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Distribution Characteristics and Ecology of the Near Shore Marine Finfish Assemblage Inhabiting Northeastern U.S. Waters

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DISTRIBUTION CHARACTERISTICS AND ECOLOGY OF THE NEAR SHORE MARINE FINFISH ASSEMBLAGE INHABITING NORTHEASTERN U.S. WATERS

BY

ETHAN DWIGHT ESTEY

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE
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2013

DOCTOR OF PHILOSOPHY DISSERTATION

OF

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2013

ABSTRACT

While the near shore marine environment has been demonstrated to be a productive habitat, little is known about this finfish resource in the adjacent surf zone area in the northeastern U.S. This is primarily due to the difficulties of sampling in this environment, high variability in fish distributions, and the lack of a standardized sampling approach, so as to be able to compare different studies. The focus of this work is to better understand the ecology of the near shore marine finfish distribution in the northeastern U.S. This is accomplished through identifying the finfish species inhabiting the surf zone environment and providing a description of their distribution variability. These findings are compared to data from adjacent marine systems and are used to make general sampling recommendations for future monitoring of this resource. Additionally, the concept of a distinct transitional zone (TZ) joining the Acadian and Virginian provinces for the near shore marine demersal finfish assemblage is introduced. Both the role of Cape Cod as a zoographic boundary and the properties of the TZ are investigated by use of a biogeographical species ratio estimator, a quantitative measure for assessing species distributions and biogeographical boundaries. Finally, variability in the finfish distribution related to tidal stage and short term migrations are investigated. These distribution characteristics are used to make sampling recommendations for both the dominant finfish species and the total finfish community.

<u>Manuscript I:</u> This study investigated the characteristics of the surf zone finfish on Cape Cod, providing an inventory of the finfish species and a description of their distribution variability. The findings are compared to the available finfish data

from adjacent marine systems and are used to make general sampling recommendations for future monitoring of this resource. A consistent seasonal pattern across water temperature, proportion of subtropical fish species, and diversity demonstrated the near shore finfish community on Cape Cod is very much like that of its nearby estuaries of Wellfleet Harbor and Pleasant Bay. Proportion of subtropical fish species was investigated by use of a biogeographic species estimator ratio calculated as: subtropical species (S) / (subtropical + temperate + polar species (A)). Future sampling efforts should include both a haul seine and beach seine as the gears detected differing finfish species and be conducted seasonally as assemblages were shown to vary by month. While this effort proved logistically difficult for consistent monitoring, these results demonstrate intermittent sampling would likely detect large perturbations to the system.

<u>Manuscript II:</u> The near shore finfish ecology is further examined with the introduction of the concept of a distinct transitional zone joining the near shore marine demersal assemblages of the Acadian and Virginian provinces. Additionally, the role of Cape Cod as a zoographic boundary was investigated by use of a biogeographical species ratio estimator (S/A ratio) calculated from the Massachusetts Division of Marine Fisheries Trawl Survey. Analyses identified the TZ as a zone of enhanced diversity where rate of change of the S/A ratio with respect to latitude was maximized. In this region the S/A ratio proved useful as a quantitative measure for assessing species distributions and biogeographical boundaries.

<u>Manuscript III:</u> Additional sampling was conducted at Matunuck Beach, Rhode Island to determine the potential to evaluate changes in the finfish distribution

with tidal stage, and the influence of tidal stage relative to that of short term variability. Recommendations for future sampling of both the dominant finfish species and the total finfish community are made based on this research. Tidal stage investigations revealed no effect of tidal stage on the number of species present among or within sampling events. Tidal stage analyses were confounded as the influence of tidal stage was exceeded by finfish short term distribution variability. A 50% reduction in daily effort, for a total of eight hauls, would identify 100% of the dominant species and 85% of the total species detected.

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PREFACE

This dissertation is written in the manuscript format specified by the University of Rhode Island Graduate School.

Manuscript I is written for the Northeast Naturalist and will be submitted for review upon completion of this dissertation.

Manuscript II is written for Estuarine, Coastal, and Shelf Science and will be submitted for review upon completion of this dissertation.

Manuscript III is written for Estuarine, Coastal, and Shelf Science and will be submitted for review upon completion of this dissertation.

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The Surf Zone Finfish Distribution of Cape Cod, Massachusetts

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Abstract - This study was the first to address the characteristics of the surf zone finfish on the northern portion of Cape Cod, providing an inventory of the finfish species and a description of their distribution variability. The findings are compared to the available finfish data from adjacent marine systems and are used to make general sampling recommendations for future monitoring of this resource. A total of 32 finfish species and loligo squid were detected during sampling in 2007 and 2008 at two locations, Fisher Beach and Coast Guard Beach, Truro, MA. The number of fish species observed is similar to that of nearby estuarine systems, Wellfleet Harbor and Pleasant Bay. In the combined catch data from Coast Guard and Fisher Beach over the two year period, ten species accounted for 91% of the total catch which is consistent with studies based on the surf zone area. Statistical analyses identified both a significantly greater number of species ($p < 0.01$) and individuals ($p < 0.05$) captured at Fisher Beach than at Coast Guard Beach. ANOSIM identified significantly different finfish communities between the two locations ($p < 0.05$). Due to the differences in catch characteristics between locations, future monitoring efforts in the surf zone should be stratified by location / habitat. A consistent temporal pattern across water temperature, ratio of subtropical fish species, and diversity demonstrated that the surf zone finfish community at Fisher Beach was similar to nearby estuaries of Wellfleet Harbor and Pleasant Bay. This pattern is characterized by a peak in both water temperatures and percentage of the subtropical fish species in the summer which is followed by a peak of diversity in the fall.

Comparisons of two different sampling gears, a modified haul seine and beach seine, at Fisher Beach yielded significant differences in number of species detected. SIMPER results identify differing finfish communities detected by the gears at both locations with the beach seine detected the smaller finfish species and juveniles and the haul seine detecting larger finfish. Based on these findings, a combination of gears including the haul seine and beach seine are recommended for future sampling efforts. Monthly sampling may be desirable as finfish assemblages were shown to vary between months. Two sampling events per month are recommended as a single day sampling event resulted in 62% of the total species detected at Coast Guard and 71% at Fisher Beach with both locations exhibiting high variability in percentage of total species detected. Additionally, results from four consecutive days of sampling conducted at Fisher Beach demonstrate two days as sufficient to identify > 80% of the total species detected: one day = 72%, two days = 91%, three days = 95%, and four days = 100%. Both findings suggest that two days is an appropriate sampling approach in terms of species detected. This study has demonstrated that the finfish inhabiting the surf zone on Cape Cod are a diverse assemblage, similar to that of adjacent estuaries. While this effort proved logistically difficult for consistent monitoring, intermittent sampling would likely detect large perturbations to the system.

Introduction

Surf zone environments extending from sandy beaches are recognized as dynamic with little habitat complexity (McLachlan et al., 1984; Robertson and Lenanton, 1984). Little is known about their associated finfish distribution when compared to deeper water habitats. Still, the surf zone habitat has been documented to be occupied by a wide variety of finfish species (Wilber et al., 2003; Lasiak, 1984a) and has been demonstrated to be a productive nursery habitat for juvenile fish (Bennet, 1989) even at locations greater than 5 km from estuaries (Strydon and d'Hotman, 2005).

In the temperate and high latitudes the primary characteristic of surf zone finfish is considered to be their variations in seasonal abundance and species composition (Ross et al., 1987). Distributions are heavily influenced by fluctuations in year class success and feeding (seasonal) migrations. While these two influences are the dominant factors, other habitat characteristics have been shown to influence the surf zone finfish distribution on a finer scale; including time of day (Lasiak, 1984a; Gibson et al., 1996; Layman, 2000; Machado and Araujo, 2003), tidal stage (Gibson et al., 1996: Romer, 1990), degree of wave exposure (Clark et al., 1996; Beyst et al., 2001), wind (Warfel and Merriman, 1944; Lasiak, 1984a), aquatic macrophytes (Robertson and Lenanton, 1984; Jenkins and Sutherland, 1997; Crawley et al., 2006), and the presence of rock or other structure (Clark et al., 1996; Wilber et al., 2003). Multiple contradictory findings have been reported regarding the influence of habitat characteristics on the near shore marine finfish distribution, which supports the lack of a strong relationship between finfish abundance and these habitat characteristics (Wilber et al., 2003).

One approach to describing the effect of these many factors on finfish distributions is to view them as hierarchical (Ross et al., 1987), where climatic events determine the success of a year class for a given species. Next, the variability in seasonal abundances for different species is determined primarily by reproductive and feeding migrations of which temperature appears as the underlying mechanism (Layman, 2000). Finally, a combination of multiple habitat characteristics determines the specific location of a species.

