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Food, Feeding, and Length-Weight Relationships of Young-of-The-Year Striped Bass, Morone saxatilis and Young-of-The-Year White Perch, Morone americana

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FOOD, FEEDING, AND LENGTH-WEIGHT RELATIONSHIPS OF YOUNG-OF-THE-YEAR STRIPED BASS, *Morone saxatilis* AND YOUNG-OF-THE-YEAR WHITE PERCH, *Morone americana*

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APPROVAL SHEET

This thesis is submitted in partial fulfillment of the requirements for the degree of

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DEDICATION

This work is dedicated to scientists that seek to promote our respect for, and preservation of nature. May their message get through.

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ABSTRACT

YOY striped bass, *Morone saxatilis*, and white perch, *Morone americana*, were collected to identify the prey, temporal and spatial feeding patterns, and length-weight relationships for these recreationally and commercially important species. Sampling with three gears was conducted every 3 h for nine 24 h periods in James River, VA from June-August, 1992. A pushnet was deployed at the channel and shoal surfaces, an otter trawl was deployed at the channel bottom, and a beach seine was deployed nearshore.

A total of 188 striped bass and 199 white perch were captured. Low catches are likely due to poor year class success of both species in the James River in 1992. Striped bass and white perch caught by seine were significantly longer, respectively, than those caught by trawl.

Copepods were the most numerous prey of both species. Fish and mysids comprised the largest volumetric percentage of striped bass and white perch prey, respectively. Using an index of relative importance, leptodorids were the most important striped bass prey and copepods were the most important white perch prey. The Spearman coefficient, Horn's index of overlap, and Shannon-Weaver diversity index found, respectively, that diets between species were highly correlated, highly overlapping, and equally diverse. With the exception of specimens caught by pushnet, there were no significant interspecific differences in feeding success.

Neither striped bass or white perch diets were significantly correlated between trawl and seine. Striped bass diets moderately overlapped between trawl and seine while white perch diets displayed low overlap between trawl and seine. Striped bass and white perch captured by seine had significantly more diverse diets, respectively, than those captured by trawl. For both species, a shift from planktonic to epibenthic foods was found with increasing length. White perch captured at twilight, and white perch captured by pushnet had significantly higher average feeding success than white perch captured at day or night, or by seine or trawl, respectively. However, no other significant intraspecific differences in feeding success were found for white perch or for striped bass, which suggests that vision, chemoreception and mechanoreception are important methods of prey detection for both species to feed in turbid nursery zones. Stepwise regression results suggest that abiotic factors have little direct relationship with striped bass and white perch feeding success. These factors may indirectly affect the abundance and diversity of available foods.

The wet weight-fork length relationship was described for striped bass as $\ln W = -11.825 + 3.111 \ln L$ and $\ln W = -12.114 + 3.230 \ln L$ for white perch. The insignificant difference between the variability of wet, dry, and ash weight for specimens of each species indicates that all three are appropriate for food studies of young fish, where accurate measurements are a concern.

FOOD, FEEDING, AND LENGTH-WEIGHT RELATIONSHIPS OF YOUNG-OF-THE-YEAR STRIPED BASS, *Morone saxatilis* AND YOUNG-OF-THE-YEAR WHITE PERCH, *Morone americana*

PART I

Food and Feeding of Young-of-the-Year Striped Bass and Young-of-the-Year White Perch

INTRODUCTION

Background Information

The striped bass, *Morone saxatilis* (Walbaum) and white perch, *Morone americana* (Gmelin) are recreationally, commercially, and ecologically important species that use the lower reaches of Chesapeake Bay tributaries as spawning and nursery grounds. The striped bass occurs sympatrically with the white perch over part of its range (Woolcott 1962). Juveniles of both species utilize similar estuarine habitats and niches (Rinaldo 1971).

Both species have historically supported significant commercial and recreational fisheries in the Chesapeake Bay and along the mid-Atlantic coast (Bigelow and Schroeder 1953). Because of its edibility the striped bass has been a very important commercial species along the United States Atlantic coast since colonial times (Merriman 1941). More recently, it has become a popular sport fish as well. The primary commercial catch of striped bass occurs in the Chesapeake Bay (Strand et al. 1980).

The striped bass is a fully anadromous species that undertakes extensive coastal migrations after spawning in the freshwater reaches of tidal rivers (Raney 1952; Bigelow and Schroeder 1953). Along the Atlantic coast, striped bass range from the St. Lawrence River southward to northern Florida, and along the northern coast of the Gulf of Mexico (Bigelow and Schroeder 1953). Striped bass may grow to 2 m total length (TL) and 45 kg in weight (Bigelow and Schroeder 1953).

The white perch is primarily a semi-anadromous, estuarine species that inhabits mesohaline sections of tidal rivers (Mansueti 1964). White perch range from Nova Scotia to South Carolina (Bigelow and Schroeder 1953; Woolcott 1962). White perch may grow to 0.4 m TL and 1 kg in weight (Mansueti 1961b). White perch constitute a large part of the resident ichthyofauna of Chesapeake Bay estuaries (St. Pierre 1971). As such, white perch have an ecological importance in cycling nutrients within estuarine food webs and contributing to the diet of larger fishes such as the striped bass (Bath and O'Conner 1982). Young white perch are distinguished from similarly aged striped bass in part by the following characteristics: white perch lack free space between the two dorsal fins, have thicker dorsal and anal fin spines than striped bass, and have a relatively short, deep caudal peduncle when compared to the striped bass (Mansueti 1964).

Atlantic coast striped bass stocks originate primarily in the major tributaries of the Chesapeake Bay, in the Roanoke River-Albermarle sound region of North Carolina, and in the Hudson River, New York (Berggren and Lieberman 1978; Van Winkle and Kumar 1982). The contribution of the Chesapeake Bay stock to the Atlantic population has been estimated to be as high as 90 percent (Berggren and Lieberman 1978).

A drastic decline in striped bass stocks occurred in the 1970's and the early 1980's along Atlantic coast. Merriman (1941) cited the destruction of spawning/nursery areas and overfishing as two major factors responsible for periodic declines in striped bass abundance. The decline in harvest of striped bass along the Atlantic Coast between 1973 and 1985 was largely attributable to the decline in production in the Chesapeake Bay (Boreman and Austin 1985). The appearance of dominant year classes like those of 1970 and 1989 depends in part on relatively good survival between the egg and juvenile stages in the nursery areas (Boreman and Austin 1985). The recovery of striped bass over the past several years has been widely attributed to the restrictions placed on commercial and recreational harvests.

A low abundance of YOY striped bass is largely attributable to habitat loss and a decline in food production which reduces survivability (Kelley 1982). Additionally, Kelley (1982) speculated that pesticides and petroleum products may reduce the survival of YOY striped bass. Price et al. (1985) speculated that juvenile striped bass are adversely affected by changes in near-shore habitat, such as declines in submerged aquatic vegetation due to turbidity (Kemp et al. 1983) and nutrient-driven planktonic shading.

Little information is available of factors that influence white perch year-class success. It is reasonable to suggest that white perch year-class strength is likely influenced by many of the same factors that influence striped bass year-class strength given many of similarities between early life stages of the two species.

Fisheries management in large rivers is complicated by many competing uses, including water supply, transportation, power generation, and recreation (Petts et al. 1989). The Chesapeake Bay's watershed is projected to increase in population by twenty percent over the next thirty years (Horton and Eichbaum 1991). Dredging and industrial development along the James River threatens the water quality, vegetative cover, near-shore habitat, and food web that are critical for striped bass and white perch survival. The disposal of chemicals into the Chesapeake Bay and its tributaries lacks adequate regulation and monitoring (Horton and Eichbaum 1991). As a consequence, ever-increasing pressure is placed on the rivers of the Chesapeake Bay that serve as nursery areas for striped bass, white perch, and other estuarine and marine species. Young-of-the-year (YOY) striped bass and white perch are important links to successfully reproducing adult stocks. Any attempt to support the production of striped bass and white perch must principally focus on Chesapeake Bay and its tributaries that serve as spawning grounds for adults and nursery areas for juveniles.

Feeding studies of YOY striped bass and white perch may be more accurate than ichthyoplankton studies because the former assessment is done at a life history stage closer to that of the fishable stock (Boynton et al. 1977). Growth rates of YOY of both species are likely inversely correlated with mortality rates (Edward Houde, Chesapeake Biol. Lab., per. comm.). Thus inadequate quantity and/or quality of food supply may be contributing factors to year-class variability and poor year-class success (Rulifson 1985). Success of future year classes of striped bass and white perch will partly be the result of favorable environmental conditions (such as those that increase food supply), and management based on the environmental conditions that increase year-class strength.

Studies examining the quantity and quality of food consumption of YOY fishes are keys to understanding the variability in their growth and survival. Food availability plays an important role in regulating juvenile striped bass growth (Dey 1981). Additionally, food availability and foraging success may help to explain the distribution and movement of juvenile fishes in their nursery zones (Rinaldo 1971; Kelley 1982).

Juvenile striped bass and juvenile white perch have similar feeding niches (Rinaldo 1971). Feeding depends on multiple factors, including size (Raney 1952; Markle and Grant 1970), overall physiological condition (Raney 1952), water flow (Heubach et al. 1963), bottom type, salinity (Raney 1952; Heubach et al. 1963; Markle and Grant 1970; Boynton et al. 1981), temperature, season, light levels, and time of day. Light is perhaps the single most important external factor governing fishes' diurnal changes in feeding activity (Woodhead 1966).

Other factors in addition to light may significantly affect YOY striped bass feeding times and areas. Food availability and foraging success may be major factors in habitat preference and movement of YOY fish within their nursery areas (Boynton et al. 1977). Rathjen and Miller (1957) and Woolcott (1962) reported that YOY striped bass are generally more abundant in areas with a pronounced current. Kerr (1953) and Sasaki (1966) reported that YOY striped bass are more concentrated over shoal areas than in deeper waters. Chadwick (1964) found by using a towed net that nighttime catches of juvenile striped bass were greater than daytime catches, and that striped bass were congregated along the shore rather than in the channel regions of the Sacramento-San Joaquin Delta, whereupon he concluded that YOY striped bass tend to maintain their position during the day and move voluntarily at night. However, YOY striped bass may have visually detected, and avoided the gear during the day. Boynton et al. (1977) suggested that YOY striped bass in the Potomac River preferred nearshore areas at day and night. Young striped bass are most often found over sand or gravel bottoms (Curran and Ries 1937; Boynton et al. 1977). Using a pushnet designed by Kriete and Loesch (1980), YOY striped bass and white perch were caught at day and night in the channel of the James River in 1991. For each species, average day and night catches were not significantly different during the four 24 h periods when both types of collections were performed (VIMS 1991 Juvenile *Alosa* Survey, unpubl. data).

Juvenile striped bass have been described as opportunistic, voracious feeders (Scofield 1931; Raney 1952; Boynton et al. 1981). Raney (1952) reported that striped bass generally consume those organisms that are most abundant. Calhoun (1953) and Thomas (1967) suggested that changes in diet are directly related to abundance and availability of specific food items. Boynton et al. (1981) noted that juvenile striped bass between 25 and 100 mm fed nonselectively at both nearshore and offshore areas of the Potomac River estuary. They felt that this strategy which allowed striped bass to adjust to variable environmental conditions would lead to decreased mortality rates and stable year-class strength.

The amount and kind of YOY striped bass prey items has been found to be largely determined by salinity at the collection site (Raney 1952; Heubach et al. 1963; Markle and Grant 1970; Boynton et al. 1981). Salinity may affect the size and distribution of prey appropriate for juvenile striped bass (Gunter 1961; Boynton et al. 1981).

Invertebrates constitute the major portion of the diet of YOY striped bass (Schapovalov 1936; Townes 1937; de Sylva et al. 1962; Stevens 1966). Scofield and Coleman (1910) and Boynton et al. (1981) found that YOY striped bass ate mainly marine worms, mysids, insect larvae, and crustaceans, and with growth added small fish to their diet. In a daytime study of the Hudson River, Curran and Ries (1937) found that striped bass between 30 and 110 mm TL fed mostly on benthic gammarid amphipods and to a lesser extent on small fish and planktonic crustaceans. Additionally, Markle and Grant (1970) found that in the James, Rappahannock and York Rivers, VA that YOY striped bass less than 70 mm TL were predominantly benthic feeders. Truit and Vladykov (1937) found in the Chesapeake Bay that YOY striped bass fed almost exclusively on crustaceans, with mysids being the principle food. In Thames River, Connecticut, Merriman (1941) found that blind striped bass appeared to feed successfully on benthic invertebrates. Bason's (1971) daytime study in the upper Chesapeake Bay found that YOY striped bass fed mainly on mysids, decapods, amphipods, copepods, isopods, small fish, and marine worms, and also scavenge to a significant degree. Heubach et al. (1963) and Kelley (1982) found in the Sacramento-San Joaquin River system and San Francisco Bay-Delta, respectively that YOY bass fed mostly on large zooplankton such as copepods.

Juvenile white perch have also been found to employ a nonselective, opportunistic feeding strategy (Bigelow and Welsh 1925; Elrod et al. 1981), generally consuming foods that are most abundant (Webster 1942; Elrod et al. 1981). Because of their consumption of a wide variety of foods, white perch may have competitors for some food items (Kelley 1982), including striped bass. Hildebrand and Schroeder (1928) reported that young white perch less than 100 mm TL fed on annelids, amphipods, isopods, copepods, and insect larvae. Webster (1942) found that white perch consumed large quantities of cladocerans and insect larvae. In the Pamunkey River, Virginia, Rinaldo (1971) found that the juvenile white perch diets consisted mainly of copepods and cladocerans, and overlapped with juvenile striped bass diets. In Lake Ontario, Elrod et al. (1981) found that YOY white perch consumed mainly cladocerans, ostracods, chironomids, and amphipods. Bath and O'Conner (1985) found in the tidal Hudson River that juvenile white perch fed primarily at the benthos as their stomachs consisted of epibenthic arthropods. Similarly, in the Susquehanna River Weisburg and Janicki (1990) found that white perch were predominantly benthic feeders of trichopterans.

Food and feeding patterns of YOY striped bass and YOY white perch are important in analyzing how natural or artificial changes in an estuary may affect year-class success and stock abundance. Food availability as measured by average stomach fullness is thought to play a major role in controlling both growth and mortality of YOY striped bass (Kline 1990). The size a fish has reached by the end of the growing season is largely dependent on food type and availability. Size is of critical importance because physiological factors such as metabolism and fat storage are size-dependent (Boynton et al. 1977). A study examining feeding patterns enhances stock management of a species following both naturally and artificially induced fluctuations in food quality and quantity (Boynton et al. 1977). Food for larval striped bass and white perch may be relatively abundant. However, food availability may be more important as a limiting growth factor for juveniles because a faster growth rate necessitates a proportionally greater food intake.

Feeding strategies of YOY striped bass have been studied minimally in the Chesapeake Bay region despite their effect on survival rates of any one cohort. Knowledge of YOY striped bass dietary patterns may aid future studies on variations in daily and seasonal migrations, growth, and year-class strength. Knowledge of feeding behavior helps to predict the effects of biological and physical mechanisms on striped bass year-class strength (Boynton et al. 1981) and will provide a scientific basis for consideration of the species in any future development (Heubach et al. 1963) along tidal rivers that serve as nursery areas.

Although numerous studies have described stomach contents of fish from large rivers, these studies have generally been conducted only during daylight hours. As a result, they fail to examine diel feeding patterns that may influence predation and competition. Additionally, daytime studies may inaccurately describe the diet if much of the foraging occurs at night (Weisburg and Janicki 1990). Few studies have thoroughly addressed the diel spatial and temporal feeding patterns of YOY striped bass and white perch despite extensive research on other aspects of these species. Therefore diel food and feeding patterns of YOY striped bass and white perch were analyzed in this study.

Objectives

The objectives of this study were to:

1) identify prey items of collected YOY striped bass and YOY white perch to the lowest practical taxon;
2) measure intra- and interspecific diet similarity, correlation and overlap, with the null hypothesis that there was no intra- and interspecific dietary

similarity or correlation;

3) make intraspecific and interspecific comparisons of diel feeding success, with the null hypothesis that juvenile striped bass and white perch had no intra- or interspecific or interspecific temporal and spatial (vertical and transectional) diel feeding pattern in the test site. The variable in question, feeding success (food consumption), was measured using an index of relative fullness (IRF); and

4) determine the relationship between several abiotic environmental variables and feeding success of striped bass and white perch, with the null hypothesis that none of the variables had a significant relationship with feeding success.

MATERIALS and METHODS

Field Sampling

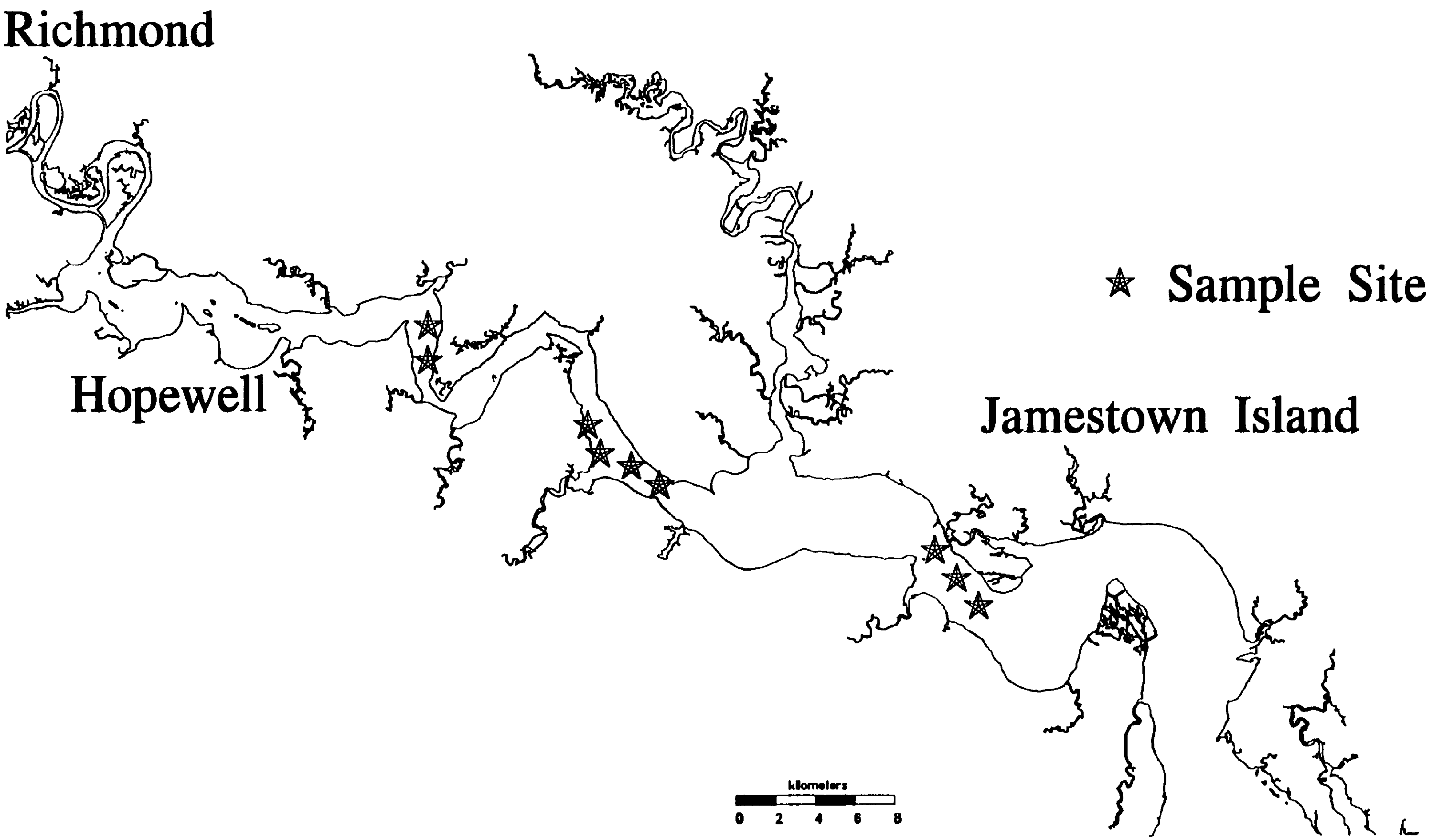
Sampling for the feeding study took place in James River, the southernmost major tributary of Chesapeake Bay. James River drains an area of 26,000 km^2 (Walburg and Sykes 1957) and is tidal for 152 km, from the river's mouth at Hampton Roads to Richmond. The turbidity maximum has historically varied between 32 km and 80 km above the river mouth, and averages 56 km above the river mouth (Brehmer and Haltiwanger 1966). Richmond's population and Hopewell's industries contribute significantly to phosphorous and nitrogen enrichment in the James River.

Sample sites ranged from 56 km to 90 km above the mouth of the James River (Figure 1). In this area YOY striped bass have previously been captured in high abundance (Colvocoresses 1989, 1990) until they are approximately 90 days old, and large enough to avoid a 30.5 m minnow seine (Kline 1990), and begin migrating downstream into higher salinity waters (Calhoun 1953; Sasaki 1966; Rinaldo 1971; Turner and Chadwick 1972; Boynton, et al. 1977; Kline 1990).

Sampling was conducted over nine 24 h cruises between June 20-21 and August 19-20, 1992. Samples were taken within the same river km during each cruise. Each 24 h

Figure 1. James River sampling sites

JAMES RIVER SAMPLING SITES



Center for Coastal Management and Policy cruise consisted of either eight or nine 3 h sampling blocks, depending on weather conditions. At the beginning of each 3 h block, samples were taken in a randomly selected order by three gears deployed in four habitats in order to detect diel feeding changes similar to the methods of Chadwick (1964).

A haul seine was used to sample the foreshore habitat by a method similar to Colvocoresses (1989): a 15.24 m long, 1.22 m high minnow seine with 6.4 mm stretch ace mesh was deployed perpendicularly to the shoreline and then, while keeping the onshore brail in a fixed position, the offshore end was pulled down current and back to the shore.

A 2.25 m^2 pushnet with 20 mm stretch mesh at the mouth and 12 mm stretch mesh at the cod end was used to sample the channel near-surface and shoal near-surface habitats. The pushnet was mounted on the bow of a 21 ft Privateer equipped with a 150 hp outboard engine. Designed by Kriete and Loesch (1980) for near-surface sampling of juvenile pelagic fishes, the pushnet is used in addition to a seine to more accurately define distribution of fishes in rivers (Tinsley et al. 1989). A 4 m semi-balloon otter trawl with 30 mm stretch mesh at the mouth and 12.7 mm stretch mesh at the cod end was used for bottom sampling in the river channel. The vessel-deployed gear was fished countercurrent for five minutes at an engine speed of 1200 RPMs.

