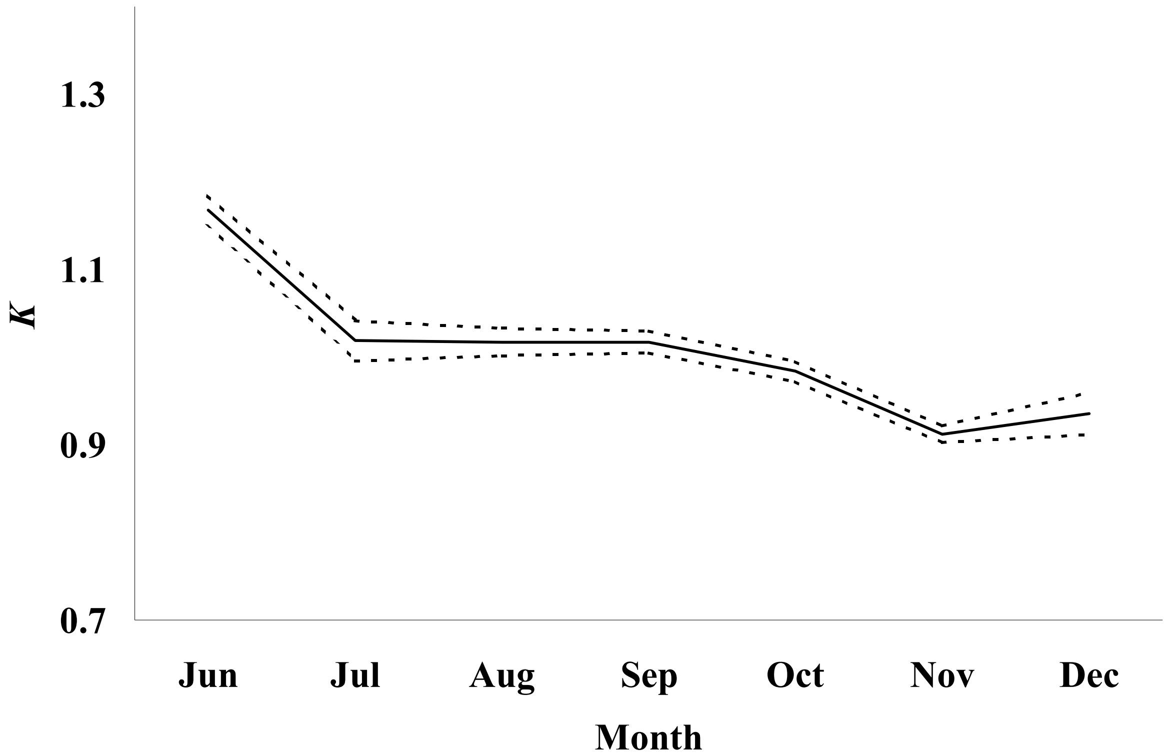

Figure 18. Temporal patterns in condition factor (*K*) for juvenile striped bass over the 2001 growing season in Claytor Lake. Mean condition factor values are represented by the solid line and 95% confidence intervals are represented by dashed lines.

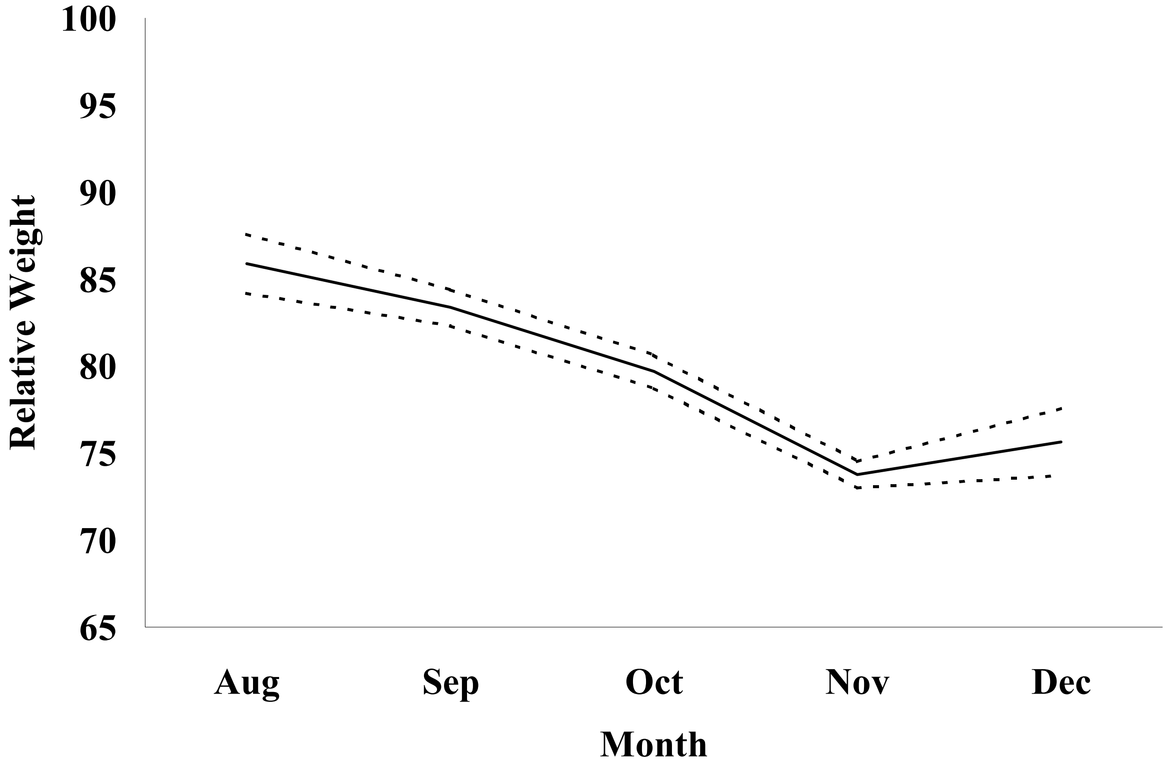

Figure 19. Temporal patterns in relative weight for juvenile striped bass over the 2001 growing season in Claytor Lake. Mean relative weight values are represented by the solid line and 95% confidence intervals are represented by dashed lines.

P < 0.074) and relative weight values (74 and 73, respectively) (ANOVA, *F* = 2.66, df = 325, *P* < 0.104) for juvenile striped bass.

Juvenile striped bass had a mean lipid index value of 37.9 in the late fall, and this value is slightly higher than the approximate mean of 30.0 observed by Sutton (1997). Juvenile striped bass mean lipid index values decreased 2% from late fall to early spring (35.7) (ANOVA, *F* = 32.15, df = 289, *P* < 0.001). The mean fall lipid index value for smaller individuals (< 150 mm TL) was 35.1, but the comparison of fall and spring lipid index values for smaller fish (< 150 mm TL) was not possible (none of the individuals processed in the spring were less than 150 mm TL). However, mean fall lipid index values were significantly higher then all corresponding spring 10-mm TL size class values, except for 160 mm TL (ANOVA, *F* = 0.66, df = 14, *P* = 0.429), 260 mm TL (ANOVA, *F* = 4.63, df = 9, *P* = 0.060), and 270 mm TL (ANOVA, *F* = 4.92, df = 4, *P* = 0.091) (Figure 20).

2002-2003. – Juvenile striped bass and juvenile hybrid striped bass exhibited indices indicative of poor health over the growing season (condition factor: range 0.68-1.22 and 0.68-1.38, respectively; relative weight: range 60-93 and 56-103, respectively). Striped bass and hybrid striped bass throughout all months of the 2002-2003 sampling season (except for hybrid striped bass in August), exhibited monthly mean *K* values below 1.00. For both fishes, all monthly mean relative weight values were below 100. Both striped bass and hybrid striped bass displayed mean lipid index values moderately higher than those values observed by Sutton (1997). Individual juvenile striped bass and hybrid striped bass had lipid index ranges of 24.6-48.2 and 28.1-40.6, respectively, with all monthly means exceeding 30.0.

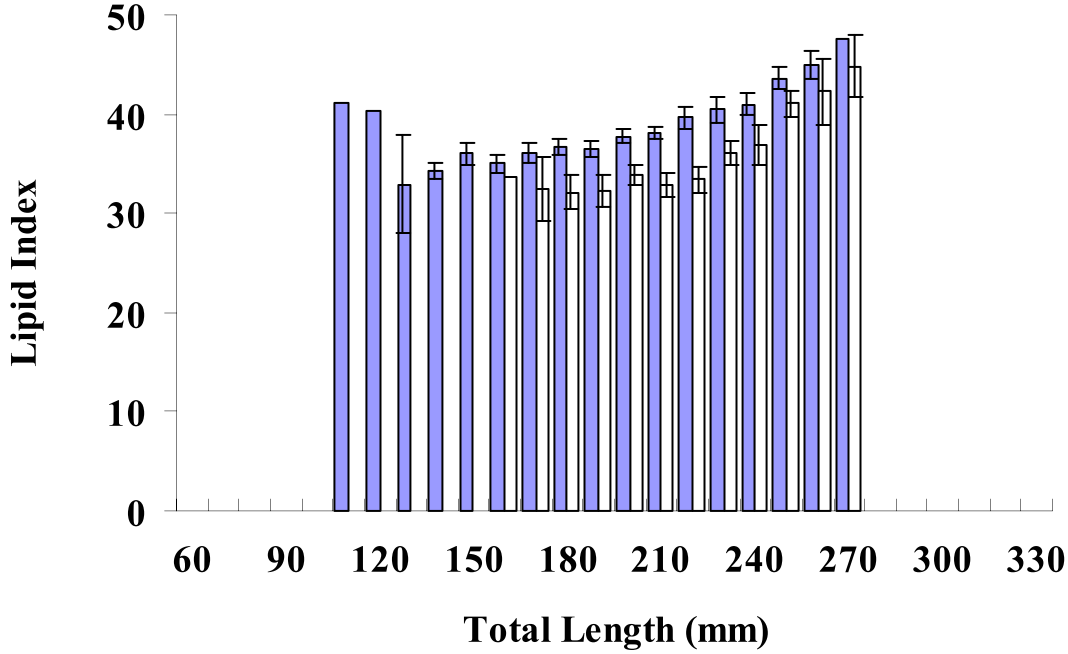

Figure 20. Size-dependent patterns in juvenile striped bass lipid index values before (shaded bars) and after (unshaded bars) wintering in Claytor Lake during the 2001-2002 sampling season. Values for each 10-mm size class are the means and error bars represent 95% confidence intervals. The 10-mm size classes without error bars are comprised of one individual.

Unlike 2001, striped bass in 2002 did not exhibit a significant decrease in mean condition factor values from the month of stocking (June) to July (ANVOA, $F = 3.87$, df = 110, $P = 0.052$) (Figure 21). However, mean condition factor values for striped bass decreased 7% over the growing season (0.93 to 0.88) (ANOVA, $F = 10.48$, df = 64, $P = 0.002$). Juvenile hybrid striped bass did, however, experience a dramatic decline in K values from the month of stocking (August) to the following month (Figure 21). Age-0 hybrid striped bass K values decreased 35% from August to a September mean of 0.91 (ANOVA, $F = 184.03$, df = 80, $P < 0.001$). This immediate decline did not continue over the remainder of the growing season (ANOVA, $F = 1.32$, df = 29, $P = 0.260$).

Upon stocking in 2002, hybrid striped bass mean K values were 19% higher (ANOVA, $F = 147.99$, df = 135, $P < 0.001$) than values for hybrid striped bass fingerlings stocked into the reservoir in 2001, and 2002 striped bass mean condition factor values at stocking were 25% less (ANOVA, $F = 113.89$, df = 169, $P < 0.001$) than fingerlings stocked into the reservoir in 2001. Also, the mean fall striped bass K value (0.91) was not significantly different from the mean spring value of 0.95 (ANOVA, $F = 3.27$, df = 283, $P = 0.071$), but the mean hybrid striped bass K value in the spring (1.09) was 14% higher than the mean fall value of 0.96 (ANOVA, $F = 18.41$, df = 84, $P < 0.001$). There was not a significant difference between 2001 and 2002 fall striped bass K values (ANOVA, $F = 0.44$, df = 386, $P = 0.506$). However, the mean condition factor value for spring 2002 was 6% higher than the mean value for spring 2001 (ANOVA, $F = 4.16$, df = 230, $P = 0.042$).