While the surf zone is recognized as a productive habitat utilized by marine finfish, little is known about the marine finfish assemblage inhabiting outer Cape Cod. While the surf zone area has varying definitions in the literature, this work will identify the surf zone area according to Komar (1976), the portion of the near shore area in which incoming waves reach instability and break. Thus far no studies have investigated the surf zone on Cape Cod, however four studies from similar systems were reviewed in order to make selected comparisons. Two studies examined nearby estuaries, Wellfleet Harbor (Curley et al., 1972) and Pleasant Bay (Fiske et al., 1967), both investigated for finfish species composition, relative abundances, and monthly distribution. Perhaps the largest surf zone finfish study was conducted at Fire Island, New York, in which 188 hauls were taken over three years (Schaefer, 1967). While other surf zone studies have greater temporal replication, this effort utilized a 396 m haul seine, providing large spatial coverage which led to the detection of 71 finfish species. Additionally, since 1978 the Massachusetts Division of Marine Fisheries

(MADMF) has conducted a ground fish stock assessment survey throughout Massachusetts waters. Many of these tows are in the waters adjacent to the surf zone on outer Cape Cod (King and Manfredi, 2010). Additionally Nauset Marsh, an estuary in close proximity to the selected sample sites was investigated for the seasonal distribution of estuarine finfish and decapod crustaceans (Able et al., 2002). The finfish catch statistics from these studies of adjacent and similar systems are compared to the findings of this surf zone finfish investigation in order to interpret the surf zone finfish assemblage characteristics on Cape Cod.

The selection of sampling gear is important for any ecological investigation as differing gear types can result in different species detected. Gear investigations began in 2007 when the five sampling strategies; angler creel survey, haul seine, beach seine, long line, and gill net were evaluated in terms of species detected, individuals collected, and effort. A comparison of catch data from these sampling gears demonstrated the haul seine and beach seine as the most capable sampling gears in terms of species detected and individuals collected (Estey, 2008). In this effort, surf zone sampling took place at two locations of Fisher Beach and Coast Guard Beach on Cape Cod, Massachusetts during 2007 and 2008 (Figure 1).

This study provides the most complete assessment of the surf zone finfish community conducted in New England to date and will be used to assess future changes in this community. This finfish inventory identified a large data gap and begins the long term monitoring of this resource. Additionally, this effort served as a pilot study with regards to both gear type and sampling strategy for the surf zone finfish in the waters of Cape Cod.

Methods

Coast Guard Beach (Lat. 41º 50’ 35’’ N, Long. 69º 56’ 45’’ W) is located on the eastern facing ocean side of Cape Cod. Fisher Beach (Lat. 41º 59’ 3’’ N, Long. 70º 4’ 40’’ W) is located on the western bay side of Cape Cod. These sampling locations were selected to best accommodate beach operations due to availability of 4 x 4 access and low foot traffic. The sample area bottom type consisted of loose unconsolidated sediments with a mean tidal range of 3.048 m (NOAA, 2013). During 2007 both locations were sampled during the months of June, July, and September with three sets of each gear type: haul seine, beach seine, gillnet, and long line. Sampling events took two days to complete, beginning at 5:00 A.M and lasting until 1:00 P.M. In 2007 the haul seine used in sampling was built to the specifications of the net used in Schaeffer (1963). The net was a 3,962 x 3.7 m commercial style beach seine with the following dimensions: outer wings 167 m of 6 – thread and 7.6 cm stretched mesh, inner wings / bunts of 27.4 m of 12 – thread and 5 cm stretched mesh, and a bag with an opening of 6 m with 15 – thread and 3.8 cm stretched mesh. The bridles were 12 m and attached to the net ends in order to aid in hauling the net to shore. The 2007 beach seine stretched 30 x 1.2 m with a 1.2 x 1.2 x 1.2 m bag. The net was comprised of 3 mm nylon webbing with 0.6 cm stretched mesh. Two gillnets were used in the 2007 field sampling. Both nets were 50 x 3 m, each consisting of two 25 m panels of varying mesh size. Net 1 consists of 3.8 and 12.7 cm mesh and net 2 consists of 7.6 and 17.8 cm mesh. The gill nets were set with a crew of four from an inflatable perpendicular to shore. A soak time of 30 minutes was adopted in order to minimize both finfish mortality and the possibility of seal or marine mammal interactions. The bottom set long line used in 2007 consisted of a 100 m mainline, alternating twine and monofilament leaders of 0.6 m each with 2 m spacing. Circle hooks of varying sizes were baited with frozen squid just prior to setting. The long line was set in a similar manner to the gill net with a soak time of 30 minutes.

After encountering a number of logistical difficulties with the sampling gears in 2007 including gear weight, currents, and manpower limitations, the two most successful sampling gears were modified and fished at a greater frequency. The haul seine was shortened to 66 m and two 33 meter bridles were attached to maximize fishing area while minimizing drag. Also, a 0.6 cm. lead core line was added to the lead line to increase the net's likelihood to tend bottom in currents, waves, and water depths > 3.7 m. The original beach seine used in sampling was replaced with identical webbing but stretching 33 x 1.8 m increasing the fishing depth. Bridles of 33 meters were attached were attached to increase the fishing area of the net. Estey (2008) provides a more complete description of the sampling gears. In 2008, both Coast Guard and Fisher Beach were scheduled to be visited twice during the months of May, June, July, September, and October and had three sets of each gear type. Just as in 2007, sampling dates were planned months in advance, and the variability in the surf zone conditions at Coast Guard Beach; wind, waves, and aquatic macrophytes led to the rescheduling of multiple sampling events.

Catch from all gear types was processed identically in both 2007 and 2008. As fish were encountered they were identified at the species level and measured to the nearest centimeter. Identifications were made according to a Peterson field guide (Robins et al., 1986). Total catch from Cape Cod during 2007 and 2008 is presented as number of individuals, % of total catch, and rank abundance for each species, and separately for Coast Guard and Fisher Beach along with monthly catch data. Recorded sampling information, which is presented in Appendix A included; sampling date, location, set, gear type, time, tidal stage, air temperature, water temperature, wind (direction and speed), significant wave height, and precipitation. No attempts were made to link the sampling information to finfish catch.

Trends in the species composition were investigated using multidimensional scaling (MDS) and analysis of similarity (ANOSIM) programs found in PRIMER 6.0 statistical package (Clarke and Gorley, 2006). Similarity matrices were constructed using the Bray Curtis similarity index (Bray and Curtis, 1957). Results were displayed for visual interpretation and grouping patterns were further observed using an ordination plot generated by MDS (Clark and Warwick, 2001). ANOSIM tested the null hypothesis (H_0) which was rejected when the significance level of the test statistic was less than $p = 0.05$. The significance of this test was determined by using the R-statistic value (Clark and Green, 1988).

Catches during 2008 from Coast Guard and Fisher Beach were compared to evaluate differences in number of species sampled, number of individuals sampled, and the finfish community assemblage during months of May, June, and July. The number of species and number of individuals detected per sampling event were compared separately for Coast Guard and Fisher Beach using a Welch’s two sample T test. In order to determine if finfish assemblages differed between locations over the duration of the sampling season the following null hypothesis was investigated: H_{01} = There is no difference between both the similarity of finfish assemblages between sampling locations and the temporal similarities of the combined finfish assemblages over the sampling season. Finfish communities sampled at Coast Guard and Fisher Beach were compared for the months of May, June, and July with ANOSIM. Daily catches from the hauls seine and the beach seine were summed to represent a single sampling event.

Trends in the proportion of warm water species at multiple northern near shore marine environments were investigated by use of subtropical / all species ratios (S/A ratios). For each haul, fish species were coded as subtropical, temperate, or polar from Fish Base (Table 1). S/A ratios were then calculated as: subtropical (S) / (subtropical + temperate + polar (all(A))) species for each individual haul. Multiple hauls taken during a sampling event are averaged for a single S/A ratio value representing that event.

Trends in water temperature, S/A ratio, and diversity were investigated at Fisher Beach over the months of May, June, July, September, and October as the largest temporal sampling effort was undertaken here. Water temperature was taken with a handheld thermometer. S/A ratios were calculated by combining catches from the haul seine and beach seine. Diversity was calculated as number of species detected. Results of water temperature, S/A ratio, and diversity are plotted by month for Fisher Beach. Additionally, water temperature, S/A ratio, and species richness were calculated for nearby estuaries Wellfleet Harbor (1972), and Pleasant Bay (1967). Wellfleet Harbor is located ~ three kilometers south of the Fisher Beach sample site, within Cape Cod Bay. Pleasant Bay is located ~ fifteen kilometers south of Coast Guard Beach. The results of water temperature, S/A ratio, and diversity for

Fisher Beach, Wellfleet Harbor, and Pleasant Bay were compared in terms of the timing of these variable's maximum values in order to test the second null hypothesis: H_{02} = There is not a consistent temporal pattern in water temperature, S/A ratio, and diversity maximum values between the surf zone and the shallows of the nearby estuarine systems.