Physical parameters were recorded during each sampling block. Current speed was qualitatively characterized as fast (3-4 knots), moderate (2-3 knots), slow (1-2 knots), or zero for each collection. Water height data supplied by VIMS, surface temperature, and salinity were recorded for each sampling block. Light readings for each block were made with a Type SA LI-COR Radiation Sensor and were taken at 0.5 m below the surface for each daylight and twilight block. After light at 0.5 m was measured to be 0 $\mu E/m^2/sec$ for all the night blocks of the first cruise, light was assumed to be 0 $\mu E/m^2/sec$ for the remainder of the night blocks. Day, twilight, and night were defined relative to light at 0.5 m below the water surface. Daytime collections were those where light exceeded 25.0 $\mu E/m^2/sec$. Twilight conditions were those when light was between 0.1 $\mu E/m^2/sec$ and 25.0 $\mu E/m^2/sec$. Nighttime conditions were those where there was less than 0.1 $\mu E/m^2/sec$ at 0.5 m below the surface.

Secchi depth readings were taken in conjunction with each daylight and twilight block. With the exception of the first cruise, there was no within-cruise change in secchi readings. Secchi depth was not measured at night, but was inferred from measurements made earlier and later in the same cruise.

Laboratory Methods

YOY striped bass and white perch were fixed in 5% neutral buffered formalin for 48 h, after which time they were rinsed with tap water and transferred to a 70% ethanol solution. Fork length (FL) and TL of each specimen were measured to the nearest mm. After rolling the fish in a dry towel and applying light blotting pressure, total weight of each specimen was measured with an analytical balance to the nearest mg. After the stomach was extracted and preserved for later analysis, each specimen was dried in an oven for 24 h at 100°C, and desiccated until a constant weight was achieved. The stomach consisted of the anterior portion of the digestive tract, extending from the base of the esophagus to the first major curve of the small intestine.

Stomach contents were identified to the lowest practical taxon and enumerated. The volume of each food item was measured using an ocular micrometer by first measuring the item's length and width, and then turning the food item on its side to measure its depth. Each stomach was then dried in an oven for 24 h at 100°C and desiccated until a constant weight was achieved. The dry stomach weight was then added to the dry weight of the remainder of the specimen to obtain the total dry weight of each specimen. Food items from each stomach were then dried, desiccated, according to the same procedures, and weighed to the nearest μg using a microbalance.

Data Analyses

An index of relative importance (IRI), developed by Pinkas et al. (1971), was used to estimate the contribution of major food groups to the diets of both species (Manooch and Mason 1983). The index of relative importance (IRI) is defined as follows:

$$IRI = F(N+V)$$

where F is the percent frequency of occurrence of a food group, N is the numerical percentage of the food group, and V is the volumetric percentage of the food group. Food items were divided into 14 categories for each species, with one category being unidentified food items. Frequency of occurrence of food items was determined relative to the total number of stomachs, regardless of whether they were full or empty. IRIs were computed for all striped bass, all white perch, and for five size classes for each species. The five size classes, by total length, were 1) 30 mm or less, 2) 31-40 mm, 3) 41-50 mm, 4) 51-60 mm, and 5) 61 mm and above.

A measure of intra- and interspecific similarity was done by applying the Spearman rank correlation coefficient and t-test to percent frequency of occurrence of food groups data, a method developed by Fritz (1974). Unlike the parametric correlation coefficient, the nonparametric Spearman coefficient does not require normally distributed data. The Spearman coefficient was used for this test because the frequency of occurrence of food groups data was not normal for either striped bass or white perch.

Once the percentage frequencies of each food group were calculated, the next step in calculating the Spearman coefficient was to serially rank food groups in descending order of their frequency of occurrence. Two or more items having the same percentage value are referred to as ties. The rank assigned to the tied values is calculated by taking the mean of the ranks that the food items would have been assigned had no ties occurred. After food items of the diets being compared were ranked, Spearman rank correlation coefficient was calculated using

$$R_s = 1.0 - \frac{6\Sigma d^2}{N^3 - N}$$

for untied ranks, or using

$$R_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d^2}{2(\Sigma x^2 + \Sigma y^2)^{1/2}}$$

for tied ranks, where

$$\Sigma x^2 = \frac{N^3 - N}{N} - \Sigma Tx$$

and

$$\Sigma y^2 = \frac{N^3 - N}{N} - \Sigma Ty$$

and

$$T = \frac{(t^3 - t)}{N}$$

where R_s is the Spearman rank correlation coefficient, N is the number ranks, d is the difference between ranks, T is the correction factor for ties, and t is the number of observations tied at a given rank.

Comparison of intra- and interspecific diet overlap was done using Horn's (1966) index of overlap. The value of R_o may range between 0 (no overlap) and 1 (complete overlap). Horn's index is calculated by the formula:

$$R_o = \frac{\Sigma(p_{ij} + p_{ik})\log(p_{ij} + p_{ik}) - \Sigma p_{ij}\log p_{ij} - \Sigma p_{ik}\log p_{ik}}{2\log 2}$$

where R_o is Horn's index of overlap for species j and k, p_{ij} is the proportion that resource i is of the total resources utilized by species j, and p_{ik} is the proportion that resource i is of the total resources utilized by species k. The volumetric portion of each food group to the total food volume of each species was used to compute intra- and interspecific food overlap (Lindquist and Kotrschal 1987).

Intra- and interspecific comparisons of the dietary diversity of striped bass and white perch were performed using the Shannon-Weaver diversity index (Shannon 1948). The Shannon-Weaver index indicates how broadly or evenly a species uses its food spectrum (Lindquist and Kotrschal 1987). The Shannon-Weaver index may be used for any nominal data taken from a random sample. This index is computed as:

$$H = \frac{n(\log n) - \Sigma f_i(\log f_i)}{n}$$

where n is the sample size and f_i is the number of observations in category i (Shannon 1948). The index, H, was calculated for the sum total of all food categories for all individuals of each species. The null hypothesis, that the diversities of the two sampled populations are equal

(Zar 1984), was tested using a t-test developed by Hutcheson (1970):

$$t = \frac{H_{i1} - H_{i2}}{s_{Hi1} - s_{Hi2}}$$

where

$$s_{Hi1} - s_{Hi2} = (s^2_{Hi1} - s^2_{Hi2})^{1/2}.$$

The variance of the H_i is approximated by

$$s^2_H = \frac{\Sigma f_i \log^2 f_i - (\Sigma f_i \log f_i)^2/n}{n^2}$$

where f_i and n are defined as above. For each group, H_i, s^2_H, and s_{Hi1}-s_{Hi2} are calculated. These calculations are then used to compute the t-statistic.

Variation in the mean total weight of stomach contents relative to fish weight is frequently used in determining a diel pattern of feeding behavior (Hyslop 1980). Smyly (1952) used weight of prey items and fish weight to arrive at a gravimetric index of relative fullness:

$$IRF = \frac{DWSC_i}{DW_i} * 100$$

where IRF is each specimen's index of relative fullness, $DWSC_i$ is the dry weight of stomach contents of specimen i, and DW_i is the total dry weight of specimen i after its stomach contents have been removed. The IRF is a useful means of measuring feeding success and detecting trends in feeding periodicity by comparing prey consumption to body weight. In this study, the IRF was used in an effort to detect temporal and spatial feeding patterns. To examine differences in feeding success (food consumption), IRFs were pooled across all sample dates in a method similar to Weisberg and Janicki (1990).

Due to either to abnormality, heterogeneity of group variances, or unequal sample sizes, or a combination of these conditions, IRFs were transformed for every intergroup comparison. Although a variety of transformations (logarithmic, square root, and arcsine) were attempted to satisfy the requirements for parametric testing, they were not successful. The t-tests and single factor analysis of variance (ANOVA) were used on transformed data because of the robustness of these two tests (Zar 1984). Despite apparent differences that existed for several comparisons, no significant intergroup IRF differences were detected using these parametric tests. The requirement of symmetry for the nonparametric Mann-Whitney (Mann and Whitney 1947) and Kruskal-Wallis ranks tests (Kruskal and Wallis 1952) could not be satisfied, and, despite apparent differences for several comparisons, these tests also failed to detect any significant differences in feeding success. Therefore χ^2 testing of contingency tables was employed as a method of making IRF comparisons by comparing whether the frequencies of occurrence in the categories of one variable were independent of the frequencies in the second variable (Zar 1984).

A fourfold (2*2) contingency table was constructed for each IRF comparison with two groups of specimens. The rows in the contingency table were the two groups being compared. One column of each table represented the number of specimens of each group with IRFs ≥ the average for all specimens of both groups and the other column represented the number of specimens of each group with IRFs < the average for all specimens of both groups.

A sixfold (3*2) contingency table was constructed when IRFs of three groups of specimens were compared (e.g. day, twilight, and night). Like the fourfold tables, the rows in the sixfold tables were the three groups being compared. One column was the number of specimens in each group with IRFs ≥ the average of all specimens of the three groups and the other column was the number of specimens in each group with IRFs < the average for all specimens of the three groups. For each intraspecific comparison, the null hypothesis,

H_0: Feeding success is independent time of capture or location of capture

was tested against the alternate hypothesis,

H_a: Feeding success is associated with time of capture or location of capture.

For each interspecific comparison, the null hypothesis,

H_0: Feeding success is independent of species

was tested against the alternate hypothesis,

H_a: Feeding success is associated with species.

For fourfold contingency tables, χ^2 was computed as

$$\chi^2 = \frac{n(f_{11}f_{22} - f_{12}f_{21})^2}{(C_1)(C_2)(R_1)(R_2)}$$

where n is the total number of observations, and each f_{ij} is the observed frequency in the cell of row i, column j. C_1, C_2, R_1, and R_2 represent the total number of observations in the first column, second column, first row, and second row, respectively (Zar 1984).

For sixfold contingency tables, χ^2 was computed as

$$\chi^2 = \sum\sum \frac{(f_{ij} - \hat{e}_{ij})^2}{\hat{e}_{ij}}$$

where f_{ij} is the observed frequency in row i, column j, and $\hat{e}_{ij}$ the is the expected frequency in row i, column j if the null hypothesis is true. Each $\hat{e}_{ij}$ was computed as

$$\hat{e}_{ij} = \frac{(R_i)(C_j)}{n}$$

where R_i is the ith row, C_j is the jth column, and n is the total number of observations (Zar 1984). The degrees of freedom for χ^2 testing of contingency tables was calculated as

$$DF = (r-1)(c-1)$$

where r and c are the numbers of rows and columns in the contingency table, respectively (Zar 1984). The α level for each comparison was 0.05.

Intraspecific temporal comparisons of feeding success were performed between the specimens captured at day, twilight, and night. Intraspecific temporal comparisons of feeding success were also performed using only beach seine specimens, and using only otter trawl specimens.

For each species, channel pushnet and shoal pushnet catches were combined due to very low catches by the channel pushnet. Intraspecific spatial comparisons of feeding success were performed between the pushnet, seine, and trawl specimens, between seine and trawl specimens, and between seine specimens and specimens caught by the three vessel-deployed gears.

Striped bass and white perch IRFs were also examined for interspecific differences in feeding success. The first interspecific comparison was between all striped bass and all white perch. Interspecific IRF comparisons were also performed for each of the three times, seine specimens, trawl specimens, specimens captured by both pushnets, and specimens captured by the three vessel-deployed gears (the trawl and both pushnets). Interspecific comparisons in feeding success were also performed with time-specific seine catches and time-specific trawl catches. An interspecific comparison was not done with the channel pushnet catches due to the lack of specimens caught by this gear.

Stepwise multiple regressions using a linear model were performed to find if each of several abiotic independent variables had a relationship with either striped bass or white perch feeding success. Stepwise regression is done by first finding the t values for each of the independent variables. If every t value is equal to or greater than the critical value, then it is concluded that all of the independent variables have a significant effect on the dependent variable. However, if some t values are less than the critical value, then the independent variable having the lowest absolute t value is deleted from the model and a new multiple regression equation is fitted using the remaining independent variables. The null hypothesis, H_o: $\beta_i = 0$ is tested against the alternate hypothesis, H_a: $\beta_i \neq 0$ for each partial regression coefficient for the new model, and if some t values are less than the critical value, then another variable is deleted and a new stepwise regression analysis is performed (Zar 1984).

A regression model in which the variables and their parameters were assumed to be linear was developed using light, temperature, salinity, secchi depth, water height, and current speed as independent variables. For current speed, which was estimated as either fast, medium, slow, or zero, dummy variables were used by assigning a value of one to the current speed at which the specimen was caught, and zero values to the other three estimates of current speed. The dependent variable, feeding success, was measured by the IRFs to make the model

$$Y = \alpha + \beta_1 L + \beta_2 T + \beta_3 S + \beta_4 SD + \beta_5 WH + \beta_6 FCS + \beta_7 MCS + \beta_8 SCS + \beta_9 CS0$$

where Y, the index of relative fullness, is the dependent variable, α is a constant denoting the Y intercept, and β_1 through β_9 are partial regression coefficients for light (at 0.5 m below the water surface), temperature, salinity, secchi depth, water height, fast current speed, medium current speed, slow current speed, and no current speed, respectively. For each species, a forward, stepwise regression was performed that had an α to enter value of 0.05, and a minimum tolerance of 0.10.

A students t-test was used for other pairwise comparisons of group means where this test's assumptions were not violated. A Mann-Whitney test was used in cases where a transformation was unsuccessful at correcting heterogeneity of group variances or abnormality of the data.

Catches in the James River in 1992 by the seine used in this study and the seine used in the VIMS survey were standardized by dividing the catch of striped bass in each of this study's 77 hauls by the length of this study's net (15.24 m) and dividing the catch of striped bass in each of the 60 hauls by Colvocoresses et al. (1993) by the length of that net (30.48 m).

James River nighttime pushnet catches of striped bass and white perch made in this study were compared with 1992 James River nighttime pushnet catches made by the VIMS *Alosa* survey.

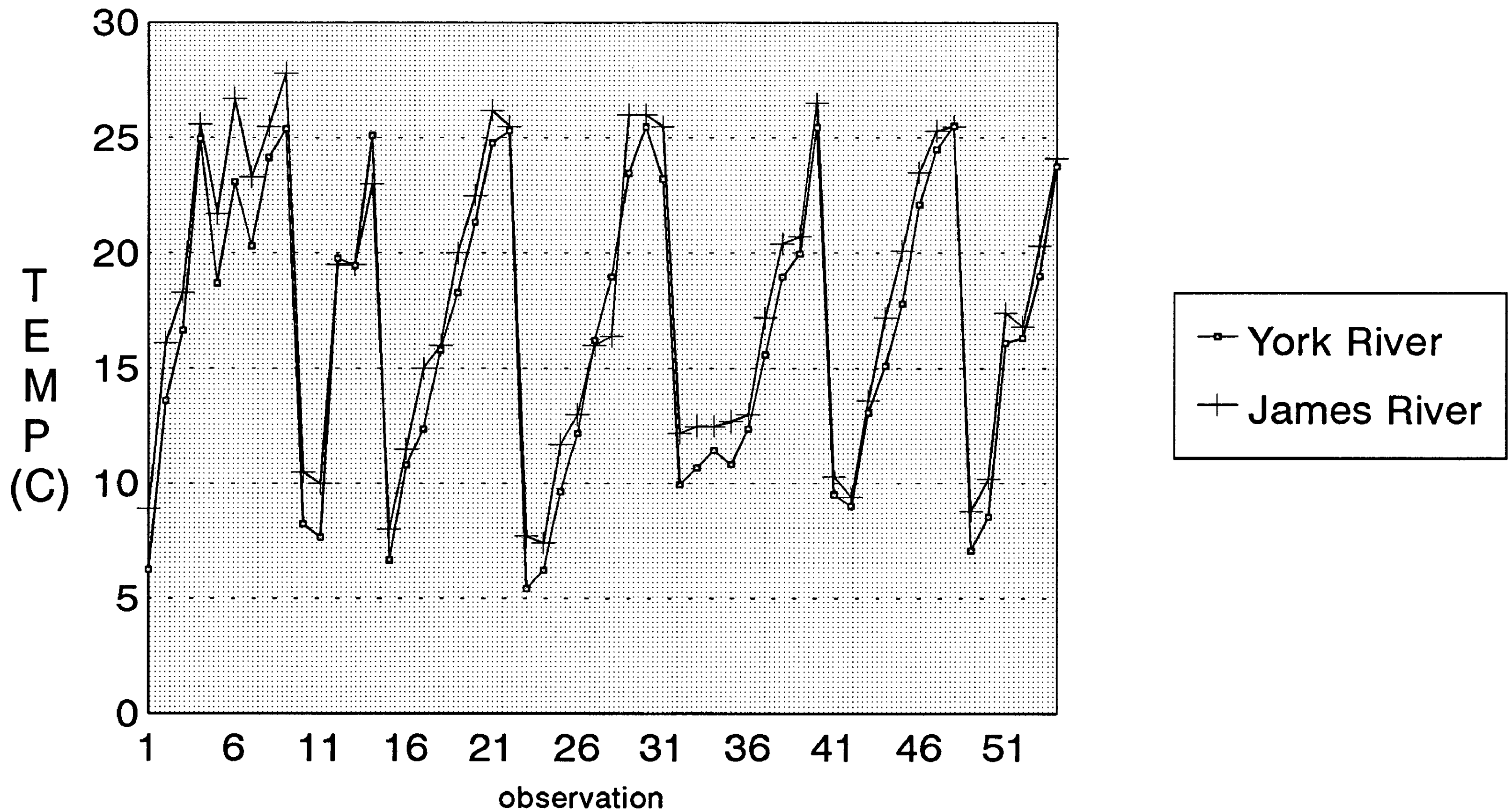
Temperature data from VIMS monitoring of the York River at Gloucester Point and water flow data for the James River

(U.S. Geological Survey Water Resources Data, VA 1968-1993) were examined to find if either of these two variables had a relationship with the number of YOY striped bass captured by the VIMS striped bass seining survey at the James River index stations for the years 1967-73 and 1980-92.

For each year that the VIMS striped bass seining survey was conducted, 1967-73 and 1980-92, the total number of striped bass caught at the James River index stations was regressed against average York River water temperature for each month between March and June. This regression assumed that the variables and their parameters were linear. Only monthly and bimonthly temperature data existed for the tidal portion of the James River (Nat Wooding, VEPCO, per comm; Vera Pollick, VA State Water Control Board, per. comm) for the years when the VIMS striped bass survey was conducted. The best available temperature data for the James River for the years under consideration was from Swan Point (VA State Water Control Board 1971-1993). On 54 days in March, April, May, and June between 1967-73 and 1980-92 temperatures were taken at both Swan Point and Gloucester Point. The average York River temperature was not significantly different from the average James River temperature (t=1.034; p=0.303). The York River and James River temperatures were in phase with each other (Figure 2). Therefore the York River water temperatures taken at Gloucester Point were used as a reference index. March 1968, 1984, and 1990, April 1968,

Figure 2. Comparison between York River (at Gloucester Point) and James River (at Swan Point) water temperatures for 54 March, April, May, and June days between 1967-1973 and 1980-92.

Comparison of York River and James River water temperatures



York River water temperatures were taken at Gloucester Point.
James River water temperatures were taken at Swan Point.

1984-85, and 1991, May 1968, 1985, and 1987, and June 1982, 1984-85, and 1987 water temperatures were excluded from the analysis because of missing data. The model

$$Y_j = \alpha + \beta X_{ij} + u$$

was used for striped bass catch-temperature analysis where Y is the James River historical index stations striped bass catch for year j, X is either the average water temperature, variability in water temperature, or total drop in temperature for month i in year j, u is the error term that is assumed to be normally distributed with a mean of zero and a constant variance, and α and β are constants. For each of these simple regressions between striped bass catch and temperature, the null hypothesis, H_0: $\beta = 0$ was tested against the alternate hypothesis, H_a: $\beta \frown 0$ using an F test.

Two multiple regression analyses were performed using James River water flow data for the years 1967-73 and 1980-92. These regressions also assumed that the variables and their parameters were linear. Water flow for the James River was averaged for each month. The first analysis was performed by regressing total YOY striped bass landings at the index stations in the James River for each year of the VIMS survey against twelve measurements of water flow for the months June of the index year (t1) through July of the previous year (t12). This model assumed a dimensional lag and was described by the equation

$$Y_t = \alpha_0 + \beta_1 X_{t1} + \beta_2 X_{t2} + \beta_3 X_{t3} + \ldots + \beta_{12} X_{t12} + u$$

where Y_t is the index for a given year, α_0 is a constant denoting the Y intercept, u is the error term that is assumed to be normally distributed with a mean of zero and a constant variance, and each β_i is the partial regression coefficient for the James River water flow, X, in month t where t1 through t12 are water flows for each of the months June of the index year, t1, through July of the previous year, t12, respectively. The second analysis was performed by regressing the same striped bass landings against six months of water flow from June of the index year (t1) through January of the index year (t6). This linear model also assumed a dimensional lag and was described by

$$Y_t = \alpha_0 + \beta_1 X_{t1} + \beta_2 X_{t2} + \beta_3 X_{t3} + \ldots + \beta_6 X_{t6}$$

where Y_t is the index for a given year, α_0 is a constant denoting the Y intercept, u is the error term that is assumed to be normally distributed with a mean of zero and a constant variance, and each β_i is the partial regression coefficient for the James River water flow, X, in month t where t1 through t6 are water flows for each of the months June of the index year, t1, through January of the index year, t6, respectively. For each of these multiple regressions between striped bass catch and temperature, the null hypothesis, H_o: $\beta_1 = \beta_2 = \ldots = \beta_n$ was tested against the alternate hypothesis, H_a: not all β_i are equal using an F test.

RESULTS

A total of 188 striped bass and 199 white perch were captured in 300 collections. Seventy-seven samples each were collected with the beach seine, shoal pushnet, and otter trawl. Sixty-nine samples were collected with the channel pushnet. Steadily decreasing catches of both species were made throughout the summer (Appendix 1).

