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Food Habits and Growth of Juvenile Striped Bass, *Morone saxatilis*, in Albemarle Sound, North Carolina

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ABSTRACT: Juvenile striped bass, *Morone saxatilis*, collected in Albemarle Sound, North Carolina, during 1988–1992 were examined for food habits and growth. Ages estimated from otoliths collected in 1990–1992 were used to determine individual spawning dates and growth in total length and weight. The majority of striped bass examined had been spawned in mid-May 1990, mid-May to early June 1991, and June to early July 1992. Mysid shrimp was the dominant prey taxon and was consumed in all size classes examined. Mysid shrimp were consumed at twice the rate of copepods and 10 times more frequently than cladocerans. Fishes were a minor prey taxon. The number of mysid shrimp consumed increased with increasing length of striped bass. A higher percentage of mysid shrimp were consumed in the more saline waters of the central sound than in the less saline western sound. The opposite trend was found for consumed fishes. Increases in total length were linear from July to October, but increases in weight were not. Weight increased less rapidly in younger striped bass and more rapidly in older striped bass than either length or age. Quadratic and logarithmic equations accurately predicted weight from measures of total length but weight could not be predicted from age nor could age be predicted from total length. Estimating growth from total length at time of capture may be comparing fish of different ages. Age estimation from otoliths allowed us to determine that growth rates were similar among years and that differences in observed total length over time were due to different spawning times and not growth rates.

Introduction

The Roanoke River-Albemarle Sound population of striped bass, *Morone saxatilis*, is the largest in North Carolina and is the southernmost population that is anadromous (Boreman and Lewis 1987). A decrease in striped bass abundance in Albemarle Sound during the past 20 yr has led to more extensive research into their early life history (Rulifson et al 1992, 1993) and the effects of river flow rate on juvenile recruitment (Rulifson and Manooch 1990). Juvenile recruitment can also be affected by the availability of adequate prey organisms and the availability of prey is largely a function of environmental conditions that can be altered by human activities. The positive relationship of juvenile fish abundance to subsequent commercial catches of adults (Goodyear 1985) underscores the importance of adequate food to the juvenile fish population. Examination of food habits and

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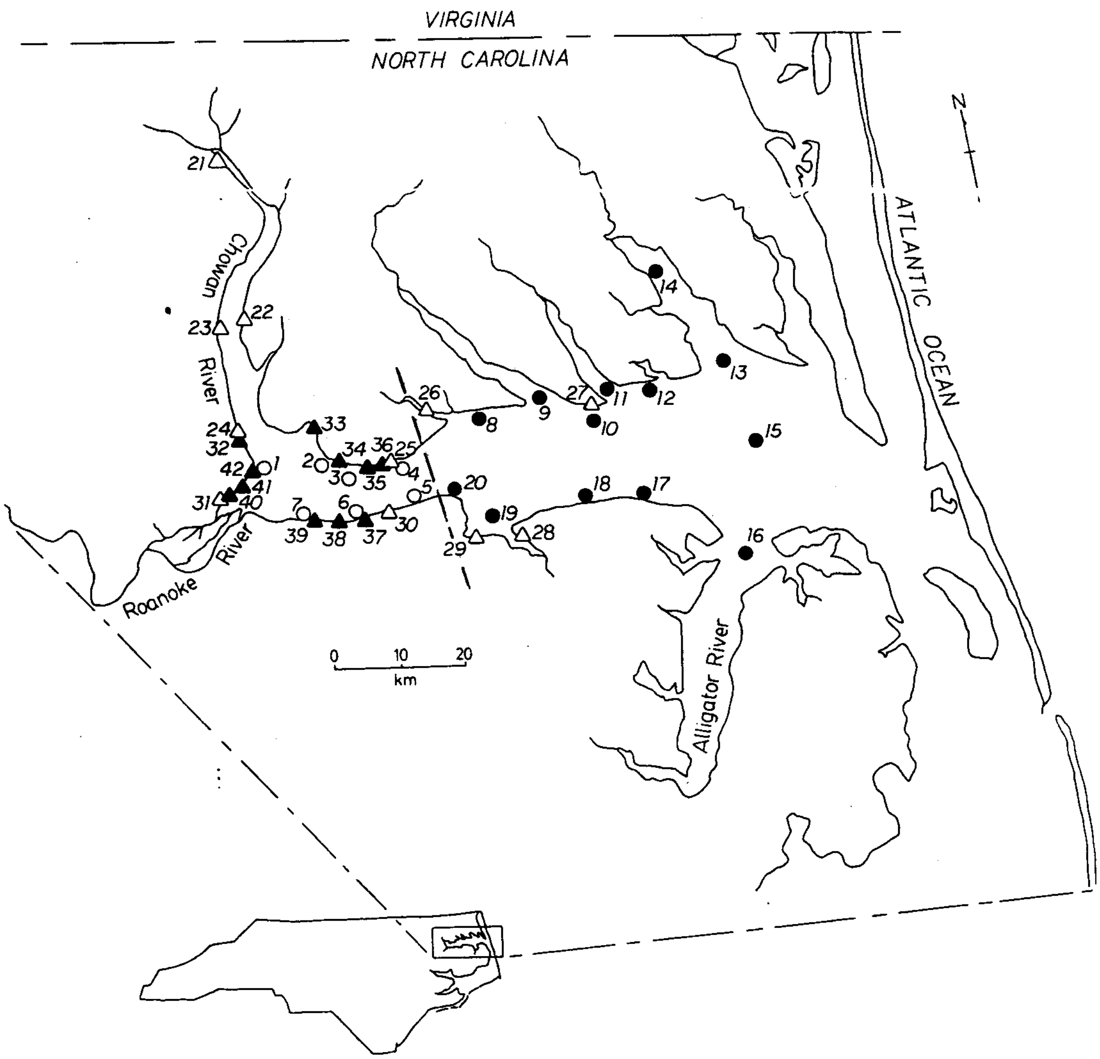

Fig. 1. Location of survey stations in Albemarle Sound from which juvenile striped bass were examined in 1988–1992. Symbols refer to survey type: open circle = western sound trawl; closed circle = central sound trawl; open triangle = *Alosa* beach seine; closed triangle = exploratory beach seine. Dashed line indicates the separation of western and central portions of the sound.

growth of juvenile fish can be useful in detecting possible changes in the well-being of the fish population.