In 2007 five gears were investigated; angler creel survey, long line, gill net, beach seine, and haul seine. This effort served as a pilot study to determine the most appropriate methods for finfish sampling in the near shore waters of Cape Cod. In 2008 the haul seine and beach seine were modified and fished again at a greater frequency. Catches from the haul seine and beach seine were compared to determine if they differed in either number of species detected per haul or number of individuals detected per haul with a one way ANOVA. Comparisons were made separately at Coast Guard and Fisher Beach. Additionally, the catch composition between the haul seine and beach seine were compared with MDS, SIMPER, and ANOSIM for the months of May, June, and July for Coast Guard and Fisher Beach separately in order to test the following null hypothesis: H_{03} = There is no difference in the catches of the haul seine and beach seine in terms of the number of finfish species, number of finfish individuals, or the finfish community sampled.

Catches from Fisher Beach were investigated to determine whether finfish assemblages differed by month with ANOSIM. Fisher Beach was selected as it had the greatest sampling coverage of six months. Individual hauls were coded by month, transformed by presence / absence, and a Bray Curtis similarity matrix was constructed in order to test the following null hypothesis: H_{04} = There is no difference in the similarity of finfish assemblages within and among the investigated months.

To determine the number of hauls needed to characterize the finfish assemblage for Coast Guard and Fisher Beach hauls were combined by day, for a total of six hauls per daily sampling event. Since sampling events took place on consecutive days, species were summed across the two days, and the percent of total species detected on only day one was calculated. The percentage of species detected in one day of a two day sampling event was averaged across the season separately for Coast Guard and Fisher Beach. Using this calculation recommendations were made as to whether monthly investigations benefited from an additional sampling day.

Additionally, an intensive four day study was undertaken in 2008 at Fisher Beach during September 19, 20, 21, and 22 to investigate the percentage of overall finfish community detected in one, two, or three days of sampling. Each day received equal effort: three haul seine and three beach seine sets. Recommendations are made as to the effort level needed to detect 80% of the total number of species.

Results

A total of 5,770 individuals representing 32 finfish species and loligo squid were detected during 2007 and 2008 at Coast Guard Beach (Table 1). Ten species comprised 91% of the total catch for the combined 2007 and 2008 catches: Atlantic silverside (*Menidia menidia*) = 31%, striped bass (*Morone saxatilis*) = 20%, American shad (*Alosa sapidissma*) = 10%, Atlantic herring (*Clupea harengus*) = 7%, alewife (*Alosa psuedoharengus*) = 7%, sand lance (*Ammodytes hexapterus*) = 4%, striped killifish (*Fundulus majalis*) = 4%, northern kingfish (*Menticirrhus saxatilis*) = 3%, bluefish (*Pomatomus saltatrix*) = 3%, and Atlantic menhaden (*Brevoortia tyrannus*) = 3%. The most abundant finfish species varied from year to year and differed between Coast Guard and Fisher Beach.

At Coast Guard Beach a total of 1,047 individuals representing 13 species were detected in the sampling conducted in 2007 and 2008 (Table 2). Five species accounting for 92% of the catch: Atlantic herring = 30%, American shad = 24%, alewife = 20%, striped bass = 11%, and sand lance = 8%. The number of species detected varied between years with five species collected in 2007 and eleven species in 2008. The most abundant species varied between 2007 and 2008 and the occurrence of finfish species by month is listed in Table 3. In both 2007 and 2008, the most abundant species varied between months: May with Atlantic herring, June with American shad, and July with alewife. The number of finfish species, including squid, also varied among months at Coast Guard Beach (May = 7, June = 9, and July = 10).

At Fisher Beach a total of 4,723 individuals representing 32 species and loligo squid were detected in the sampling conducted in 2007 and 2008 (Table 4). Twelve species accounted for 96% of the catch: Atlantic silverside = 38%, striped bass = 22%, American shad = 7%, striped killifish = 5%, sand lance = 4%, alewife = 4%, northern kingfish = 3%, Atlantic menhaden = 3%, bluefish = 3%, northern pipefish (*Syngnathus fuscus*) = 3%, cunner (*Tautogolabrus adspersus*) = 3%, and Atlantic herring = 2%. The number of species detected varied between years with 14 species detected in 2007 and 32 finfish species and loligo squid detected in 2008. All species detected in 2007 were present in the 2008 catch. The occurrence of finfish species detected by month at Fisher Beach is presented in Table 5. The dominant species varied among months: May with Atlantic silverside, June with American shad, July with striped bass, September with Atlantic silverside, and October with sand lance. The number of finfish species, including squid, also varied among months (May = 10, June = 10, July = 13, September = 27, and October = 12).

Catches in 2008 during May, June, and July from Coast Guard and Fisher Beach were compared in terms of species richness (S), number of individuals (N), and finfish community composition. Counts of both number of species and number of individuals were log transformed to meet assumptions of normality with a Shapiro Wilks test (species: $W = 0.97$, $p = 0.65$; individuals: $W = 0.98$, $p = 0.83$) and heterogeneity of variance with a Levene's test (species: $F = 1.20$, $p = 0.32$). Fisher Beach had both a greater number of species detected (Fisher Beach = 19; Coast Guard = 13) and individuals captured (Fisher Beach = 1,407; Coast Guard = 724). Results of two sample t tests show significant differences between individuals ($t = 2.60$, $df = 69.98$, $p = 0.01$) and species ($t = 4.48$, $df = 70.00$, $p = < 0.01$).

Finfish assemblage spatial similarities for Coast Guard and Fisher Beach were compared to temporal similarities for the months of May, June, and July to investigate the first null hypothesis. ANOSIM results between Coast Guard and Fisher Beach show significantly differing finfish assemblages ($R = 0.46$; $p = 0.02$). Results are displayed in MDS in Figure 2. ANOSIM results between months for combined Coast Guard and Fisher Beach show no significant differences in finfish assemblages between months ($R = -0.74$; $p = 0.70$). These findings result in the rejection of the first null hypothesis: H_{01} = There is no difference between both the similarity of finfish assemblages between sampling locations and the temporal similarities of the combined finfish assemblages over the sampling season. These results demonstrate different surf zone finfish communities between sampling locations.

Results from visual evaluation of temporal patterns in water temperature, S/A index values, and species richness are displayed in Figure 3. At Fisher Beach, the water temperature peaks in July, coinciding with a peak in the S/A ratio. In September, as the water temperature and S/A ratio decrease, diversity is maximized. At Fisher Beach, sampling was limited to five months of the year (and excluded August). Yearly temporal patterns in these variables were investigated from catch and environmental data contained in the state estuarine reports for the nearby estuaries of Wellfleet Harbor and Pleasant Bay. The same patterns are present with a peak of water temperatures and S/A ratio in the summer, followed by a peak of diversity in the fall. Based on these results, the second null hypothesis is rejected: H_{02} = There is not a consistent temporal pattern in water temperature, S/A ratio, and diversity maximum values between the surf zone and the shallows of the nearby estuarine systems.

During the 2008 sampling season, catches from the haul seine and beach seine were compared for number of species (S) and individuals (N). Counts of both number of species and number of individuals were square root transformed to meet assumptions of normality and homogeneity of variance. Results of Shapiro-Wilk normality test shows data are normally distributed for individuals (W = 0.98, p = 0.83) and species (W = 0.98, p = 0.65). At Fisher Beach catches significantly differed between the haul seine and beach seine for both mean number of species (haul seine, S = 2.11, beach seine, S = 4.11; df = 35, p = 0.001) and number of individuals (haul seine, N = 16.5, beach seine, N = 56.0; df = 35, $p = 0.001$) collected per haul. Catches were not significantly different at Coast Guard Beach between the haul seine and beach seine for number of species detected (haul seine, S = 1.61, beach seine, S = 1.11; df = 35, $p = 0.17$) and individuals collected (haul seine, N = 17.3, beach seine, N = 21.4; df = 35, $p = 0.72$). Additionally, the finfish communities detected by the haul seine and beach seine were compared separately at Coast Guard and Fisher Beaches. ANOSIM results show significantly different finfish assemblages detected between the haul seine and the beach seine at both locations (Coast Guard Beach R = 0.35, $p = 0.01$; Fisher Beach R = 0.19, $p = 0.01$). SIMPER identified the finfish species contributing the greatest amount of dissimilarity between the haul seine and beach seine catches. At Coast Guard Beach, four species (sand lance, alewife, striped bass, and windowpane flounder) each contributed over 10% for a total SIMPER average dissimilarity of 90.87%. At Fisher Beach, SIMPER identified two species (Atlantic silverside and northern pipefish) each contributing over 10% to the total 76.61% dissimilarity. These findings result in the rejection of the third null hypothesis: H_{03} = There is no difference in the catches of the haul seine and beach seine in terms of the number of finfish species, number of finfish individuals, or the finfish community sampled.