The beach seine captured 45, 15, and 14 striped bass at day, twilight, and night, respectively. The channel pushnet captured 1, 1, and 2 striped bass at day, twilight, and night, respectively. The shoal pushnet captured 13, 13, and 2 striped bass at day, twilight, and night, respectively. The otter trawl captured 38, 22, and 22 striped bass at day, twilight, and night, respectively. Striped bass captured by seine were significantly longer than striped bass captured by trawl ($t=15.04$; $p<0.0005$)

The beach seine captured 43, 6, and 17 white perch at day, twilight, and night, respectively. The channel pushnet captured 0, 1, and 0 white perch at day, twilight, and night, respectively. The shoal pushnet captured 1, 60, and 0 white perch at day, twilight, and night, respectively. The otter trawl captured 30, 25, and 16 white perch at day, twilight, and night, respectively. White perch captured by the beach seine were significantly longer than white perch captured by the otter trawl ($t=19.94$; $p<0.0005$). A summary of striped bass and white perch catches is given in Table 1. Catches and environmental data are detailed in Appendix 1.

A total of 6,402 food items were found in striped bass stomachs and 11,278 food items were found in white perch stomachs. Volumetrically, 1,145.04 mm^3 of food was found in striped bass stomachs and 689.92 mm^3 of food was found in white perch stomachs. Copepods (adult copepods) were the most numerous food item of both striped bass and white perch. Fish comprised the largest volumetric percentage of striped bass food items while mysids comprised the largest volumetric percentage of white perch food items. Leptodorid cladocerans (leptodorids) were the most frequently occurring food item of striped bass while copepods were the most frequently occurring food item of white perch. Five striped bass stomachs and four white perch stomachs were empty.

Using an index of relative importance, the five most important striped bass food groups were, in descending order, leptodorids, copepods, insect pupae, fish, and insect larvae (Figure 3). Copepods, leptodorids, insect larvae, bosminid cladocerans, and insect pupae were the five most important food groups for white perch (Figure 4). The frequency, number, volume, and IRIs for striped bass and white perch are summarized in Table 2.

For striped bass, the five most important food groups,

Table 1. Catches of striped bass and white perch summarized by time and gear.

A. Catches of striped bass/collection

Gear \ Time	A) Day	B) Twilight	C) Night	D) Gear Totals
1) Seine	45/43	15/15	14/19	74/77
2) Trawl	38/43	22/15	22/19	82/77
3) C. Pushnet	1/38	1/14	2/17	4/69
4) S. Pushnet	13/43	13/15	2/19	28/77
5) Time Totals	97/167	51/59	40/74	188/300

B. Catches of white perch/collection

Gear \ Time	A) Day	B) Twilight	C) Night	D) Gear Totals
1) Seine	43/43	6/15	17/19	66/77
2) Trawl	30/43	25/15	16/19	71/77
3) C. Pushnet	0/38	1/14	0/17	1/69
4) S. Pushnet	1/43	60/15	0/19	61/77
5) Time Totals	74/167	92/59	33/74	199/300

Table 2. Percent frequency of occurrence (F), numerical percentage (N), volumetric percentage (V), and relative importance (IRI) of striped bass and white perch food groups.

A. Food items of all striped bass

Food item	#Bass	#Eaten	Vol (mm^3)	F	N	V	IRI
Leptodorids	119	2186	255.18	.633	.341	.223	3570.1
Copepods	113	2526	39.68	.601	.395	.035	2584.3
Insect pupae	36	271	104.43	.191	.042	.091	254.0
Fish	11	16	424.57	.059	.002	.371	220.1
Insect larvae	37	272	69.36	.197	.042	.061	202.9
Bosminids	41	258	2.22	.218	.040	.002	91.6
Mysids	7	177	185.38	.037	.028	.162	70.3
Eggs	16	278	3.04	.085	.043	.003	39.1
Unidentified	14	231	18.77	.074	.036	.016	38.5
Cope. nauplii	25	129	.88	.133	.020	.001	27.7
Amphipods	13	24	21.25	.069	.004	.019	15.9
Decapods	4	7	12.33	.021	.001	.011	2.5
Other	5	14	7.80	.027	.002	.007	2.4
Ostracods	9	13	.15	.048	.002	.000	1.0
All Foods	183	6402	1145.04				

B. Food items of all white perch

Food item	#Perch	#Eaten	Vol (mm^3)	F	N	V	IRI
Copepods	151	7183	117.03	.759	.637	.170	6125.1
Leptodorids	109	1024	113.22	.548	.091	.164	1397.4
Insect larvae	50	326	127.89	.251	.029	.185	537.1
Bosminids	48	1458	10.57	.241	.129	.015	347.0
Insect pupae	32	161	79.39	.161	.014	.115	207.7
Cope. nauplii	59	500	3.28	.296	.044	.005	145.0
Mysids	11	174	159.19	.055	.015	.231	135.3
Unident.	27	284	29.32	.136	.025	.042	91.1
Amphipods	21	35	22.34	.106	.003	.032	37.1
Ostracods	21	65	1.58	.106	.006	.002	8.5
Decapods	8	20	4.48	.040	.002	.006	3.2
Fish	2	2	19.82	.010	.000	.029	2.9
Eggs	11	33	0.21	.056	.003	.000	1.9
Other	10	13	1.60	.050	.001	.002	1.5
All Foods	195	11278	689.92				

Figure 3. Percent frequency of occurrence, numerical percentage, volumetric percentage, and indices of relative importance for major striped bass food groups.

Indices of relative importance for striped bass food groups

Numbers are IRI values of food groups.

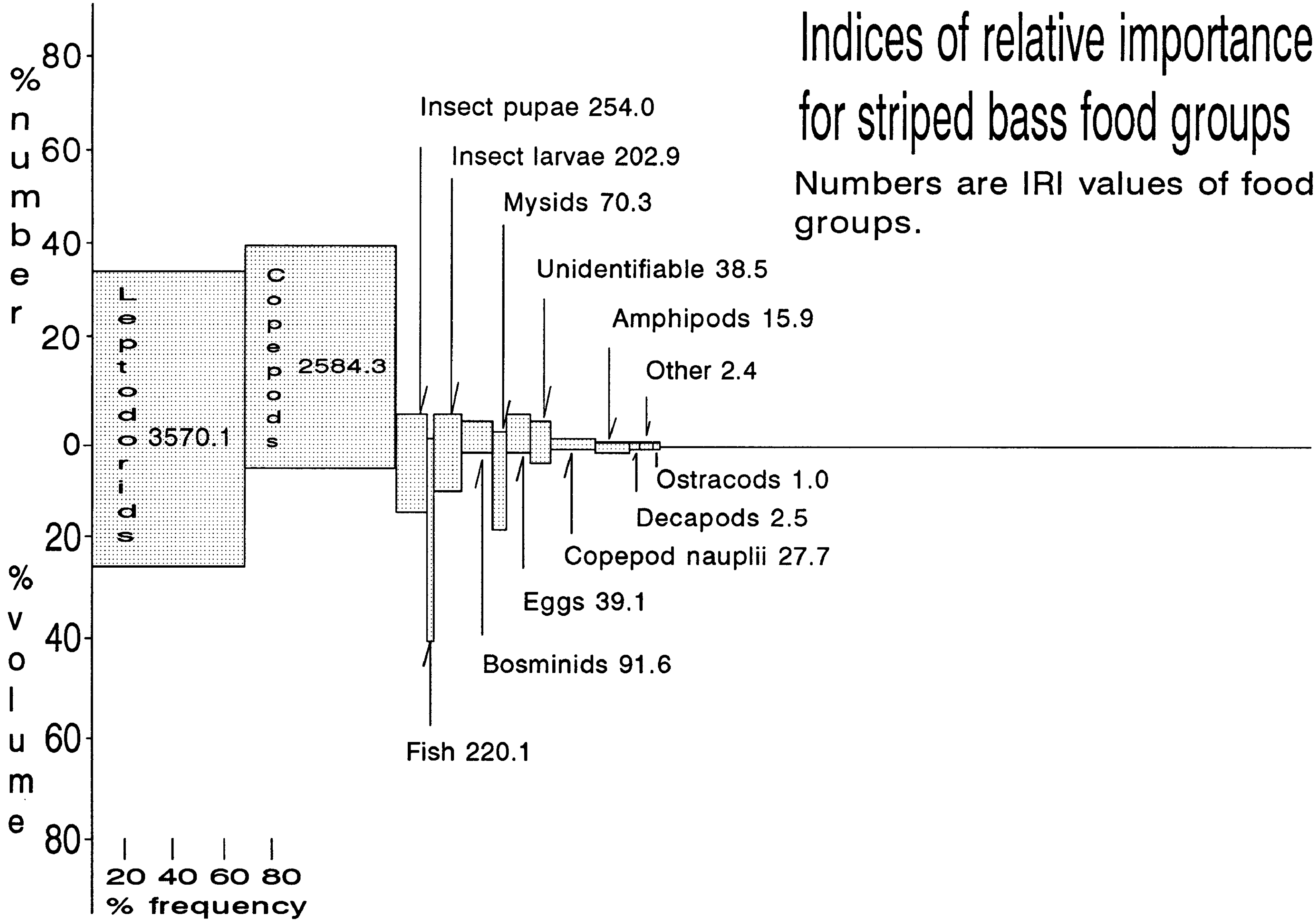
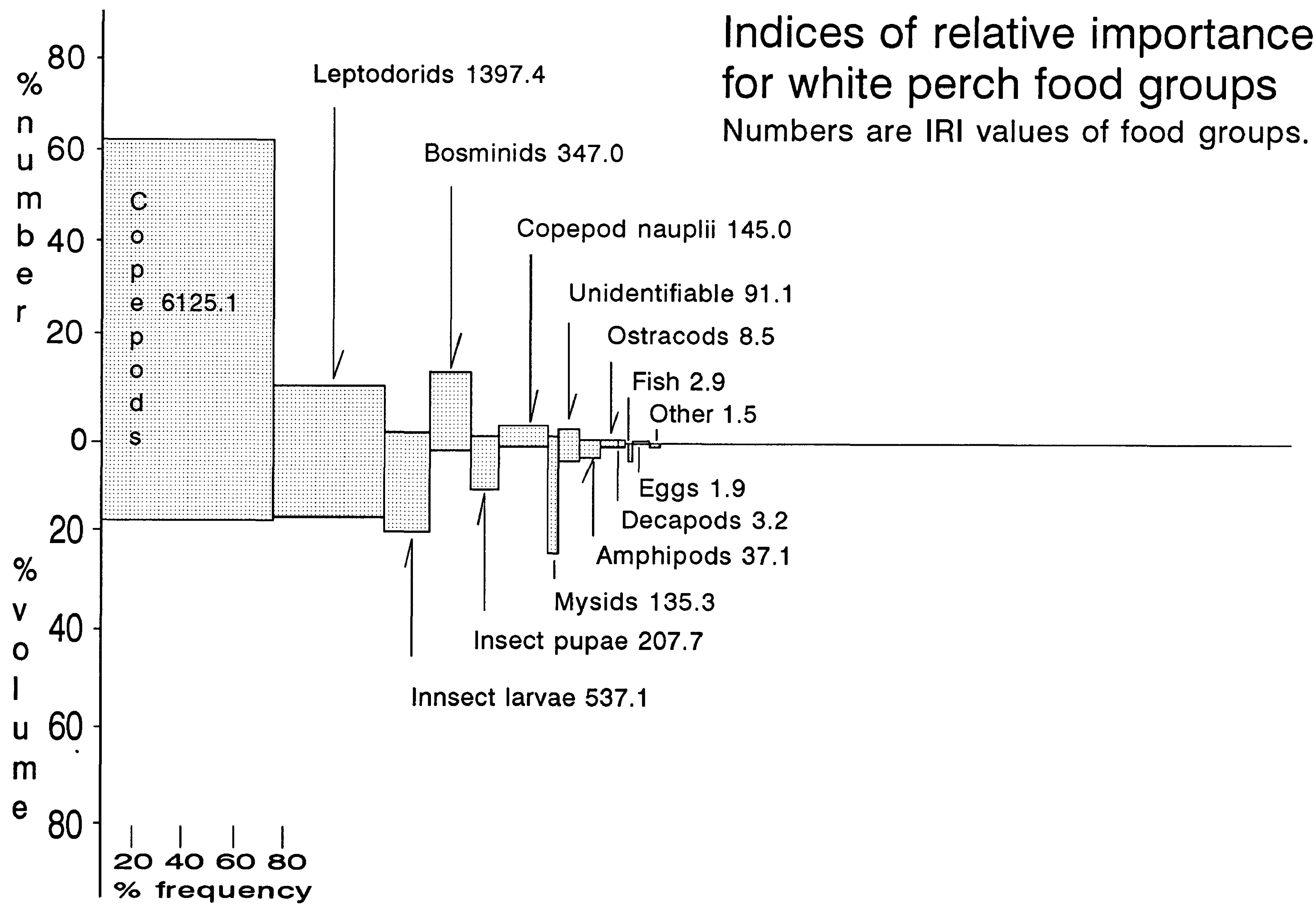


Figure 4. Percent frequency of occurrence, numerical percentage, volumetric percentage, and indices of relative importance for major white perch food groups.



Indices of relative importance
for white perch food groups
Numbers are IRI values of food groups.
% number
% volume
80
60
40
20
0
20
40
60
80
Copepods 6125.1
Leptodorids 1397.4
Bosminids 347.0
Copepod nauplii 145.0
Unidentifiable 91.1
Ostracods 8.5
Fish 2.9
Other 1.5
Eggs 1.9
Decapods 3.2
Amphipods 37.1
Mysids 135.3
Insect pupae 207.7
Innsect larvae 537.1
20 40 60 80
% frequency

listed in descending order for each size class of specimens, were as follows: for striped bass 30 mm and less, adult copepods, leptodorid cladocerans, bosminid cladocerans, and copepod nauplii; for striped bass 31-40 mm, leptodorid cladocerans, adult copepods, insect larvae, insect pupae, and bosminid cladocerans; for striped bass 41-50 mm, leptodorid cladocerans, adult copepods, insect larvae, insect pupae, and unidentified eggs; for striped bass 51-60 mm, adult copepods, mysids, fish, insect larvae, and insect pupae; and for striped bass striped 61 mm and above, insect pupae, fish, insect larvae, mysids, and adult copepods. IRIs for the striped bass size classes are shown in Table 3.

For white perch, the most important food groups, listed in descending order for each size class of specimens, were: for white perch 30 mm and less, adult copepods, leptodorid cladocerans, copepod nauplii, bosminid cladocerans, and unidentified eggs; for white perch 31-40 mm, adult copepods, leptodorid cladocerans, insect larvae, copepod nauplii, and mysids; for white perch 41-50 mm, adult copepods, leptodorid cladocerans, mysids, insect larvae, and copepod nauplii; for white perch 51-60 mm, insect larvae, insect pupae, adult copepods, bosminid cladocerans, and leptodorid cladocerans; and for white perch 61 mm and above, mysids, bosminid cladocerans, insect larvae, ostracods, and decapods. IRIs for the five size classes of white perch size are detailed in Table 4.

Table 3. Percent frequency of occurrence (F), numerical percentage (N), volumetric percentage (V), and relative importance (IRI) of major food groups for five size classes of striped bass.

Class I: Foods of all striped bass <30 mm

Food item	#Bass	#Eaten	Vol(mm^3)	F	N	V	IRI
Copepods	50	1175	18.73	.833	.716	.367	9021.4
Leptodorids	50	242	29.87	.833	.148	.586	6114.2
Bosminids	17	153	1.32	.283	.093	.026	336.8
Cope nauplii	17	45	0.33	.283	.027	.007	94.8
Eggs	5	16	0.13	.083	.010	.002	10.0

Class II: Foods of all striped bass 31-40 mm

Food item	#Bass	#Eaten	Vol(mm^3)	F	N	V	IRI
Leptodorids	37	653	71.90	.740	.404	.621	7585.0
Copepods	29	660	9.42	.580	.408	.081	2836.2
Insect larvae	7	62	7.04	.140	.038	.061	138.6
Insect pupae	6	19	14.42	.120	.012	.125	164.4
Bosminids	14	57	0.50	.280	.035	.004	109.2

Class III: Foods of all striped bass 41-50 mm

Food item	#Bass	#Eaten	Vol(mm^3)	F	N	V	IRI
Leptodorids	23	1262	149.98	.575	.655	.731	7965.5
Copepods	23	295	4.68	.575	.153	.023	1012.0
Ins.larvae	13	126	20.49	.325	.165	.100	536.3
Insect pupae	7	65	13.49	.175	.034	.066	175.0
Eggs	6	23	1.97	.150	.012	.010	32.4

Class IV: Foods of all striped bass 51-60 mm

Food item	#Bass	#Eaten	Vol(mm^3)	F	N	V	IRI
Copepods	7	385	6.67	.333	.408	.018	1418.6
Mysids	5	142	151.35	.238	.150	.402	1314.3
Fish	4	8	151.18	.191	.008	.402	781.1
Insect larvae	11	44	21.42	.524	.047	.057	544.8
Insect pupae	12	23	19.65	.571	.024	.052	434.3

Class V: Foods of all striped bass >60 mm

Food item	#Bass	#Eaten	Vol(mm^3)	F	N	V	IRI
Insect pupae	9	162	56.52	.529	.596	.142	3907.0
Fish	6	7	266.74	.353	.026	.672	2463.9
Insect larvae	5	39	20.29	.294	.143	.051	570.4
Mysids	1	31	32.85	.059	.114	.083	115.8
Copepods	4	11	.18	.236	.040	.001	95.5

Table 4. Percent frequency of occurrence (F), numerical percentage (N), volumetric percentage (V), and relative importance (IRI) of major food groups for five size classes of white perch.

Class I: Foods of all white perch <30 mm

Food item	#Perch	#Eaten	Vol (mm^3)	F	N	V	IRI
Copepods	75	3295	53.80	.904	.815	.476	11670.6
Leptodorids	67	404	52.80	.807	.010	.468	4583.8
Cope nauplii	34	167	1.07	.410	.041	.010	206.8
Bosminids	23	117	1.01	.277	.029	.009	105.0
Eggs	6	22	.14	.072	.005	.001	4.8

Class II: Foods of all white perch 31-40 mm

Food item	#Perch	#Eaten	Vol (mm^3)	F	N	V	IRI
Copepods	31	1975	34.30	.674	.837	.358	8054.3
Leptodorids	18	219	31.12	.391	.092	.325	1630.5
Insect larvae	6	15	7.66	.130	.006	.080	112.7
Cope nauplii	17	61	0.36	.370	.026	.004	110.1
Mysids	1	14	14.45	.022	.006	.150	33.8

Class III: Foods of all white perch 41-50 mm

Food item	#Perch	#Eaten	Vol (mm^3)	F	N	V	IRI
Copepods	21	1478	22.28	.700	.686	.154	5876.5
Leptodorids	11	254	24.63	.366	.118	.170	1053.3
Mysids	5	53	58.16	.166	.025	.402	708.2
Ins. larvae	12	35	10.38	.400	.016	.072	352.0
Cope. nauplii	7	254	1.74	.233	.118	.012	302.4

Class IV: Foods of all white perch 51-60 mm

Food item	#Perch	#Eaten	Vol (mm^3)	F	N	V	IRI
Ins.larvae	24	243	101.74	.774	.135	.408	4202.0
Insect pupae	21	138	65.81	.677	.077	.264	2308.6
Copepods	22	431	6.60	.710	.239	.026	1881.5
Bosminids	12	644	4.51	.387	.358	.018	1455.5
Leptodorids	12	140	4.13	.387	.078	.017	365.7

Class V: Foods of all white perch >60 mm

Food item	#Perch	#Eaten	Vol (mm^3)	F	N	V	IRI
Mysids	3	82	62.89	.333	.089	.721	2697.3
Bosminids	2	680	4.88	.222	.741	.056	1769.3
Ins. larvae	5	30	7.59	.555	.033	.087	666.0
Ostracods	2	9	.29	.222	.010	.003	29.1
Decapods	2	2	0.89	.222	.002	.010	27.1

The Spearman rank correlation coefficient, R_s, between striped bass and white perch diets was 0.86, and was highly significant ($p<0.001$). Although tied ranks existed for white perch, no ties existed for striped bass foods. Thus the tied Spearman ranks equations could not be used to compute R_s.

The computed Horn's index of overlap, R_o, between striped bass and white perch was 0.77.

To perform the Shannon-Weaver analysis, food items of both striped bass and white perch were divided into twelve categories. The computed t was not significant ($t=1.24$; $0.2<p<0.5$), suggesting that the diversity of striped bass and white perch diets was not significantly different.

In descending order, copepods, leptodorid cladocerans, and bosminid cladocerans were the three most important food groups for striped bass captured by the otter trawl while leptodorid cladocerans, insect larvae, and insect pupae were the three most important food groups of striped bass captured by the beach seine (Table 5).

Using the equations for tied ranks, the diets of striped bass captured by the otter trawl and beach seine were found not to be significantly correlated with one another at $\alpha=0.05$ ($R_s=0.47$; $0.1<p<0.2$).

The relatively high value for Horn's index of overlap, R_o, 0.64, between trawl bass and seine bass diets is attributable to the consumption of fish by two trawl striped bass. Had these two specimens not consumed fish, R_0 would have been 0.151.

The diets of striped bass captured by the beach seine were significantly more diverse than the diets of striped bass captured by the otter trawl ($t=8.90$; $p<0.0005$).

Copepods, leptodorid cladocerans, and bosminid cladocerans were the three most important food groups of white perch captured by the otter trawl while copepods, insect larvae, and bosminid cladocerans were the three most important food groups of white perch captured by the beach seine (Table 6).

Using the equations for untied ranks, the diets of white perch captured by the otter trawl and beach seine were not significantly correlated with one another at $\alpha=0.05$ ($R_s=0.08$; $0.5<p$).

Horn's index of overlap, R_0, between otter trawl white perch and beach seine white perch was 0.27.

The diets of white perch captured by the beach seine were significantly more diverse than the diets of white perch captured by the otter trawl ($t=12.51$; $p<0.0005$).

A gradual dietary shift in each species was found between specimens captured by the trawl and specimens captured by the seine. Striped bass and white perch captured by trawl had diets that overwhelmingly consisted of zooplankton. In descending order, adult copepods, leptodorids, and bosminids were the three most important food groups of striped bass and white perch captured by the otter trawl. These three groups of zooplankton were 98.1% of the total IRI value summed across all food groups of trawl striped bass while for trawl white perch they were 98.5% of the total IRI value summed across all food groups. Zooplankton remained important in specimens captured by the seine, but their importance diminished as insect larvae, insect pupae, mysids, and fish became substantial components of striped bass and white perch diets. For seine striped bass the same three groups of zooplankton comprised 55.0% of the total of all IRI values, while for seine white perch they were 46.6% of the total of all IRI values. These shifts in IRIs for striped bass and white perch are shown in Tables 5 and 6, and in Figures 5 and 6, respectively.