Only one previous study of juvenile striped bass food habits (Manooch 1973) has been conducted in Albemarle Sound and limited data are available on juvenile striped bass growth in this system (Trent 1962; Hassler and Taylor 1984). Our objectives in this study were to examine juvenile striped bass food habits and to describe the growth of striped bass during the first 7 mo of life.

Study Area

Albemarle Sound is oriented in an east-west direction and is approximately 85 km in length (Fig. 1). The western portion of the sound is primarily fresh water (0–2‰) due to the large inflow from the Roanoke and Chowan rivers. Salinity increases in an easterly direction reaching about 18‰ near the Outer Banks. Saltwater intrusion from the Atlantic Ocean is blocked by barrier islands (the Outer Banks) with only one opening, Oregon Inlet, in the vicinity of Albemarle Sound. Salt water entering Albemarle Sound through Pamlico Sound is diluted by fresh water flowing into Pamlico Sound, thus the salinity is diminished (Geise et al. 1979). Tides within Albemarle Sound are caused more by wind than by lunar influences. Surface sediments are generally sand and mud, with sand increasing at the river mouths and along the shorelines of the sound (Riggs et al. 1991). The Roanoke River serves as the primary spawning area for Albemarle

Sound striped bass with a limited (if any) contribution from the Chowan River. The western portion of the sound serves as the primary nursery area for juvenile striped bass.

Methods

Juvenile striped bass were collected by the North Carolina Division of Marine Fisheries at 42 stations in four separate surveys in Albemarle Sound (Fig. 1). Two of the surveys were conducted from July to October: the western sound trawl survey (annual striped bass juvenile abundance index) and the central sound trawl survey (relative striped bass abundance index: CPUE). The remaining two surveys were conducted from June through November: the *Alosa* beach seine survey (juvenile shad and river herring assessment), and the exploratory beach seine survey (striped bass habitat utilization index). The juvenile abundance index trawl survey was initiated by W. W. Hassler (North Carolina State University) in 1955 and has remained essentially unchanged. Samples were collected with an 18.3-m bag seine (6.35-mm mesh body, 3.2-mm mesh bag) and a 5.5-m semi-balloon trawl (3.8-cm mesh body, 1.3-cm mesh bag). A complete description of methods is given in Rulifson et al. (1993). Striped bass examined in this study were collected from July 8 to August 9, 1988; July 6 to October 25, 1989–1990; June 27 to August 24, 1991; and June 18 to September 22, 1992. Collection sites in the sound were divided into western and central portions by a line extending from Drummond Point southward across the sound to just west of Laurel Point. This division separated the primary nursery area from the remainder of the sound and facilitated the detection of possible movements of larger striped bass juveniles.

The striped bass collected at each station were placed in plastic bags labeled with location, date, and gear type. Water temperature and salinity were measured at surface and bottom at each collection site. Striped bass were preserved in 10% formalin in 1988 and 1989 and iced in 1990 through 1992 prior to transport to East Carolina University. Iced fish were frozen upon receipt. Fish were measured for total length (TL) and fork length (FL) in each year. Fish collected in 1990–1992 were weighed (0.01g) while frozen. Preserved fish were measured shortly after arrival to minimize the effects of shrinkage. The frozen fish were not formalin-preserved to prevent dissolution of the otoliths.

Sagittal otoliths were shipped to Panama City, Florida, for preparation and increment estimation. The following methods were used in each year: whole otoliths were mounted on glass microscope slides using thermoplastic cement with the proximal surface of the otolith against the slide. The concave surface of each otolith was ground by hand using a wet sheet of number 600 carborundum paper until the nucleus was exposed. The daily rings were examined through immersion oil at magnifications of 100–400× with transmitted polarized light. One count was used for each otolith after it was determined that repeated counts resulted in a range of less than five rings from minimum to maximum counts throughout the range of ages represented in the samples (Isely and Manooch 1991). Otolith rings were counted once by a single reader. Daily rings on otoliths from known-age striped bass juveniles raised under hatchery conditions were counted and age was consistently underestimated by 1 d (Rulifson et al. 1993). The count of daily rings was therefore increased by one. The hatching date was estimated by subtracting the adjusted ring count from the capture date. A spawning date was estimated by subtracting 2 d from the hatching date based on the time required for hatching (Polgar et al. 1976) at the mean water temperature on the hatching date. Age of each striped bass was estimated by subtracting the hatching date from the capture date.

The principal spawning area in the Roanoke River is between Halifax (river mile 120) and Weldon (river mile 130; Rulifson et al. 1993). Water temperature was taken at Barnhill's Landing (river mile 117) at 4-h intervals (and means calculated) prior to the estimated time of spawning and measurements continued until spawning activity was low, thus some fish may have been spawned at times when temperature data were not taken. Estimated spawning dates of striped bass were used to analyze changes in TL and weight. Only those fish examined for food habits were used for age estimation in this study so the results may differ from that in Rulifson et al. (1993).