Analysis of finfish assemblage by month was conducted only at Fisher Beach due to its greater temporal coverage. MDS analysis was attempted but did not further inform the interpretation. ANOSIM finds all months with the exception of June and July significantly different at the $p < 0.05$. These findings result in the rejection of the null hypothesis: H_{04} = There is no difference in the similarity of finfish assemblages within and among the investigated months. Results from the analysis of sample days needed to characterize the assemblage at Coast Guard and Fisher Beach are shown in Table 6. A single day's sampling event resulted in 62% at Coast Guard (range = 14 - 83%) and 71% at Fisher Beach (range = 42 - 91%) of the two day species totals. Additionally, species accumulation curves conducted during the September 19, 29, 21, and 22 (2008) sampling events show the percent of species detected for alternative sampling approaches over 1, 2, 3, or 4 consecutive days. The percentage of total species detected is as follows: 1 day = 71%, 2 days = 91%, 3 days = 95%, and 4 days 100% (Figure 4).

Discussion

A total of 32 finfish species and loligo squid were detected during sampling during 2007 and 2008 on Cape Cod. Monthly sampling in both Wellfleet Harbor (1968) and Pleasant Bay (1965) during the MA state estuarine monitoring program identified a similar number of fish, 35 and 36 finfish species respectively. Additionally, investigations in nearby Nauset Marsh (Able et al., 2002) identified 35 finfish species. These findings are similar to those of sampling location Fisher Beach in which 32 species were identified suggesting that the near shore Cape Cod Bay surf zone environment has similar diversity to its nearby estuaries.

In selected MADMF survey trawls near the sample locations of Coast Guard and Fisher Beach, 63 finfish species were identified. Many more species were recorded in the MADMF trawl survey than the surf zone due to the massive effort of 237 hauls over 31 years. While this higher spatial and temporal effort contributes to the greater diversity than that identified in this work, the MADMF survey demonstrates the large number of species inhabiting the near shore environment, the area immediately seaward of the surf zone. Since the defined borders of this near shore environment and adjacent surf zone fluctuate with wave size, many of these species identified in the trawl survey inhabit the surf zone. A total of 71 species were detected by Schaefer (1967) in Long Island, New York. Multiple factors contributed to the greater number of species detected in this sampling of the surf zone than that of Cape Cod. Schaefer's study undertook a much greater spatial and temporal effort and sampled a more southerly location known to exhibit higher diversity (Collette and MacPhee, 2002).

When combining the catch data from both locations over the two year period, ten species accounted for 91% of the total catch which is consistent with other studies based on the surf zone area (Lasiak, 1984a; Machado and Arujo, 2003; Layman, 2000) including Schaeffer (1967). While accurate relative abundance calculations were not permitted from Pleasant Bay catch data, in Wellfleet harbor four species accounted for over 95% of the total catch. Selected tows from the MADMF trawl survey adjacent to the sample locations show similar results. For MADMF ocean side surveys, seven species accounted for 84% of the total abundance with the remaining 40 species comprising 1% or less. On the bay side, six species accounted for 88% of the finfish detected with the remaining 52 species each accounting for 1% or less of the total catch. This characteristic of dominance by only a few species in the surf zone environment appears consistent across multiple sampling gears and locations.

Fisher Beach was found to have both a significantly greater number of species detected and individuals collected. Results from multivariate analysis also show Coast Guard and Fisher Beach having differing finfish communities. In freshwater systems the nekton abundance spatial variability is much higher than temporal variability due to habitat heterogeneity (Peterson and Rabeni, 1995). In the Northeastern U.S., surf zone finfish temporal variability is much higher than spatial variability due to fluctuations in year class success, climatic events, and seasonal migrations (Ross, 1987). These results demonstrate that within the surf zone area, there are multiple sub habitats which should be stratified when sampling to account for differing finfish diversity, abundances, and overall community composition.

The primary characteristic of surf zone fish in the temperate and high latitudes is their variations in seasonal abundance and species composition (Ross et. al., 1987). This effort characterized the surf zone's species seasonal distribution based on water temperature, S/A index, and diversity and compared the findings among estuarine locations of nearby Wellfleet Harbor and Pleasant Bay. This investigation was a qualitative investigation, as the available data would not support quantitative analysis. The results demonstrate that the finfish distribution of the near shore environment following a similar pattern with the shallows of the nearby estuaries, which is characterized by a peak of water temperatures and S/A ratio in the summer months, followed by a peak of diversity in the early fall. Additionally in Nauset Marsh, a nearby estuarine location, finfish diversity peaked during September (Able et al., 2002). This variability in seasonal abundance is thought to be primarily determined by reproductive and feeding migrations of which temperature appears to underlying mechanism (Layman, 2000). Since food webs in the surf zone systems are phytoplankton based (Ross et. al., 1987), the observed seasonal variation in finfish communities in the Northeastern U.S. may be largely due to the winter decline in phytoplankton productivity due to colder temperatures. A consistent temporal pattern across water temperature, S/A index, and diversity demonstrates that the surf zone finfish species composition at Fisher Beach is very much like that of Wellfleet and Pleasant Bay.

The main goal of this 2008 comparison was to test whether both gears were justified in the inclusion of a sampling strategy by comparing their finfish catches in terms of species detected, individuals captured, and finfish community composition. Haul seine and beach seine catches of species detected and individuals captured differed at Coast Guard and Fisher Beach. At Fisher Beach the beach seine detected a greater number of both species and individuals. At Coast Guard Beach gear comparisons did not produce significant results. This lack of significance was due to higher variability associated with relatively low catches at Coast Guard Beach.

ANOSIM results show significantly different finfish assemblages detected between the haul seine and the beach seine at both locations (Coast Guard Beach $R = 0.345$, $p < 0.01$); Fisher Beach $R = 0.193$, $p < 0.01$). At Coast Guard Beach, SIMPER results identified differences in the finfish communities detected by the haul seine and beach seine were primarily due to the beach seine detecting sand lance more frequently and the haul seine identifying alewife, striped bass, and windowpane flounder more frequently. At Fisher Beach the differences in catch composition were primarily due to the beach seine detecting Atlantic silversides and northern pipefish more frequently than the larger meshed haul seine. Results of the sampling gear performance were similar at both locations as the beach seine detected the smaller species and juveniles and the haul seine detected larger finfish. These tests were conducted during the months of May, June, and July which provides only a partial comparison of the finfish communities. Had the comparison been made throughout the year greater differences likely would have been observed. The differences in the catch composition of the two sampling gears suggest that both sampling gears should be included in a sampling program.

This study was designed to make sampling recommendations with respect to seasonal effort. ANOSIM results demonstrate that the finfish assemblage at Fisher Beach differs from month to month. The goals of a specific monitoring program dictate the level of seasonal coverage, although for sampling to most accurately describe this location in terms of species detected, a year round sampling schedule is recommended. However, if the sampling goal is to identify the maximum number of finfish species, a concentrated sampling effort in the month of September is recommended as all reviewed works, including Nauset Marsh (Able et al., 2002), identified this month to possess the greatest finfish diversity.

Investigations into the appropriate number of sampling days suggest that two sampling days per month are sufficient to identify the majority of the observed species. A single day’s sampling event resulted in 62% of the two day total catch at Coast Guard Beach (range = 14 - 83%) and 71% at Fisher Beach (range = 42 - 91%). The results of the single day sampling events show high variability associated with a single day’s sampling. Results from the four consecutive day sampling effort conducted at Fisher Beach demonstrate two days as sufficient to identify >80% of the total species detected: (1 day = 72%, 2 days = 91%, 3 days = 95%, and 4 days = 100%). During the investigated months, May – October, both findings suggest that two days is the most appropriate sampling approach to identify the majority of the finfish species characterizing the community.

The surf zone finfish assemblage inhabiting the waters adjacent to the Cape Cod National Seashore exhibits relatively high finfish diversity, similar to that of nearby estuaries. Investigations suggest it is possible to successfully monitor this finfish resource depending on the required level of precision. While this finfish distribution is characterized by high variability, large scale perturbations to this habitat altering species composition and relative abundances would be apparent with intermittent sampling.

Table 1. List of finfish and molluscan species collected, number of individuals captured, percent of catch, rank, and distribution of finfish collected during sampling conducted at Coast Guard Beach and Fisher Beach during 2007 and 2008. Distribution is identified as; S = subtropical, T = temperate, and P = polar.