For striped bass, feeding success (as measured by IRFs) was independent of time or location of capture. Table 7 summarizes the test results for striped bass IRF comparisons, while temporal and spatial IRF comparisons for striped bass are depicted in Figures 7 and 8, respectively.

For white perch, feeding success was associated with time of capture (χ^2=15.010; $p<0.001$), with the frequency of twilight white perch having IRFs ≥ the average IRF being greater than the frequency for day or night white perch. The frequency of night trawl white perch having IRFs ≥ the average IRF was significantly less than the frequency for day trawl or twilight trawl perch (χ^2=7.104; $0.025<p<0.05$).

Table 5. Percent frequency of occurrence (F), numerical percentage (N), volumetric percentage (V), and relative importance (IRI) of major food groups of trawl striped bass and seine striped bass.

A. Food items of all otter trawl striped bass

Food item	#Bass	#Eaten	Vol (mm^3)	F	N	V	IRI
Copepods	67	1812	27.94	.817	.717	.162	7181.4
Leptodorids	71	449	57.40	.866	.178	.334	4433.9
Bosminids	23	144	1.24	.280	.057	.007	179.2
Fish	2	6	84.10	.024	.002	.489	117.8
Cope. naup.	21	78	0.56	.256	.031	.003	87.0
Eggs	19	22	0.15	.231	.009	.001	22.9
Unident.	4	8	0.25	.049	.003	.001	2.0
Insect pupae	2	2	0.36	.024	.001	.002	0.7
Ostracods	2	4	0.05	.024	.002	.001	0.5
Amphipods	1	1	0.04	.012	.001	.001	0.1
All Foods	80	2526	172.08				12025.5

B. Food items of all beach seine striped bass.

Food item	#Bass	#Eaten	Vol (mm^3)	F	N	V	IRI
Leptodorids	30	1004	113.15	.405	.403	.153	2251.8
Inst. larvae	30	260	63.25	.405	.104	.085	765.5
Insect pupae	23	249	90.29	.311	.100	.122	690.4
Copepods	30	265	4.11	.405	.106	.006	453.6
Mysids	8	181	185.38	.108	.073	.250	348.8
Fish	5	6	232.65	.068	.002	.314	214.9
Unident.	15	102	8.02	.203	.041	.011	105.6
Bosminids	14	94	0.82	.189	.038	.001	73.7
Eggs	5	251	2.85	.068	.101	.004	71.4
Amphipods	9	21	19.79	.122	.008	.027	42.7
Ostracods	6	8	0.10	.081	.003	.001	2.5
Decapods	1	4	11.85	.014	.002	.016	2.5
Cope. naup.	1	32	0.22	.014	.013	.001	1.9
Polychaetes	1	2	0.69	.014	.001	.001	0.3
All Foods	72	2492	740.28				5041.0

Table 6. Percent frequency of occurrence (F), numerical percentage (N), volumetric percentage (V), and relative importance (IRI) of major food groups of trawl white perch and seine white perch.

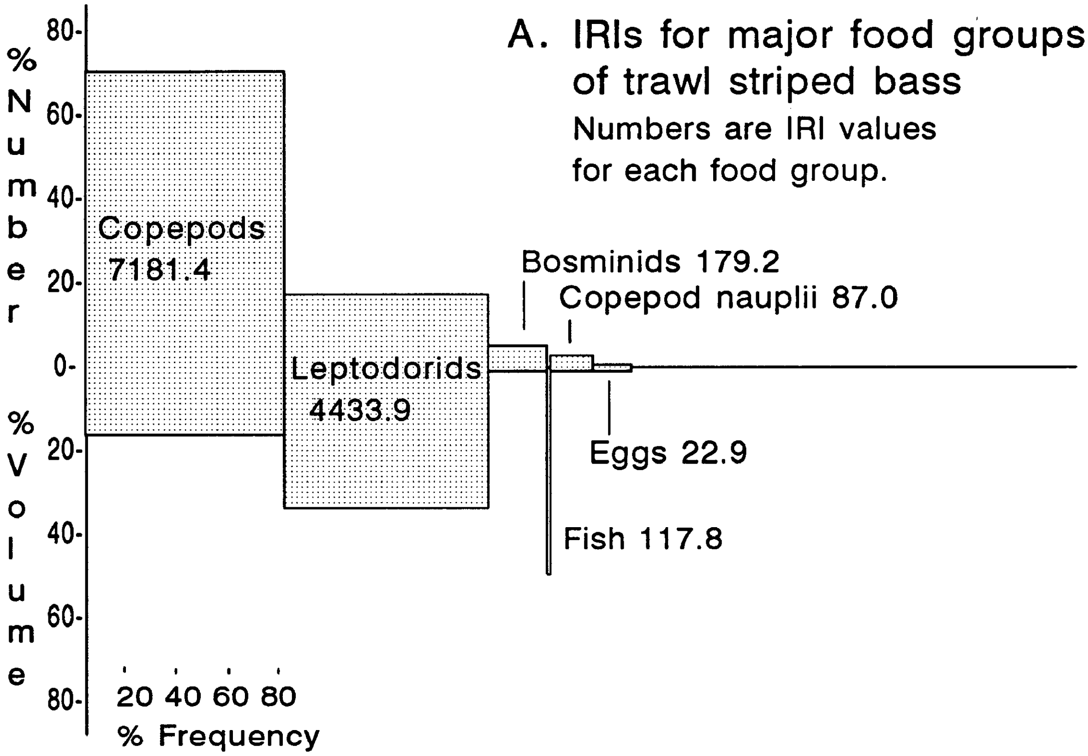
A. Food items of all otter trawl white perch

Food item	#Perch	#Eaten	Vol (mm^3)	F	N	V	IRI
Copepods	62	1213	20.23	.873	.684	.317	8738.7
Leptodorids	56	302	38.77	.789	.170	.608	6138.4
Bosminids	24	129	1.11	.338	.073	.017	304.2
Cope. naup.	22	91	0.56	.310	.051	.009	186.0
Eggs	14	22	0.14	.197	.012	.002	27.6
Decapods	2	11	2.62	.028	.006	.041	13.2
Larvae	1	1	0.24	.014	.001	.004	0.6
Unidentified	1	1	0.01	.014	.001	.001	0.2
Mysids	1	1	0.03	.014	.001	.001	0.1
Ostracods	1	2	0.03	.014	.001	.001	0.1
All Foods	70	1173	63.75				15409.1

B. Foods items of all beach seine white perch.

Food item	#Perch	#Eaten	Vol (mm^3)	F	N	V	IRI
Copepods	38	1410	20.23	.576	.325	.043	2119.7
Inst. larvae	40	306	111.10	.606	.071	.235	1854.4
Bosminids	18	1325	9.43	.273	.305	.020	887.3
Insect pupae	25	155	77.83	.379	.036	.164	758.0
Mysids	10	173	159.16	.152	.040	.336	571.5
Leptodorids	21	369	23.30	.318	.085	.049	426.1
Unident.	22	214	23.70	.333	.049	.050	329.7
Amphipods	17	35	22.34	.258	.068	.047	296.7
Ostracods	19	63	1.56	.288	.015	.003	51.8
Cope. naup.	5	269	1.84	.075	.062	.004	49.5
Fish	2	2	19.82	.030	.001	.042	12.8
Decapods	6	9	1.86	.091	.002	.004	5.5
Polychaetes	1	1	0.24	.015	.001	.001	0.1
Eggs	1	1	0.03	.015	.001	.001	0.1
All Foods	65	4338	473.74				7365.0

Figure 5. Percent frequency of occurrence, numerical percentage, volumetric percentage, and indices of relative importance for major food groups of trawl striped bass and seine striped bass.


A. IRIs for major food groups of trawl striped bass
Numbers are IRI values for each food group.
% Number
% Volume
80- 60- 40- 20- 0- 20- 40- 60- 80-
Copepods 7181.4
Leptodorids 4433.9
Bosminids 179.2
Copepod nauplii 87.0
Eggs 22.9
Fish 117.8
20 40 60 80
% Frequency

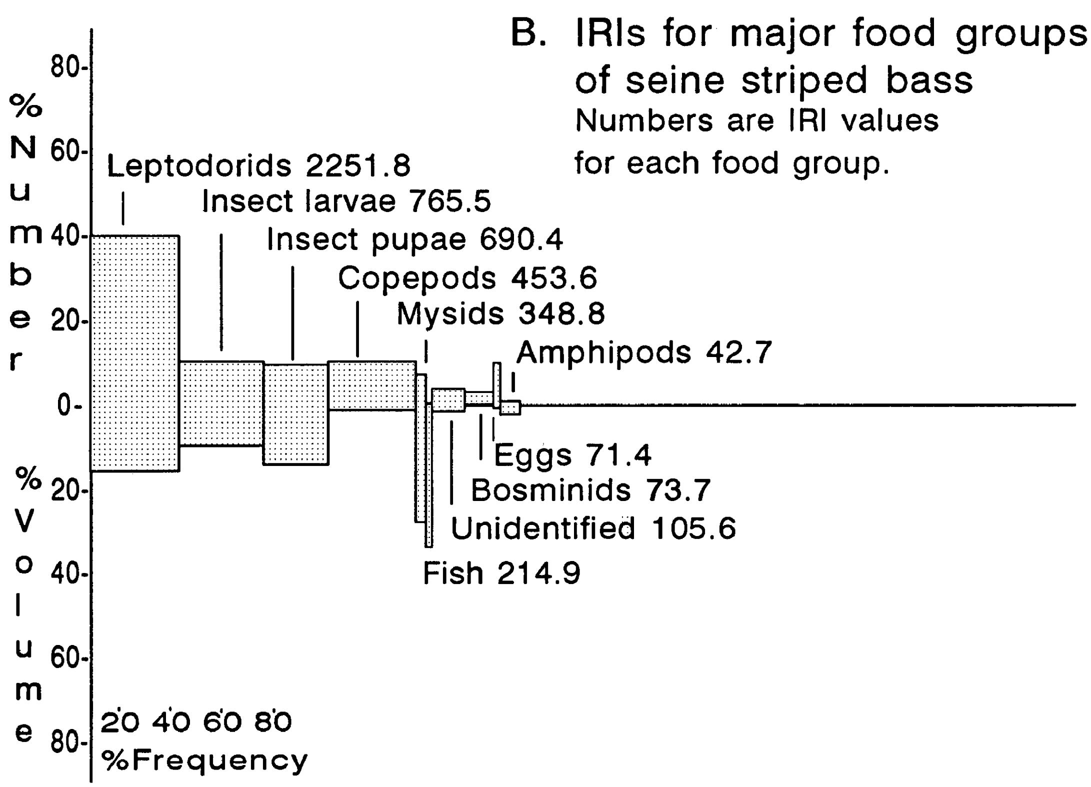
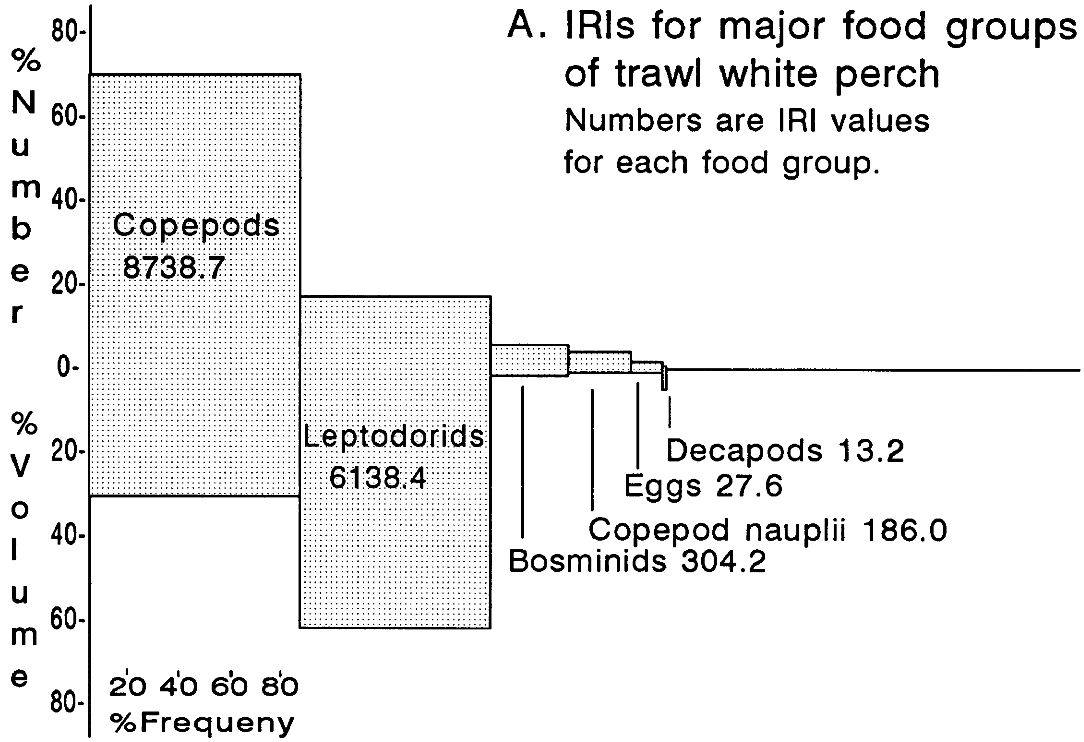

B. IRIs for major food groups of seine striped bass
Numbers are IRI values for each food group.
% Number
% Volume
80- 60- 40- 20- 0- 20- 40- 60- 80-
Leptodorids 2251.8
Insect larvae 765.5
Insect pupae 690.4
Copepods 453.6
Mysids 348.8
Amphipods 42.7
Eggs 71.4
Bosminids 73.7
Unidentified 105.6
Fish 214.9
20 40 60 80
%Frequency

Figure 6. Percent frequency of occurrence, numerical percentage, volumetric percentage, and indices of relative importance for major food groups of trawl white perch and seine white perch.


A. IRIs for major food groups of trawl white perch
Numbers are IRI values for each food group.
%Number
%Volume
80-
60-
40-
20-
0-
20-
40-
60-
80-
Copepods 8738.7
Leptodorids 6138.4
Bosminids 304.2
Copepod nauplii 186.0
Eggs 27.6
Decapods 13.2
20 40 60 80
%Frequeny

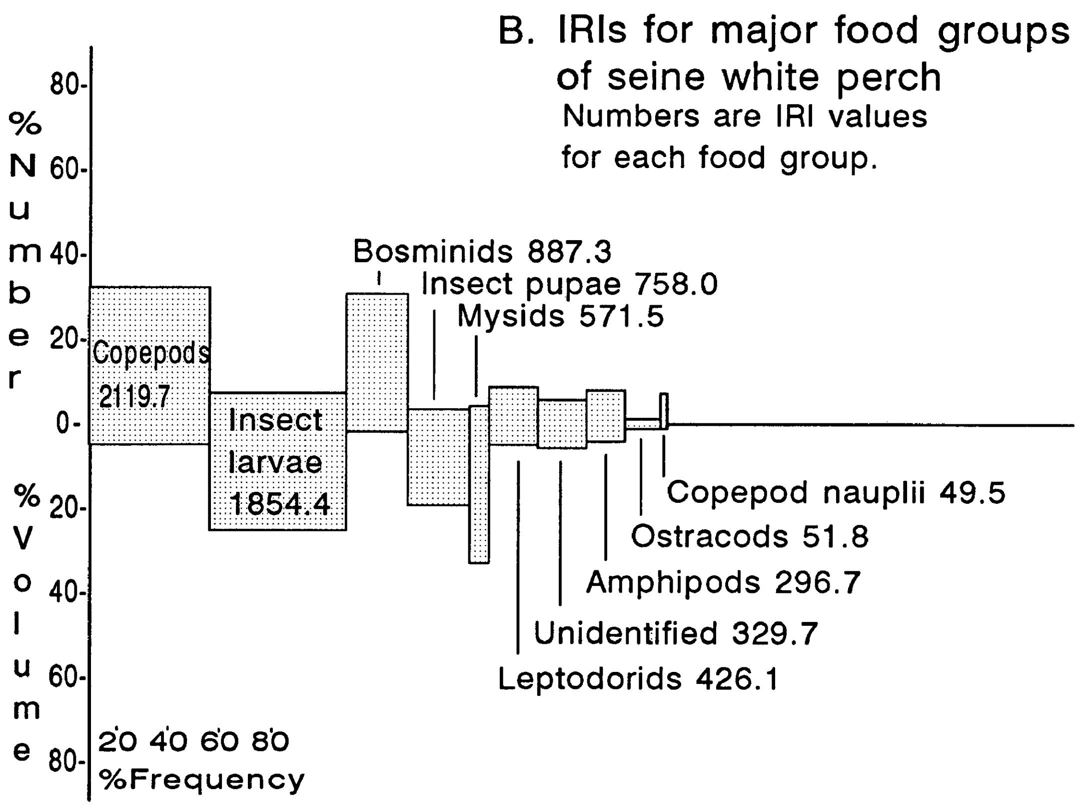

B. IRIs for major food groups of seine white perch
Numbers are IRI values for each food group.
%Number
%Volume
80-
60-
40-
20-
0-
20-
40-
60-
80-
Copepods 2119.7
Insect larvae 1854.4
Bosminids 887.3
Insect pupae 758.0
Mysids 571.5
Leptodorids 426.1
Unidentified 329.7
Amphipods 296.7
Ostracods 51.8
Copepod nauplii 49.5
20 40 60 80
%Frequency

Table 7. Intraspecific index of relative fullness (IRF) comparisons for striped bass.

H_0: Feeding success is independent of time of capture or location of capture.
H_a: Feeding success is associated with time of capture or location of capture.

Comparison	Mean IRF	χ^2	p	Conclusion
1. Day	0.379			
Twilight	0.481	4.249	0.1<p<0.25	Don't reject H_0
Night	0.312			
2. Pushnets	0.348			
Seine	0.457	1.060	0.5<p	Don't reject H_0
Trawl	0.350			
3. Seine	0.457	0.382	0.5<p	Don't reject H_0
Trawl	0.350			
4. Other gears	0.494	0.582	0.25<p<0.5	Don't reject H_0
Seine	0.314			
5. Seine, Day	0.413			
Seine, Twi.	0.656	1.618	0.25<p<0.5	Don't reject H_0
Seine, Nite	0.386			
6. Trawl, Day	0.382			
Trawl, Twi.	0.368	3.768	0.1<p<0.25	Don't reject H_0
Trawl, Nite	0.275			

Figure 7. Temporal indices of relative fullness for striped bass.

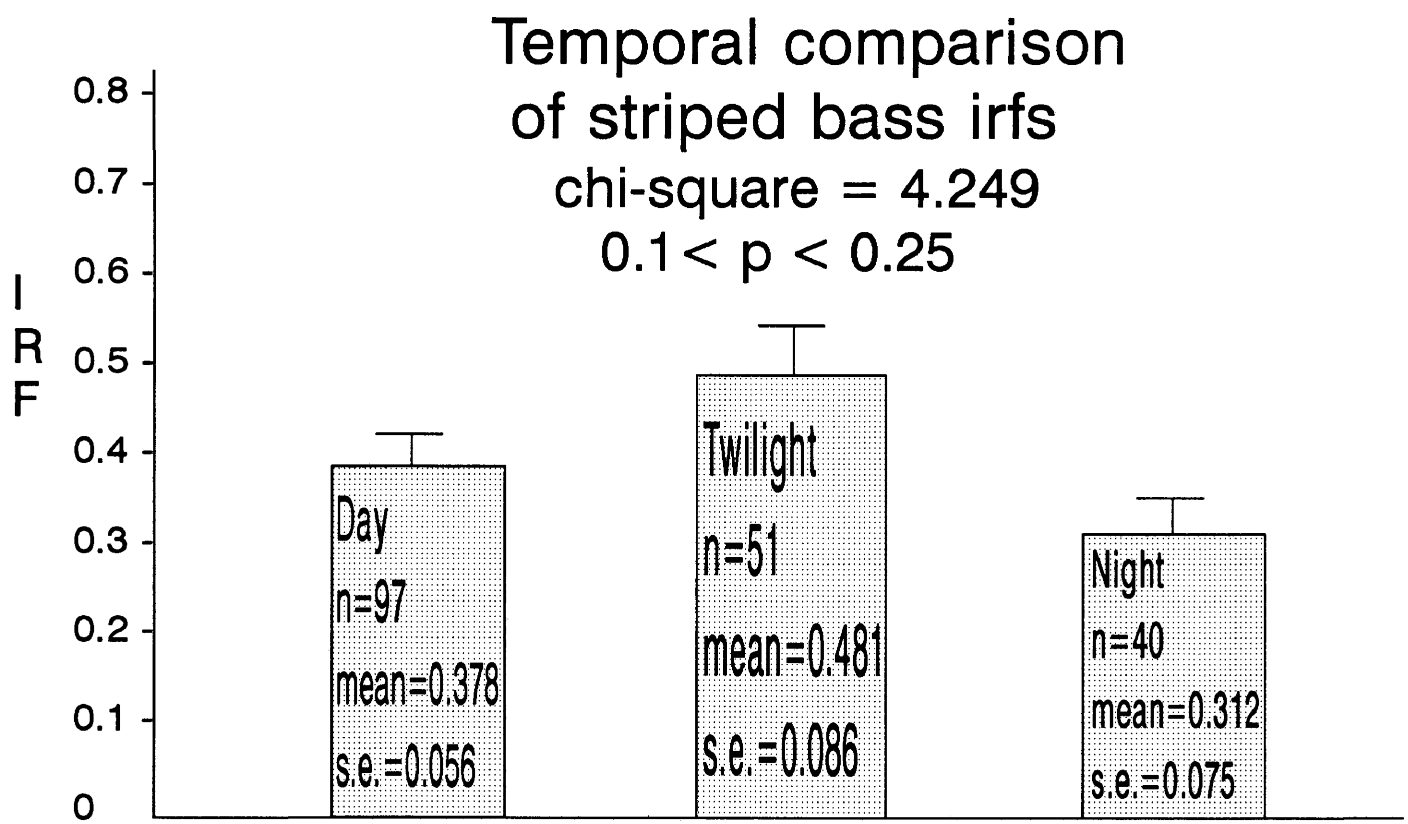
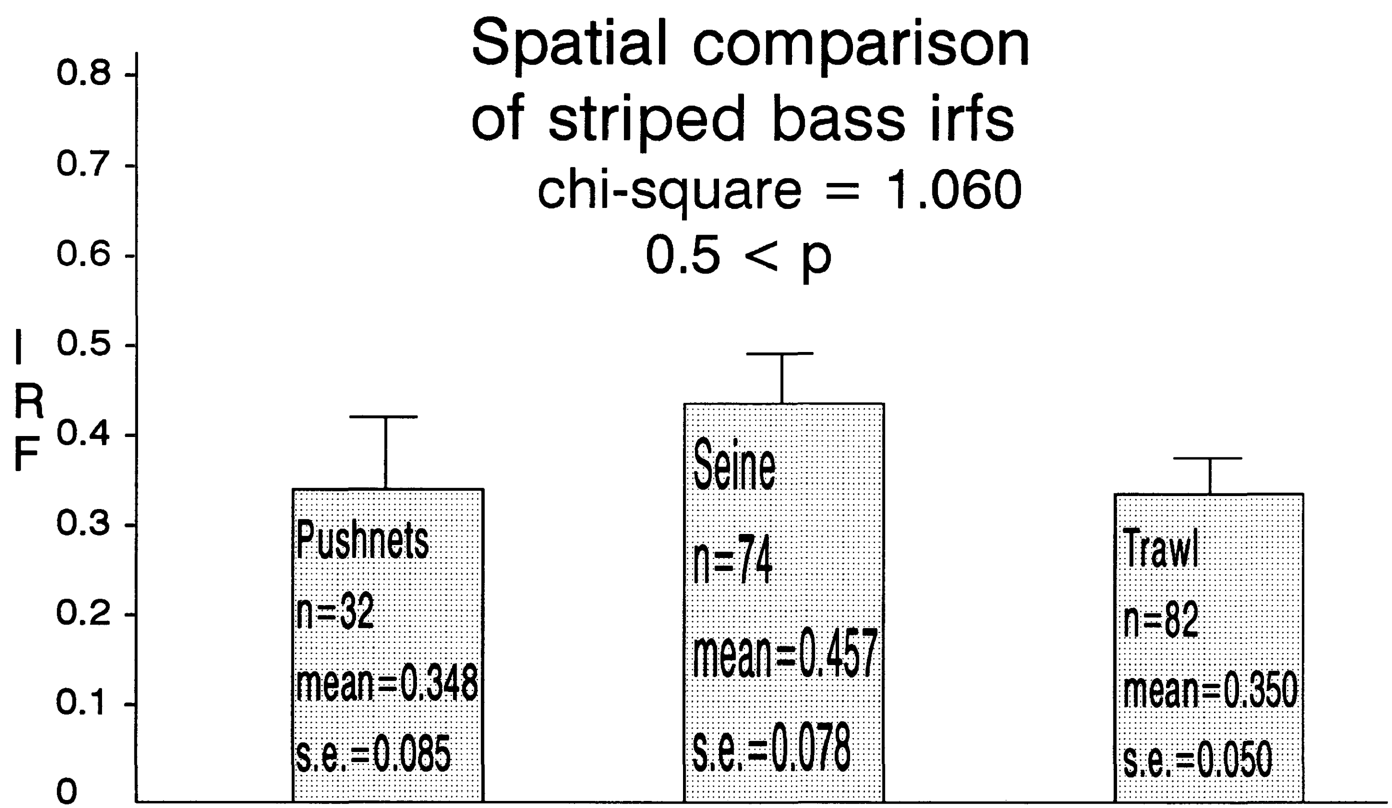