The entire gut from each striped bass was removed by dissection and then examined, or, for frozen striped bass, preserved in 10% formalin prior to examination. Gut contents were examined under magnification and each prey taxon counted in each year except 1991. Weights of prey taxa were estimated in 1991 (Cooper and Wood 1993) and were not included in this study.

Estimates of body condition were made for striped bass collected in 1992 to compare those fish with empty guts to those with food. The assumption was that if those fish without food were chronically starved, their mean weight at length would be less than those that had fed. Least squares means of logWT for both groups were compared using the General Linear Model (PROC GLM, SAS, Inc. 1988). Comparisons were not made among striped bass collected in 1990 or 1991 since few of these had empty guts.

Statistical analyses (SAS Institute, Inc. 1988) were made using an overall α of 0.05. The mean TL among years was compared by ANOVA with multiple comparisons made using the Tukey test. Linear and quadratic regressions were made (PROC GLM) of TL with age, weight with age, and TL with weight. Regressions of logWT and logTL among years were analyzed using the least squares means procedure (ANCOVA), with year as the covariate under the General Linear Model (PROC GLM), a Bonferroni correction for multiple comparisons ($\alpha = 0.017$), and the F-test for the null hypothesis of equal slopes. Striped bass mean TL and weight were compared in striped bass collected in the western and central portions of the sound using the Kruskal-Wallis Chi-square approximation.

Results

Within each year, the mean water temperature was similar by month and between the western and central portions of Albemarle Sound. Mean water temperature was 25°C in June (range 23°C–25°C), 29°C in July (range 27°C–31°C), 27°C in August (range 26°C–30°C), 25°C in September (range 21°C–29°C), and 23°C in October (range 20°C–25°C). Salinity in the western sound was never recorded above 0.5‰ and ranged from 0.3‰ to 2.6‰ in the central sound. Salinity increased from July to October.

The mean TL of striped bass collected in 1988, 1991, and 1992 (Fig. 2) were not significantly different from each other; however, the mean TL for 1989 and 1990 were significantly larger (PROC GLM; Tukey critical value 3.87; $\alpha = 0.05$). The mean TL of striped bass in 1990 was significantly larger than that in 1989.

The estimation of individual spawning dates from otoliths showed that recruitment of juvenile striped bass came primarily from those eggs spawned in mid-May in 1990, mid-May to early June in 1991, and from June to early July in 1992 (Fig. 3). Recruits were spawned as early as March 26, 1990 and as late as July 18, 1992. Spawning began at or near a river temperature of 18°C in each year (Fig. 3).

Food Habits

Mysid shrimp was the dominant prey, occurring at nearly twice the rate of copepods and 10 times the rate of cladocerans (Table 1). Fishes were a minor prey taxon. The number of mysid shrimp and fishes consumed per striped bass increased with increasing length of striped bass. Consumption of copepods similarly increased up to a striped bass length of 85 mm TL but were not consumed thereafter. Consumption of fishes as prey increased rapidly after striped bass reached 85 mm TL. The remaining prey taxa showed no relationship to changes in striped bass length.

In 1990, mysid shrimp were consumed in greater numbers than any other prey except for copepods (Table 2). Consumption of mysids was fairly stable in the first 3 yr but declined in 1992. Mysids, chironomids, and amphipods were the only prey taxa to be consumed in each year. More prey taxa were consumed in 1989 and 1990 than in the other 2 yr combined. Several taxa were consumed only in 1 yr: mosquitos in 1988; cladocerans, turbellarians, and cumaceans in 1989; and phantom midges, other dipterans, and *Argulus* in 1992. Consumption (number of prey per striped bass) was highest in 1990 and lowest in 1992. The number of striped bass with empty stomachs was less than 9% in each year except for 1992, in which nearly 40% had empty stomachs. The majority (75%) of striped bass without food in 1992 were collected at stations 2 and 34 (Fig. 1) on August 10 and accounted for 51% of all fish examined in that year. Excluding these striped bass would have reduced the percentage of empty stomachs to 9.7%. Striped bass were collected at all stations during the study period except for the Chowan and Alligator rivers.

More striped bass were examined for food habits from the western sound (358) than from the central sound (109). More central sound striped bass (76.1%) consumed mysid shrimp than did western sound striped bass (43.6%). The opposite trend was found for prey fishes. Less than 1% of central sound striped bass consumed prey fishes while 10.9% of western sound striped bass did so. Mysids were consumed as prey at all of the western sound stations but not in the central sound east of station 10. Fishes were consumed at eight of 11 western sound stations and only at station 20 in the central sound. Copepods and cladocerans were consumed only in the western sound.

Mean TL and weight of striped bass from the western and central portions of the sound were compared to determine if the differences in selection of fishes and mysids as prey was due to larger striped bass remaining in the western sound. Western striped bass were larger in 1989 (Table 3), but there was no significant difference in TL or weight in other years.

Growth

A comparison of mean TL by sample month would suggest that those striped bass examined in 1990 grew faster than those in other years (Fig. 4) since their mean TL was larger in each month, when, in fact, growth in TL was similar based on the otolith-estimated ages (Fig. 5). The striped bass examined in 1990 were spawned earlier in the sea-