Species	Common name	N	Percent of Catch	Rank	Distribution
Menidia menidia	Atlantic silverside	1795	31	1	T
Morone saxatilis	striped bass	1132	20	2	T
Alosa sapidissma	American shad	582	10	3	T
Clupea harengus	Atlantic herring	409	7	4	T
Alosa psuedoharengus	alewife	380	7	5	T
Ammodytes hexapterus	northern sand lance	255	4	6	P
Fundulus majalis	striped killifish	238	4	7	T
Menticirrhus saxatilis	northern kingfish	164	3	8	S
Pomatomus saltatrix	bluefish	162	3	9	S
Brevoortia tyrannus	Atlantic menhaden	161	3	10	S
Syngnathus fuscus	northern pipefish	133	2	11	S
Tautogolabrus adspersus	cunner	123	2	12	T
Loligo pealei	squid	51	1	13	T
P. americanus	winter flounder	38	1	14	T
Centropristis striata	black sea bass	37	1	15	T
Tautoga onitits	tautog	30	1	16	S
Scomber scombrus	Atlantic mackerel	30	1	16	T
Scophthalmus aquosus	windowpane flounder	24		18	T
Peprilis triacanthus	butterfish	3		19	S
Decapterus macarellus	mackerel scad	3		19	S
Fundulus heteroclitus	mummichog	3		19	T
Cyprinodon veriegatus	sheepshead minnow	2		22	S
Anguilla rostrata	American eel	2		22	S
Microgadus tomcod	Atlantic tomcod	2		22	T
Mugil curema	white mullet	2		22	S
Priontus carolinus	northern searobin	1		26	T
Macrozoarces americanus	oceanpout	1		26	T
Myoxocephalus aenaeus	grubby	1		26	T
Melanogrammus aeglefinus	haddock	1		26	T
Raja erinacea	little skate	1		26	T
Selene vomer	lookdown	1		26	S
Opasnus tau	oyster toadfish	1		26	S
Limanda ferruginea	yellowtail flounder	1		26	T

Table 2. List of finfish and molluscan species collected, number or individuals, percent of total catch, and rank at Coast Guard Beach for the years 2007, 2008, and combined.

	2007			2008			Total		
Species	N	%	Rank	N	%	Rank	N	%	Rank
Atlantic herring				309	41	1	309	30	1
American shad	236	81	1	13	2	7	249	24	2
alewife				211	28	2	211	20	3
striped bass	50	17	2	62	8	4	112	11	4
northern sand lance				79	10	3	79	8	5
Atlantic mackerel				24	4	5	28	3	6
squid				28	4	5	28	3	6
bluefish	4	1	3	5	1	9	9	1	8
windowpane flounder				7	1	8	7	1	9
Atlantic silverside				5	1	10	5		10
winter flounder				4	1	11	4		11
Atlantic menhaden	1		4	2		12	3		12
butterfish				2		12	2		13

Table 3. List of finfish and molluscan species collected and number of individuals by month for Coast Guard Beach for the years 2007, 2008, and combined.

	2007			2008				Total			
Common Name	Ju	Jy	Total	M	Ju	Jy	Total	M	Ju	Jy	Total
Atlantic herring				309			309	309			309
American shad	234	2	236	11		2	13	11	234	4	239
alewife				4	36	171	211	4	36	171	211
striped bass	49	1	50	59	2	1	62	59	52	2	112
northern sand lance				29	23	27	79	29	23	27	79
Atlantic mackerel						28	28			28	28
squid					17	11	28		17	11	28
bluefish	1	3	4		1	4	5		2	7	9
windowpane flounder				5	2		7	5	2		7
Atlantic silverside						5	5			5	5
winter flounder				4			4	4			4
Atlantic menhaden	1		1		1	1	2		2	1	3
butterfish					1	1	2		1	1	2

Table 4. List of finfish and molluscan species collected, number of individuals, percent of total catch, and rank, at Fisher Beach for the years 2007, 2008, and combined.

	2007			2008			Combined		
Common Name	N	%	Rank	N	%	Rank	N	%	Rank
Atlantic silverside	401	21	2	1389	49	1	1790	38	1
striped bass	962	51	1	58	2	9	1020	22	2
American shad	331	18	3	2		16	333	7	3
striped killifish	1		9	237	8	2	238	5	4
northern sand lance				176	6	3	176	4	5
alewife				169	6	4	169	4	6
northern kingfish	1		9	163	6	5	164	3	7
Atlantic menhaden	138	7	4	20	1	13	158	3	8
bluefish	18	1	5	135	5	6	153	3	9
northern pipefish	7		7	126	4	7	133	3	10
cunner				123	4	8	123	3	11
Atlantic herring	4		8	96	3	9	100	2	12
black sea bass				37	1	10	37	1	13
winter flounder	1		9	33	1	11	34	1	14
tautog	1		9	29	1	12	30	1	15
squid				23	1	14	23		16
windowpane flounder	11	1	6	6		14	17		17
mackerel scad				3		15	3		18
mummichog	1		9	2		16	3		18
sheepshead minnow				2		16	2		20
American eel	1		9	1		15	2		20
Atlantic mackerel				2		16	2		20
Atlantic tomcod				2		16	2		20
white mullet				2		16	2		20
northern searobin				1		17	1		25
butterfish				1		17	1		25

	2007			2008			Combined		
Common Name	N	%	Rank	N	%	Rank	N	%	Rank
oceanpout				1		17	1		25
grubby				1		17	1		25
haddock				1		17	1		25
little skate				1		17	1		25
lookdown				1		17	1		25
oyster toadfish				1		17	1		25
yellowtail flounder				1		17	1		25

Table 5. List of finfish and molluscan species collected and number of individuals by month at Fisher Beach for the years 2007, 2008, and combined.

	2007				2008						Combined					
Common Name	Ju	Jy	Sep	Tot	M	Ju	Jy	S	O	Tot	M	Ju	Jy	S	O	Tot
Atlantic silverside	3	45	353	401	217	27	580	547	18	1389	217	30	625	900	18	1790
striped bass	58	894	10	962	9	32	9	6	2	58	9	90	903	16	2	1020
American shad	331			331		2				2		333				333
striped killifish			1	1	1		65	167	4	237	1		65	168	4	238
northern sand lance					2		139	1	34	176	2		139	1	34	176
alewife						9	66	78	16	169		9	66	78	16	169
northern kingfish			1	1				163		163				164		164
Atlantic menhaden		21	117	138	14	1			5	20	14	1	21	117	5	158
bluefish	2	3	13	18		1	2	132		135		3	5	145		153
northern pipefish			7	7	11	8	48	54	5	126	11	8	48	61	5	133
cunner					4			117	2	123	4			117	2	123
Atlantic herring			4	4	28			66	2	96	28			70	2	100
black sea bass								37		37				37		37
winter flounder			1	1	9		2	18	4	33	9		2	19	4	34
tautog			1	1			10	19		29			10	20		30
squid							14	9		23			14	9		23
windowpane flounder	1	1	9	11		1	4	1		6		2	5	10		17
mackerel scad								3		3				3		3
mummichog	1			1				2		2		1		2	3	
sheepshead minnow								2		2				2		2
American eel		1		1			1			1				2		2
Atlantic mackerel								2		2				2		2
Atlantic tomcod								2		2				2		2
white mullet								2		2				2		2
northern searobin									1	1					1	1
butterfish							1			1				1		1
oceanpout								1		1				1		1

Common Name	Ju	Jy	Sep	Tot	M	Ju	Jy	S	O	Tot	M	Ju	Jy	S	O	Tot
grubby					1					1	1					1
haddock						1				1		1				1
little skate	1			1									1			1
lookdown								1		1				1		1
oyster toadfish									1	1					1	1
yellowtail flounder							1			1				1		1

Table 6. Percentage of total species detected, averaged monthly values for Coast Guard and Fisher Beach, day 1 and day 2, haul seine and beach seine combined.

% Species Detected	Coast Guard		Fisher	
	Day 1	Day 2	Day 1	Day 2
Average	62	100	71	100
Standard Deviation	25	0.00	15	0.00
Range	14 – 83	0.00	42 – 91	0.00

Figure 1. Sampling locations of Coast Guard Beach, Truro MA (A) and Fisher Beach, Truro MA (B).