As in 2001, age-0 striped bass did not attain lengths greater than the 150 mm TL until August. However, in contrast to 2001, 2002 striped bass weight values during

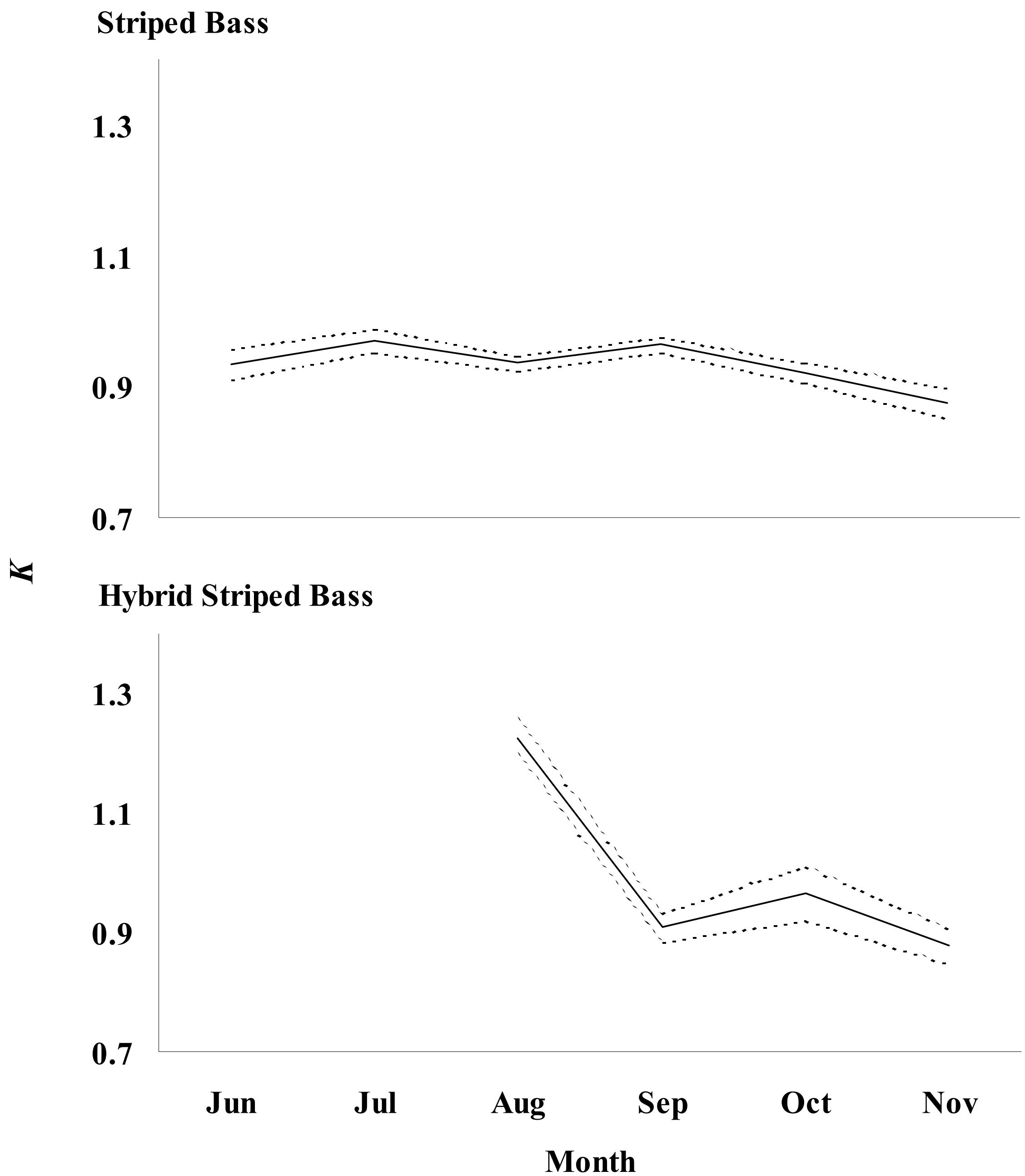

Figure 21. Temporal patterns in condition factor (*K*) for juvenile striped bass and juvenile hybrid striped bass over the 2002 growing season in Claytor Lake. Mean condition factor values are represented by solid lines and 95% confidence intervals are represented by dashed lines.

the first months of the growing season (Figure 22). Age-0 striped bass mean relative weight values increased 5% from August to a mean in September of 81 (ANOVA, F = 7.12, df = 90, P =0.002), but as observed for 2001, mean relative weight values experienced a decline (12%) from September to November (ANOVA, F = 67.05, df = 118, P <0.001).

Like striped bass, juvenile hybrid striped bass attained lengths greater than the minimum requirement for relative weight calculation (115 mm TL) during the month of August. These individuals did not display a significant difference between relative weight values in their first and second month in Claytor Lake, but did exhibit a 20% decline in mean relative weight values over the growing season, concluding the growing season with a November mean of 71 (ANOVA, F = 378.22, df = 4, P < 0.001).

Comparison of fall and spring relative weight values failed to reveal significant differences between the two periods for either striped bass (76 and 76, respectively) (ANOVA, F = 0.00, df = 219, P = 0.959) or hybrid striped bass (77 and 80, respectively) (ANOVA, F = 1.01, df = 73, P = 0.319). Also, there was not a significant difference between fall striped bass and fall hybrid striped bass (ANOVA, F = 0.63, df = 175, P = 0.429) or spring striped bass and spring hybrid striped bass (ANOVA, F = 1.65, df = 117, P = 0.202) relative weight values. However, in 2002, mean fall striped bass relative weight values were 3% greater than mean 2001 fall striped bass relative weight values (ANOVA, F = 8.56, df = 318, P = 0.004). Also, mean spring 2003 striped bass relative weight values were 4% larger than mean spring 2002 striped bass relative weight values (ANOVA, F = 4.12, df = 226, P = 0.044). Nevertheless, mean relative weight values for both fishes were well below the benchmark of 100.

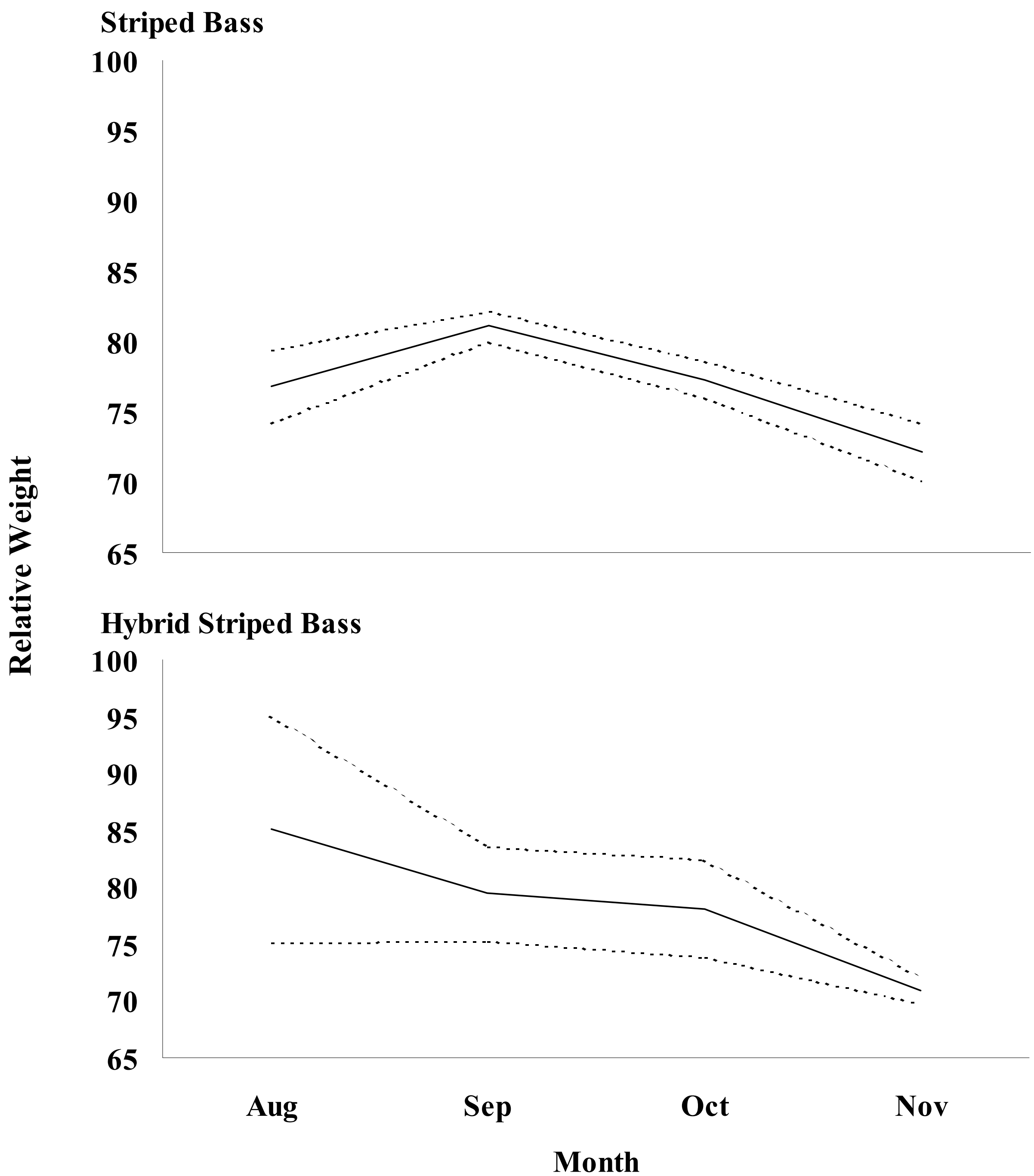

Figure 22. Temporal patterns in relative weight for juvenile striped bass and juvenile hybrid striped bass over the 2002 growing season in Claytor Lake. Mean relative weight values are represented by solid lines and 95% confidence intervals are represented by dashed lines.

Over the 2002 growing season mean lipid index values increased 18% (ANOVA, $F = 67.18$, df = 81, $P < 0.001$) for striped bass (30.0 to 35.4) and decreased 16% (ANOVA, $F = 42.87$, df = 13, $P < 0.001$) for hybrid striped bass (38.4 to 33.1), with the most remarkable changes occurring early in their respective growing seasons (Figure 23). Juvenile striped bass mean lipid index values increased 9% from July to August (ANOVA, $F = 68.89$, df = 147, $P < 0.001$) and for juvenile hybrid striped bass mean lipid index values decreased 11% from August to September (ANOVA, $F = 53.88$, df = 33, $P < 0.001$). Juvenile striped bass experienced a size-dependent increase in lipid index values over the 2002 growing season (Jonckheere- Terpstra, $J = 21.1$, $P < 0.001$), while juvenile hybrid striped bass did not (Jonckheere-Terpstra, $J = -0.4$, $P \approx 0.642$) (Figure 24). Juvenile striped bass mean lipid index values decreased 4% (ANOVA, $F = 6.11$, df = 287, $P = 0.014$) and juvenile hybrid striped bass mean lipid index values increased 8% (ANOVA, $F = 16.28$, df = 85, $P < 0.001$) between the late fall and early spring periods. During the late fall, the mean juvenile striped bass mean lipid index value was 7% (ANOVA, $F = 21.17$, df = 250, $P < 0.001$) greater than the mean hybrid striped bass lipid index value of 32.9. However, there was no significant difference between striped bass and hybrid striped bass spring lipid index values (34.1 and 35.5, respectively) (ANOVA, $F = 3.17$, df = 122, $P = 0.077$).