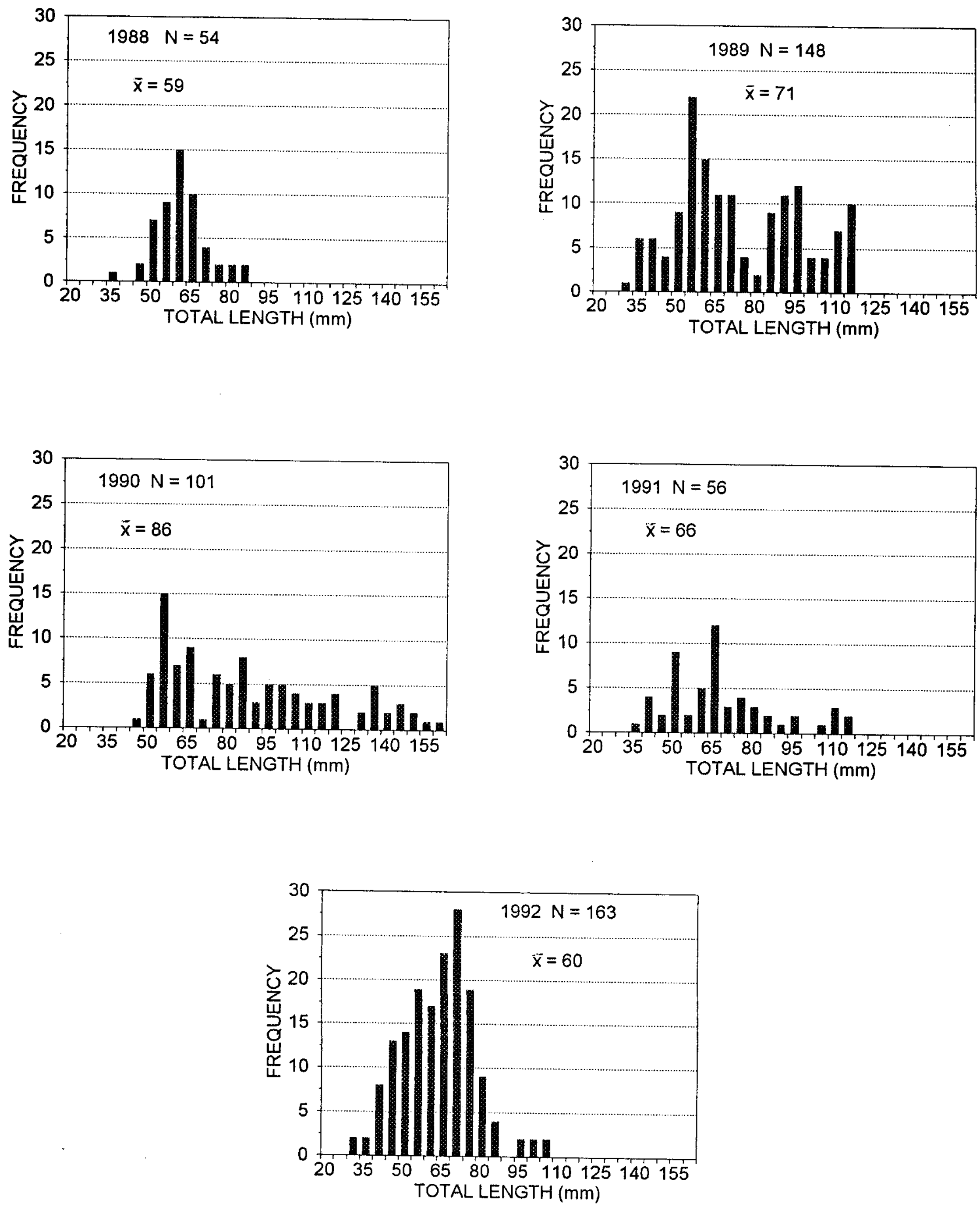

Fig. 2. Length frequencies and mean (x̄) total length of juvenile striped bass from Albemarle Sound, 1988–1992. n is the number of striped bass examined.

son (Fig. 3) than those examined in 1991 or 1992 and were therefore sampled after reaching greater lengths. Striped bass from 1991 were older and longer when sampled than were those from 1992. The instantaneous rate of growth in TL in 1991 ($G = 0.017$) was greater than that in 1990 ($G = 0.009$) or 1992 ($G = 0.013$). Daily growth rates (TL) were 0.8 mm in 1990, 1.1 mm in 1991, and 0.7 mm in 1992.

Growth in TL was linear when regressed against age, but age could only be accurately predicted from observed TL in 1990:

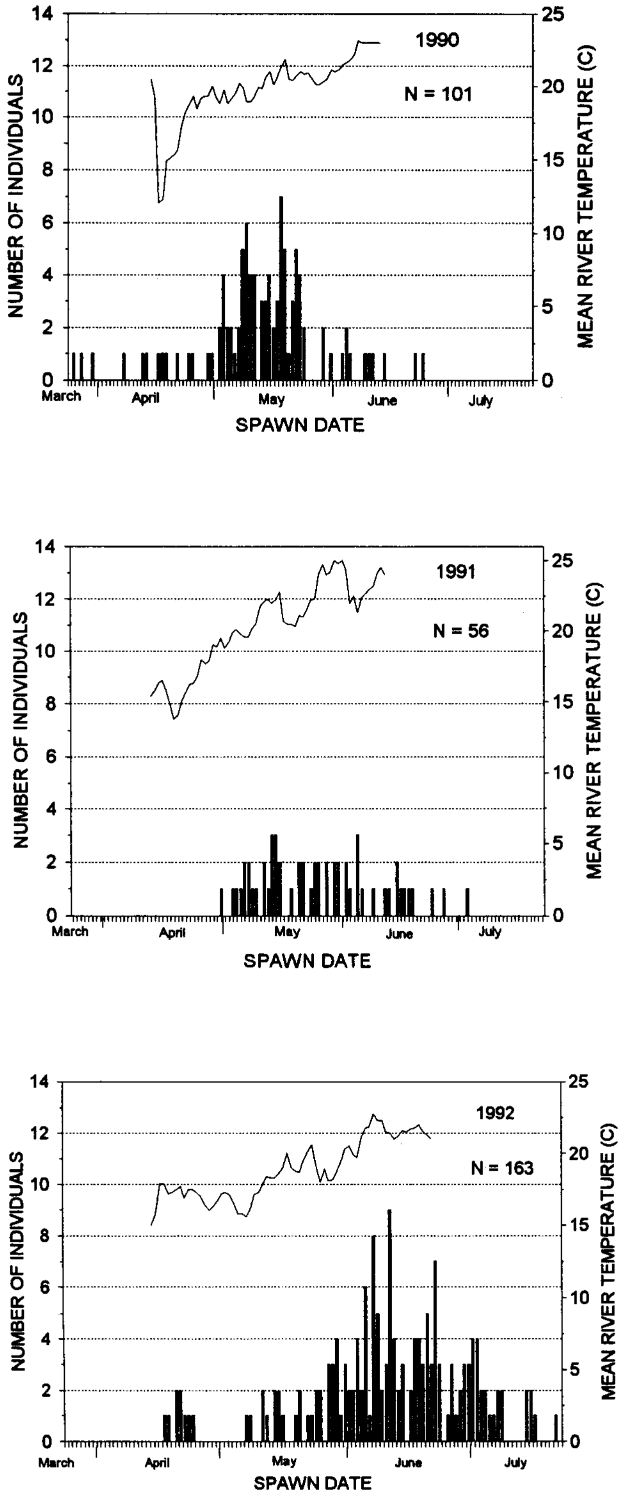

Fig. 3. Mean daily water temperature of the Roanoke River (solid line) near Barnhill's Landing and spawning dates (bars) of juvenile striped bass from 1990 to 1992 estimated from otolith daily rings.

$$1990\text{: age} = 10.896 + 0.940\text{TL},\ r^2 = 0.84$$

$$1991\text{: age} = 14.665 + 0.735\text{TL},\ r^2 = 0.77$$

$$1992\text{: age} = 19.565 + 0.615\text{TL},\ r^2 = 0.55$$

The magnitude in the variation in individual growth rates increased in fish older than 70 d. The low correlation of age and TL in 1991 and 1992 indicated that factors not accounted for were important in the relationship of age and TL.

Mean weight at age was similar in each of the 3 yr up to 80 d of age (Fig. 6). Instantaneous rates of growth in weight were the same in 1991 and 1992 ($G = 0.04$), and both were larger than that in 1990 ($G = 0.03$). Daily increases up to 95 d of age were 0.10 g in 1990, 0.15 g in 1991, and 0.09 g in 1992. The high percentage of striped bass with empty stomachs in 1992 was examined to determine if the mean logWT at length of those striped bass was significantly smaller than those striped bass with food. There was no significant difference between these two groups (PROC GLM: least squares mean of logWT of fish without food = 0.25, with food = 0.27; $p = 0.13$).

Growth in weight was not linear when regressed against age or TL. Weight increased less rapidly than age or length in striped bass younger than 95 d of age and more rapidly in striped bass older than 135 d. Examination of the residuals from ANOVA of weight and age indicated that quadratic equations would best describe the weight-age relationships (Fig. 6), but the addition of the quadratic term did not improve the predictive value of any of the weight-age regressions. Individual variation in weight increased in striped bass older than 55 d of age and the magnitude of variation increased with increasing age. Each regression underestimated the weight of older striped bass. The weight-age regressions were

$$1990\text{: weight} = -8.351 + 0.115\text{AGE} + 0.007\text{AGE}^2,\ r^2 = 0.79$$

$$1991\text{: weight} = 2.864 - 0.141\text{AGE} + 0.002\text{AGE}^2,\ r^2 = 0.73$$

$$1992\text{: weight} = -4.229 + 0.137\text{AGE} - 0.0003\text{AGE}^2,\ r^2 = 0.43$$

Weight could be predicted from the quadratic regressions with TL for each year:

$$1990\text{: wt} = 4.211 - 0.189\text{TL} + 0.002\text{TL}^2,\ r^2 = 0.98$$

$$1991\text{: wt} = 0.673 - 0.063\text{TL} + 0.001\text{TL}^2,\ r^2 = 0.95$$

$$1992\text{: wt} = 2.314 - 0.117\text{TL} + 0.002\text{TL}^2,\ r^2 = 0.98$$

There was no evidence of autocorrelation in these relationships (Durbin-Watson D ranged from 1.9 to 2.2).

TABLE 1. Mean number of prey items per juvenile striped bass by size class from Albemarle Sound 1988–1990 and 1992. n = number of fish examined. Fish from 1991 were not included because of different methods of analysis.

	Size Class (TL in mm)													
Prey Taxa n	25–35 12	36–45 35	46–55 100	56–65 109	66–75 73	76–85 41	86–95 33	96–105 21	106–115 23	116–125 4	126–135 7	136–145 5	146–160 4	Total Mean 467
Mysid shrimp	0.58	1.34	8.32	13.94	9.11	32.51	46.12	30.19	67.83	0	44.71	104.00	131.75	20.300
Copepods	1.83	5.20	17.18	8.65	12.21	40.41	0	0	0	0	0	0	0	11.591
Cladocerans	15.67	17.66	1.29	0	0	0	0	0	0	0	0	0	0	2.002
Turbellarians	3.67	6.31	0	0.91	2.37	0	0	0	0	0	0	0	0	1.150
Chironomids	1.33	1.57	1.09	1.23	1.37	1.20	0.64	0	0	0	0	0	0	1.036
Amphipods	0.08	0.51	0.21	0.74	0.21	0	0.55	0.10	0.04	0	0	0	0	0.336
Fish	0	0	0	0.05	0.04	0	0.15	0.57	0.70	5.00	3.29	1.40	0	0.152
Isopods	0	0.03	0	0.02	0.04	0.02	0	0.71	0	0	2.00	0	0	0.077
Cumaceans	0.08	0.06	0.06	0.03	0.01	0.02	0.12	0.10	0.30	0	0	0	0	0.058
Argulus spp.	0	0.11	0.01	0.01	0.07	0.02	0	0.05	0	0	0	0	0	0.028
Mosquito, adult	0	0	0	0.06	0	0	0	0	0	0	0	0	0	0.015
Mayfly, adult	0	0	0	0.06	0.01	0	0	0	0	0	0	0	0	0.015
Phantom midge	0.08	0	0	0	0	0.07	0	0	0	0	0	0	0	0.009
Other dipterans	0	0.03	0	0	0.01	0.02	0	0	0	0	0	0	0	0.006
Hemiptera	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0.002