Temporal comparison
of striped bass irfs
chi-square = 4.249
0.1< p < 0.25
IRF
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Day
n=97
mean=0.378
s.e.=0.056
Twilight
n=51
mean=0.481
s.e.=0.086
Night
n=40
mean=0.312
s.e.=0.075

Figure 8. Spatial indices of relative fullness for striped bass.


Spatial comparison
of striped bass irfs
chi-square = 1.060
0.5 < p
IRF
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Pushnets
n=32
mean=0.348
s.e.=0.085
Seine
n=74
mean=0.457
s.e.=0.078
Trawl
n=82
mean=0.350
s.e.=0.050

Feeding success of white perch was also associated with location of capture (χ^2=14.811; $p<0.001$), with the frequency of pushnet white perch having IRFs ≥ the average IRF being greater than the frequency for seine or trawl white perch. The frequency of white perch captured by the vessel-deployed gears having IRFs ≥ the average IRF was significantly greater than the frequency for seine white perch (χ^2=4.433; $0.025<p<0.05$). Table 8 summarizes the test results for white perch IRF comparisons, while temporal and spatial IRF comparisons for white perch are depicted in Figures 9 and 10, respectively.

Feeding success was associated with species for the specimens captured by the pushnets (χ^2=4.897; $0.025<p<0.05$), with the frequency of pushnet white perch having IRFs ≥ the average IRF being greater than the frequency for pushnet striped bass. All other interspecific temporal and spatial IRF comparisons were not significant. Table 9 summarizes the test results for the interspecific IRF comparisons. Interspecific temporal and spatial IRF comparisons are depicted in Figues 11 and 12, respectively.

Examining results of the striped bass stepwise regression, salinity was found to be significantly and positively related to feeding success at α=0.05. The adjusted R^2 was 0.12. The fitted equation was:

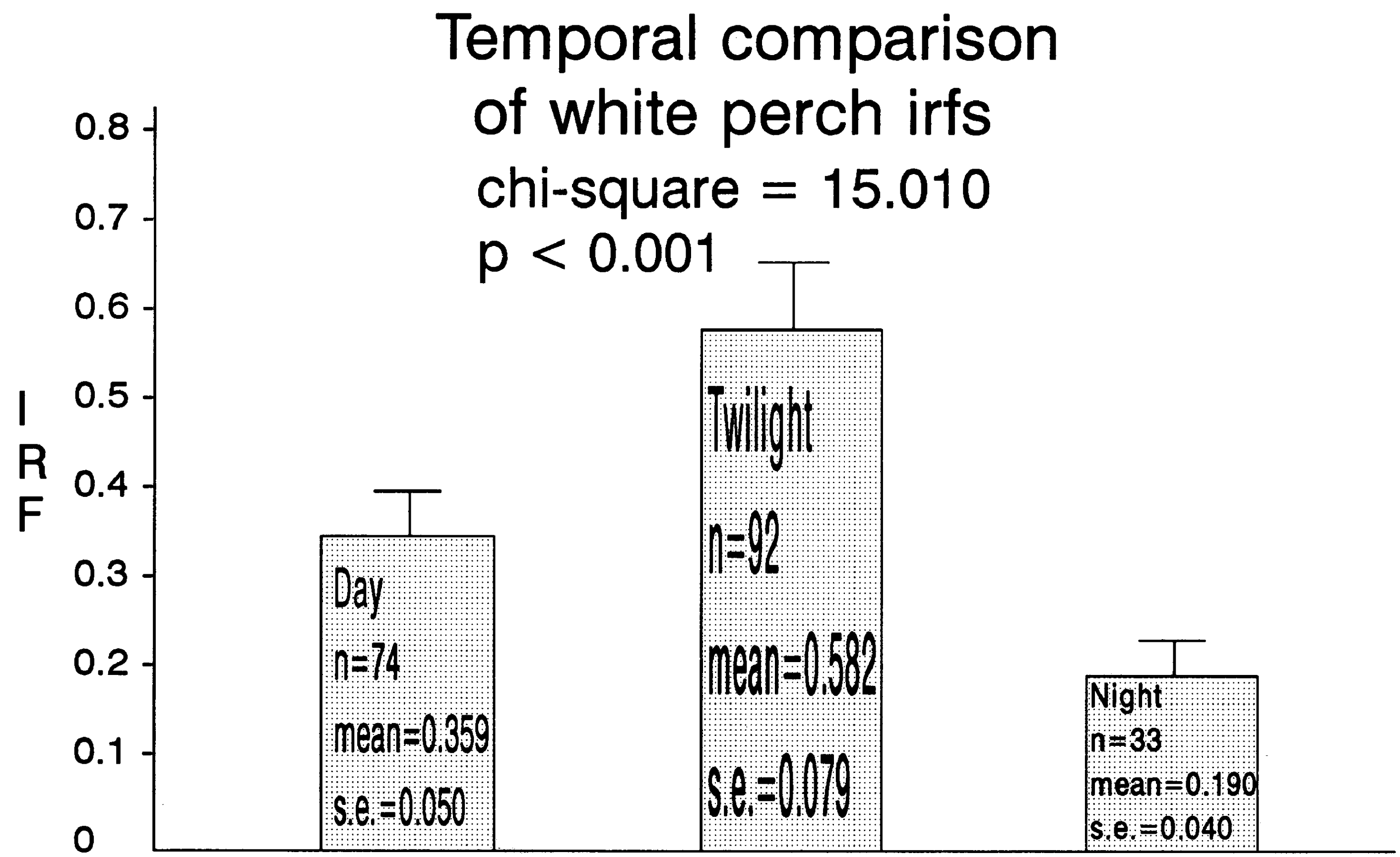
$$Y = \underset{(t=8.87)}{0.346} + \underset{(t=5.021)}{0.235\ S}$$

Table 8. Intraspecific index of relative fullness (IRF) comparisons for white perch.

H_0: Feeding success is independent of time of capture or location of capture.
H_a: Feeding success is associated with time of capture or location of capture.

Comparison	Mean IRF	χ^2	p	Conclusion
1. Day	0.379			
Twilight	0.582	15.010	$p<0.001$	Reject H_0
Night	0.190			
2. Pushnets	0.727			
Seine	0.314	14.811	$p<0.001$	Reject H_0
Trawl	0.292			
3. Seine	0.457	0.399	$0.5<p$	Don't reject H_0
Trawl	0.350			
4. Other gears	0.494	4.433	$0.025<p<0.05$	Reject H_0
Seine	0.314			
5. Seine, Day	0.378			
Seine, Twi.	0.174	3.039	$0.1<p<0.25$	Don't reject H_0
Seine, Nite	0.228			
6. Trawl, Day	0.352			
Trawl, Twi.	0.309	7.104	$0.025<p<0.05$	Reject H_0
Trawl, Nite	0.154			

Figure 9. Temporal indices of relative fullness for white perch.



Temporal comparison
of white perch irfs
chi-square = 15.010
p < 0.001
IRF
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Day
n=74
mean=0.359
s.e.=0.050
Twilight
n=92
mean=0.582
s.e.=0.079
Night
n=33
mean=0.190
s.e.=0.040

Figure 10. Spatial indices of relative fullness for white perch.

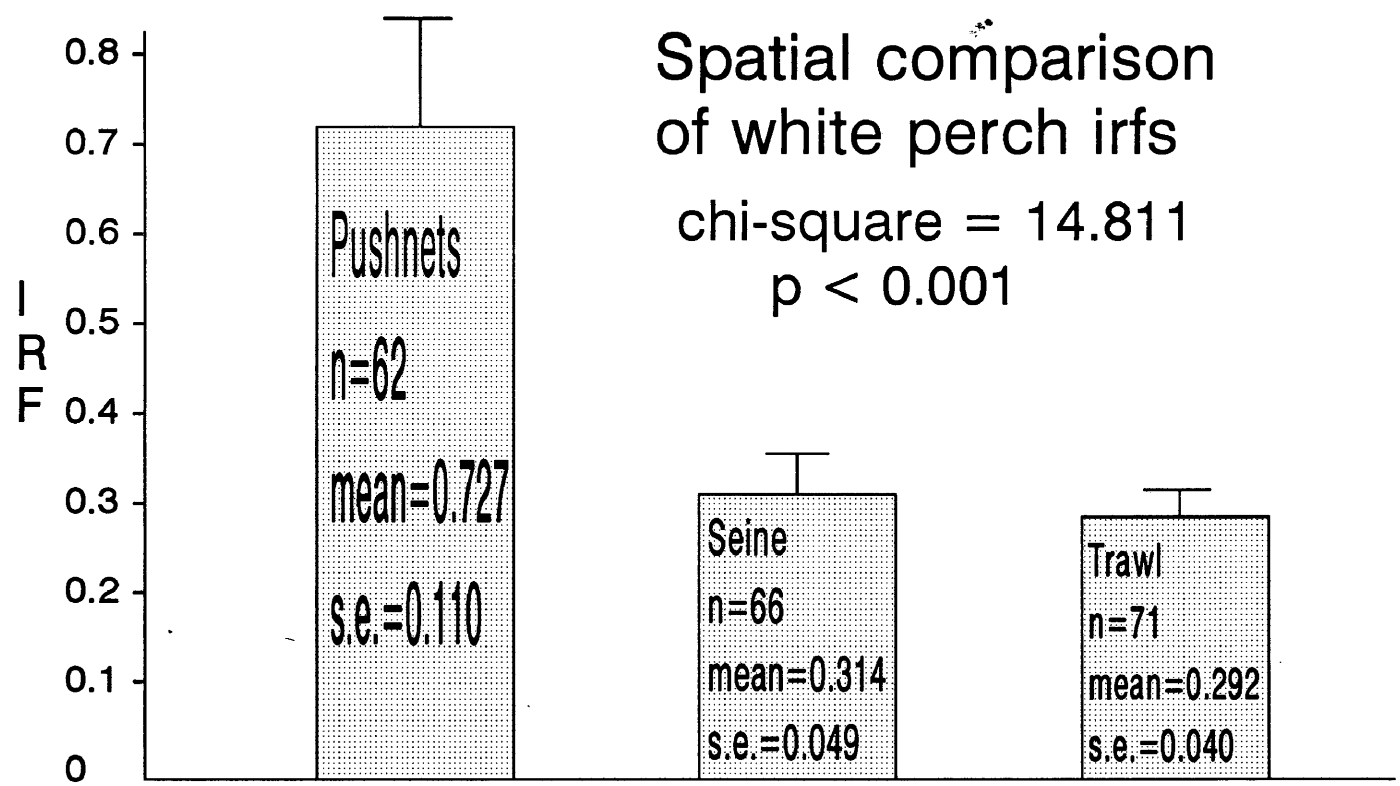

Spatial comparison
of white perch irfs
chi-square = 14.811
p < 0.001
IRF
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Pushnets
n=62
mean=0.727
s.e.=0.110
Seine
n=66
mean=0.314
s.e.=0.049
Trawl
n=71
mean=0.292
s.e.=0.040

Table 9. Interspecific index of relative fullness (IRF) comparisons between striped bass and white perch.

H_0 Feeding success is independent of species.
H_a Feeding success is associated with species.

Comparison	Mean IRF	χ^2	p	Conclusion
1. All bass	0.391	0.246	0.5<p	Don't reject H_0
All perch	0.435			
2. Day bass	0.379	0.284	0.5<p	Don't reject H_0
Day perch	0.359			
3. Twi. bass	0.481	0.449	0.5<p	Don't reject H_0
Twi. perch	0.582			
4. Nite bass	0.312	2.929	0.05<p<0.1	Don't reject H_0
Nite perch	0.192			
5. Trawl bass	0.350	1.711	0.1<p<0.25	Don't reject H_0
Trawl perch	0.292			
6. Seine bass	0.455	2.593	0.1<p<0.25	Don't reject H_0
Seine perch	0.314			
7. Pushnet bass	0.348	4.897	0.025<p<0.05	Reject H_0
Pushnet perch	0.727			
8. Pushnet and trawl bass	0.349	3.566	0.05<p<0.1	Don't reject H_0
Pushnet and trawl perch	0.495			
9. Day trawl b.	0.382	0.659	0.25<p<0.5	Don't reject H_0
Day trawl p.	0.352			
10. Twi trawl b.	0.368	0.142	0.5<p	Don't reject H_0
Twi trawl p.	0.311			
11. Nite trawl b.	0.275	0.372	0.5<p	Don't reject H_0
Nite trawl p.	0.154			
12. Day seine b.	0.414	0.008	0.5<p	Don't reject H_0
Day seine p.	0.367			
13. Twi. seine b.	0.656	3.360	0.05<p<0.1	Don't reject H_0
Twi. seine p.	0.174			
14. Nite seine b.	0.374	2.519	0.1<p<0.25	Don't reject H_0
Nite seine p.	0.228			

Figure 11. Interspecific comparisons between striped bass and white perch IRFs by time of day.

Interspecific comparisons of striped bass and white perch irfs by time of day.

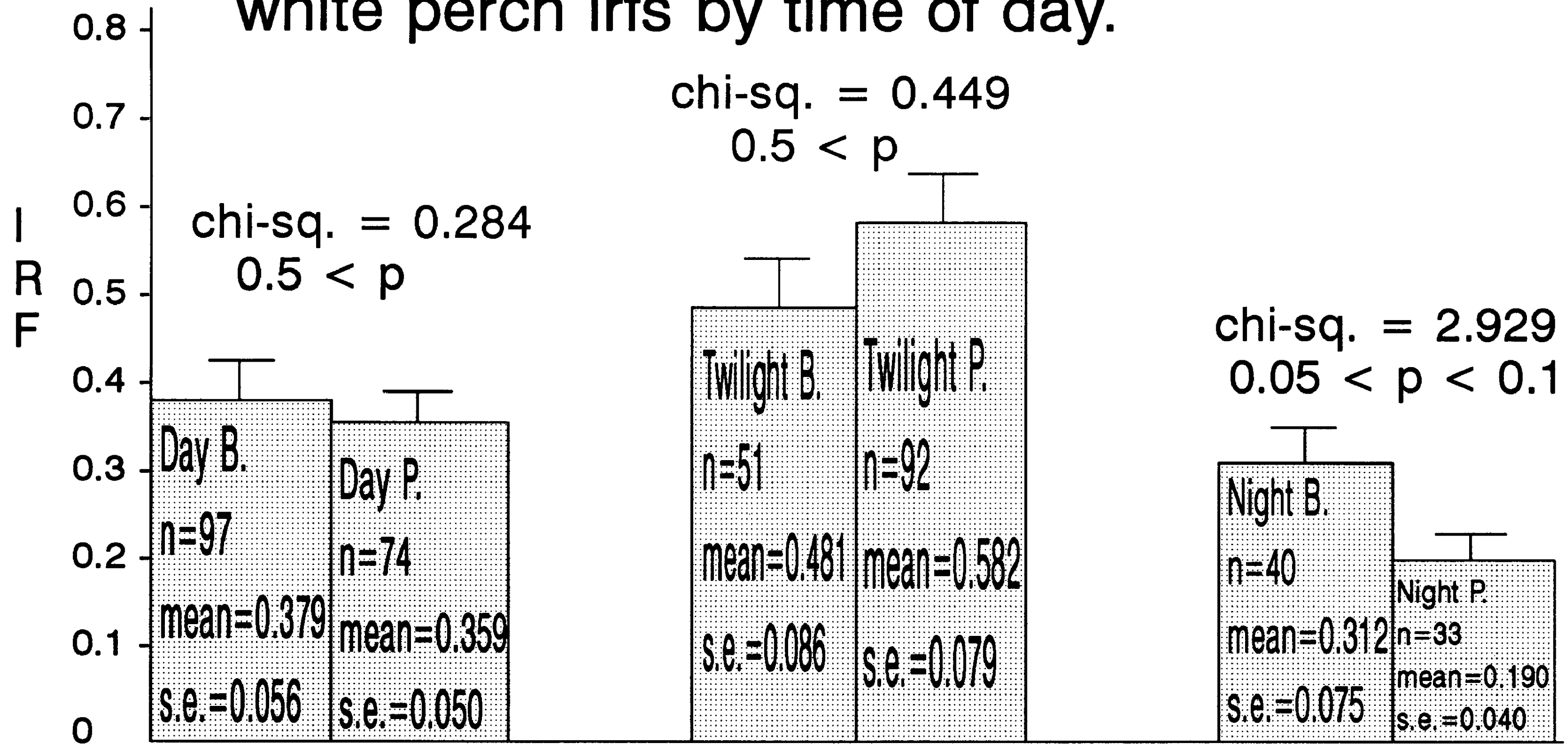
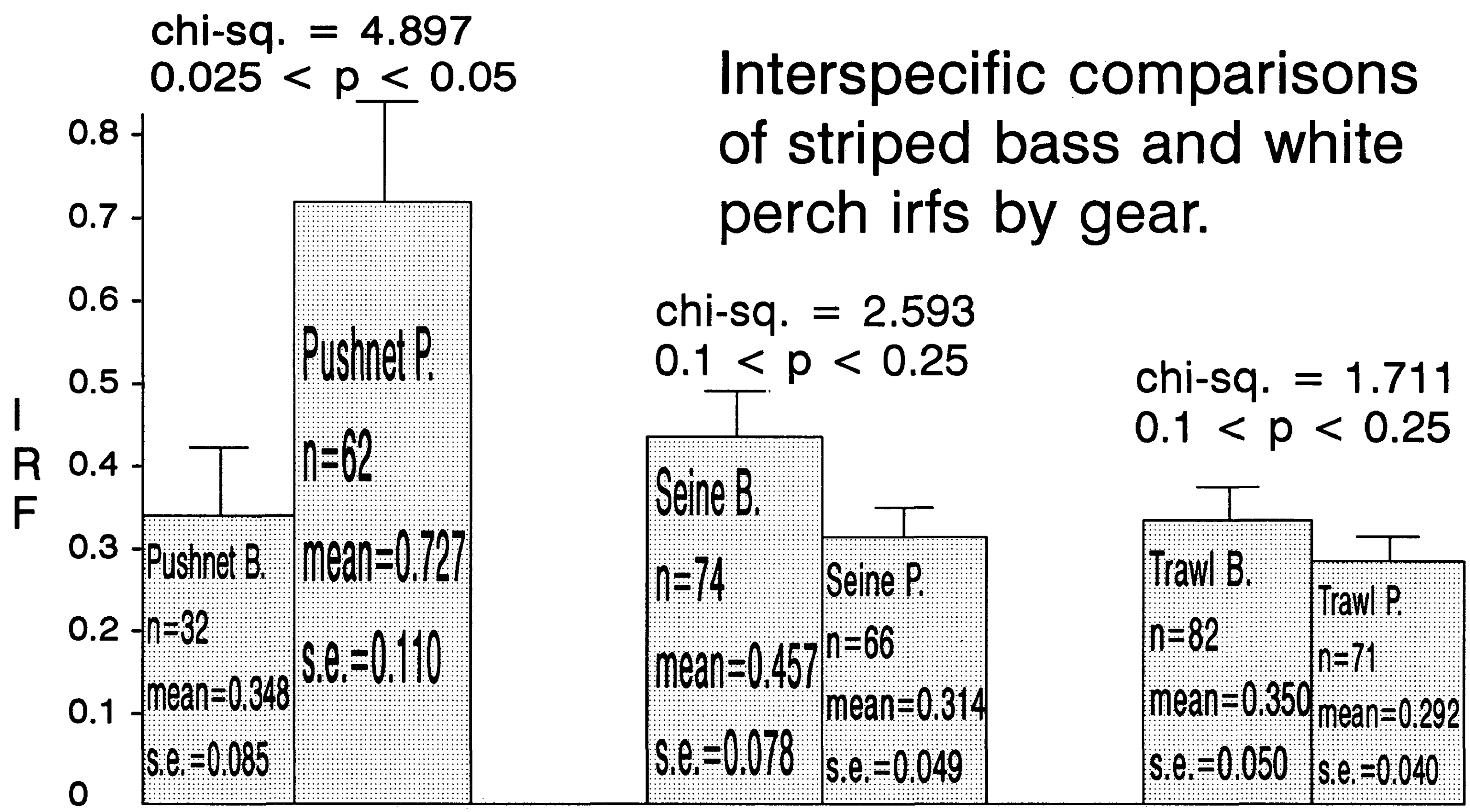


Figure 12. Interspecific comparisons between striped bass and white perch IRFs by gear.