Mean fall lipid index values were significantly lower than all corresponding spring striped bass 10-mm TL size class values, except for 160 mm TL (ANOVA, $F = 2.40$, df = 28, $P = 0.132$), 220 mm TL (ANOVA, $F = 4.04$, df = 8, $P = 0.079$), and 240 mm TL (ANOVA, $F = 0.38$, df = 3, $P = 0.582$) (Figure 25). Only one small mode (<150 mm TL) striped bass was collected following winter in 2003, and its lipid index value

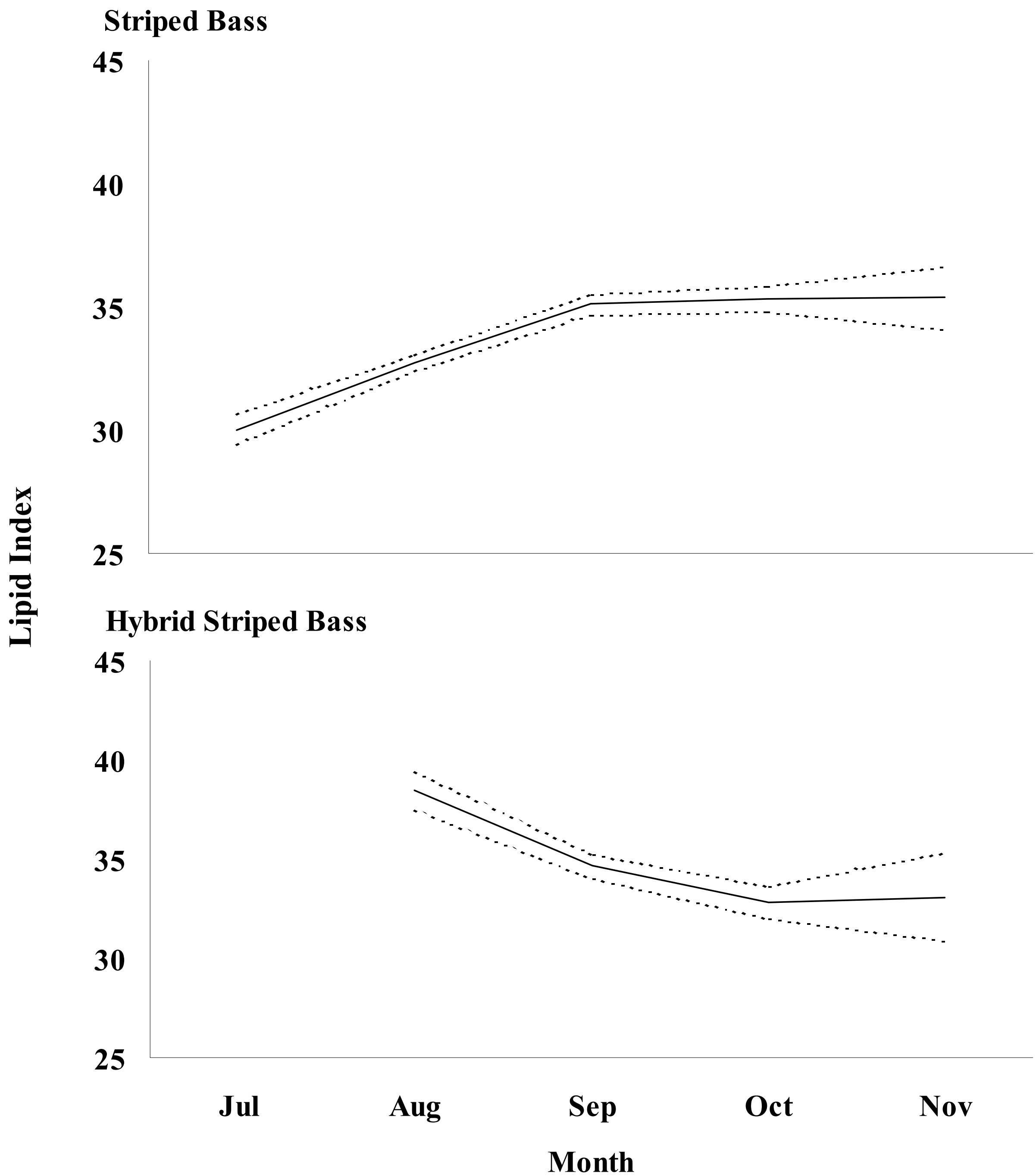

Figure 23. Temporal patterns in lipid index for juvenile striped bass and juvenile hybrid striped bass over the 2002 growing season in Claytor Lake. Mean total lipid index values are represented by solid lines and 95% confidence intervals are represented by dashed lines.

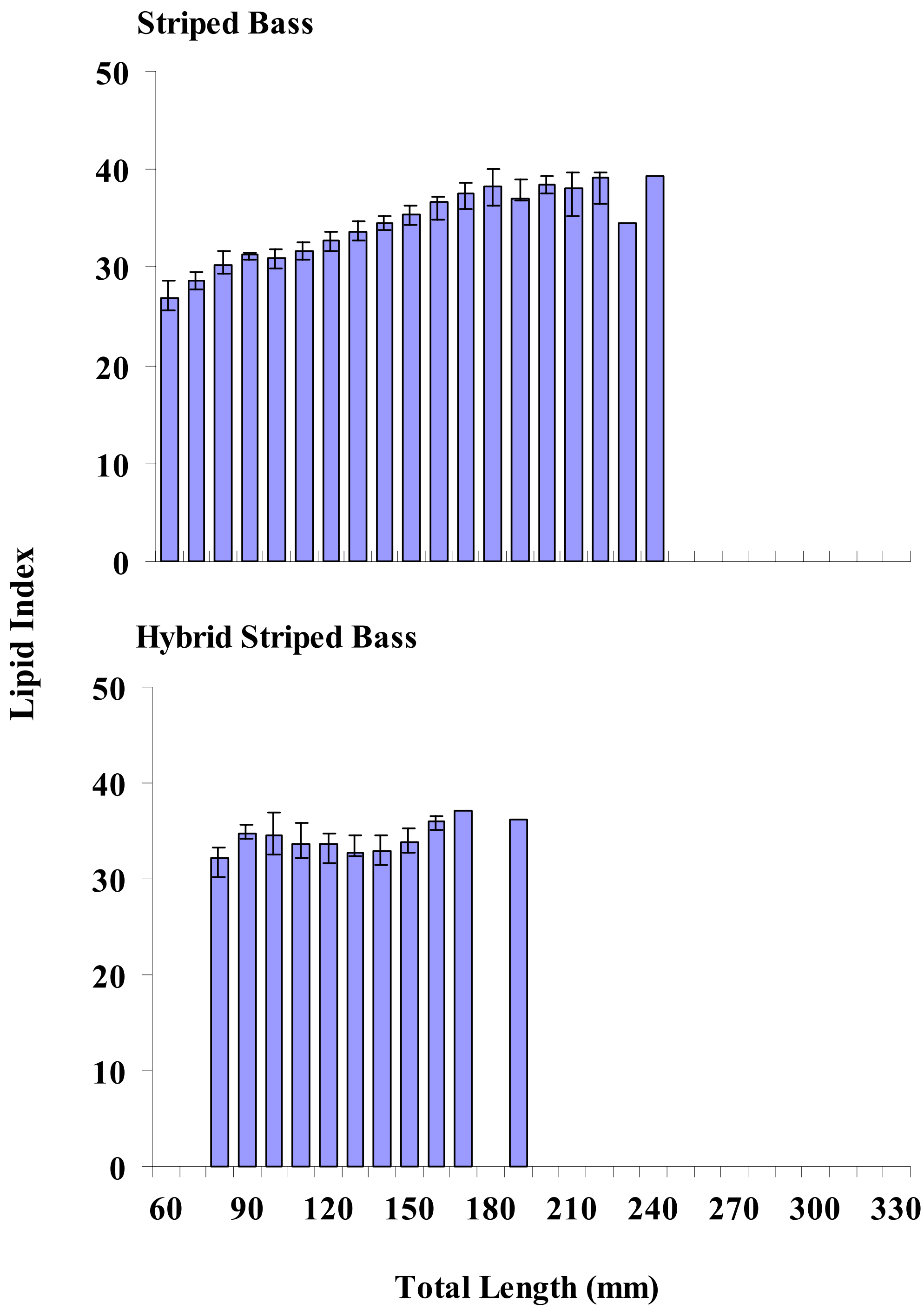

Figure 24. Size-dependent patterns in juvenile striped bass and juvenile hybrid striped bass lipid index values over the 2002 growing season in Claytor Lake. Values for each 10-mm size class are the means and error bars represent the 95% confidence intervals. The 10-mm size classes without error bars are comprised of one individual.

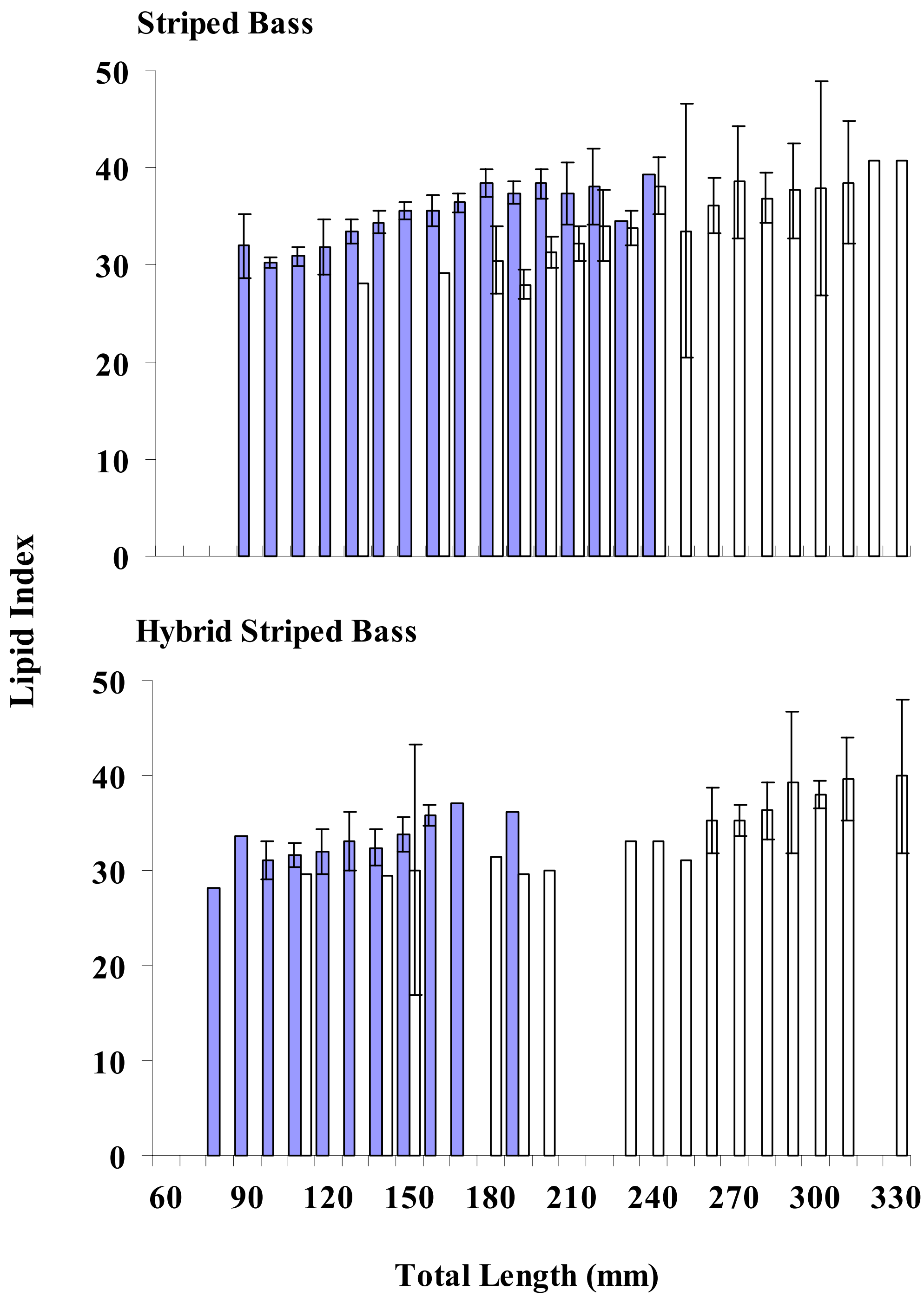

Figure 25. Size-dependent patterns in juvenile striped bass and juvenile hybrid striped bass lipid index values before (shaded bars) and after (unshaded bars) wintering in Claytor Lake during the 2002-2003 sampling season. Values for each 10-mm size class are the means and error bars represent 95% confidence intervals. The 10-mm size classes without error bars are comprised of one individual.

(28.2) was substantially less than the mean lipid index value of larger (>150 mm TL) individuals in the spring (34.2).

Fall lipid index values did not differ significantly between corresponding spring 10 mm TL sizes classes for hybrid striped bass (110 mm TL: ANOVA, $F = 1.46$, df = 8, $P = 0.260$; 140 mm TL: ANOVA, $F = 2.82$, df = 4, $P = 0.169$; 150 mm TL: ANOVA, $F = 5.68$, df = 7, $P = 0.050$) (Figure 25). However, larger (> 150 mm TL) hybrid striped bass displayed a 21% higher mean lipid index value than smaller (< 150 mm TL) individuals that survived the winter.

Juvenile striped bass in fall 2001 exhibited a mean lipid index value 9% greater than juvenile striped bass in fall 2002 (ANOVA, $F = 87.17$, df = 416, $P < 0.001$). However, there was no significant difference between mean spring lipid index values for 2001 and 2002 juvenile striped bass (ANOVA, $F = 3.12$, df = 230, $P = 0.079$). Also, in 2002, the juvenile hybrid striped bass mean lipid index value at the time of stocking (46.7) was 14% higher than that for those stocked in 2001 (ANOVA, $F = 49.14$, df = 58, $P < 0.001$).

Habitat Usage

Positive habitat electivity values reflect the preference of both juvenile striped bass and juvenile hybrid striped bass for sand and gravel substrates without cover in 2002 (Table 10). During the month of November, striped bass exhibited a slight preference for cobble substrate without cover, but the total electivity value (all monthly values pooled) did not indicate preference for the habitat consisting of cobble substrate without cover (Table 10). No striped bass or hybrid striped bass were captured or observed over sand with cover, cobble with cover, boulder, and boulder with cover habitat units (Table 10).