The relationships of weight and TL in this study were supported by the logWT to logTL relationship (Fig. 7). The slopes of these regressions were not significantly different from each other (PROC GLM, F = 1.43, p = 0.24) and were similar to that calculated by Trent (1962). The more recently collected striped bass, however, were lighter in weight for any given length. We calculated a logWT to logTL regression for striped bass collected in 1982 by Hassler and Taylor (1984) (logWT = 2.982logTL − 11.483, r^2 = 0.98). These striped bass were also lighter in weight for a given length than those in Trent (1962) but were heavier than the striped bass collected in our study. We compared the slope of the logarithmic regression from Hassler and Taylor (1984) with ours, but a significant interaction of logTL with year (p = 0.014) prevented us from determining if the slopes were different.

TABLE 2. Mean number of prey items per striped bass juvenile and, in parentheses, the percent of the diet in each year.

Prey Taxa	1988 (n = 54)	1989 (n = 148)	1990 (n = 101)	1992 (n = 164)
Mysid shrimp	28.15 (97)	26.17 (63)	32.18 (40)	5.1 (74)
Copepods		3.22 (8)	47.0 (57)	1.16 (17)
Cladocerans		6.32 (15)		
Turbellarians		3.63 (9)		
Chironomids	0.48 (2)	1.35 (3)	2.4 (3)	0.03 (0.4)
Amphipods	0.07 (0.2)	0.57 (1)	0.04 (0.05)	0.39 (6)
Fish		0.03 (0.1)	0.78 (0.9)	0.04 (0.6)
Isopods		0.007 (0.02)	0.35 (0.4)	
Cumaceans		0.18 (0.4)		
Argulus spp.				0.08 (1)
Mosquito, adult	0.13 (0.4)			
Mayfly, nymph	0.09 (0.3)		0.012 (0.2)	
Phantom midge			0.02 (0.3)	
Other dipterans		0.007 (0.02)	0.012 (0.2)	
Hemiptera			0.006 (0.09)	

Discussion

Food Habits

Striped bass in marine or brackish water areas are generally considered to be opportunistic or nonselective feeders, consuming prey in accordance with the local community structure. Heubach et al. (1963), Markle and Grant (1970), and Boynton et al. (1981) have shown that consumption of mysid shrimp by striped bass decreased as

TABLE 3. Comparison of mean TL (mm) and mean weight (g) of striped bass juveniles from eastern and western Albemarle Sound using the nonparametric Kruskal-Wallis chi-square approximation (α = 0.05).

	Total Length				Weight			
	East	West	χ^2	p	East	West	χ^2	p
1988	55	59	1.46	0.23	—	—	—	—
1989	66	74	4.14	0.04[a]	—	—	—	—
1990	78	88	0.78	0.38	6.01	9.62	0.61	0.43
1991	66	65	0.82	0.36	3.14	3.41	0.76	0.38
1992	60	60	0.007	0.96	2.21	2.38	0.003	0.95

[a] Significant difference at p = 0.05.

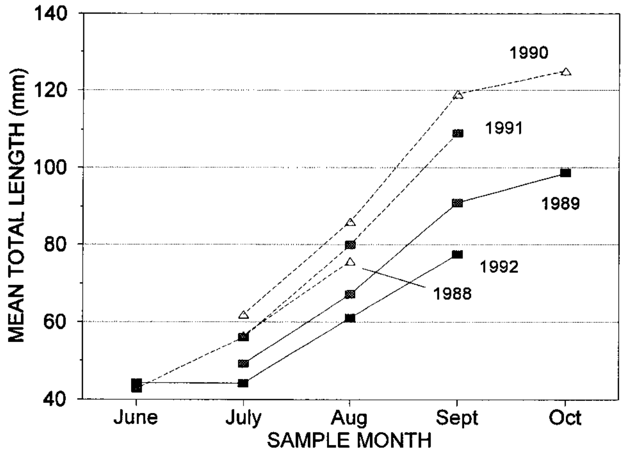

Fig. 4. Mean total length of juvenile striped bass by sample month from Albemarle Sound, 1988–1992.

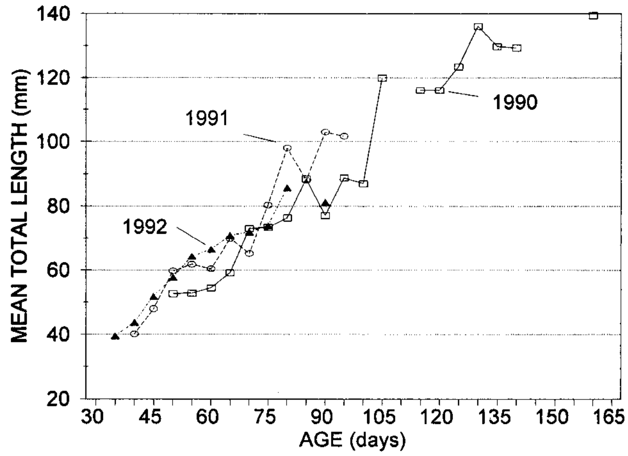

Fig. 5. Relationship of mean total length and otolith-derived age of juvenile striped bass in Albemarle Sound. Breaks in lines occur where no individuals of that age were present.

salinity decreased. Our study supports this hypothesis: consumption of mysids was higher in the more saline central portion of Albemarle Sound than in the less saline western sound. The opposite trend for prey fishes has been shown by Markle and Grant (1970) and Boynton et al. (1981) and is also supported by our study. The salinity regimes of their study areas (tributaries of Chesapeake Bay) were similar to that of Albemarle Sound.