Interspecific comparisons of striped bass and white perch irfs by gear.
chi-sq. = 4.897
0.025 < p < 0.05
chi-sq. = 2.593
0.1 < p < 0.25
chi-sq. = 1.711
0.1 < p < 0.25
IRF
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Pushnet B. n=32 mean=0.348 s.e.=0.085
Pushnet P. n=62 mean=0.727 s.e.=0.110
Seine B. n=74 mean=0.457 s.e.=0.078
Seine P. n=66 mean=0.314 s.e.=0.049
Trawl B. n=82 mean=0.350 s.e.=0.050
Trawl P. n=71 mean=0.292 s.e.=0.040

where Y is the fitted IRF value, 0.346 is the constant α, and 0.235 is the regression coefficient, β, for salinity, S.

For white perch, a fast current speed had a significant, positive relationship with feeding success while temperature had a significant, negative relationship with feeding success at α=0.05. The adjusted R^2 was 0.26. The fitted equation was:

$$\underset{(t=2.838)}{Y = 1.149} + \underset{(t=8.364)}{0.779\ FCS} - \underset{(t=2.301)}{0.044\ T}$$

where Y is the fitted IRF value, 1.149 is the constant, α, and 0.779 and -0.044 are partial regression coefficients, β_i's, for fast current speed and temperature, respectively. Stepwise regression results are summarized in Table 10.

The average of 0.010 striped bass per meter of net for this study's beach seine was significantly different from the average of 0.024 striped bass per meter of net for the VIMS beach seine (U=3313; $p<0.0005$). While this study's 15.24 m seine captured an average of 0.961 striped bass per haul, the VIMS survey captured an average of 2.417 striped bass per 30.48 m haul at the index stations in the James River in 1992 (Colvocoresses et al. 1993).

There was no significant difference between the average number of striped bass and white perch caught at night by both pushnets in this study and the average number of striped bass and white perch caught at night by the VIMS

Table 10. Results of striped bass and white perch stepwise regressions.

A. Striped bass stepwise regression.

Dependent variable: striped bass indices of relative fullness.

Independent variables considered: light, temperature, salinity, secchi depth, water height, and current speed (fast, medium, slow, or zero).

Results:

r^2=0.119 adjusted r^2=0.115 std. error of estimate=0.515

variable	coef.	std. e.	std coef.	Tol.	T	P
constant	0.346	0.039	0.000	-	8.873	0.000
salinity	0.235	0.047	0.345	1.000	5.021	0.000

ANOVA

source	sum squares	df	mean sq.	F	P
regression	6.826	1	6.826	25.207	0.000
residual	50.365	186	0.271		

B. White perch stepwise regression.

Dependent variable: white perch indices of relative fullness

Independent variables considered: light, temperature, salinity, secchi depth, water height, and current speed (fast, medium, slow, or zero).

Results:

r^2=0.268 adjusted r^2=0.260 std. err. of estimate=0.518

variable	coef.	std. e.	std coef.	Tol.	T	P
constant	1.499	0.528	0.000	-	2.838	0.005
fast current	0.779	0.093	0.515	0.986	8.364	0.000
temperature	-0.044	0.019	-0.142	0.986	-2.301	0.022

ANOVA

source	sum squares	df	mean sq.	F	P
regression	19.212	2	9.606	35.830	0.000
residual	52.548	196	0.268		

Alosa survey in the James River in 1992 (U=4390; p=0.073 for striped bass, and U=4068; p=0.573 for white perch).

There was no observed linear relationship between any year's catch of striped bass at the James River index stations and: 1) average monthly water temperature for the months March through June; 2) coefficients of variation for each month's water temperature; and 3) the total drop in each month's water temperature. Appendix 3 summarizes these results.

There was no observed linear relationship between the number of YOY striped bass captured at the James River index stations and James River flow for the 12 months prior to each year's striped bass survey. Similarly, there was no observed relationship between the number of YOY striped bass captured at the James River index stations and James River flow for the six months prior to each year's survey. Appendix 4 summarizes these results.

DISCUSSION

The average number of striped bass per meter of seine in this study was fewer than the average per meter of seine by the VIMS seining survey in James River in 1992. However, the nighttime pushnet catches of striped bass and white perch in this study are comparable, respectively, to the nighttime catches of striped bass and white perch by the VIMS *Alosa* survey in James River in 1992.

The low catches of YOY striped bass in the James River in this study are consistent with YOY striped bass population data collected by Colvocoresses et al. (1993) who caught less than the average number of YOY striped bass in the James River in 1992. For the index stations in the James River, the scaled geometric average of 3.71 striped bass per VIMS haul in 1992 was below the 1991 average of 4.50, and below the river's 20 year scaled geometric average of 5.37. The steadily decreasing catch rate of striped bass throughout the summer in this study parallels typical findings of the VIMS juvenile striped bass seining survey (Colvocoresses 1990).

A similar trend was found in the comparison between 1991 and 1992 June through August nighttime pushnet collections made by the VIMS *Alosa* survey in James River. The average of 0.070 striped bass and 0.013 white perch in

1992 was significantly different (U=24094; p<0.0005, and U=20458; p=0.035, respectively) than the average of 1.138 striped bass and 0.052 white perch in 1991 (unpubl. data).

A combination of several factors may have led to the relatively low catches of striped bass and white perch in this study (and other studies) in the James River in 1992. These factors include patchiness (McGovern and Olney 1988), gear avoidance, downstream drift or dispersal from the sampling area (Raney 1952; Calhoun 1953; Sasaki 1966; Markle and Grant 1970; Rinaldo 1971; Turner and Chadwick 1972; Boynton et al. 1977; Kernehan et. al 1981; Kline 1990), and relatively poor year-class success.

The patchiness and schooling behavior of YOY striped bass has been reported by Abbott (1878) and Calhoun (1953), who found that juvenile striped bass school at approximately 25 mm and longer. Eighty-three (44%) of the striped bass in this study were captured in 11 (4%) of the 300 collections. Young white perch also appear to exhibit patchiness and schooling. Ninety-two (46%) of the white perch of this study were captured in 6 (2%) of the collections. The patchiness of both species may have contributed to the relatively low catches, a condition that may have been rectified at least for striped bass if sampling had been expanded outside of the historical center of YOY striped bass abundance in the James River. Colvocoresses et al. (1993) found no consistent center of abundance of YOY striped bass in 1992 in the James River, with catches often being higher at the upper and lower ends of the survey area than in the central reaches. Although patchiness may have contributed to the low catches, the intensity of this study's sampling (300 collections) over a nine week period should have reduced the effects of patchiness.

Gear avoidance may have also contributed to the low catches. Because of its ability to be handled by two persons, a 15.24 m seine was used in this study instead of a 30.48 m seine that the VIMS survey employs. Some larger juvenile striped bass and white perch may have escaped this study's seine by swimming the length of the seine before the outer brail was fully ashore. Kline (1990) suggested that YOY striped bass are fully recruited to a 30.48 m long, 1.22 m high, beach seine with 6.4 mm mesh at approximately 60 days of age, and are no longer fully recruited to the gear after about 90 days of age. Considering the shorter length of the seine used in this study, and that striped bass spawn in the James River between late April and early May (Grant and Olney 1990), gear avoidance by larger YOY striped bass and white perch may have contributed to reduced catch rates, particularly as the sampling season progressed.

The other two gears used in this study, an otter trawl and a pushnet, have been proven to catch juvenile striped bass. Kernehan et al. (1981) towed a comparably sized otter trawl (3 m mouth diameter, 6.4 mm mesh) to catch an average of 7.53 post larval and early juvenile striped bass per 10 minute collection in the Elk and Bohemia Rivers, Maryland. The pushnet, used at night in channel of the Rappahannock River in 1992 for the VIMS *Alosa* survey, caught an average of 1.54 striped bass and 0.56 white perch per collection compared to this study's average of 0.11 striped bass and 0 white perch in 36 nighttime channel and shoal pushnet collections in the James River. The high average nighttime pushnet catches of striped bass in the Rappahannock River in 1992 (compared to this study's 1992 James River nighttime pushnet catches and the VIMS *Alosa* survey pushnet catches of striped bass in James River in 1992) parallel the average of 28.740 striped bass per haul by Colvocoresses et al. (1993) at the Rappahannock River index stations in 1992. Therefore, the pushnet and otter trawl appear to be relatively effective for capturing YOY striped bass.

Downstream drift of YOY bass has been noted by several authors (Raney 1952; Calhoun 1953; Sasaki 1966; Markle and Grant 1970; Rinaldo 1971; Turner and Chadwick 1972; Boynton et al. 1977; Kernehan et. al 1981; Kline 1990), and may have also contributed to the low catches of both species. Highest catch rates of YOY striped bass in the James River are normally observed close the center of the sampling area of the VIMS index stations (Colvocoresses et al. 1993). Yet there was no indication of a consistent center of abundance of YOY bass in the James River in 1992 (Colvocoresses et al.

1993). Particularly as the sampling season progressed, downstream drift may have worked in combination with gear avoidance to reduce catches of striped bass and white perch in this study.

The most plausible explanation for low catches of striped bass is relatively poor year class success in the James River in 1992. The low catches of white perch are also likely because of relatively poor year class success. The suggestion of poor striped bass year class strength is consistent with the lower than average catches by Colvocoresses et al. (1993). That a seine survey can indicate year class strength was confirmed by Chadwick (1964), who found a direct relationship between abundance of YOY striped bass and their recruitment to a beach seine. Additionally, Goodyear (1985) found strong evidence that the Maryland YOY striped bass index was a good estimator of year-class strength of striped bass produced in Maryland waters of the Chesapeake Bay.

Although Colvocoresses et al. (1993) cited the six year pattern of higher-than-average YOY striped bass catches in Virginia tributaries as coinciding with possible increases in spawning stock due to harvest reductions, striped bass year-class strength appears to be largely attributable to a number of density-independent factors that directly or indirectly affect survival of eggs and larvae (Ulancowicz and Polgar 1980; Boynton et al. 1981; Logan 1985; Uphoff

1989). Density-dependent factors can be overshadowed by density-independent food availability (Boynton et al. 1981) which is primarily a function of environmental conditions, including temperature, salinity, dissolved oxygen, and eutrophication that govern prey populations (Mansueti 1961; May 1974). It is often difficult to determine which factors or combination of factors are most important in any given year (McGovern 1991).

Factors such as sudden temperature changes or decreases in water temperature during larval development may cause high mortality (Hollis 1967; Dey 1981; Kernehan et al. 1981). Water temperature is perhaps the most important factor determining striped bass year class strength (Dey 1981). Rapidly changing or fluctuating water temperatures cause metabolic stress and reduce densities of zooplankton that larvae feed on (Dey 1981). In turn, low prey densities lead to poor survival and growth (Ware 1975) as striped bass larvae become increasingly dependent on their ability to detect and capture distant prey in order to fulfill their nutritional requirements (Breitburg 1988). Crance (1984) found that a temperature below 12°C is lethal to striped bass larvae. Water flow, which is often inversely correlated with water temperature, has an ambiguous effect on year-class success. While Uphoff (1989) found that striped bass larval mortality in the Choptank River, Maryland was positively correlated with rainfall and river flow, Boynton et al. (1977) reported that in the Potomac River dominant year classes occurred with colder-than-normal winters and greater-than-normal spring river flows. It is likely that striped bass year class success is attributable to unique factors or combinations of factors in each of Chesapeake Bay's major striped bass spawning tributaries. Although James River striped bass catches had no significant relationship with water temperature or river flow, combinations of these density-independent factors and density-dependent factors may have contributed to the relatively low catches of YOY striped bass in the James River in 1992.

Year-class strength may also be due to density-dependent phenomena (Kline 1990; McGovern 1991) such as predation on young striped bass by other species (Christensen et al. 1977), cannibalism (McGovern and Olney 1988), and competition for food (Christensen et al. 1977; Kline 1990). Boynton et al. (1981) found that fish replaced insect larvae as the dominant food item of juvenile striped bass in some areas of the Potomac River. Thus slow-growing or late-spawned striped bass might cannibalized be within the duration of a normal spawning season (McGovern and Olney 1988). Fluctuations in water temperature may lower populations of zooplankton upon which larval and juvenile striped bass feed (Kernehan et al. 1981), which may decrease striped bass survival rates (Rulifson 1985). The availability and size of suitable zooplankton during the period when striped bass larvae switch from endogenous to exogenous nutrition could be important to year class strength (Kernehan et al. 1981). This condition of abnormal temperatures may have increased the rate of intra- and interspecific predation, cannibalism, and competition for food.

While the average 1992 James River striped bass catch by the VIMS survey was below the historical average, the Rappahannock River's 1992 average of 30.92 was well above its average of 5.17. The spring of 1992 was relatively cold. VIMS temperature data indicate that the average daily water temperature during May, 1992 at Gloucester Point was 1.5°C below the average May temperature for years 1980-84, 1986, and 1988-92, while the average daily water temperature during June, 1992 was 2.0°C below the average June temperature for the years 1980-81, 1983, 1986, and 1988-92. (VIMS, unpubl. data). A cold period during the spring of 1992 may have depressed zooplankton populations and led to decreased growth and survival rates of larval striped bass in the James River.

The Rappahannock River, approximately 80 km north of the James River, likely experienced many of the same environmental conditions as the James River during the winter and spring of 1992. Yet the critical temperature to trigger striped bass spawning may not have been reached in the Rappahannock River until unseasonably cold weather had passed. Although the water temperature between the nontidal and the tidal portions of the Bay's tributaries may be very different, the Rappahannock River water temperature averaged 1.2°C colder than the temperature in the James River over the ten times when the temperatures at the nontidal Rappahannock River site (Fredericksburg) and the nontidal James River site (Cartersville) were taken within 15 minutes of each other from 1989-92 (U.S. Geological Survey Water Resources Data, VA). Striped bass in the Rappahannock may have waited to spawn until seasonal temperatures returned in late spring.

Although striped bass and white perch captured by seine were significantly longer, respectively, than striped bass and white perch captured by trawl, it is unclear whether these intraspecific size differences were due to a true migration, avoidance of the trawl, or a combination of these factors. As larvae, striped bass and white perch are planktonic, and appear to show a shoreward migration as they become nektonic juveniles. This evidence of a shoreward movement by young striped bass supports research by Dey (1981) and Setzler-Hamilton et al. (1981), who found that post-larval and juvenile striped bass can maintain longitudinal position within tidal rivers. Boynton et al. (1977) found a greater abundance of YOY striped bass and higher feeding success (weight of food items per individual) at nearshore collection sights in the Potomac River. Boynton et al. (1977) felt that these findings indicated that nearshore areas were the preferred habitat of YOY striped bass. Additionally, Dey (1981) found in the Hudson River that post-larval and juvenile striped bass moved shoreward and onto shoal areas, and Kernehan et al. (1981) found that progressively larger striped bass were taken closer to shore in upper Chesapeake Bay nursery areas.

This study's findings of shoreward movements of both species may be due to the nature of the sampling gear. There is an indication that striped bass and white perch are able to avoid capture by vessel-deployed gear at an earlier age than a seine. After striped bass and white perch became available to a pushnet at night in the Rappahannock River in 1992, the June-July averages of 2.18 striped bass and 0.83 white perch were significantly different, respectively, than the August averages of 0.34 striped bass and 0.02 white perch ($U=3909$; $p=0.024$; and $U=4044$; $p<0.0005$, respectively) (VIMS *Alosa* survey, unpubl. data). Despite these differences in pushnet catches, a seine continued to catch striped bass into September at upper Rappahannock River sites (Colvocoresses et al. 1993). It is likely that in this study older striped bass and white perch were less susceptible to capture by the trawl but still were available to the seine.

Striped bass and white perch captured by the trawl used in this study had diets consisting principally of zooplankton. Although zooplankton remained important in the diets of striped bass and white perch captured by seine, epibenthic organisms such as insect larvae, insect pupae, and mysids contributed substantially to the diets of seine specimens. The Shannon-Weaver index found that striped bass and white perch captured by seine had significantly more diverse diets, respectively, than striped bass and white perch captured by trawl. Older, more mobile striped bass and white perch begin to consume larger, epibenthic prey items presumably to more efficiently meet greater nutritional requirements (Elrod et al. 1981). The finding that striped bass and white perch fed to a large degree on epibenthic prey is consistent with other research on YOY striped bass feeding (Markle and Grant 1970; Bason 1971) and YOY white perch feeding (Hildebrand and Schroeder 1928; Elrod et al. 1981; Bath and O'Conner 1985; Weisberg and Janicki; 1990). These dietary changes may have also been related to seasonal abundance and availability of specific food items (Calhoun 1953; Thomas 1967).

Notably lacking in the diets were soft-bodied planktonic prey such as rotifers. Despite the availability of rotifers in plankton samples that were simultaneously conducted with the shoal pushnet sampling, no rotifers could be positively identified as stomach contents of any of the striped bass or white perch captured in this study.

Skewness of a food habits study may be due, in part, to the rapid digestion of soft-bodied prey (McGovern and Olney 1988).

Although there were no significant intraspecific IRF differences between seine and trawl specimens in this study, Boynton et al. (1981) found higher striped bass feeding success (weight of food items per individual) at nearshore collection sights in the Potomac River. The number of striped bass that survive in a particular year may be proportional to the number of postlarvae and early young that reach these areas (Kernehan et al. 1981), which may be due in part to the changing dietary needs of striped bass as they grow. Additionally, it is likely that young striped bass and white perch have fewer predators nearshore than in the channels of tidal rivers. White perch likely use nearshore reasons for similar reasons as striped bass.

The similarity in feeding niches between young striped bass and white perch is shown by a high value for the Horn's index of overlap, a highly significant Spearman rank correlation coefficient, and the similar Shannon-Weaver indices. Although Rinaldo (1971) found in the Pamunkey River that striped bass greater than 19 mm showed more diversity in food items than similarly sized white perch, the Shannon-Weaver index showed no significant interspecific differences in dietary diversity in this study. Additionally, with the exception of individuals captured by pushnet, there were no significant interspecific differences in feeding success (as measured by IRFs). The similarity in feeding niches, feeding success, and habitat of juvenile striped bass and white perch indicates that interspecific competition may occur, which could be critical if food items should become limited in any way (Rinaldo 1971). However, YOY white perch exhibit less downstream drift than YOY striped bass (Rinaldo 1971), which may help to reduce interspecific niche overlap and competition for food.

In several studies a low abundance of fish has coincided with faster growth rates (Mansueti 1961b; Chadwick 1964; Dey 1981; Bosclair and Leggett 1989; Kline 1990) or a high average condition factor (weight/length^3 where the superscript 3 is the allometric growth coefficient of an ideal fish) (Kramer and Smith 1960; Kline 1990). This would indicate that food is a limiting factor in growth of some fishes. Kline (1990) found that striped bass growth in g/day and mm/day was positively correlated with condition factor and average stomach fullness, which the author felt was evidence that growth rates of YOY striped bass may be controlled by prey availability. Chadwick (1964) not only found that growth of YOY striped bass was negatively related to abundance in the Sacramento-San Joaquin Delta, but that juvenile striped bass abundance was closely associated with a 13 year low of the prey item, *Neomysis mercedis* (Chadwick 1974).

Similar growth rate and abundance relationships have been found for white perch. Mansueti (1961b) found in the Patuxent River that a highly significant negative correlation existed between first year growth in length of white perch and their population density in the form of the commercial haul seine catch five years later when perch entered the commercial fishery in the Patuxent. That white perch with small first year growth were related to large populations led Mansueti (1961b) to believe that there was high intraspecific competition for available food, a potential primary limiting factor. The findings of an inverse relationship between growth and abundance underscore the ramifications of intra- and interspecific competition for food when large numbers of young of one or both species are produced. It has been suggested that fish community density rather than population density of any one species is most important to the growth of individuals of a species (Bosclair and Leggett 1989). An interesting topic of future research would be to compare feeding success (stomach fullness) and condition factors of striped bass and white perch between years of high and low abundances.

Upon examination of the stepwise regressions performed to detect relationships between environmental factors and feeding success (measured by IRFs) of each of the two species, only salinity was significantly related to striped bass IRFs. That increasing salinity was positively related to striped bass IRFs is attributable to the contribution of mysids to the diets of striped bass collected at higher salinity sites. Mysids were 66.9% of the total volume of food items consumed by striped bass at the four stations with measurable salinities. Striped bass that had eaten mysids had an average IRF of 1.176, compared to the average IRF for all striped bass of 0.391.

A fast water current and temperature were significantly related to white perch IRFs. The positive relationship between fast current and white perch IRFs is contrary to Woolcott's (1962) report that immature white perch are most often collected in sluggish water. The negative relationship between temperature and white perch IRFs is perplexing as well. The white perch in this study were captured at an average of 27.7°C. Kellogg and Gift (1983) found through laboratory experiments that white perch had an optimum growth temperature of 28.5°C, and a preference of 30.0°C. Therefore the temperatures at which white perch were caught in this study should have been suitable for normal feeding behavior. However, the low adjusted R^2 for the striped bass (R^2=0.12) and white perch (R^2=0.26) stepwise regressions indicates that using a linear regression model, only a small percentage of the total variation in striped bass and white perch IRFs was accounted for. It is would appear that striped bass and white perch feeding success is directly due to the availability of food (Calhoun 1953;

Thomas 1967) which is indirectly determined by a combination of abiotic environmental factors (Boynton et al. 1981).