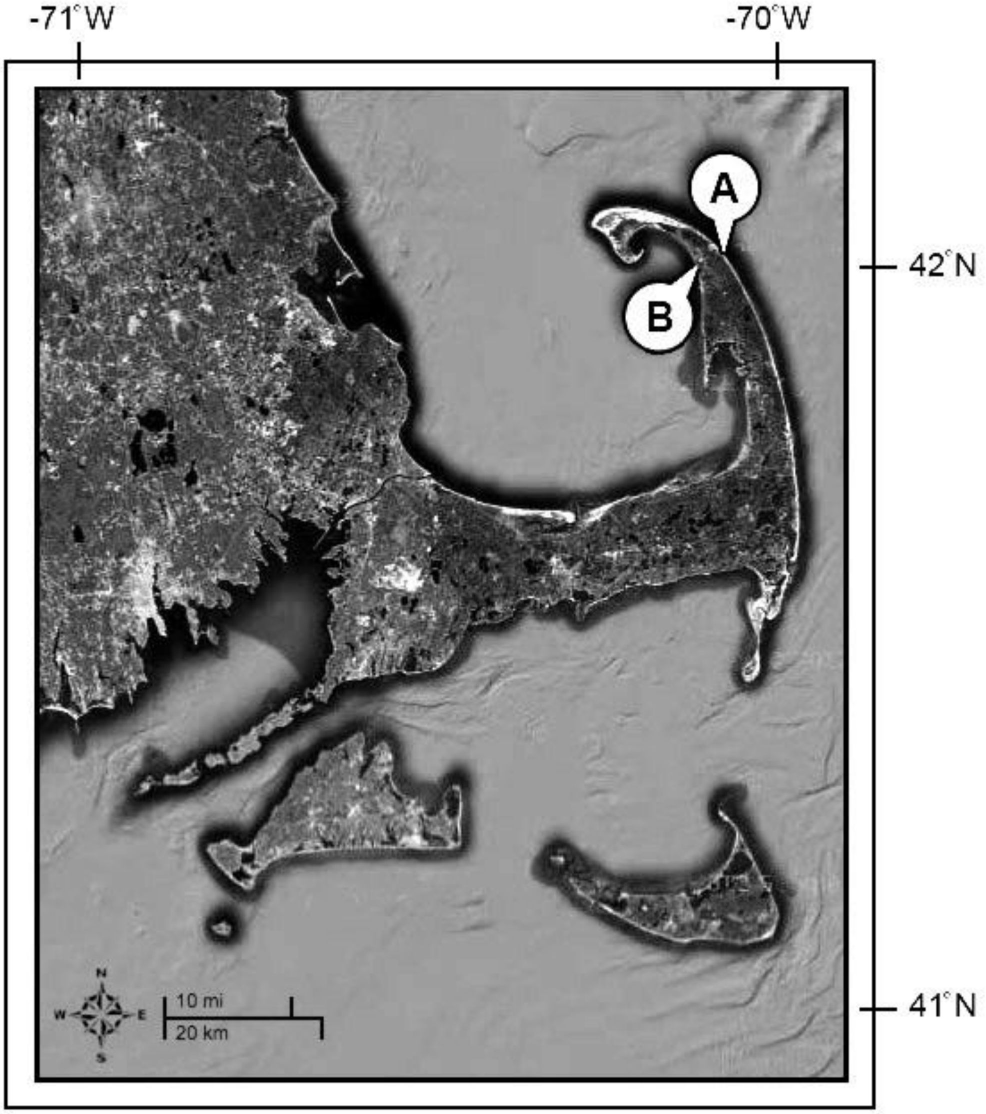


Figure 2. MDS results comparing summed catches of finfish sampling events at Coast Guard (CG) and Fisher Beach (F). Samples show greater similarity (40%) by location than month; M = May, J = June, and Ju = July.

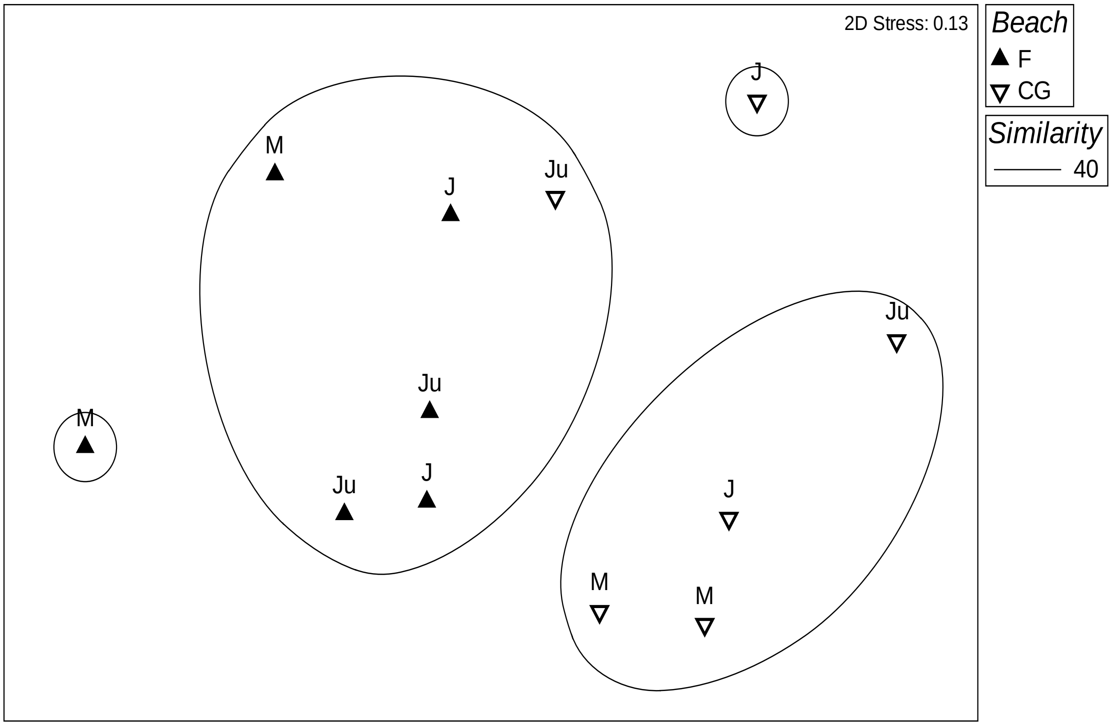


Figure 3. Comparison of water temperature, S/A ratio, and species richness at Fisher Beach (A), Wellfleet Harbor (B), and Pleasant Bay (C). (3A Fisher Beach: No sampling data available for August).