Table 10. Temporal patterns in linear selection habitat electivity values for juvenile striped bass and juvenile hybrid striped bass during the 2002 growing season in Claytor Lake. The total electivity values reflect the pooling of all individuals from each month. Positive electivity values are in bold. Hybrid striped bass were not captured in October.

Month	Habitat Unit	Striped Bass Electivity Value	Hybrid Striped Bass Electivity Value
September	Sand	**0.19**	**0.86**
	Sand With Cover	-0.14	-0.14
	Gravel	**0.52**	-0.14
	Cobble	-0.14	-0.14
	Cobble With Cover	-0.14	-0.14
	Boulder	-0.14	-0.14
	Boulder With Cover	-0.14	-0.14
October	Sand	**0.23**	-----
	Sand With Cover	-0.14	-----
	Gravel	**0.38**	-----
	Cobble	-0.14	-----
	Cobble With Cover	-0.14	-----
	Boulder	-0.14	-----
	Boulder With Cover	-0.14	-----
November	Sand	**0.52**	-0.14
	Sand With Cover	-0.14	-0.14
	Gravel	**0.02**	**0.86**
	Cobble	**0.02**	-0.14
	Cobble With Cover	-0.14	-0.14
	Boulder	-0.14	-0.14
	Boulder With Cover	-0.14	-0.14
Total	Sand	**0.25**	**0.69**
	Sand With Cover	-0.14	-0.14
	Gravel	**0.39**	**0.02**
	Cobble	-0.07	-0.14
	Cobble With Cover	-0.14	-0.14
	Boulder	-0.14	-0.14
	Boulder With Cover	-0.14	-0.14

Each habitat type represented approximately 14% of the total, and the failure to collect moronids over these habitat types resulted in electivities of –0.14 (r_i = 0 and p_i = 0.14).

Habitat overlap values greater than 0.6 were not detected for any individual month of the growing season or for all months combined (Table 11). Low overlap may be attributed to a species exhibiting preference for one habitat type one month and not in a subsequent month, while the other species may have been doing the opposite, without the habitat usage of the two fishes coinciding in the same month. For example, in September, striped bass exhibited a greater preference for gravel than for sand, but hybrid striped bass exhibited a preference for sand only for that same month (Table 10). During the month of October, no hybrid striped bass were collected (Table 10). In November, the species essentially reversed the trends displayed in the month of September, with striped bass favoring sand and hybrid striped bass preferring gravel. Thus, it is possible for each species to prefer the same habitat units (sand and gravel substrates without cover), but the monthly variation did not result in significant overlap values.

Predation

The frequency of occurrence of juvenile striped bass and juvenile hybrid striped bass fingerlings in the diets of potential predators was minimal (Table 12). Predators evaluated after striped bass stocking in 2002 consisted of 55 largemouth bass *M. salmoides*, 20 smallmouth bass *M. dolomieu*, 17 spotted bass *M. punctulatus*, 7 yellow perch *Perca flavescens*, 3 striped bass, 2 rock bass *Ambloplites rupestris*, and 1 flathead catfish. None of the 105 predators sampled following striped bass introductions contained an age-0 striped bass (Table 12).

Table 11. Temporal patterns in habitat overlap values for juvenile striped bass and juvenile hybrid striped bass over the 2002 growing season in Claytor Lake. The total overlap value reflects the pooling of all individuals from each month.

Month	Overlap Value
Total	0.56
September	0.33
October	-----
November	0.17

Table 12. Frequency of occurrence of striped bass and hybrid striped bass fingerlings in the diets of potential predators, following the 2002-stocking of striped bass and hybrid striped bass in Claytor Lake.

Stock	Number of Predators Sampled	Frequency of Occurrence (%)
Striped Bass	105	0.00
Hybrid Striped Bass	95	3.26

Predators investigated for the consumption of fingerling hybrid striped bass were 40 spotted bass, 29 smallmouth bass, 12 largemouth bass, 6 flathead catfish, 5 yellow perch, 2 yellow bullhead *Ameiurus natalis*, and 1 rock bass. A single largemouth bass, smallmouth bass, and spotted bass each contained a fingerling hybrid striped bass on the night of stocking. Only 3 of the 95 predators sampled following hybrid striped bass stocking in 2002 contained a hybrid striped bass fingerling (Table 12).

DISCUSSION

This study focused upon the comparative ecology of age-0 striped bass and age-0 hybrid striped bass in order to identify potentially deleterious interactions between the two fishes that may limit recruitment to age 1. These interactions were considered in particular within the context of trophic relationships, physiological indices of health, overwinter survival, and habitat usage. Also, the impact of poststocking predation was examined as a possible source of fingerling mortality.

Stock Identification

In late September 2001, Claytor Lake was stocked with approximately 33,500 age-0 hybrid striped bass from Keo Fish Farm (Keo, AR). These individuals were received one month after the period of requested delivery (John Copeland, VDGIF, pers. comm.). Upon arrival, the 2001 hybrid striped bass mean total length (68) and lipid index (41.1) values were 40% and 14%, respectively less than values for the August 2002 fingerlings provided by Southland Fisheries Corp. (Hopkins, SC), the usual supplier. Also, 2001 hybrid striped bass were in poorer condition (mean $K = 1.03$) than those stocked in 2002 (mean $K = 1.23$). The mean K value of 1.03 is substantially lower than the average K value of approximately 1.25 reported for juvenile hybrid striped bass stocked into East Fork Lake, Ohio (Austin and Hurley 1987). Thus, relatively poor survival of these less-fit, 2001 hybrid striped bass fingerlings might be expected, especially because they were stocked late in the growing season. Capture of only three juvenile hybrid striped bass during the weeks following their stocking in 2001 and the failure to capture any juvenile hybrid striped bass following the post-winter period in 2002 supports the hypothesis of poor survival of 2001 hybrid striped bass.

Alternatively, so few hybrid striped bass may have been identified because the stocked fish were not true F1 (white bass x striped bass) hybrids. However, comparisons of allele frequencies supported the conclusion that the 2001 fish were F1 hybrids, lending further credence to the assumption of poor survival. Regardless of the underlying explanation, I caught too few hybrid striped bass from the 2001 stocking to compare their performance to the 2001 age-0 striped bass.

First-Year Growth

Both striped bass and hybrid striped bass in Claytor Lake demonstrated progressive increases in total length from time of stocking through the end of the growing season. The growth for striped bass in Claytor Lake is consistent with the descriptions of first-year growth reported for age-0 striped bass in other southeastern reservoirs, with some specimens achieving total lengths greater than 200 mm (Table 13). In contrast, age-0 hybrid striped bass (maximum = 157 mm TL) did not display total lengths as great as those reported within the literature for first-year growth (Table 13). Juvenile hybrid striped bass did not exhibit the more rapid growth rate than striped bass as reported for these fishes in other systems (Bishop 1967; Logan 1967; Tuncer et al. 1990; Jenkins and Burkhead 1993), perhaps because hybrid striped bass were stocked two months later than striped bass.

Both striped bass and hybrid striped bass in this study exhibited S-shaped growth curves during their first year of growth. During the period of linear growth (June to October) in both 2001 and 2002, juvenile striped bass monthly mean total lengths increased by 1.10 and 0.81 mm/day, respectively. This difference in growth rate between years is likely due to annual variability of water levels within the reservoir, coupled with

Table 13. Total lengths attained by juvenile striped bass (STB) and juvenile hybrid striped bass (HSB) for the first-year of growth reported in the literature. Total lengths presented are means, with ranges in parentheses.

Stock	Author	System	Total Length (mm)
STB	Stevens (1958)	Santee-Cooper Reservoir, SC	216 (74 – 351)
	Mesinger (1970)	Keystone Reservoir, OK	259
	Ware (1970)	Lakes Hollingsworth, Parker, and Hunter, FL	282
	Erickson et al. (1971)	Keystone Reservoir, OK	282
	Van Den Avyle and Higginbotham (1973)	Watts Bar Reservoir, TN	182 (154 – 244)
	Axon (1979)	Herrington Lake, KY	(254-305)
	Dey (1981)	Hudson River, NY	100
	Van Den Avyle et al. (1983)	Watts Bar Reservoir, TN	219
	Moss and Lawson (1987)	Alabama Public Fishing Lakes	245
	Sutton and Ney (2001)	Smith Mountain Lake, VA	(80 – 268)
	Present Study	Claytor Lake, VA	
	2001		229 (174-272)
	2002		173 (112-227)
HSB	Crandall (1978)	Lake Bastrop, TX	(303 – 351)
	Ott and Malvestuto (1981)	West Point Reservoir, AL	290
	Saul and Wilson (1981)	Cherokee Reservoir, TN	215
	Austin and Hurley (1987)	East Fork Lake, OH	220
	Kinman (1987)	Herrington Lake, KY	252
	Moss and Lawson (1987)	Alabama Public Fishing Lakes	230
	Present Study	Claytor Lake, VA	
	2002		133 (98-157)

19% lower initial *K* values for 2002 striped bass fingerlings in comparison to those in 2001. Perhaps, due to the loss of preferred juvenile habitat within the littoral zone via the reduced flow into the reservoir during summer 2002, foraging success of recently stocked fingerlings was decreased. Thus, these juveniles in poorer condition may have been forced to reallocate energy from initial growth to storage of energy reserves during this period of environmental stress (as noted by juvenile striped bass lipid index values increasing from a mean of 30.0 in July to a mean of 35.1 in September) (Post and Parkinson 2001). Additionally, variation in ration may account for the yearly difference in growth, but determination of forage availability was beyond the scope of this study.

The initial rapid increase in growth observed for striped bass in Claytor Lake is consistent with reports from other systems. Mesinger (1970) reported that age-0 striped bass displayed a rapid increase in total length during the months of June to September in Keystone Reservoir, Oklahoma. Sutton and Ney (2001) observed a similar pattern in growth for juvenile striped bass in Smith Mountain Lake, Virginia, with growth rates slowing during the month of October. In Lakes Hollingsworth, Parker, and Hunter, Florida, juvenile striped bass growth rates were characterized by swift growth from August to September, with only a gradual increase in total length for the remainder of the growing season (Ware 1970). Additionally, Dey (1981) found linear growth of juvenile striped bass from June to August, followed by a plateau in growth rates through December, for age-0 striped bass in the Hudson River, New York.

In contrast, during the period of linear growth (August to October 2002) juvenile hybrid striped bass displayed a growth rate of only 0.52 mm/day, while juvenile striped bass increased at the same rate (0.52 mm/day) during this same period. The observed length at the end of the growing season of age-0 hybrid striped bass in Claytor Lake was significantly less than that of age-0 striped bass in this study and those reported in the literature (Table 13). In addition, the plateau of growth in October is inconsistent with hybrid striped bass growth in other systems. Austin and Hurley (1987) reported that age-0 hybrid striped bass in East Fork Lake, Ohio, did not display a plateau in growth during the growing season. Also, in Cherokee Reservoir, Tennessee, juvenile hybrid striped bass exhibited a continuous rapid increase in total length in the first year of growth until the onset of winter (Saul and Wilson 1981).

Post-Winter Survival

Analysis of the differences in length-frequency distributions between fall and spring sampling periods for striped bass in 2001-2002 suggests that size-dependent mortality over the winter period limits the recruitment of juveniles in Claytor Lake. The observation of smaller individuals experiencing disproportionately higher overwinter mortality than larger individuals is reported in numerous studies for a variety of age-0 fishes. Sutton and Ney (2001) reported substantial mortality of smaller (< 150 mm TL) age-0 striped bass during the overwinter period in Smith Mountain Lake, Virginia. The loss of small-mode (< 150 mm TL) individuals from the age-0 cohort also was observed for hybrid striped bass in East Fork Lake, Ohio (Austin and Hurley 1987). Similar size-dependent overwinter mortality has been documented for largemouth bass (Timmons et al. 1980; Toneys and Coble 1980; Garvey et al. 1998; Fullerton et al. 2000), walleye (Nielsen 1980), brook trout *Salvelinus fontinalis* (Toneys and Coble 1980; Cunjak and Power 1986), yellow perch (Toneys and Coble 1980; Post and Evans 1991), Colorado squawfish *Ptychocheilus lucius* (Thompson et al. 1991), green sunfish *Lepomis cyanellus*

(Toneys and Coble 1980), pumpkinseed *Lepomis gibbosus* (Benard and Fox 1997), and Atlantic cod *Gadus morhua* (Gotceitas et al. 1999).