The wide array of food items consumed by juvenile striped bass and white perch (Table 1) suggests that a nonselective, opportunistic feeding strategy is employed by young of these two species. Such a feeding strategy by juvenile striped bass has also been suggested by Scofield (1931), Raney (1952), and Boynton et al. (1981). Raney (1952) reported that young striped bass ate appropriately sized foods that were most abundant. Bigelow and Welsh (1925) and Elrod et al. (1981) concluded that juvenile white perch employed the same opportunistic, nonselective feeding approach. Such a feeding strategy likely allows juvenile striped bass and white perch to adjust to variable environmental conditions (Boynton et al. 1981).

The amount and kind of YOY striped bass prey has been found to be largely determined by salinity (Raney 1952; Heubach et al. 1963; Markle and Grant 1970; Boynton et al. 1981), which may affect the size and distribution of prey appropriate for juvenile striped bass (Gunter 1961; Boynton et al. 1981). There was a shift at higher salinities towards consumption of mysids by both species. Similarly, Markle and Grant (1970) found in the James River that due to the unavailability of mysids at low salinity sites, insect larvae became the most frequent food item of striped bass between 25 and 100 mm. Mysids and decapods would have likely comprised a much larger numeric and volumetric percentage of prey of both species in this study if more sampling was conducted at higher salinities.

Although no significant intraspecific temporal or spatial IRF differences existed for striped bass, there were significant IRF differences between several groups of white perch. The temporal and spatial differences with significantly higher frequencies of ≥ average IRFs for twilight white perch and pushnet white perch, respectively are attributable to the high average IRF (1.609) for the 22 white perch captured by the shoal pushnet at twilight of the fourth cruise. Consistent with this study, Webster (1942) found that young white perch taken from freshwater fed most heavily early in the evening, and much less later in the night and into the morning. Although this study also suggests that young white perch feed heavily prior to sunset, further inquiry is needed before a conclusion may be reached.

Despite the above findings of IRF differences for white perch, relatively few stomachs of either species were gorged with food. Only 3% (5) of striped bass stomachs and 2% (4) of white perch stomachs were empty. The majority of stomachs examined were partially full, which suggests that a moderate level of feeding had taken place prior to capture, and that young of both species successfully forage and capture prey in widely varying habitats and light levels.

Several authors have suggested that once striped bass become nektonic that they predominantly inhabit nearshore areas rather than moving shoreward on a daily basis (Boynton et al. 1981; Dey 1981; Kernehan et al. 1981). The lack of a daily movement would increase the importance of analyzing within-gear catches to detect temporal feeding patterns. Yet striped bass and white perch captured by seine and by trawl did not show significant intraspecific, within-gear IRF trends. These findings support the widely held view that YOY striped bass and white perch feed when food becomes available (Bigelow and Welsh 1925; Scofield 1931; Raney 1952; Boynton et al. 1981; Elrod et al. 1981). This feeding style contrasts with that of planktivorous, pelagic clupeids such as the blueback herring, *Alosa aestivalis* that searches for food as it swims (Janssen 1982), and exhibits a negative phototropic behavior (Loesch et al. 1982). Such a diel periodicity reflects either an activity pattern characteristic of a fish species or a response to movement of prey organisms (Loesch et al. 1982; Ringler and Johnson 1982). However, the conclusions from both the temporal and spatial comparisons of striped bass and white perch feeding success should be greeted with caution because of the lack of specimens that were captured. The aforementioned influence of a single shoal pushnet collection of 22 white perch on the white perch IRF comparisons suggests that caution should be exercised when analyzing this result.

Striped bass were captured in only 64 of 300 collections while white perch were captured in only 52 of 300 collections. Greater catches would have increased the power of tests, and may have led to the detection of movements and feeding patterns that were not found in this study.

Optic, chemical, and acoustic senses are involved in the search for food by teleost fishes. Clues that initiate a searching behavior for food depend on the fish species as well as environmental conditions (Hara 1971). While some species use primarily vision, others rely more on chemoreception (gustation and olfaction) and mechanoreception (Hara 1971). Bowles (1976) found in laboratory experiments that visual cueing was important for juvenile striped bass to successfully feed. YOY striped bass and white perch fed successfully in darkness and at depth in highly turbid waters of the James River, which confirms that they use modes of prey detection in addition to vision.

The similarly structured and innervated integumental terminal buds and the oral taste buds of teleost fishes act as gustatory mechanisms (Herrick 1902; Katsuki and Onada 1973). The terminal buds are one of a series of integumental sense organs collectively known as the lateral line system (Tavolga 1971). Fishes that possess terminal buds habitually find their food by means of these organs. Fishes that lack terminal buds have gustation confined to the oral taste buds (Herrick 1902). The olfactory pits (nasal cavity or olfactory chamber) are the olfactory mechanisms in teleosts (Blaxter 1986; Hara 1993): olfactory epithelium at the base of the naval cavity is lined with receptor cells, which detect, encode, and transmit chemical information via the first cranial nerve to the olfactory bulb in the telencephalon (Hara 1993). Feeding stimulants that elicit olfactory and oral gustatory responses in teleosts are primarily a mixture of nucleotides and/or amino acids such as L-proline, an abundant amino acid in invertebrate tissues (Hara 1993).

Katsuki and Onada (1973) have found that the lateral line system is also a chemoreceptor of salts. Fishes such as siluroids (catfishes) that live in muddy water have a well-developed external chemoreceptory senses that include terminal buds on the body surface, fins, and barbels (Herrick 1902) that have receptors for ammonium ions (Katsuki and Onada 1973).

In addition to chemoreception, the lateral line system functions as a mechanoreceptor of water current, pressure waves produced by moving objects, and vibration caused by low frequency sound waves (Herrick 1902; Katsuki and Onada 1973). The inner ear also serves as a mechanoreceptor by detecting vibration. The lateral line's receptor units, neuromasts, and the inner ear are supplied by branches of the acoustic nerve (Tavolga 1971).

A preliminary study of larval striped bass feeding was conducted by Ozkizilcik and Chu (S. Ozkizilcik, VIMS, per comm). Thirteen-day-old larval striped bass were fed live *Artemia* nauplii. One group of larvae was fed in light while the other group was fed in complete darkness. After 4 h, both groups had consumed 97% of the *Artemia* nauplii. A similar test was performed using decapsulated *Artemia* eggs. Striped bass larvae again fed successfully in light and dark conditions. The fact that larval striped bass successfully fed in darkness on mobile and immobile prey supports the importance of mechanoreception, and particularly chemoreception in feeding by YOY striped bass and white perch.

Chesney (1989) also suggested that a mechanosensory and chemosensory strategy is used by larval striped bass as they fed and grew effectively in laboratory situations at relatively low food concentrations, and extremes of light, turbidity, and turbulence. However, Chesney (1989) found that low light in combination with turbidity and turbulence reduced the survival and growth rate of larval striped bass. Margulies (1989) found in larval white sea bass, *Atractoscion nobilis*, a sciaenid, that 75-80% of the improvement in visual acuity between hatching and adulthood occurred by the late larval stage. The number and pattern formations of neuromasts increase from the larval to juvenile stage in white sea bass, which likely contributes to increased predator and prey detection (Margulies 1989). It has been reported that fish larvae are predominantly sight feeders (Hunter 1981). That juvenile striped bass and white perch successfully fed at night suggests that their mechanosensory and chemosensory systems are important in the detection of prey.

PART II

Length-Weight Relationships for Young-of-the-Year Striped Bass and Young-of-the-Year White Perch

INTRODUCTION

Background Information

Length-weight relationships are an important regulatory tool in fisheries management. It is frequently necessary to estimate the weight or length of fish in absence of the other measurement (Mansueti 1961b). Length-weight data are used to construct growth curves for fishes. Estimated growth curves are often used in conjunction with size frequency data for regulation of important recreational and commercial species. In addition, length-weight relationships may indicate if density dependent factors limit growth of first year fishes. Length-weight data may be used to indicate relative food availability and forage success by comparing allometric growth coefficients between cohorts, or by using a condition factor (calculated as a ratio between the observed weight and the weight expected from the observed length) (Le Cren 1951).

Length-weight relationships for adult striped bass have been described by several authors. Robinson (1960) found in the Sacramento-San Joaquin Delta that the length-weight relationship for striped bass was described by the equation log W = -2.1393 + 3.0038 log L where W is wet weight and L is fork length. In the Chesapeake Bay, Maryland, Mansueti (1961a) found for female striped bass that log W = -2.238 + 3.153 log L and that for male striped bass log W = -2.406 + 3.234 log L.

Length-weight relationships for adult white perch have also been described by Mansueti (1961b), who found that in Patuxent River, Maryland that the length-weight relationship for female white perch was log W = -4.814 + 3.123 log L, and for males white perch was log W = -4.611 + 3.023 log L. Bath and O'Conner (1982) found in the Hudson River that the combined length-weight relationship for male and female white perch was log W = -4.743 + 3.093 log L.

Because of its practicality, wet weight has been the standard weight measurement for fisheries studies. Yet because of a greater surface area:volume ratio for smaller fishes, one may suspect that wet weight has a relatively high variability. Dry weight and ash weight are two alternative measurements that may have less variability because the water weight of each specimen has been removed.

Organic (ash-free) weight is yet another measure of weight for length-weight computations. Organic weight is a measure of carbon content of fishes, which is useful in estimating carbon flow to make standing stock and carrying capacity estimates for various species.

Objectives

The objectives of this study were to

1) develop fork length-wet weight relationships for YOY striped bass and white perch;
2) compare the variability of three types of weight (wet-weight, dry weight, and ash weight) for YOY striped bass and white perch, with the null hypothesis that there was no difference between the variability of any two of the weights, and
3) develop fork length-organic (ash-free) weight relationships for YOY striped bass and white perch.

METHODS

Young-of-the-year striped bass and young-of-the-year white perch were obtained by pushnet from the Rappahannock River in June-August 1992 and from the Mattaponi River in June-July 1993. Specimens were fixed according to the procedures for fixation described in Part I. Fork length was taken for each of 74 striped bass and 72 white perch. After rolling each specimen in a towel and applying light blotting pressure, wet weight was measured. Each specimen was then dried in an oven for 24 h at 100°C, and desiccated to a constant dry weight. Each specimen was then placed in a furnace for 2 h at 500°C, and desiccated to a constant ash weight. Ash-free (organic) weight was calculated by subtracting the ash weight from the dry weight for each specimen.

An allometric relationship exists between length and weight of fish. To express the length-weight relationships for bass and perch as linear equations, numbers for length and wet weight were converted to their natural logarithms. The equation

$$W = \alpha L^{\beta} e^{u}$$

was used in the form

$$\ln W = \ln \alpha + \beta \ln L + \ln u$$

where ln is the natural logarithm, W is wet weight (g), L is fork length (mm), α and β are constants estimated by least squares regression, and u is the error term that is assumed to be normally distributed with a mean of zero and a constant variance.

The relative variability between wet weight, dry weight, and ash weight was tested with the coefficient of variation. An F-test may be used to test the difference between two coefficients of variation by using the variance of the natural logarithms of the data (Lewontin 1966):

$$F = \frac{(s^2_{ln})_1}{(s^2_{ln})_2}$$

However, the F-test may not be used if the two sets of sample data are from *normal* populations (Zar 1984). For normal populations, the procedure to compare two coefficients of variation is to compute the normal deviate, Z, where

$$Z = \frac{V_1 - V_2}{[(V_p^2/n_1 + V_p^2/n_2)(0.5 + V_p^2)]^{1/2}}$$

where V_i is the coefficient of variation of each sample, n_i is the sample size of each sample, and V_p is the pooled coefficient of variation of each sample where

$$V_p = \frac{n_1V_1 + n_2V_2}{n_1 + n_2}$$ (Miller 1991).

RESULTS

The relationship between wet weight and fork length for YOY striped bass was described by the linear regression

$$\text{Ln W} = \underset{(t = -88.91)}{-11.825} + \underset{(t = 85.66)}{3.111 \ln L}$$

$$\text{adjusted } R^2 = 0.99$$

and the relationship for white perch was

$$\text{Ln W} = \underset{(t = -57.71)}{-12.114} + \underset{(t = 54.06)}{3.230 \ln L}$$

$$\text{adjusted } R^2 = 0.98.$$

Each R^2 was adjusted for degrees of freedom. The wet-weight-fork length relationships for striped bass and white perch are shown in Figures 13 and 14, respectively.

Length-weight relationships between organic weight and fork length were also described for both species. The relationship for striped bass was described by the linear regression

$$\text{Ln W} = \underset{(t = -65.31)}{-14.467} + \underset{(t = 54.73)}{3.310 \ln L}$$

$$\text{adjusted } R^2 = 0.98$$

while the relationship for white perch was described by the linear regression

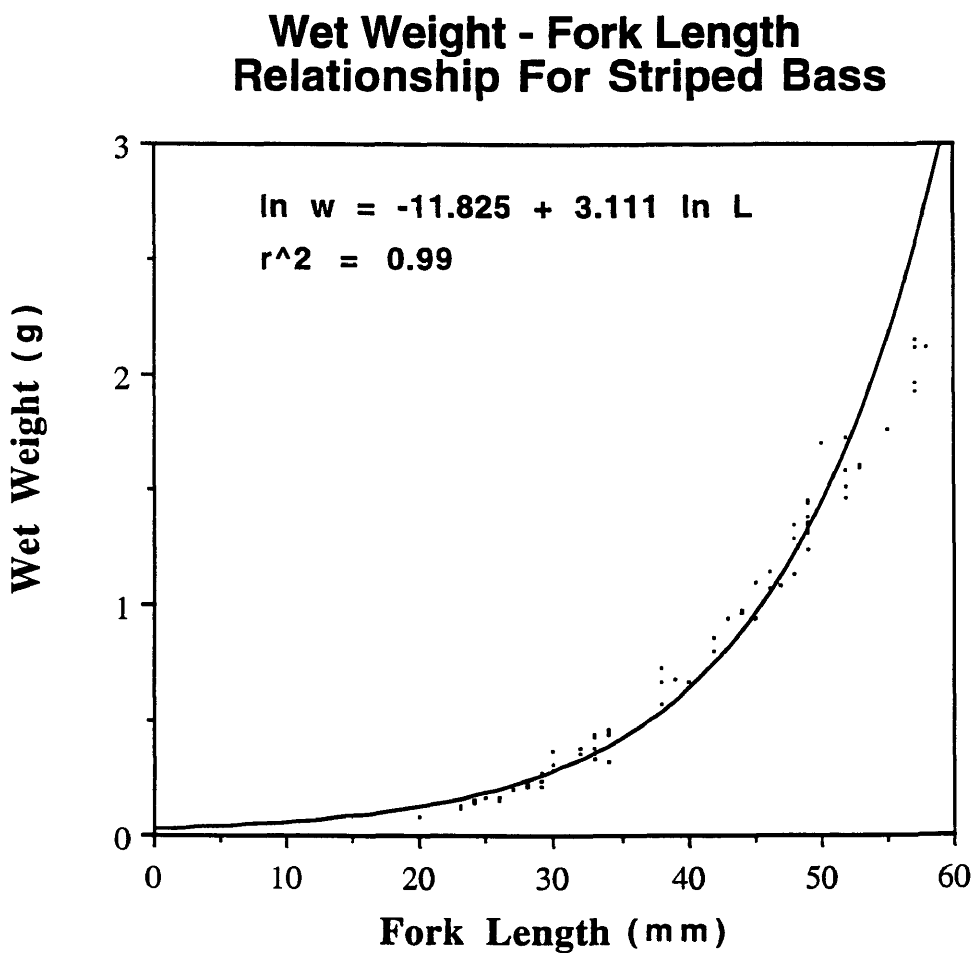
$$\text{Ln W} = \underset{(t = -57.70)}{-15.012} + \underset{(t = -47.54)}{3.521 \ln L}$$

$$\text{adjusted } R^2 = 0.97.$$

The organic weight-fork length relationships for striped bass and white perch are shown in Figures 15 and 16, respectively.

The coefficients of variation between three measures of weight for specimens of each species were not significantly different for either striped bass or white perch. Table 11 summarizes the results of testing differences between coefficients of variation.

Figure 13. Wet weight-fork length relationship for striped bass.



Wet Weight - Fork Length
Relationship For Striped Bass
ln w = -11.825 + 3.111 ln L
r^2 = 0.99
Wet Weight (g)
Fork Length (mm)
0
1
2
3
0
10
20
30
40
50
60

Figure 14. Wet weight-fork length relationship for white perch.

Wet Weight - Fork Length Relationship For White Perch

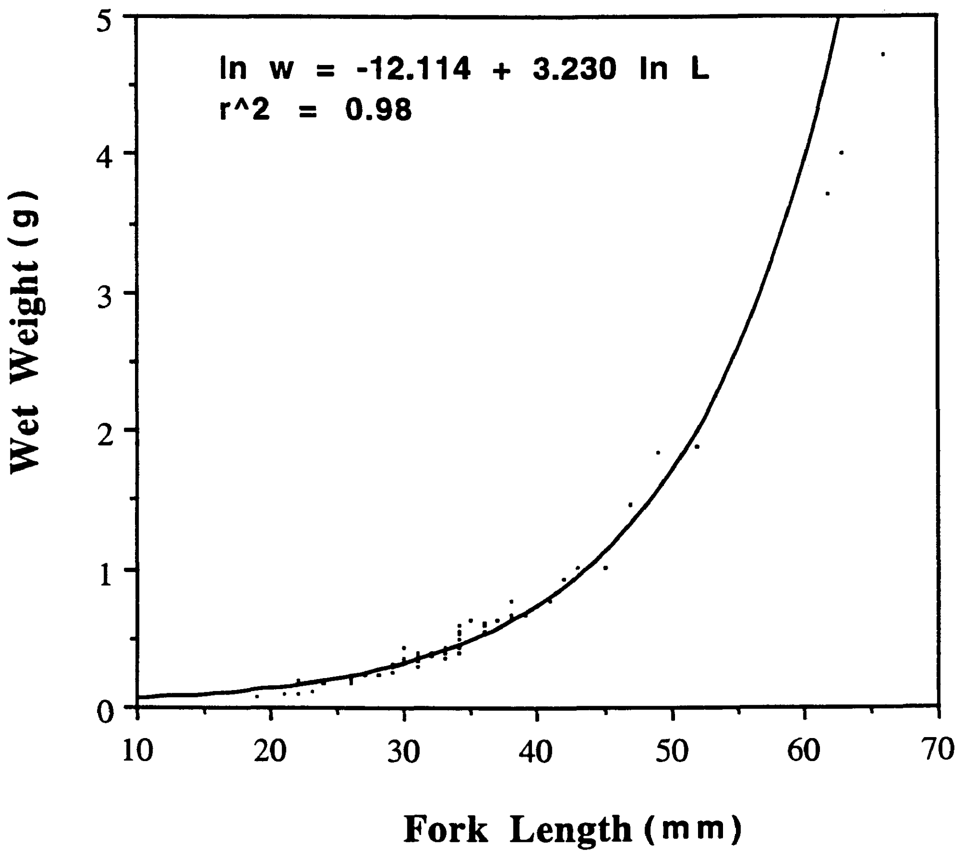


Figure 15. Organic weight-fork length relationship for striped bass.

Organic Weight - Fork Length Relationship for Striped Bass

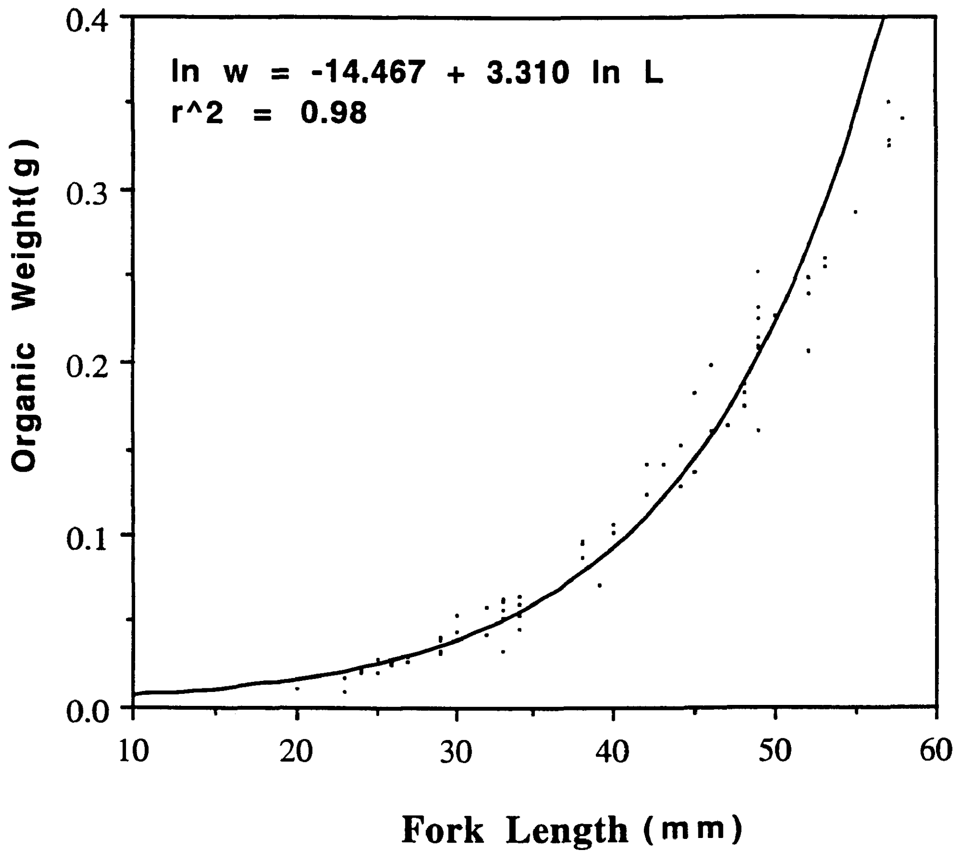


Figure 16. Organic weight-fork length relationship for white perch.