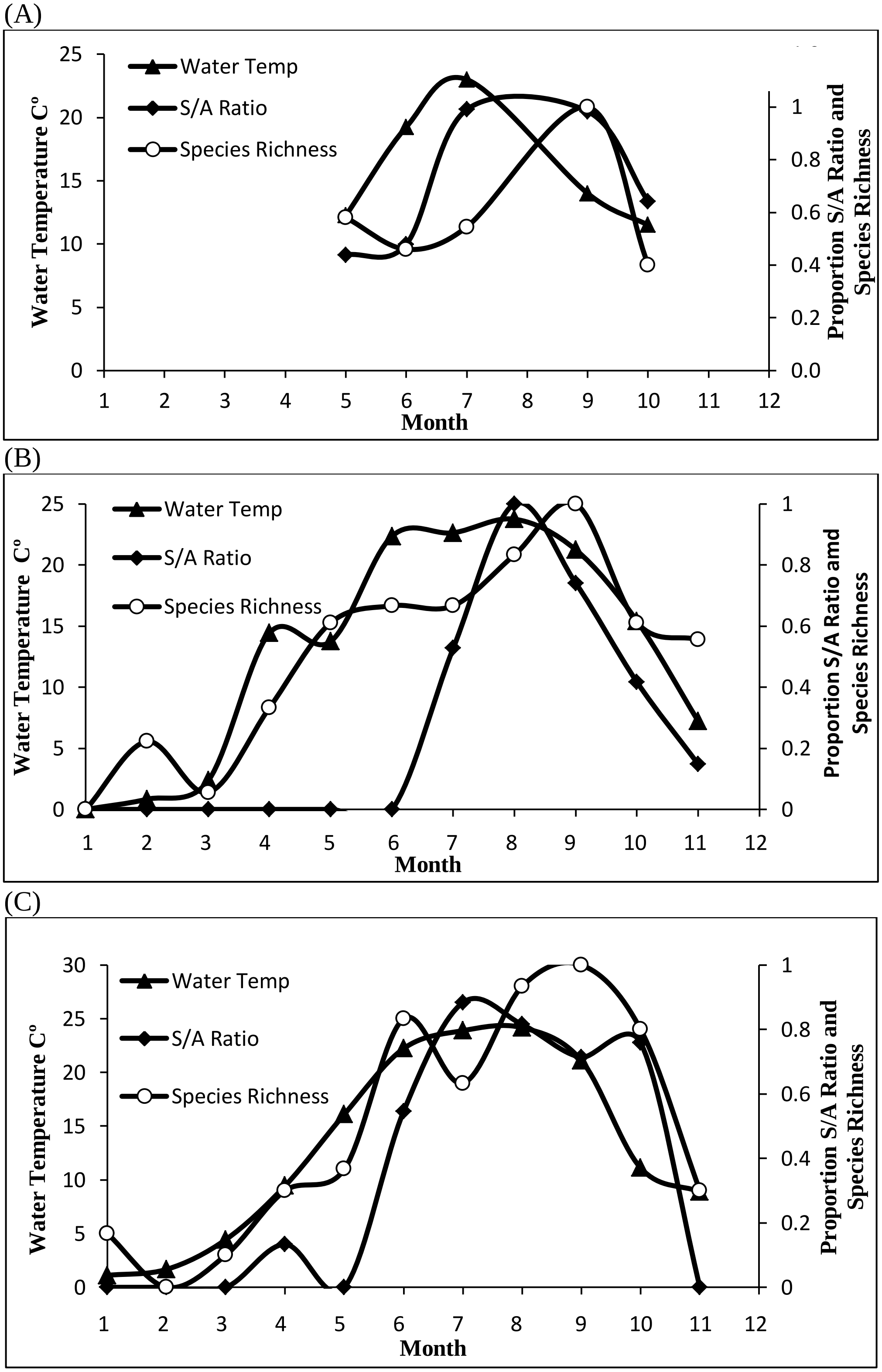
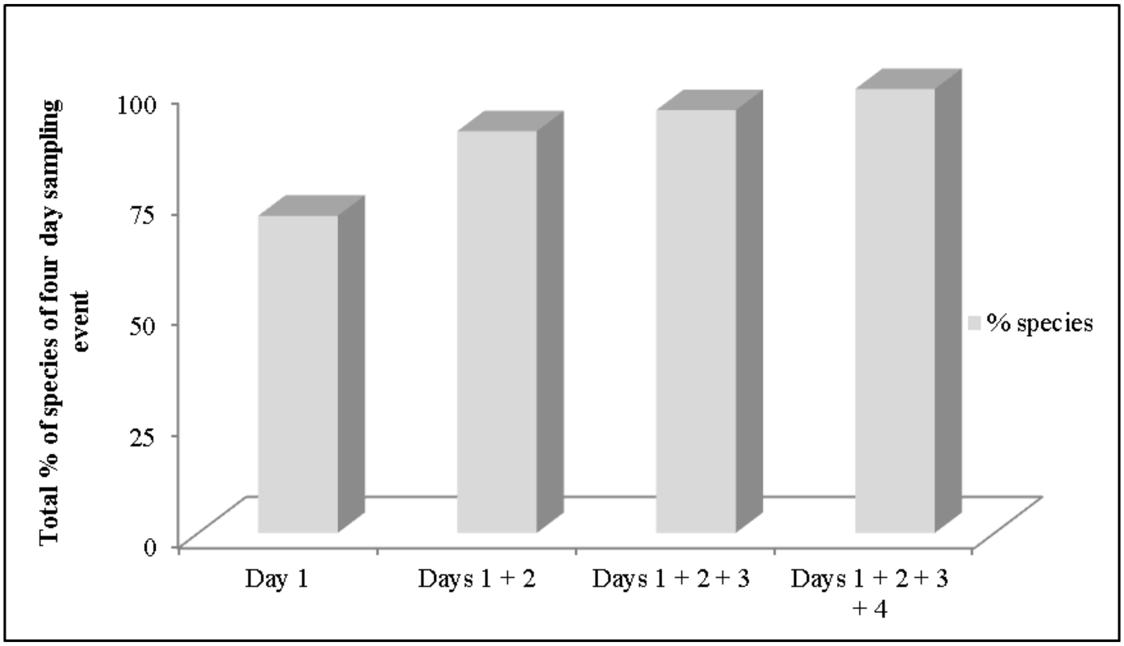


Figure 4. Total percent of all species detected at Fisher Beach over four consecutive days of sampling. Each sampling event consisted of three haul seine and three beach seine sets.



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MANUSCRIPT – II

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Distribution of Near Shore Marine Demersal Finfish, Cape Cod, MA, USA: A Transitional Zone

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Abstract

The concept of a distinct transitional zone (TZ) joining the Acadian and Virginian provinces for the near shore marine demersal finfish assemblage is introduced as opposed to a gradual transition in the species composition between these provinces. Both the role of Cape Cod as a zoographic boundary and the properties of the TZ are investigated by use of a biogeographical species ratio estimator (S/A) calculated per haul as: subtropical species (S) / (subtropical + temperate + polar species (all (A)) from the Massachusetts Division of Marine Fisheries Trawl Survey. Five differing finfish assemblages were identified by both distinct discontinuities in the finfish assemblages among regions and significantly different S/A ratios suggesting that Cape Cod acts as a zoographic barrier. Additionally, these five assemblages overlap in latitude, are in close proximity relative to their size, and have differing fish communities explained primarily by bottom temperatures. Analyses identified the location of the TZ (sub region C) between average latitudes 41º18.67’ N and 41º33.45’ N where the S/A ratio declines abruptly from 0.51 to 0.37 within ~ 4.6 km. The TZ is shown to have enhanced diversity (13.65 species per tow) over all surrounding sub-regions (A = 11.65, B = 10.60, D = 12.20, E = 11.00, and F = 10.90 species per tow). This enhanced diversity coincides with the abrupt decline of the S/A ratio indicating the addition of temperate and polar species which is to be expected in the area of the TZ. Furthermore, at approximately 41º25.00’ N the Δ S/A ratio / Δ latitude is maximized, coinciding with the maximum diversity, indicating a distinct TZ. Decadal comparisons show an increase in the S/A ratio (1980s = 0.29, 1990s = 0.38, and 2000s = 0.42). Here the S/A ratio is demonstrated as an appropriate

quantitative measure for assessing species distributions and biogeographical boundaries that will be applicable across varying sampling methods as it relies on presence-absence data.

1. Introduction

Demersal finfish and their associated distributions are an important resource for coastal communities in all the world's oceans. These finfish assemblages are mainly shaped by depth and further modified by latitude, sediment, temperature (Beentjest et. al., 2002), and habitat preferences (Collaca, 2003). Due to the large influence of habitat on shaping finfish distribution, the near shore environment is often biogeographically distinct from deeper seaward waters (Ekman, 1953; Briggs, 1974; Ray, 1996).

Biogeography is the study of the distribution of organisms through time and space. Ekman (1953) made a large contribution to biogeography by identifying regions or sub-regions within the marine system and dividing oceans into warm, temperate, and polar waters. Later, Briggs (1974) divided the continental shelf into biographic regions containing smaller provinces. These biogeographical provinces have been defined primarily on the basis of where clusters of range boundaries occur for selected groups of species, and vary depending on the taxa of interest (Briggs, 2012). This definition is dependent on the assumption that the biogeography of coastal marine fauna reflects the geographic structure of its physical environment (Hayden and Dolan, 1976). Large scale environmental factors such as water body characteristics, currents, and climate act to define a species range. These combinations of ranges define the biogeographic provinces (Ray, 1996).

The east coast of North America has been classified into five biogeographical provinces: Arctic, Nova-Scotian, Virginian, Carolinian, and Caribbean (Hayden and Dolan, 1976). The boundaries between these provinces are considered to be at about:

Cape Race, Newfoundland (47°N); Cape Cod, Massachusetts (41°N); Cape Hatteras, North Carolina (35°N); and near Jacksonville, Florida (30°N) (Mahon, 1998). Cape Cod forms the northern edge of the American Atlantic Temperate Region (Gosner, 1971), and the resident fauna are limited by summer conditions in the north and by winter conditions in the south (Hutchins, 1947; Engle, 1999). It has been identified as a zoographic barrier but to varying extents, as the divisions between warm temperate and cold temperate fauna are temporally variable. Cold temperate fauna are thought to be continuous around Cape Cod (Briggs, 1974) and periodically even more tropical species may be transported north. Additionally, seasonal variation alters distributions and complicates the assessment of Cape Cod as a zoographic boundary (Ekman, 1953).

These boundaries or transition zones between adjacent regions have been defined primarily with regard to the distribution of near shore marine fauna and flora (Briggs, 1974). Transitional species and zones have varying definitions in the literature. Some refer to the Virginian Province as transitional between two regions of relative thermal stability, as it experiences a wide range of temperature fluctuations. It is also referred to as a transitional zone between the boreal and warm water provinces as it contains transitional fauna (Gosner, 1971) or lacks unique fauna of its own (Coomans, 1962). Previous findings (Able et al., 2002) in the estuarine environment suggest that the transitional boundary will lie at the elbow of Cape Cod where the warm and cold waters meet. Genetic data shows a phylogenetic break just south of the Cape Cod landmass in the vicinity of a boundary of oceanic water masses, which distribute genes in an asymmetric manner consistent with coastal current patterns

(Jennings et al., 1996). This work will focus on the effect of Cape Cod as a zoographic barrier on the associated near shore marine finfish distribution and specifically the location and attributes of the TZ (Figure 1).