Overwinter loss of smaller individuals occurred in this study was not as dramatic as that observed by Sutton and Ney (2001). Unlike Smith Mountain Lake, Virginia (Sutton and Ney 2001), Claytor Lake lacked the large proportion of small striped bass (< 150 mm TL) entering into the winter. As a result, a clear bimodal size distribution never developed for either striped bass or hybrid striped bass juveniles during this study. Thus, greater attention was placed upon detecting the presence of an upward shift in the mean, without an increase in the maximum total length of the population (Sutton and Ney 2001). Examination of length-frequency distributions did in fact reveal the loss of smaller individuals (< 150 mm TL) over winter in the 2001-2002 sampling season. By spring, the mean total length had increased 9% from fall, while the maximum total length remained at approximately 270 mm TL. In addition, only 1% of individuals in the spring were less than 150 mm TL, compared the 5% that had entered into the winter.

In late fall 2002, juvenile striped bass were smaller (32% < 150 mm TL versus 5% < 150 mm TL in 2001) and exhibited lipid reserves 9% lower than individuals of late fall 2001. Thus, with striped bass individuals entering the harsh winter of 2002 at smaller sizes and at a poorer condition in comparison to juvenile striped bass in 2001, the potential existed for overwinter mortality in the 2002-2003 sampling season. In spring 2003, striped bass and hybrid striped bass were significantly longer than in the previous fall (45% and 97% differences in total lengths, respectively). However, it was not possible to accurately detect size-dependent overwinter mortality in 2002-2003 fish, because the upward shift in the minimum and mean lengths of striped bass and hybrid striped bass in the spring 2003 was accompanied by an increase in the maximum total length for both fishes of 105 and 173 mm, respectively. The increase in the maximum indicates that overwinter disappearance of small individuals may simply be due to their growth beyond that size range. However, alternative explanations are possible for my failure to collect the larger individuals in fall 2002 that were collected in spring 2003. First, the sampling techniques utilized may have failed to representatively capture larger individuals that may have been present in the fall. I feel this explanation is not plausible due to the fact that sampling efforts were consistent between years and seasons, and these efforts failed to reveal any anomalies until spring 2003. Second, individuals may have grown over the winter, but that appears unlikely as well. Age-0 *Morone* have been reported to cease growth at temperatures less than 10ºC (Cox and Coutant 1981; Kerby et al. 1987; Woiwode and Adelman 1991; Hurst and Conover 1998; Sutton 1997). The reported monthly mean air temperatures for Whitethorne, Virginia (approximately 14 km north of Claytor Lake Dam) for November 2002 through April 2003 are 5.5, 0.0, 0.0, 0.5, 7.6, and 11.2ºC, respectively (Virginia Agricultural Experiment Station, 2003). During the months of November and December 2002, Kilpatrick (2003) reported mean monthly temperatures of Claytor Lake to be 11.7 and 5.5ºC, respectively. Due to the extreme low temperatures experienced during this period, I feel that it is doubtful that overwinter growth occurred. The third and most probable explanation for the dramatic increase in total lengths from fall 2002 to spring 2003 is that individuals resumed growth in the spring period before becoming susceptible to sampling gear. Sampling during spring 2002 and spring 2003 began in March and continued through May 2003. This sampling regime yielded 150 striped bass in 2002, and 86 striped bass and 40 hybrid striped bass in

2003. In 2002 the majority of individuals were caught during March and the first two weeks of April, but in 2003 individuals were not collected until the last two weeks of April and the first two weeks of May. In addition, by the time both striped bass and hybrid striped bass were collected in 2003, both fishes had established diets composed of sunfish, crayfish, and predominately, alewife. Striped bass collected in spring 2002, were found to have a mixed diet of invertebrates and fish. Thus, the additional time to grow, coupled with the switch to an energetically profitable diet, more than likely gave juvenile striped bass and juvenile hybrid striped bass the opportunity to grow before becoming susceptible to the sampling gear deployed in spring 2003.

Nonetheless, in 2001-2002 juvenile striped bass experienced a legitimate loss of small (< 150 mm TL) individuals over the winter. Sutton (1997) presented evidence that small striped bass in Smith Mountain Lake, Virginia, had less energy reserves (i.e., lipid index value was 37% less) than larger individuals entering winter, and thus were required to utilize these limited stores to survive the winter. Sutton (1997) reported a positive allometric relationship between body size and energy reserves and negative allometric relationships between body size and metabolism. The emergence of larger juveniles from the overwinter period, in better physiological health than smaller fish, substantiates the relationship of energy variance and body size in determining overwinter survival in age-0 fishes (Sutton 1997). In this study, 2001-striped bass individuals greater than 150 mm TL possessed lipid index values 8% higher than smaller (< 150 mm TL) individuals entering into the winter, but due to the loss of small individuals over the winter, the comparison of small and large size classes (> 150 mm TL) in the spring was not possible. However, Sutton (1997) reported spring lipid index values for large size classes to be

67% higher than values for smaller (< 150 mm TL) individuals. The lack of smaller individuals in the spring further supports the hypothesis of the relationship of energy variance and body size in determining winter mortality. Fall versus spring indices of health (condition factor, relative weight, and lipid index) are below (see Indices of Health).

Food Habits

Both juvenile striped bass and juvenile hybrid striped bass exhibited size-dependent shifts in food habits at approximately 120 mm TL. Fish 80 to 120 mm TL principally utilized aquatic insects and zooplankton, while individuals over 120 mm TL mostly preyed upon age-0 fishes. This ontogenetic shift in food habits has also been observed for other reservoir populations of age-0 striped bass (Ware 1970; Axon 1979; Van Den Avyle et al. 1983; Matthews et al. 1992; Sutton 1997) and age-0 hybrid striped bass (Ott and Malvestuto 1981; Saul and Wilson 1981; Austin and Hurley 1987; Kinman 1987), with the switch from mainly zooplankton and aquatic insects (chironomids) to principally young-of-the-year fishes (alewife, gizzard shad, cyprinids, inland silversides *Menidia beryllina*, and/or sunfishes) at total lengths greater than 100 mm. The shift in diet at approximately 120 mm TL for striped bass in Claytor Lake was most similar to that exhibited by striped bass in Smith Mountain Lake, Virginia, where individuals less than 120 mm TL consumed a mixed diet comprised mainly of zooplankton and aquatic insects and those greater than 120 mm TL preyed upon age-0 fishes (Sutton 1997). In addition, the change in hybrid striped bass diet observed in this study closely resembles the alteration in diet reported for hybrid striped bass in Cherokee Reservoir, Tennessee, where individuals that achieved lengths of approximately 126 mm TL began to feed predominately upon clupeid forage fishes (Saul and Wilson 1981).

Even though the two moronids were primarily piscivorous, they did not concentrate on the same prey items during the growing season, resulting in low diet overlap. Examination of stomach contents for juvenile striped bass and juvenile hybrid striped bass revealed time-dependent feeding patterns. Given the early June stocking date for fingerling striped bass, they were able to forage on young-of-the-year alewife by July 2001 and 2002. The consumption of age-0 alewife was continued throughout the growing season, albeit less frequently when alewife began to move to deeper waters during October through December. In contrast, juvenile hybrid striped bass (stocked two months later in the growing season at a mean of approximately 94 mm TL) did not exhibit the same utilization of age-0 alewife as shown by juvenile striped bass, which in August averaged approximately 122 mm TL. Instead, juvenile hybrid striped bass preyed upon age-0 sunfish and cladocerans throughout the growing season. The delayed stocking of hybrid striped bass within Claytor Lake may be limiting the ability of juvenile hybrid striped bass to utilize age-0 alewife as a continuous food source throughout the growing season.

Nigro (1980) found that by August, age-0 alewife in Claytor Lake exhibited mean total lengths of approximately 110 and 90 mm in 1978 and 1979, respectively. In addition, Tisa (1988) reported age-0 alewife in Smith Mountain Lake, Virginia, to reach a mean total length of approximately 70 mm by early August. In 2002, hybrid striped bass fingerlings were stocked into Claytor Lake in August at a mean total length of 93.6 mm. Based on the relationship between predator mouth gape and prey body depth (Sutton

1997), age-0 striped bass 90 mm TL can only ingest alewife less than or equal to 30 mm TL. If the maximum total length ingestibility limit values developed for Smith Mountain Lake are applied to the juvenile hybrid striped bass entering Claytor Lake in August, hybrid striped bass could not ingest age-0 alewife. Alewife possess the highest gross energy values amongst clupeid forage fishes (Strange and Pelton 1987). The inability of juvenile hybrid striped to utilize the energetically profitable, age-0 alewife during the growing season has two potentially significant impacts upon the trophic interactions within Claytor Lake. First, it allows the young-of-the-year alewife forage base to be utilized more heavily by other lake piscivores (especially, age-0 striped bass). Second, the inability to take advantage of alewife as a source of prey may force juvenile hybrid striped bass to seek alternative prey items, such as cyprinids, age-0 gizzard shad, and age-0 sunfishes.

Although low overlap was observed during the growing season, juvenile striped bass and juvenile hybrid striped bass exhibited a significant diet overlap in the post-winter period (0.80). By spring 2003, hybrid striped bass were large enough to overcome their apparent initial inability to ingest alewife, forcing higher overlap values indicative of potential competition, but these values were only observed after the “critical period” of winter. Thus, it appears that due to the late stocking of hybrid striped bass, it is unlikely (based on 2002-2003) that juvenile hybrid striped bass are causing overwinter starvation mortality in juvenile striped bass. However, because I was unable to capture striped bass in the spring of 2003 prior to the onset of new growth, I could not compare late fall versus spring length-frequency distributions for evidence of size-dependent mortality. It seems likely that some size-dependent overwinter mortality occurred as in 2001-2002 because; striped bass were small and in poor condition in fall and the winter was cold and prolonged. If hybrid striped bass were able to feed, and grow during some winter periods when striped bass could not, it is possible that undetected late-winter/early-spring trophic competition could have occurred.

Indices of Health

Condition Factor (K). - The condition factor values for both striped bass and hybrid striped bass in Claytor Lake, except at stocking, were lower than values reported for these species within the literature. Mean monthly condition factor values for individuals in this study following the month of stocking were below 1.00. Condition factor values for age-0 striped bass stocked in the Choctawhatchee River, Florida, ranged from 1.65 to 2.54 (Wigfall and Burkuloo 1975). Ware (1970) reported condition factor values of striped bass stocked in Lakes Hollingsworth, Parker, and Hunter, Florida, to range between 1.31 and 2.79. Kinman (1987) found yearly condition factor values for hybrid striped bass in Herrington Lake, Kentucky, to average 1.24. Austin and Hurley (1987) reported hybrid striped bass to exhibit condition factor values greater than 1.25 during the growing season in East Fork Lake, Ohio.

Both juvenile striped bass and juvenile hybrid striped bass experienced a decline in condition factor index and relative weight values over each growing season, with the greatest change having occurred in the month immediately following the stocking of heavy, hatchery-reared fingerlings. High initial *K* values at stocking, and the failure of these values to increase proportionally with fish growth, has been reported for juvenile striped bass in Lakes Hollingsworth, Parker, and Hunter (Ware 1970) and the Choctawatchee River System, Flordia (Wigfall and Burkuloo 1975). This temporal trend in condition values is unlike that observed for juvenile striped bass in Smith Mountain Lake, Virginia (Sutton 1997). Sutton (1997) found relative condition factor (K_n) values increased over the growing season for juvenile striped bass. However, the weight-length regression equation used by Sutton (1997) was developed from all individuals within the sample. Thus, when applied to all size classes, the temporal trend could be skewed by data from the larger individuals of the late fall being applied to the weight-length regression.

The decrease in condition factor values that was observed during this study has been observed for juvenile hybrid striped bass in other systems. Saul and Wilson (1981) also noted that the initial plumpness of fingerling hybrid striped bass at time of stocking and a higher initial condition value followed by a subsequent decline for age-0 hybrid striped bass in Cherokee Reservoir, Tennessee. Austin and Hurley (1986) reported mean K values in one year of their study of age-0 hybrid striped bass in East Fork Lake, Ohio, to be highest in the month of August and lowest in November. However, in the remaining two years of the study, Austin and Hurley (1986) found the inverse trend to occur, with condition factor values increasing over the growing season.

During both sampling seasons, juvenile striped bass did not exhibit a difference between late fall and early spring K values. However, hybrid striped bass during the 2002-2003 sampling season experienced an increase in K values leaving the overwinter period. This increase can be attributed to the heightened consumption of alewife and apparent growth of hybrid striped bass during the spring.

Relative Weight. - Due to the two fishes having different body shapes, the condition factor values of striped bass cannot be compared to values of hybrid striped bass (Anderson and Neuman 1996). However, relative weight (*Wr*) values can be compared between the two fishes above their respective cutoffs (striped bass: > 150 mm TL and hybrid striped bass: >115 mm TL). Comparisons within this study revealed that there were no significant differences between late fall and early spring relative weight values for either striped bass or hybrid striped bass. In addition, comparison between species did not reveal a significant difference in either spring or fall. Relative weight values for both striped bass and hybrid striped bass declined over the growing season, and relative weight values for each stock during both fall and spring periods were well below the mark (100) for fish in "desirable" condition (Anderson and Neuman 1996). During the growing season of 2001 and spring of 2002, only 1 and 0%, respectively, of striped bass relative weights were above 100, and in the growing seasons of 2002 and spring 2003, only 0 and 6% of individuals, respectively, exceeded the mark. Only 2% of hybrid striped bass during the 2002 growing season possessed relative weight values greater than 100, and 3% of hybrid striped bass in the spring 2003 surpassed relative weight values of 100 as well.