Organic Weight - Fork Length Relationship For White Perch

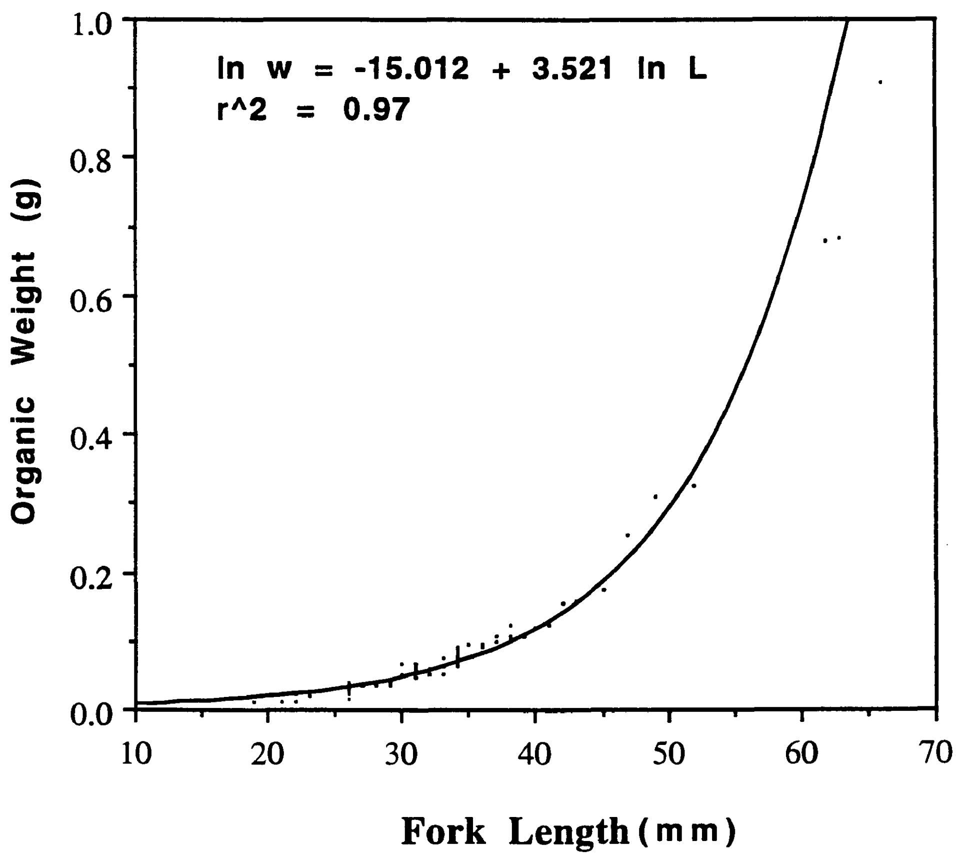


Table 11. Coefficients of variation of three weights for YOY striped bass and YOY white perch.

H_0: The population coefficients of variation are the same for two measures of weight.
H_a: The population coefficients of variation are not the same for two measures of weight.

A. Striped bass: n = 74

WW = Wet Weight: C.V. = 0.697
DW = Dry Weight: C.V. = 0.729
AW = Ash Weight: C.V. = 0.746

Comparison	Z	% of normal curve ≥ Z	Result
WW vs. DW	0.248	0.4013	Do not reject H_0
WW vs. AW	0.408	0.3409	Do not reject H_0
DW vs. AW	0.137	0.4443	Do not reject H_0

B. White Perch: n = 72

WW = Wet Weight: C.V. = 1.283
DW = Dry Weight: C.V. = 1.442
AW = Ash Weight: C.V. = 1.504

Comparison	Z	% of normal curve ≥ Z	Result
WW vs. DW	0.456	0.3228	Do not reject H_0
WW vs. AW	0.610	0.2709	Do not reject H_0
DW vs. AW	0.155	0.4364	Do not reject H_0

DISCUSSION

The wet weight-fork length, and organic weight-fork length relationships found for YOY striped bass and YOY white perch in this study appear to be consistent with the results of double logarithmic weight-length relationships for adult striped bass (Robinson 1960; Mansueti 1961a) and adult white perch (Mansueti 1961b; Bath and O'Conner 1982) because an allometric relationship appears between weight and length for the four weight-length comparisons. Alpha has a negative value, and β, the allometric growth coefficient, has a value of approximately three. For an ideal fish that maintains its shape, the relationship between length and weight is close to the cube (Le Cren 1951; Mansueti 1961b). This similarity between allometric growth coefficients of this study and the allometric coefficients previously described for adult striped bass and adult white perch indicates that neither species drastically changes its external morphology between adolescence and adulthood.

Parker (1963) demonstrated that a standardized method of blotting wet fish can yield reproducible results of wet weight with an insignificant standard deviation. This appears to be the case for this study as well. For each species, no significant differences were found between the variability of wet weight, dry weight, and ash weight. The time and cost advantages in weighing fish wet makes this a an accurate unit of weight for food, weight-length, growth, and condition factor studies.

Intuitively, dry weight and ash weight should be less variable a measure than wet weight. Although organic weight is an important tool for studying carbon cycling by trophic levels and carbon assimilation by various estuarine species, the findings of this study suggest that the variability in ash weight may potentially be reduced by keeping the methods of drying, ashing, desiccating, and weighing as consistent as possible.

SUGGESTIONS FOR FUTURE RESEARCH

The low catches of YOY striped bass and YOY white perch may have prevented detection of daily and seasonal movements of each species. Do young striped bass and white perch make diel vertical or horizontal movements? If they do move on a daily basis, are the movements in response to food or some other factor? The finding that striped bass and white perch captured by seine were significantly longer than those captured by trawl is attributable to gear avoidance and/or a seasonal migration. The validity of either a diel or seasonal movement hypothesis can be best tested with greater sample sizes and a more intensive sampling scheme.

If YOY striped bass and white perch are making true migrations, is feeding or another factor that precipitates the migration? This study's conclusion of no significant intraspecific spatial differences in feeding success may underestimate the importance of the nearshore zone to young striped bass and white perch. However, YOY striped bass have previously been shown to feed more successfully nearshore (Boynton et al. 1977), and this study did find qualitative changes in the diets of striped bass and white perch captured by seine. These shallow areas may be critical for growth and survival of striped bass and white perch not only because they can adjust their diets to meet greater nutritional requirements but because they can increase their rates of consumption. Particularly the topic of quantitative consumption warrants further research.

Further research also needs to focus on the measurement of prey electivity by each species and dietary overlap between species. Striped bass and white perch may consider copepods and cladocerans to be highly desirable, or they may consume these prey because more desirable prey is unavailable. Striped bass and white perch diets may overlap with other fishes such as silversides (*Menidia* spp). A high dietary overlap between particulate feeding estuarine species such as striped bass and white perch may limit the growth and survival of the outcompeted or less adaptable species.

The major topic for further research is to examine whether growth and survival of striped bass and white perch is a density-dependent phenomenon. Because white perch with small first year growth in length were related to large catches when they first entered the Patuxent River commercial fishery, Mansueti (1961b) believed that food supply is a primary limiting factor. The findings by Mansueti (1961b) for white perch and similar findings by Kline (1990) for striped bass can be tested by intraspecifically comparing striped bass and white perch growth rates, survival rates, and condition factors between years of high and low abundance of each species. A more comprehensive approach to the question of density-dependence is to compute the daily ration (in carbon) of striped bass and white perch. With estimates of daily ration, estuarine primary production, and standing stock of a species, one can compute the actual and biologically maximum amount of an estuarine carbon pool contained in a cohort of striped bass or white perch.

SUMMARY

1. One-hundred-eighty-eight YOY striped bass and 199 YOY white perch were captured by three different types of gear in 300 collections in the James River between June and August, 1992. The relatively low catches of striped bass and white perch are likely attributable to poor year-class success of both species. Year-class success is likely determined by a unique combination of density-independent and density-dependent factors occurring in a nursery area.

2. Striped bass and white perch captured by beach seine were significantly longer, respectively, than striped bass and white perch captured by otter trawl. Whether these size differences were due to differences in gear selectivity or a shoreward migration is unclear.

3. YOY striped bass and YOY white perch appear to feed nonselectively and opportunistically. Striped bass and white perch captured by seine had significantly more diverse diets, respectively, than striped bass and white perch captured by trawl. Diets between trawl and seine specimens were not significantly correlated for either species. As they increased in length, both species showed a gradual dietary shift from zooplankton to epibenthic prey.

4. The Spearman rank correlation coefficient revealed that

striped bass and white perch diets were highly correlated. Horn's index revealed that diets of both species were highly overlapping. There was no significant difference between the diversity of striped bass and white perch diets. With the exception of specimens caught by pushnet, there were no significant interspecific differences in feeding success. The similarity in the diets and habitat of YOY striped bass and YOY white perch may lead them to compete for the same prey.

5. No significant intraspecific temporal or spatial differences in feeding success were found for striped bass. White perch captured at twilight, and by pushnet had significantly higher feeding success than white perch captured at day or night, or by the seine or trawl, respectively. This finding is attributable to a single twilight shoal pushnet collection of 22 white perch that had fed heavily prior to capture. With the exception of this collection, the results of the comparisons of feeding success suggest that in addition to vision, young striped bass and white perch use chemoreception and mechanoreception to locate prey planktonic and epibenthic prey.

6. Results of stepwise regressions indicate that, using a linear regression model to analyze the relationship between abiotic factors and feeding success, little variability in striped bass and white perch feeding success can be accounted for. Abiotic environmental factors may have an

indirect relationship with feeding success by influencing the quantity and/or quality of food items available to young of both species.

7. The wet weight-fork length relationship for YOY striped bass was described by the linear equation

$$\text{Ln } W = -11.825 + 3.111 \ln L$$

while the relationship for YOY white perch was described by the linear equation

$$\text{Ln } W = -12.114 + 3.230 \ln L.$$

An allometric growth coefficient of close to three for each species is consistent with other research. The insignificant differences between the variability of wet weight, dry weight, and ash weight indicates that wet weight is an accurate method of weighing small fish for feeding and weight-length studies.

Appendix 1. Catches of striped bass and white perch, and meteorological data separated by block and cruise.

			Catches[1]							
C/B[2]	Time	CP[3]	BS	SP	OT	°C	ppt	Lite[5]	curr[6]	s[7]
1:1	1300	0/0	5/0	0/0	0/1	24.5	0	45.5	2/3	0.4
1:2	1600	0/0	0/0	0/0	0/0	25.0	0	32.0	1/1	0.5
1:3	1900	0/0	0/0	0/0	1/1	24.5	0	21.0	2/2	0.4
1:4	0000	0/0	0/0	0/0	3/2	24.5	0	0	2/2	-
1:5	0300	1/0	1/0	0/0	7/0	24.2	0	0	1/1	-
1:6	0600	1/0	3/0	0/0	4/5	24.2	0	1.8	2/1	0.5
1:7	0900	0/0	0/0	0/0	9/4	24.0	0	35.0	1/1	0.5
1:8	1300	0/0	10/0	0/0	5/4	24.4	0	48.0	1/1	0.5
2:1	1200	0/0	9/0	3/0	1/0	24.0	0	74.0	1/2	0.5
2:2	1500	0/0	2/0	0/0	1/1	25.0	0	83.0	1/2	0.5
2:3	1800	0/0	0/0	0/0	3/2	24.0	0	59.0	2/3	0.5
2:4	2100	0/1	4/0	4/5	6/4	24.0	0	0.2	3/3	0.5
2:5	0000	0/0	1/0	0/0	0/0	24.0	0	0	1/1	-
2:6	0300	0/0	0/0	0/0	7/4	23.5	0	0	1/1	-
2:7	0700	0/0	0/0	1/0	1/1	24.0	0	29.0	2/3	0.5
2:8	0900	0/0	0/0	2/0	0/0	24.5	0	173.0	2/2	0.5
2:9	1200	1/0	0/0	0/0	0/0	24.0	0	41.0	1/1	0.5
3:1	1200	-	4/0	0/0	0/0	26.0	0.5	26.0	2/3	0.4
3:2	1500	-	1/0	0/0	0/0	26.0	0.5	77.0	3/3	0.4
3:3	1800	-	0/2	3/0	0/0	26.0	0.5	38.0	3/3	0.4
3:4	2100	-	0/0	0/0	0/0	25.8	0.5	0.1	2/2	0.4
3:5	0000	-	1/0	0/0	0/0	25.8	0.5	0	1/1	-
3:6	0400	-	3/0	1/0	0/0	26.0	0.5	0	2/2	-
3:7	0800	-	7/1	0/0	0/0	26.0	0.5	82.0	0/3	0.4
3:8	1200	-	2/0	0/0	0/0	25.9	0.5	33.0	2/3	0.4
4:1	1200	0/0	0/4	1/1	0/0	28.0	0	69.0	1/3	0.3
4:2	1500	0/0	0/0	1/0	2/0	28.0	0	112.0	0/3	0.3
4:3	1800	0/0	0/6	0/0	10/11	28.2	0	254.0	1/1	0.3
4:4	2100	0/0	2/0	1/22	3/4	28.0	0	0.2	1/3	0.3
4:5	0000	0/0	2/3	0/0	2/2	27.0	0	0	1/3	-
4:6	0300	0/0	1/3	0/0	2/4	27.0	0	0	1/2	-
4:7	0600	0/0	3/0	1/0	8/10	28.0	0	16.9	1/2	0.3
4:8	0900	0/0	0/1	0/0	4/3	27.7	0	148.0	2/1	0.3
4:9	1200	0/0	0/0	0/0	2/0	28.5	0	79.0	1/1	0.3
5:1	1200	0/0	0/0	0/0	0/1	30.0	0	58.0	0/2	0.4
5:2	1500	0/0	0/0	1/0	0/0	29.0	0	92.4	1/2	0.4
5:3	1800	0/0	0/0	0/0	0/0	29.2	0	64.4	1/3	0.4
5:4	2100	0/0	0/0	1/33	0/0	30.0	0	2.0	2/2	0.4
5:5	0000	0/0	2/1	1/0	0/0	29.0	0	0	1/2	-
5:6	0300	0/0	0/0	0/0	0/1	29.0	0	0	0/2	-
5:7	0600	0/0	0/0	0/0	0/0	28.0	0	19.8	1/2	0.4
5:8	0900	0/0	1/1	1/0	0/0	29.0	0	60.2	0/2	0.4

5:9	1200	0/0	0/0	0/0	0/1	29.5	0	95.3	1/3	0.4
6:1	1500	0/0	0/10	0/0	0/0	28.5	0	98.0	2/2	0.6
6:2	1800	0/0	0/2	0/0	0/0	29.1	0	26.6	3/3	0.6
6:3	2100	0/0	3/4	6/0	0/0	29.0	0	0.8	1/3	0.6
6:4	0000	0/0	0/2	0/0	1/3	29.0	0	0	1/3	-
6:5	0300	1/0	1/3	0/0	0/0	28.0	0	0	2/2	-
6:6	0600	0/0	0/1	0/0	0/1	29.1	0	4.8	2/2	0.6
6:7	0900	0/0	0/0	0/0	0/0	28.9	0	51.0	2/2	0.6
6:8	1200	0/0	1/3	0/0	0/1	29.5	0	60.0	1/3	0.6
6:9	1500	0/0	0/1	0/0	0/0	29.2	0	55.0	1/1	0.6
7:1	1900	0/0	3/4	0/0	0/0	29.0	4.0	31.0	2/2	0.7
7:2	0000	0/0	2/0	0/0	0/0	29.0	4.5	0	2/3	-
7:3	0300	0/0	0/1	0/0	0/0	29.0	4.5	0	3/2	-
7:4	0700	0/0	0/1	0/0	0/0	29.0	4.5	23.0	3/3	0.7
7:5	1000	0/0	0/1	0/0	0/0	28.0	4.5	115.2	0/0	0.7
7:6	1200	0/0	0/0	0/0	0/0	30.0	4.5	58.0	1/2	0.7
7:7	1500	0/0	0/0	0/0	0/0	31.0	5.0	136.0	3/3	0.7
7:8	1900	0/0	0/0	0/0	0/0	30.0	5.0	86.1	3/3	0.7
8:1	1600	0/0	0/0	0/0	0/0	26.5	1.0	26.3	1/1	0.6
8:2	1900	0/0	0/0	0/0	0/0	27.5	1.0	0.8	2/3	0.6
8:3	2200	0/0	0/0	0/0	0/0	27.2	1.0	0	2/3	-
8:4	0200	0/0	0/0	0/0	0/0	27.0	1.0	0	1/2	-
8:5	0600	0/0	0/4	0/0	0/0	26.5	1.0	0	2/2	0.6
8:6	1000	0/0	0/0	0/0	0/0	26.5	1.0	42.3	0/3	0.6
8:7	1300	0/0	0/3	0/0	0/0	27.0	1.0	30.5	2/2	0.6
8:8	1600	0/0	0/0	0/0	0/0	26.5	1.0	48.3	1/1	0.6
9:1	1500	0/0	0/0	0/0	0/0	26.8	6.0	48.2	1/2	0.6
9:2	1800	0/0	0/0	0/0	0/0	26.1	6.0	21.8	1/1	0.6
9:3	2000	0/0	0/0	0/0	0/0	25.7	6.0	1.0	3/2	-
9:4	0000	0/0	0/0	0/0	0/0	26.0	6.0	0	0/2	-
9:5	0300	0/0	0/0	0/0	0/0	26.0	6.0	0	1/1	-
9:6	0700	0/0	0/0	0/0	0/0	25.8	6.0	22.6	3/3	0.6
9:7	1000	0/0	0/0	0/0	0/0	25.5	6.0	96.8	2/2	0.6
9:8	1300	0/0	0/4	0/0	0/0	26.0	6.0	37.9	1/1	0.6
9:9	1500	0/0	0/0	0/0	0/0	26.5	6.0	30.7	3/3	0.6

[1] CP is channel pushnet, BS is beach seine, SP is shoal pushnet, and OT is otter trawl. The first and second numbers are striped bass and white perch, respectively.

[2] C/B is cruise and block.

[3] The channel pushnet was not used on the third cruise.

[4] Light is the amount of light, in micro Einsteins/m^2/sec at 0.5 m below the water surface.

[5] Cur is current speed, and is either fast (3), medium (2), slow (1), or none (0). The first and second numbers are nearshore and channel current speeds, respectively.

[6] S is secchi depth, in meters.

Appendix 2. Relationship between York River water temperatures (at Gloucester Point) and James River striped bass catches at historical index stations: 1967-73 and 1980-92.

Dependent variable: VIMS striped bass catches at James River historical index stations: 1967-73 and 1980-92.

Independent variable: water temperature taken at Gloucester Point on the York River.

H_0: $\beta = 0$
H_a: $\beta \neq 0$

Striped bass catches	Results of simple regressions F	p
A. March[1]		
average March temperature	1.663	0.217
March coefficient of variation	1.558	0.227
drop in March temperature	2.570	0.130
B. April[2]		
average April temperature	0.484	0.498
April coefficient of variation	0.922	0.353
drop in April temperature	0.554	0.469
C. May[3]		
average May temperature	0.420	0.526
May coefficient of variation	0.091	0.766
drop in May temperature	0.082	0.788
D. June[4]		
average June temperature	0.114	0.740
June coefficient of variation	0.536	0.476
drop in June temperature	0.985	0.338

[1] March 1968, 1984, and 1990 temperatures were not used due to lack of data.
[2] April 1968, 1984, 1985, and 1991 temperatures were not used due to lack of data.
[3] May 1968, 1985, and 1987 temperatures were not used due to lack of data.
[4] June 1982, 1984, 1985, and 1987 temperatures were not used due to lack of data.

Appendix 3. Relationship between James River water flow and James River striped bass catches at historical index stations: 1967-73 and 1980-92.

The analysis used 12 months of river flow data.

Dependent variable: VIMS striped bass catches at James River historical index stations: 1967-73 and 1980-92.

Independent variable: James River monthly water flow for June of index year (t1) through July of previous year (t12).

H_o: $\beta_i = 0$
H_a: $\beta_i \neq 0$

Results: n=20
r^2=0.450 adjusted r^2=0.000 std. error of estimate=270.025

variable	coef.	std. Error	std coef.	Tol.	T	P
constant	17.710	359.145	0.000	-	0.049	0.962
t1 (June)	-0.008	0.011	0.307	0.392	0.686	0.515
t2 (May)	0.014	0.011	0.437	0.670	1.275	0.243
t3 (April)	0.006	0.009	0.350	0.308	0.693	0.510
t4 (March)	0.006	0.021	0.197	0.184	-0.301	0.772
t5 (Feb.)	0.003	0.013	0.087	0.446	0.207	0.842
t6 (Jan.)	0.012	0.020	0.329	0.271	0.611	0.561
t7 (Dec.)	0.000	0.021	-0.002	0.221	-0.003	0.998
t8 (Nov.)	0.003	0.012	0.116	0.365	0.251	0.809
t9 (Oct.)	-0.017	0.024	-0.565	0.119	-0.697	0.509
t10 (Sep.)	0.010	0.017	0.285	0.380	0.627	0.551
t11 (Aug.)	-0.006	0.018	-0.149	0.419	-0.343	0.742
t12 (July)	0.001	0.032	0.015	0.304	0.029	0.977

ANOVA

source	sum squares	df	mean square	F	P
regression	416779.887	12	34731.657	0.476	0.876
residual	510393.113	7	72913.302		

Appendix 4. Relationship between James River water flow and James River striped bass catches at historical index stations: 1967-73 and 1980-92.

The analysis used 6 months of river flow data.

Dependent variable: VIMS striped bass catches at James River historical index stations

Independent variable: James River monthly water flow for June of index year (t1) through January of index year (t6).

H_o: $\beta_i = 0$
H_a: $\beta_i \neq 0$

Results: n=20
r^2=0.362 adjusted r^2=0.067 std. error of estimate=213.364

variable	coef.	std. Error	std coef.	Tol.	T	P
constant	158.275	178.873	0.000	-	0.885	0.392
t1 (June)	-0.010	0.007	-0.412	0.652	-1.502	0.157
t2 (May)	0.014	0.008	0.452	0.786	1.809	0.094
t3 (April)	0.007	0.005	0.393	0.639	1.417	0.180
t4 (March)	-0.010	0.011	-0.313	0.431	-0.926	0.371
t5 (Feb.)	0.001	0.008	0.036	0.619	0.127	0.901
t6 (Jan.)	0.002	0.009	0.062	0.794	0.248	0.808

ANOVA

source	sum squares	df	mean square	F	P
regress.	335358.822	6	55893.137	1.228	0.353
residual	591814.178	13	45524.168		

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