Markle and Grant (1970) found that striped bass less than 70 mm TL did not consume mysid shrimp, and Boynton et al. (1981) reported that striped bass less than 50 mm TL did not consume mysid shrimp. Consumption of mysid shrimp occurred in all size classes in our study. Copepods, cladocerans (Heubach et al. 1963), and amphipods (Boynton et al. 1981) replaced mysids in importance at low salinity in other study areas, but this was not apparent in Albemarle Sound as mysids were consumed at all of the western sound stations and most of the central stations. Salinity may have been a factor in restricting the consumption of cladocerans and copepods to only the western sound stations.

Boynton et al. (1981) did not find any changes in food habits in striped bass between 25 mm TL and 100 mm TL. Our study shows specific changes in consumption of prey taxa with increases in striped bass length. These food habit changes indicate either preferences or differences in food availability rather than changes due to larger fish moving out of the study area (larger striped bass did not show any eastward migration).

Manooch (1973) found that Albemarle Sound striped bass at 125–304 mm TL fed primarily on juvenile clupeids and bay anchovies (*Anchoa mitchilli*). The quantities of blue crabs and penaeid shrimp consumed were measurable but minor as prey taxa. There was no consumption of mysid shrimp. The majority of striped bass examined by Manooch (1973) may have been larger than those in our study, which would account for the differences in prey consumed.

Striped bass food habits in freshwater reservoirs do not always follow the opportunistic model evident in brackish water (Matthews et al. 1988). Striped bass did not feed on available grass shrimp (*Palaeamonetes*) (Matthews et al. 1992) and ignored prey fishes other than shad (*Dorosoma*) even though starvation was imminent (Matthews et al. 1988). Prey fishes were more important by weight than other prey taxa, although copepods and chi-

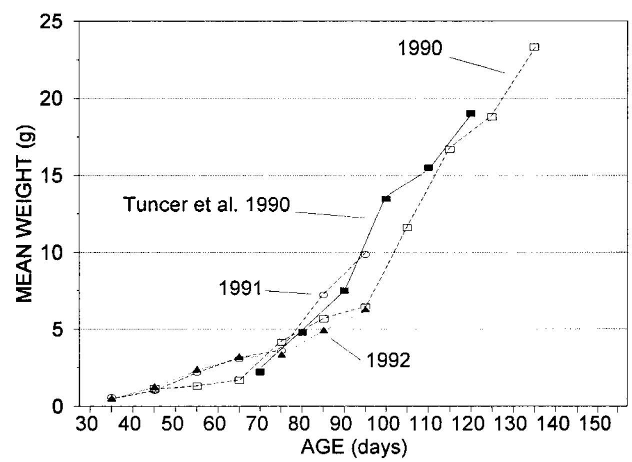

Fig. 6. Mean weight by estimated age for juvenile striped bass for 1990–1992. Values are means for 10-d groups set at the mid-point of the group. Values from Tuncer et al. (1990) are the means of five fish grouped at 10-d intervals. Symbols represent years: open square = 1990; open circle = 1991; and closed triangle = 1992.

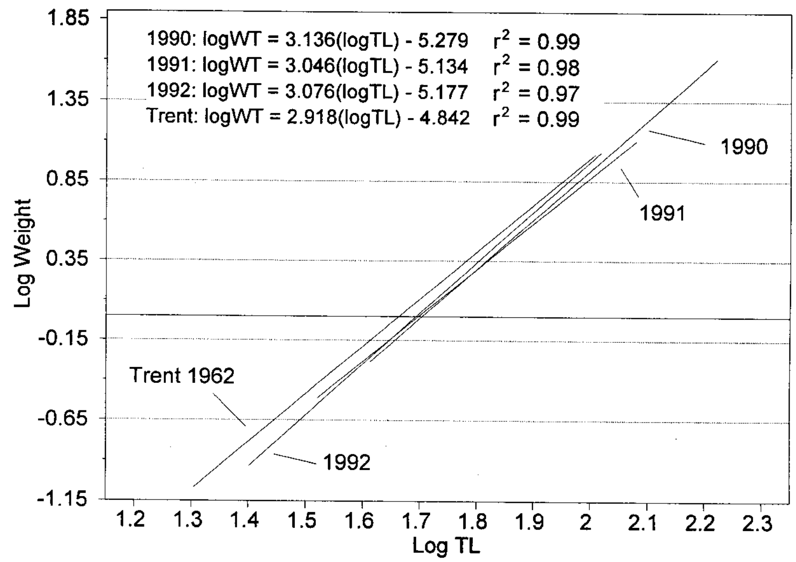

Fig. 7. Logarithmic regressions of total length and weight for juvenile striped bass from 1990 to 1992. Regression line of Trent (1962) is for juvenile striped bass examined from 1955 to 1961.

ronomids were more abundant (Van Den Avyle et al. 1983; Matthews et al. 1992). Although we did not weigh prey items, an estimate of calories (Cummins and Wuycheck 1971) derived from the number of prey items consumed would indicate that mysid shrimp were more important than fishes in Albemarle Sound.