Brown and Murphy (1991b) comprised a weight-length database for striped bass and hybrid striped bass, which was developed from populations representative of striped bass and hybrid striped bass distributions in the United States. From the 43 striped bass populations and the 72 hybrid striped bass populations examined, the twenty-fifth percentile of population means for striped bass and hybrid striped bass were 82 and 86, respectively (Brown and Murphy 1991b). Monthly mean relative weight values for striped bass (range = 72-86) and hybrid striped bass (range = 71-85) in this study fall among the lowest percentiles of moronid population means.

Lipid Index. - Lipid index values increased for striped bass over each growing season, but declined for hybrid striped bass during the 2002 growing season. However, the decline in hybrid striped bass lipid index values can be attributed to the high fat content of fingerlings upon stocking (mean = 46.7). Sutton (1997) noted the increase of lipid index values for striped bass over the growing season to a mean of approximately 30.0, followed by the decline in values over winter to a mean of approximately 26.0. Lipid index values for both striped bass and hybrid striped bass in Claytor Lake were found to be slightly higher in late fall by Sutton (1997). Mean late fall lipid index values were 37.9 and 35.4 in 2001 and 2002, respectively, and hybrid striped bass late fall lipid index values in 2002 were 33.1.

Nevertheless, in 2001-2002 striped bass did not exhibit a significant difference in mean lipid index values between fall and spring periods, but individuals less than 150 mm TL possessed mean lipid index values 8% lower than larger (> 150 mm TL) individuals entering the winter. Sutton (1997) found smaller (<150 mm TL) individuals to have lipid index values 47% less than larger individuals in the late fall. Subsequently, Sutton (1997) reported lipid index values for larger individuals to be 67% higher than values for smaller striped bass that survived the winter, with lipid index values for smaller individuals having declined 72% from the fall. In my study, comparisons between these size classes were not possible in the 2001-2002 sampling season, due to the disappearance of individuals less than 150 mm TL over the winter. Given the large decline in lipid index values for smaller individuals found by Sutton (1997), the loss of these individuals during the overwinter period of 2001-2002 may in fact be due to their lack of adequate energy reserves needed to survive the winter.

During late fall 2002, there was no significant difference between juvenile striped bass and juvenile hybrid striped bass lipid index values. However, as observed by Sutton (1997), both fishes experienced a decline in lipid index values over the winter (striped bass: 4% and hybrid striped bass: 8%). In 2002-2003, lipid index values for both fishes declined over the winter, but as in the 2001-2002 season, the disproportionate decline for small (<150 mm TL) individuals observed by Sutton (1997) (72%), was not found. However, with both fishes having utilized lipid stores over the winter, there was not a difference between striped bass and hybrid striped bass lipid index values in late spring 2003.

In summary, *K* and relative weight values for both striped bass and hybrid striped bass during this study were low in comparison to values reported for young-of-the-year moronids in other systems, but lipid levels were high relative to those reported by Sutton (1997) for Smith Mountain Lake, Virginia, juvenile striped bass. These indices appear to be contradictory; fish are thin (relatively), but have high fat content. Condition factor (*K*) is difficult to interpret in between-waters comparisons, due to the lack of standardization for the index (i.e., a *K* value indicative of a healthy fish in one population, may not be representative of good condition in another system). The application of standard weight equations to smaller fish, like the ones in this study, could be inaccurate due to increased variance associated with the weights at length (Anderson and Neuman 1996). However, Bonds (2000) found similar low relative weight values (mean of approximately 90) for both adult striped bass and adult hybrid striped bass in Claytor Lake. Also, lipid index values in comparison to Sutton (1997) were high. The difference that was observed in this study may be the result of my utilization of Sutton's (1997) relationship of lipid index and percent body water. The regression equation developed for striped bass in Smith Mountain Lake, by Sutton (1997), was species- and population-specific, and when it was applied to both species in this study, it may have resulted in less-than-accurate values. Regardless, the catch-per-unit-effort of 2001 striped bass that recruited to age 1 remained consistent in comparison to previous year classes (Figure 26), which have produced a popular and productive fishery. Thus, the juvenile moronids observed in this study appear to be surviving well within the reservoir.

Habitat Usage

Habitat electivity values indicated preference by juvenile striped bass and juvenile hybrid striped bass for similar habitat units during the months of September through November 2002. The preference of both species for sand or gravel substrates without cover is consistent with the findings reported within the literature. Mesinger (1970) reported sandy littoral areas of Keystone Reservoir, Oklahoma, to be the predominant habitat used by juvenile striped bass. In Watts Bar Reservoir, Tennessee, age-0 striped bass were found to exhibit a strong preference for clay or sand substrates (Van Den Avyle and Higginbotham 1979 and Van Den Avyle et al. 1983). Juvenile hybrid striped bass in East Fork Lake, Ohio, were discovered to overwhelmingly prefer fine sand and clay substrates, and no age-0 hybrid striped bass were captured in areas containing cover (woody debris) (Austin and Hurley 1987). Inshore habitat use of juvenile striped bass in Lake Texoma, Oklahoma-Texas, was found to be the highest for areas with substrates of either fine gravel or sand (Matthews et al. 1992). Additionally, Sutton (1997) reported catch-per-unit-effort of striped bass in Smith Mountain Lake, Virginia, to be highest in

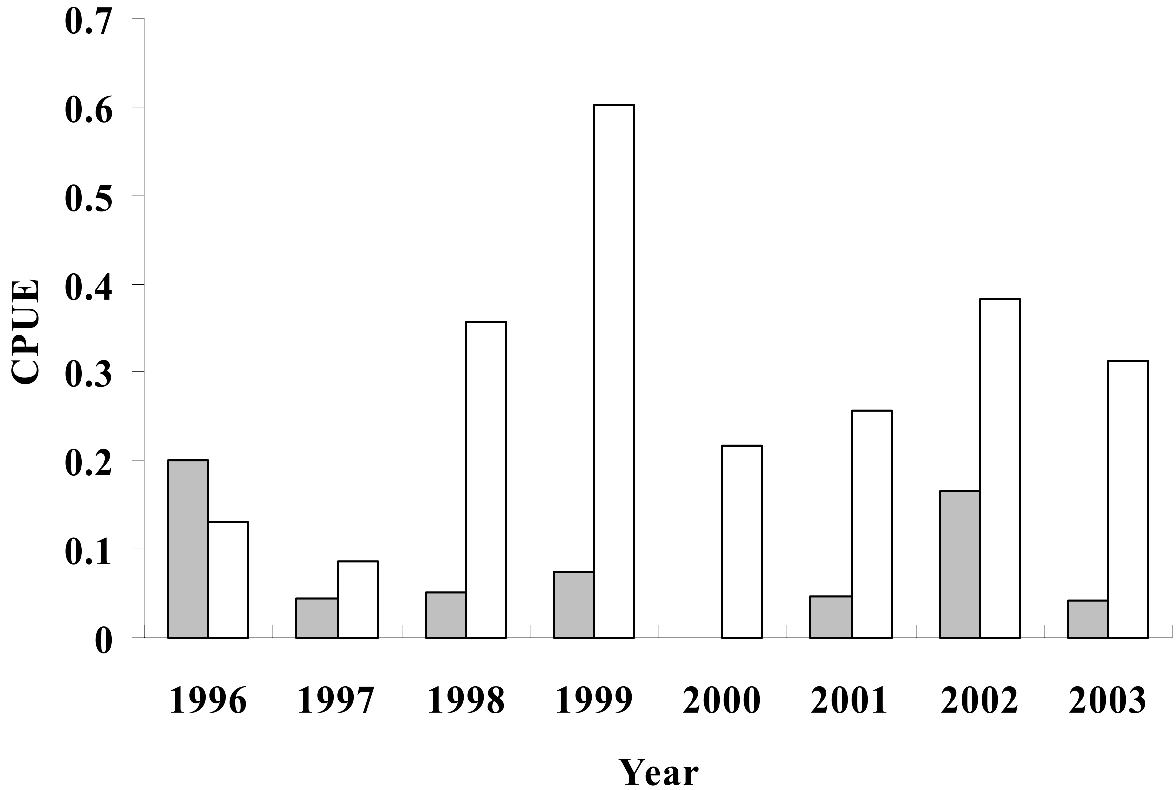

Figure 26. Catch-per-unit-effort for age 1 striped bass (shaded bars) and age 1 hybrid striped bass (unshaded bars) via Virginia Department of Game and Inland Fisheries annual gillnet sampling in Claytor Lake. Catch-per-unit-effort (CPUE) = number of fish caught per 9.29 m^2 of gillnet.

shallow, structureless zones containing a mixture of sand and gravel that graded gradually to deep water.

Habitat overlap values as calculated in this study were low due to striped bass and hybrid striped bass utilizing the same habitats, but not having habitat use coincide temporally. Perhaps, increased monitoring of habitat overlap (more than once a month) would have revealed higher overlap values. During weekly specimen collection for the remaining objectives of the study, juvenile hybrid striped bass were always collected in the presence of juvenile striped bass. Thus, it appears that habitat overlap values in this study may be unrepresentative of the actual habitat utilization of age-0 striped bass and age-0 hybrid striped bass, and habitat electivity values were accurate regarding the habitat preference for these fishes in Claytor Lake as sand and gravel substrates lacking cover.

Predation

The effects of predation upon the first-year survival of juvenile striped bass and juvenile hybrid striped bass in Claytor Lake were minimal. None of the predators sampled following striped bass stocking were found to have consumed a fingerling striped bass, and only three of ninety-five predator stomachs examined after the stocking of hybrid striped bass contained a hybrid striped bass fingerling. The insignificant amount of predation on juvenile *Morone* in Claytor Lake is consistent with that reported within the literature. Austin and Hurley (1987) reported that post-stocking predation was not a significant source of mortality of newly-stocked hybrid striped bass in East Fork Lake, Ohio. In the Pamunkey River, Virginia, predation by fishes upon both eggs and larvae of striped bass was not observed (McGovern and Olney 1998).

In addition, the loss of fingerling striped bass in Smith Mountain Lake, Virginia, via predation by largemouth bass was not found to significantly contribute to the mortality of fingerlings (Michaelson 1996; Michaelson et al. 2001). Michaelson et al. (2001) estimated largemouth bass population size and daily consumption (bioenergetics modeling) to calculate the total number of striped bass consumed. When applied to a bioenergetics model, the minute percentage of largemouth bass that consumed a fingerling striped bass only equaled an estimated percentage loss of striped bass to largemouth bass in Smith Mountain Lake of 0.1 to 1.2%, which equates to 360 to 3062 fingerlings lost to predation (Michaelson et al. 2001). If the total percentages of fingerlings lost to predation, as estimated by Michaelson et al. (2001), were applied to fingerlings stocked in Claytor Lake, loss of fingerling hybrid striped bass would only range from 35 to 420 individuals. In addition, during this period of increased fingerling vulnerability following stocking, *Micropterus spp.* (the principal littoral predator in Claytor Lake) were found to primarily consume bluegill and crayfish in Claytor Lake (Bonds 2000).

The higher incidence of predation on hybrid striped bass than on striped bass may be associated with the larger size at stocking of hybrid striped bass versus striped bass. Michaelson et al. (2001) found that in pool experiments, largemouth bass preferred adult alewife (mean = 109 mm TL) to smaller striped bass fingerlings (mean = 66 mm TL). Thus, the larger size of hybrid striped bass fingerlings at the time of stocking (mean = 94 mm TL) may prove to be more attractive to potential predators, especially black basses. However, such a low percentage of occurrence (3%) for hybrid striped bass in the diets of Claytor Lake predators is also indicative of incidental, opportunistic feeding.

Regardless, immediate post-stocking predation upon fingerling striped bass and fingerling hybrid striped bass had a negligible impact upon first-year mortality of these fishes in Claytor Lake.

SUMMARY AND CONCLUSIONS

1. In 2001, approximately 70,000 striped bass were stocked in early June and approximately 33,500 hybrid striped bass were stocked in mid-September. The following year, approximately 70,000 striped bass were stocked in mid-June, and approximately 33,500 hybrid striped bass were stocked in late August. In the 2001-2002 sampling season, I recaptured 842 striped bass and only three hybrid striped bass, and during the 2002-2003 sampling season, I recaptured 665 and 119, striped bass and hybrid striped bass, respectively.
2. Diagnostic meristic features failed to positively differentiate striped bass and hybrid striped bass fingerlings from the 2001 stockings (although they worked well for moronids stocked in 2002). Genetic analysis supported the conclusion that F1 hybrids were supplied by Keo Fish Farm (Keo, Arkansas). However, only three specimens of the approximately 33,500 stocked in late September, at a mean total length of 68 mm, were recaptured in this study.
3. Due to low capture success for hybrid striped bass, I was unable to compare performance of striped bass and hybrid striped bass in the 2001-2002 sampling season. However, in the 2002-2003 sampling season, comparisons between the fishes were possible due to the collection of 119 hybrid striped bass and 665 striped bass throughout the sampling period.
4. Both striped bass and hybrid striped bass exhibited accelerated initial growth, followed by a plateau in growth from October until the end of the growing season. During the period of linear growth, striped bass displayed growth rates of 1.10 and 0.81 mm/day in 2001 and 2002, respectively. Hybrid striped bass during the

period of linear growth were found to grow at a rate of only 0.52 mm/day in 2002. The rates observed in this study were consistent with those reported within the literature for striped bass, but the growth rate was lower for hybrid striped bass, possibly because they were stocked late in the growing season.

5. In 2001-2002, striped bass suffered from size-dependent overwinter mortality, as evidenced by the loss of individuals less than 150 mm TL from the population. However, both species increased in mean total length between fall 2002 and spring 2003 collections, most likely due to early spring growth.
6. During the growing season, both striped bass and hybrid striped bass each demonstrated a shift in food habits at approximately 120 mm TL. Smaller individuals preyed predominately upon aquatic insects and zooplankton, while individuals over 120 mm TL ate mainly age-0 fishes. Striped bass fed mainly upon age-0 alewife, while hybrid striped bass utilized age-0 sunfishes as prey. Striped bass and hybrid striped bass diets did not significantly overlap during the growing season.
7. Striped bass and hybrid striped bass exhibited significant diet overlap in spring 2003 when both predominately ate alewife and were growing rapidly.
8. In 2001, striped bass experienced decreases in condition factor (*K*) and relative weight values over the growing season of 15 and 14%, respectively. Condition factor and relative weight values declined for both striped bass (7 and 12%, respectively) and hybrid striped bass (35 and 20%, respectively) over the 2002 growing season. However, both fishes were found to be in poor condition throughout the duration of this study, with striped bass monthly mean condition

factor and relative weight values ranging from 0.88-1.17 and 74-86, respectively, and hybrid striped bass exhibited a range in monthly mean condition factor and relative weight values of 0.88-1.22 and 70-85, respectively.

9. In the 2001-2002 sampling season, when loss of individuals less than 150 mm TL due to overwinter mortality was documented, these smaller striped bass (< 150 mm TL) had 8% lower lipid index values than larger (> 150 mm TL) individuals entering the winter. Lipid index values for all individuals declined 2% from fall 2001 to spring 2002. In the 2002-2003 sampling season, striped bass lipid index values decreased 4%, while hybrid striped bass lipid index values increased 8% over the winter. There was no significant difference between spring striped bass and hybrid striped bass lipid index values.
10. Habitat overlap values were not found to be significant, but habitat electivity values indicated a preference by both age-0 fishes for sand or gravel substrates without cover.
11. Predation upon fingerling striped bass and fingerling hybrid striped bass was not significant in limiting juvenile recruitment to age 1. None of the 105 predators sampled following the stocking of striped bass contained a striped bass fingerling, and only 3 of the 95 predators sampled following the stocking of hybrid striped bass consumed a hybrid striped bass fingerling.

Since the 1993 introduction of hybrid striped bass, VDGIF catch-per-unit-effort data from fall gillnet monitoring has shown that striped bass relative abundance declined 79% by 2000 (Bonds 2000; Kilpatrick 2003) while hybrid striped bass numbers have continued to climb (J. Copeland, VDGIF, pers. comm.). The results of this study indicate that the decline in striped bass numbers since the introduction of hybrid striped bass is not likely due to competitive interactions at the age-0 life-stage. Although both fishes were found to prefer the same habitat types, they did not eat the same prey items during the growing season. In addition, both fishes had equivalent indices of health values. Thus, under the current management plan, it appears that the delayed stocking of hybrid striped bass helps to alleviate the competition between these age-0 fishes before the onset of winter.

Perhaps loss of biomass is occurring in a later life-stage of striped bass in Claytor Lake. Kilpatrick (2003) reported adult striped bass and adult hybrid striped bass to occupy similar habitats within Claytor Lake, but hybrid striped bass were not limited by the constraints of summer time habitat loss, due to higher thermal tolerance. Thus, during this period of increased stress, hybrid striped bass are able to utilize additional resources within the reservoir, while striped bass are habitat limited (Kilpatrick 2003).

Although less probable, another potential cause of the striped bass decline in Claytor Lake could be related to changes in Claytor Dam operations. Since 1991, Claytor Dam has operated under run-of-the-river conditions from April to October and hydropeaking operations from October to April, in contrast to year round hydropeaking operations before 1991 (J. Copeland, VDGIF, pers. comm.). Kilpatrick (2003) reported suitable summertime refuge habitat for adult striped bass (< 25°C, > 2.5 mg/L of dissolved oxygen) to exist at depths level with penstock openings for water discharge through Claytor Dam. In fact, Kilpatrick (2003) found the temperature of Claytor Dam's discharge into the New River to correspond to the temperature of critical summertime habitat within the reservoir. Along with the documentation of loss of habitat through the dam, Kilpatrick (2003) also noted the presence of adult moronids below Claytor Dam. Thus, given the continuous flow of critical habitat out of the reservoir during summer months and the highly migratory nature of striped bass, increased emigration of adults, which are confined to summertime refuge habitat, could be occurring.

Lastly, this study was inadequate to definitively prove that juvenile striped bass and juvenile hybrid striped bass are trophically compatible. It appears that trophic overlap in the fall is avoided via late stocking of hybrid striped bass, but perhaps significant trophic overlap occurs in the spring before growth starts. I did find high diet overlap among striped bass and hybrid striped bass once I was able to capture them in late April 2003, when both fishes primarily consumed alewife. If both striped bass and hybrid striped bass rely upon alewife as forage following winter, potential trophic competition could occur at this period. This is especially important because energy reserves of juvenile moronids are significantly reduced over the winter, and the immediate acquisition of food following winter is required to maintain metabolic processes. Thus, if hybrid striped bass are able to feed upon alewife (that may become scarce if overwinter die-offs occur) at a period when less temperature-tolerant striped bass could not, hybrid striped bass could in fact out compete striped bass for the necessary food sources in early spring. Therefore, given my inability to assess trophic compatibility across all seasons for these fishes during their first year of life, further investigation into the understanding of the mechanisms influencing post-winter survival is warranted.

MANAGEMENT RECOMMENDATIONS

1. To avoid substantial diet overlap between striped bass and hybrid striped bass, hybrid striped bass should continue to be stocked later in the growing season than striped bass. Stocking hybrid striped bass fingerlings in August allows striped bass (stocked in June) to utilize age-0 alewife as prey throughout the growing season, while not having to share the resource with age-0 hybrid striped bass. In addition, the later stocking date of hybrid striped bass does not appear to limit their recruitment to adults. As a result, VDGIF should continue to stock striped bass in early June and hybrid striped bass in mid to late August to minimize potential competition between the two fishes.
2. It is important to carefully choose suppliers, along with size, of hybrid striped bass fingerlings. This recommendation is especially applicable if VDGIF is satisfied with the product being received and performance of the fish is to be monitored. Based upon the current stocking rate of approximately 33,500 hybrid striped bass fingerlings per year, VDGIF should request fingerlings at a limit of approximately 45 fish/lb. This will enable VDGIF to receive large, phase I fingerlings (approximately 10 g) that should possess adequate energy reserves to survive the over winter period.
3. VDGIF should target age-0 moronids in both fall (November and December) and spring (March and April) sampling efforts to gain further insight into potential overwinter mortality of these fishes. Collection efforts should include the use of both gillnets and electrofishing to capture juveniles representative of all size ranges present. Comparisons of length-frequency distributions before and after

winter should be made to detect the overwinter loss of smaller individuals. In addition, diet analysis during both periods should be conducted. Further knowledge of post-winter compatibility of these fishes is warranted, and if diet analysis reveals trophic overlap before spring growth occurs, further study of the compatibility of striped bass and hybrid striped bass is needed. Continued monitoring of these juvenile fishes is especially important given the brevity of this study, and my inability to compare the performance of the two fishes for more than one year.

LITERATURE CITED

Anderson, R. O. and R. M. Neuman. 1996. Length, weight, and associated structural indices. Pages 447-482 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Austin, M. R., and S. T. Hurley. 1987. Evaluation of a striped bass (*Morone saxatilis*) x white bass (*Morone chrysops*) hybrid introduction in East Fork Lake, Ohio. Ohio Division of Wildlife, Federal Aid in Fish Restoration Project F-29-R, Study 20, Final Report, Columbus, Ohio, USA.

Axon, J. R. 1979. An evaluation of striped bass introductions in Herrington Lake. Kentucky Department of Fish and Wildlife Resources, Fisheries Bulletin 63.

Axon, J. R., and D. K. Whitehurst. 1985. Striped bass management in lakes with emphasis on management problems. Transactions of the American Fisheries Society 114:8-11.

Bailey, W. M. 1975. An evaluation of striped bass introductions in the Southeastern United States. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 28:54-68.

Bain, B. B.1999. Substrate. Pages 95-104 *in* M. B. Bain and N. J. Stevenson, editors. Aquatic Habitat Assessment. American Fisheries Society, Bethesda, Maryland.

Bishop, D. R. 1967. Evaluation of the striped bass (Roccus saxatilis) and white bass (R. chrysops) hybrids after two years. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 21:245-254.

Benard, G., and M. G. Fox. 1997. Effects of body size and population density on overwinter survival of age-0 pumpkinseeds. North American Journal of Fisheries Management 17:581-590.

Boaze, J. L. 1972. Effects of landlocked alewife introductions on white bass and walleye populations, Claytor Lake, Virginia. Master's thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Bonds, C. C. 2000. Assessment of the response of piscivorous sportfishes to the establishment of gizzard shad in Claytor Lake, Virginia. Master's thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Bowen, S. H. 1996. Quantitative description of the diet. Pages 513-532 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Brown, M. L., and B. R. Murphy. 1991a. Relationship of relative weight (*Wr*) to proximate composition of juvenile striped bass and hybrid striped bass. Transactions of the American Fisheries Society 120:509-518.

Brown, M. L., and B. R. Murphy. 1991b. Standard weights (*Ws*) for striped bass, white bass, and hybrid striped bass. North American Journal of Fisheries Management 11:451-467.

Busacker, G. P., I. R. Adelman, and E. M. Goolish. 1990. Growth, Pages 363-387 *in* C. B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Cheek, T. E., M. J. Van Den Avyle, and C. C. Coutant. 1985. Influences of water quality on distribution of striped bass in a Tennessee River impoundment. Transactions of the American Fisheries Society 114:67-76.

Chevalier, J. R. 1973. Cannibalism as a factor in first year survival of walleye in Oneida Lake. Transactions of the American Fisheries Society 102:739-744.

Copeland, J. R. 1999. Claytor Lake management report 1998. F111R7, Final Report. Virginia Department of Game and Inland Fisheries, Richmond, Virginia.

Coutant, C. C. 1985. Striped bass, temperature, and dissolved oxygen: a speculative hypothesis for environmental risk. Transactions of the American Fisheries Society 114:31-61.

Cox, D. K., and C. C. Coutant. 1981. Growth dynamics of juvenile striped bass as functions of temperature and ration. Transactions of the American Fisheries Society 110:226-238.

Craig, J. F. 1982. Population dynamics of Windermere perch. Report of the Freshwater Biological Association 50:49-59.

Crandall, P. S. 1978. Evaluation of striped bass x white bass hybrids in a heated Texas reservoir. Proceedings of the Annual Conference of the Southeastern Association of Fish and Widllife Agencies 32:588-598.

Crowder, L. B. 1990. Community ecology. Pages 609-632 *in* C. B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Cunjak, R. A., and G. Power. 1986. Seasonal changes in the physiology of brook trout, *Salvelinus fontinalis* (Mitchill), in a sub-Arctic river system. Journal of Fish Biology 29:279-288.

Dey, W. P. 1981. Mortality and growth of young-of-the-year striped bass in the Hudson River estuary. Transactions of the American Fisheries Society 110:151-157.

Erickson, K. E., J. Harper, G. C. Mesinger, and D. Hicks. 1971. Status and artificial reproduction of striped bass from Keystone Reservoir, Oklahoma. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 25:513-522.

Forney, J. L. 1966. Factors affecting first-year growth of walleyes in Oneida Lake, New York. New York Fish and Game Journal 13:146-167.