The percentage of empty stomachs in striped bass was lower in our study (except for 1992) than the 10% reported by Markle and Grant (1970) or the 36% reported by Boynton et al. (1981). Boynton et al. (1981) were concerned that a high percentage of empty stomachs might indicate a possible bias in the data caused by time of collection or rates of digestion, but they were unable to find any evidence of this. The high percentage of empty stomachs in 1992 in our study may have been an isolated occurrence since the majority of those striped bass were from stations in close proximity on the same date. The high percentage may have been caused by different handling of the striped bass on that date or may indicate a short-term decrease in food availability at those stations. The lack of any difference in mean logWT between these striped bass and those with food in their stomachs suggested starvation was not a chronic problem.

Growth

Increases in TL were linear in separate regressions for the 3 yr examined, although the regressions were not good predictors of TL using age. Trent (1962) also reported that growth from June to October was linear, based on 7 yr of combined data. Daily growth rates in our study were higher than those reported by Trent (1962), but the estimation methods differed. Trent's mean TL data were estimated by averaging TL of striped bass collected on an equal number of days after the estimated peak spawning (since otolith daily aging techniques were not developed at that time). This could result in an underestimate of growth since younger, shorter fish would be combined with older, longer fish in each sample. Our data utilized estimated ages of individual fish derived from otoliths and therefore combined fish of similar ages.

The time required for first increment (daily ring) formation is a potential source of error in estimating ages from otoliths. Jones and Brothers (1987) found the first daily ring formed between 3 d and 5 d posthatch at 18°C under hatchery conditions. Secor and Dean (1989) reported that the first increment formed between 4 d and 5 d in pond-raised fish. Houde and Morin (1990) used a decreasing function of temperature to estimate the age at first increment formation and then corrected the assigned ages by adding two days at 20°C and three days at 17°C. We used an adjustment of 1 d based on otoliths from known-age striped bass and this may have underestimated the true age of the wild striped bass. Most studies have reported age underestimation and this can be a significant problem when dealing with larval fish. The consequences are much less when dealing with juveniles over a period of 3 mo as we have done. We have assessed the effect of a 4-d underestimation of the true age of the striped bass in this study. Not all parameters examined were affected to the same degree, but the maximum amounted to less than a 1% change in instantaneous increases in total length or weight and less than 5% in the value of the weight or total length intercepts in the regressions. Underestimation of the true age had little effect on the distribution of ages over time and would not change our conclusions regarding the spawning date distributions.

The logarithmic relationship of length and weight in the studies compared here suggests that more recent striped bass are lighter in weight for any given length and that this trend has been increasing over the past 30 yr. How this could be determined accurately is unclear. The year-to-year variability of striped bass length by collection period could obscure the true relationships because of differing spawning times and we cannot go back in time to reconstruct the missing data from earlier years.

Tuncer et al. (1990) raised juvenile striped bass from 70 d of age to 120 d of age to determine weight changes of fish fed at various rates. One of those rates was ad libitum and the resulting growth was compared to the growth rates of Albemarle Sound striped bass (Fig. 6). Growth of striped bass from Albemarle Sound was greater than that described by the raised striped bass up to 75–80 d of age and but less thereafter. Assuming that the ad libitum rate would result in optimum growth, the wild striped bass were consuming an adequate ration up to 80 d of age but it is not clear if this continued in older striped bass.

The FL of juvenile striped bass at the end of the first growing season (September to November) was compared by Conover (1990) for various populations along the east coast of North America. One of his conclusions was that juvenile striped bass from Canadian populations (94 mm FL: Magnin and Beaulieu 1967; 106 mm FL, Conover unpublished data) were larger than those from more southern populations, particularly the Albemarle Sound area (76 mm FL; Trent 1962). Our data suggest that there may be more variability in FL at the end of the growing season than that described by Conover. The mean FL of striped bass in October 1989 in our study was 93 mm and 119 mm in 1990. Data from other years of our study did not extend into October, but the FL at the end of each sampling period (77 mm in August 1991 and 73 mm in September 1992) would suggest that these striped bass would achieve lengths similar to those of the northern populations. Those striped bass from 1991 and 1992 would have at least another month for growth since water temperature in Albemarle Sound can remain above 18°C in October. Data from Hassler and Taylor (1984) produced an estimated FL of 84 mm for striped bass collected on October 1, 1982. This variability in lengths may reflect the effect of spawning dates and the resultant time for growth within each year and may not be an indication of adaptation in different latitudes. Daily growth rates in our study (as calculated by Conover 1990, Table 1) ranged from 0.5 mm d^{-1} to 0.7 mm d^{-1}, similar to those found in more northern latitudes. These differences do not necessarily disprove the hypothesis of countergradient variation, but they do underscore the need for examining a larger dataset to uncover variability in the length of the growing season that is determined, in part, by variations in the spawning period.

Freshwater flow rate in the Roanoke River, and by extension, Albemarle Sound, is an important factor influencing the development of the phytoplankton and zooplankton communities and subsequent juvenile striped bass recruitment (Rulifson and Manooch 1990). The effect of flow rates on the mysid shrimp population is unknown. The successful recruitment of juvenile striped bass in the sound may be dependent upon an adequate density of mysid shrimp, but little is known of the life cycle dynamics of mysid shrimp in Albemarle Sound. The decline of juvenile striped bass recruitment in the Sacramento-San Joaquin Delta was partly attributed by Stevens et al. (1985) to changes in water regulation and the subsequent salinity regimes which affected production of phytoplankton and zooplankton, including the mysid shrimp *Neomysis,* a primary food source of juvenile striped bass. The apparent decline in weight at length of Albemarle Sound juvenile striped bass may be an indication of a less than optimal mysid shrimp population.

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