Fullerton, A. H., J. E. Garvey, R. A. Wright, and R. A. Stein. 2000. Overwinter growth and survival of largemouth bass: interactions among size, food, origin, and winter severity. Transactions of the American Fisheries Society 129:1-12.

Garvey, J. E., A. Wright, and R. A. Stein. 1998. Overwinter growth and survival of age-0 largemouth bass (*Micropterus salmoides*): revisiting the role of body size. Canadian Journal of Fisheries and Aquatic Sciences 55:2414-2424.

Gilliland, E. R., and M. D. Clady. 1981. Diet overlap of striped bass x white bass hybrids and largemouth bass in Sooner Lake, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 35:317-330.

Goodwin, K. R. and P. L. Angermeier. 2003. Demographic characteristics of American eel in the Potomac River Drainage, Virginia. Transactions of the American Fisheries Society 132:524-535.

Gotceitas, V., D. A. Methven, S. Fraser, and J. Brown. 1999. Effects of body size and food ration on over-winter survival and growth of age-0 Atlantic cod, *Gadus morhua*. Environmental Biology of Fishes 54:413-420.

Han, K., L. Li, G. M. Leclerc, A. M. Hays, and B. Ely. 2000. Isolation and characterization of microsatellite loci for striped bass (*Morone saxatilis*). Marine Biotechnology 2:405-408.

Harper, J. L., and R. Jarman. 1971. Investigation of striped bass, *Morone saxatilis* (Walbaum), culture in Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 25:501-512.

Harrell, R. M., and J. M. Dean. 1988. Identification of juvenile hybrids of *Morone* based on meristics and morphometerics. Transactions of the American Fisheries Society 117:529-535.

Harrell, R. M., D. W. Meritt, J. N. Hochheimer, D. W. Webster, and W. D. Miller. 1988. Overwintering success of striped bass and hybrid striped bass held in cages in Maryland. The Progressive Fish-Culturist 50:120-121.

Hollander, M. and D. A. Wolfe. 1999. Nonparametric statistical methods, second editon. John Wiley and Sons, Inc., New York, New York.

Hurst, T. P., and D. O. Conover. 1998. Winter mortality of young-of-the-year Hudson River striped bass (*Morone saxatilis*): size-dependent patterns and effects on recruitment. Canadian Journal of Fisheries and Aquatic Sciences 55:112-1130.

Hyslop, E. J. 1980. Stomach contents analysis – a review of methods and their application. Journal of Fish Biology 17:411-429.

Jenkins, R. E., and N. M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Johnson, T. B., and D. O. Evans. 1990. Size dependent winter mortality of young-of-the-year white perch: climate warming and invasion of the Laurentian Great Lakes. Transactions of the American Fisheries Society 119:301-313.

Kerby, J. H. 1979a. Morphometric characters of two *Morone* hybrids. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 33:344-352.

Kerby, J. H. 1979b. Meristic characters of two *Morone* hybrids. Copeia 1979:513-518.

Kerby, J. H., J. M. Hinshaw, and M. T. Huish. 1987. Increased growth and production of striped bass x white bass hybrids in earthen ponds. Journal of the World Aquaculture Society 18:35-43.

Kilpatrick, J. M. 2003. Habitat use, movements, and exploitation of striped bass and hybrid striped bass in Claytor Lake,Virginia. Master's thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Kinman, B. T. 1987. Evaluation of hybrid striped bass introductions in Herrington Lake. Fisheries Bulletin of the Kentucky Department of Fish and Wildlife Resources No. 82.

Kohler, C. C., J. J. Ney, and W. E. Kelso. 1986. Filling the void: development of a pelagic fishery and its consequences to littoral fishes in a Virginia mainstream reservoir. Pages 166-177 *in* G. E. Hall and M. J. Van Den Avyle, editors. Reservoir Fisheries Management: Strategies for the 80s. American Fisheries Society, Bethesda, Maryland.

Layzer, J. B., and M. D. Clady. 1981. Evaluation of the striped bass x white bass hybrid for controlling stunted bluegills. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 35:297-310.

Le Cren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca flavescens*). Journal of Animal Ecology 20:201-219.

Logan, H. J. 1967. Comparison of growth and survival rates of striped bass and striped bass x white bass hybrids under controlled environments. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 21:260-263.

Markle, D. F., and G. C. Grant. 1970. The summer food habits of young-of-the-year striped bass in three Virginia rivers. Chesapeake Science 11:50-54.

Matthews, W. J., L. G. Hill, D. R. Edds, J. J. Hoover, and T. G. Heger. 1988. Trophic ecology of striped bass, *Morone saxatilis*, in a freshwater reservoir (Lake Texoma, U. S. A). Journal of Fish Biology 33:273-288.

Matthews, W. J., F. P. Gelwick, and J. J. Hoover. 1992. Food and habitat use by juveniles of species of *Micropterus* and *Morone* in a southwestern reservoir. Transactions of the American Fisheries Society 121:54-66.

McGovern, J. C., and J. E. Olney. 1988. Potential predation by fish and invertebrates on early life history stages of striped bass in Pamunkey River, Virginia. Transactions of the American Fisheries Society 117:152-161.

Mensinger, G. C. 1970. Observations on the striped bass, *Morone saxatilis*, in Keystone Reservoir, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 24:447-463.

Michaelson, D. P. 1996. Impacts of stocking stress and largemouth bass predation on the survivorship of juvenile striped bass stocked in Smith Mountain Lake, Virginia. Master's thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Michaelson, D. P., J. J. Ney, and T. M. Sutton. 2001. Largemouth bass predation on stocked striped bass in Smith Mountain Lake, Virginia. Transactions of the American Fisheries Society 21:326-332.

Minton, J. W. and R. B. McLean. 1982. Measurements of growth and consumption of sauger (*Stizostedion canadense*): implication for fish energetics studies. Canadian Journal of Fisheries and Aquatic Sciences 39:1396-1403.

Moore, C. M., R. J. Neves, and J. J. Ney. 1991. Survival and abundance of stocked striped bass in Smith Mountain Lake, Virginia. North American Journal of Fisheries Management 11:393-399.

Moss, L. J., and C. S. Lawson. 1982. Evaluation of striped bass and hybrid striped bass stockings in eight Alabama public fishing lakes. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 36:33-41.

Muoneke, M. I., O. E. Maughan, and M. E. Douglas. 1991. Multivariate morphometric analysis of striped bass, white bass, and striped bass x white bass. North American Journal of Fisheries Management 11:330-338.

Nielsen, L. A. 1980. Effect of walleye (*Stizostedion vitreum vitreum*) predation on juvenile mortality and recruitment of yellow perch (*Perca flavescens*) in Oneida Lake, New York. Canadian Journal of Fisheries and Aquatic Sciences 37:11-19.

Ott, L. R. and M. Longnecker. 2001. Statistical methods and data analysis, fifth edition. Wadsworth Group, Pacific Grove, California.

Ott, R. A., Jr., and S. P. Malvestuto. 1981. The striped bass x white bass hybrid in West Point Reservoir. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 35:641-646.

Palmer, G. C. 1999. Genetic characterization and intermixing of walleye stocks in Claytor Lake and the upper New River, Virginia. Master's thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Post, J. R., and D. O. Evans. 1989. Size-dependent overwinter mortality of young-of-the-year yellow perch (*Perca flavenscens*): laboratory, in situ enclosure, and field experiments. Canadian Journal of Fisheries and Aquatic Sciences 46:1958-1968.

Post, J. R., and E. A. Parkinson. 2001. Energy allocation strategy in youn fish: allometry and survival. Ecology 82:1040-1051.

Roy, N. K., L. Maceda, and I. Wirgin. 2000. Isolation of microsatellites in striped bass *Morone saxatilis* (Teleostei) and their preliminary use in population identification. Molecular Ecology 9:817-829.

Rudacille, J. B. and C. C. Kohler. 2000. Aquaculture performance comparison of sunshine bass, palmetto bass, and white bass. North American Journal of Aquaculture 62:114-124.

Santucci, V. J., and D. H. Wahl. 1993. Factors influencing survival and growth of stocked walleye (S*tizostedion vitreum*) in a centrarchid-dominated impoundment. Canadian Journal of Fisheries and Aquatic Sciences 50:1548-1558.

Saul, B. M., and J. L. Wilson. 1981. Food habits and growth of young-of-the-year white bass x striped bass hybrids in Cherokee Reservoir, Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 35:311-316.

Schoener, T. W. 1970. Non-synchronous spatial overlap of lizards in patchy habitats. Ecology 51:408-418.

Stein, R. A., R. F. Carline, and R. S. Hayward. 1981. Largemouth bass predation on stocked tiger muskellunge. Transactions of the American Fisheries Society 110:604-612.

Stevens, R. E. 1958. The striped bass of the Santee-Cooper reservoir. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 11:253-264.

Strange, R. J., and J. C. Pelton. 1987. Nutrient content of clupeid forage fishes. Transactions of the American Fisheries Society 116:60-66.

Sutton, T. M. 1997. Early life history dynamics of a stocked striped bass (*Morone saxatilis*) population and assessment of strategies for improving stocking success in Smith Mountain Lake, Virginia. Doctoral dissertation. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Sutton, T. M. and J. J. Ney. 2001. Size-dependent mechanisms influencing first-year growth and winter survival of stocked striped bass in a Virginia mainstream reservoir. Transactions of the American Fisheries Society 130:1-17.

Thompson, J. M., E. P. Bergersen, C. A. Carlson, and L. R. Kaeding. 1991. Role of size, condition, and lipid content in the overwinter survival of age-0 Colorado squawfish. Transactions of the American Fisheries Society 120:346-353.

Timmons, T. J., W. L. Shelton, and W. D. Davies. 1980. Differential growth of largemouth bass in West Point Reservoir, Alabama-Georgia. Transactions of the American Fisheries Society 109:176-186.

Tisa, M. S. 1988. Compatibility and complementarity of alewife *Alosa pseudoharengus* and gizzard shad *Dorosoma cepedianum* as forage fish in Smith Mountain Lake,Virginia. Doctoral dissertation. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Toneys, M. L., and D. W. Coble. 1980. Mortality, hematocrit, osmolality, electrolyte regulation, and fat depletion of young-of-the-year freshwater fishes under simulated water conditions. Canadian Journal of Fisheries and Aquatic Sciences 37:225-232.

Tuncer, H., R. M. Harrell, and E. D. Houde. 1990. Comparative energetics of striped bass (*Morone saxatilis*) and hybrids (*M. saxatilis* x *M. chrysops*) juveniles. Aquaculture 86:387-400.

Van Den Avyle, M. J., and B. J. Higginbotham. 1979. Growth, survival, and distribution of striped bass stocked into Watts Bar Reservoir, Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 33:361-370.

Van Den Avyle, M. J., B. J. Higginbotham, B. T. James, and F. J. Bulow. 1983. Habitat preferences and food habits of young-of-the-year striped bass, white bass, and yellow bass in Watts Bar Reservoir, Tennessee. North American Journal of Fisheries Management 3:163-170.

Virginia Agricultural Experiment Station. 2003. Kentland Farm Operation-Weather Data, 1999-2003. Virginia Polytechnic Institute and State University. Available: www.vaes.vt.edu/colleges/kentland/weather/. (September 2003).

Wege, G. J., and R. O. Anderson. 1978. Relative weight (*Wr*): a new index of condition for largemouth bass. Pages 79-91 *in* G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, North Central Division, Special Publication 5, Besthesda, Maryland.

Ware, F. J. 1970. Some early life history of Florida's inland striped bass, *Morone saxatilis*. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 24:439-447.

Woiwode, J. G. and I. R. Adelman. 1991. Effects of temperature, photoperiod, and ration size on growth of hybrid striped bass x white bass. Transaction of the American Fisheries Society 120:217-229.

Zhang, Q., R. C. Reigh, and W. R. Wolters. 1994. Growth and body composition of pond-raised hybrid striped basses, *Morone saxatilis* x *M. chrysops* and *M. saxatilis* x *M. mississippiensis*, fed low and moderate levels of dietary lipid. Aquaculture 125:119-129.

VITA

Jacob Michael Rash was born on April 20, 1978, in Statesville, North Carolina. His love for the aquatic world was fostered by the numerous fishing trips that he and his father enjoyed. Following graduation from North Iredell High School in 1996, he began his collegiate studies at North Carolina State University in Raleigh, North Carolina. After receiving his Bachelor's degree in Zoology from North Carolina State University, he entered the graduate program in the department of Fisheries and Wildlife Sciences in August 2001 at Virginia Polytechnic Institute and State University to pursue a Master of Science degree in Fisheries Science. During his stay at Virginia Polytechnic Institute and State University, he served as both a Teaching Assistant and Research Assistant, studying the ecology of juvenile striped bass and juvenile hybrid striped bass in Claytor Lake, Virginia.