Due to increasing worldwide pressure on the limited coastal marine resources, the ability to understand the complete system and anticipate change is essential for effective planning and efficient use. Additionally, with the apparent increase in the rate of measurable attributes of climate change (CO2, emissions, sea level rise, ocean acidification, global mean temperature (Meehl et al., 2007) long term planning should now include the anticipated coastal ecosystem responses to future climate change as the associated fluctuations of boundaries will confound spatial designations. Thus far, no studies have addressed the location, size, diversity, and historical distribution of the transitional zone for the near shore marine finfish distribution inhabiting Cape Cod and Massachusetts waters. This study will accomplish this primarily through the development of a subtropical / all species ratio (S/A ratio) to be used as a quantitative measure for investigating the location of a discrete transitional zone and its characteristics.

2. Methods

This work used a subset of the Massachusetts Division of Marine Fisheries (MADMF) trawl survey data. The survey divides the inshore waters of Massachusetts into five regions and within each region six different depth strata in areas of unconsolidated sediment where trawling is feasible. From within these strata, stations are randomly selected for sampling during each research trip. This analysis used strata

11, 15, 17, 25, and 31 which represent the near shore strata from each of the five regions within Massachusetts waters. These strata will be referred to herein as regions 1, 2, 3, 4, and 5 (Figure 1). There is no singular delineation of the near shore zone in oceanography. For the purpose of this work the near shore zone is defined as the area extending from shore seaward to 9.15 meters, which coincides with the delineation of the shallowest depth strata in the MADMF trawl survey. This study utilized the fall survey data set from years 1980 – 2010. For a more complete description of survey methods refer to: http://www.mass.gov/dfwele/dmf/publications/tr_38.pdf.

While diversity measurements have long been used to evaluate and compare species assemblages, these univariate descriptors have limited comparative ability because they do not include the actual species detected in the diversity “value” (i.e., samples with the same diversity value could drastically differ in species composition). Ordination and cluster analysis are techniques capable of comparing species composition between samples. The spatial and temporal trends in the species composition were investigated using multidimensional scaling (MDS) and analysis of similarity (ANOSIM) programs found in PRIMER 6.0 statistical package (Clarke and Gorley, 2006). Prior to analysis data was dispersion weighted and square root transformed to down weight the effect of the dominant species across samples. Similarity matrices were constructed using the Bray Curtis similarity index (Bray and Curtis, 1957). Results were displayed for visual interpretation and grouping patterns were further observed using an ordination plot generated by MDS. MDS is an increasingly popular ordination technique that is considered relatively robust (Clarke and Ainsworth, 1993). MDS constructs a configuration of the samples, satisfying the constraints of a rank similarity matrix, in a specified number of dimensions (Clark and Warwick, 2001). ANOSIM was used to determine if significant differences in the finfish assemblages were detected in the differing strata (spatial) or time periods (temporal). ANOSIM tested the null hypothesis that there is no significant temporal/spatial difference among the observed finfish communities. The null hypothesis (H_0) will be rejected when the significance level of the test statistic is less than $p = 0.05$. The significance of this test is determined by using the R-statistic value (Clark and Green, 1988).

The presence of discrete finfish assemblages will be investigated by comparing finfish assemblages among strata (areas) with a Bray Curtis similarity matrix. When two strata have similar fish assemblages their between-strata differences in catch composition are less than their within strata differences which demonstrates a greater variability in species composition within areas than between areas. To identify whether discrete finfish assemblages exist in the five regions of Massachusetts near shore waters the following null hypothesis will be tested with ANOSIM: H_{01} = The between-area dissimilarities of fish assemblages in regions 1, 2, 3, 4, and 5 are not significantly different from the within strata dissimilarities between fish assemblages for each region 1, 2, 3, 4, and 5. First, selected tows will be coded by region (1-5). ANOSIM will be used to investigate and describe the presence of discrete finfish assemblages within regions and results will be displayed by MDS.

Each fish species detected in the trawl survey was coded as sub-tropical, temperate, or polar (Table 1) from FishBase (Froese and Pauly, 2012). For each haul, the ratio of subtropical / (subtropical + temperate + polar (all)) species (S/A ratio) was calculated from presence absence data and the averaged S/A ratios were calculated for the five regions. An ANOVA was conducted to test the null hypothesis: H_{02} = There are no significant differences in average regional S/A ratios among each region 1, 2, 3, 4, and 5. Since water temperature is the dominant factor affecting the S/A ratio, between region average fall bottom temperatures were compared with a Kruskal Wallis test to test the following null hypothesis: H_{03} = There are no significant differences in average regional water temperatures between each region 1, 2, 3, 4, and 5. Comparisons of bottom temperatures were made with non-parametric methods after failing to meet assumptions of heterogeneity of variance.

Region 3 was selected to describe the location, diversity, and community change of the transitional zone due to the abrupt change in S/A ratio between regions 2 and 3. Hauls within region 3 were divided into 6 sub-regions (A, B, C, D, E, and F; Figure 1) of 20 hauls each for which the average S/A ratio and latitude were calculated. Diversity (species richness) values were calculated for each sub-region and were compared using an ANOVA. Finally, follow up tests were made with a Tukey's test. In order to investigate whether a discrete transitional zone exists, the following null hypothesis was tested: H_{04} = The sub-region defined as the transition zone (TZ) does not have significantly different diversity than all other sub-regions within region 3.

Results from diversity and the S/A ratio analysis were plotted by latitude to identify whether an increase in diversity and a decrease in the S/A ratio coincided at the same location. The TZ location is defined as the latitude at which the Δ S/A ratio / Δ latitude reaches a maximum value. Next, the following null hypothesis will be tested: H_{05} = The sub-region with the greatest Δ S/A ratio with Δ latitude does not exhibit a significantly different diversity value than all other sub-regions. To investigate the temporal change in the finfish community inhabiting the TZ an ANOVA followed by a Tukey's test were performed on average S/A ratio values between decades to test the following null hypothesis: H_{06} = The average S/A ratios for region 3 are not significantly different among the 1980s, 1990s, and 2000s.

3. Results

Species detected in stratum 17 were coded as subtropical, temperate, or polar based on FishBase (Table 1). ANOSIM results (Table 2) showed the five regions were found to be significantly different in species assemblage. These findings result in the rejection of the first null hypothesis: H_{01} = The between-area dissimilarities of fish assemblages in regions 1, 2, 3, 4, and 5 are not significantly different from the within strata dissimilarities between fish assemblages for each region 1, 2, 3, 4, and 5. Similarity between regions generally decreased with distance with the exception of southerly region 2 often having less similarity with northern regions than region 1. Results from MDS are displayed for visual interpretation in Figure 2.

Areas were compared for their mean value of S/A ratio. An ANOVA detected significant differences between areas ($F = 61.77$, $p < 0.01$). A post-hoc Tukey's test detected significant differences between all regions except 1 and 2 and 4 and 5, those two areas which had the least dissimilarity between regions. This results in the rejection of the null hypothesis: H_{02} = There are no significant differences in average regional S/A ratios among each region 1, 2, 3, 4, and 5. The mean S/A ratio for each region are shown in Table 3.

Bottom temperatures for each region were compared over the last 30 years. After Log(x) transformation both assumptions of normality and heterogeneity of variance are violated ($W = 0.94$, $p < 0.001$; $F = 7.20$ $p < 0.001$). A Kruskal Wallis test found significant differences between areas ($p < 0.001$). A post-hoc Wilcox test found significant differences in bottom temperatures between all areas except 3 and 4. Average bottom temperatures for all regions are shown in Table 3. Region 2 has higher mean temperatures than region 1, which explains the lack of significant differences in S/A ratio (Table 3). These findings result in the rejection of the null hypothesis: H_{03} = There are no significant differences in average regional water temperatures between each region 1, 2, 3, 4, and 5.

Region 3 was selected for additional analysis due to the large difference in average S/A ratio values between regions 2 (0.52) and 3 (0.36). Within region 3 where the S/A index drops from 0.51 to 0.37 in ~4 minutes of latitude, sub-region B-C is the steepest rate of decline within the region and is defined as the transitional zone (Table 4).

Species richness within the sub-regions of Region 3 was investigated to test for variations in diversity. Tukey’s tests detected significant differences in diversity between regions 2 and 3 ($p < 0.05$). Within Region 3 the location of the transitional zone, sub-region C, is the most diverse segment (Table 4). These findings result in the rejection of the null hypothesis: H_{04} = The sub-region defined as the transition zone

(TZ) does not have a significantly different diversity than all other sub-regions within region 3.

The location of the TZ was identified at 41º25.00' N where the greatest increase in diversity was accompanied with the greatest decrease in the S/A ratio (Figure 3). Additionally, the Δ S/A ratio / Δ latitude is greatest (Figure 4) at 41º25.00' N indicating the greatest rate of community change as the subtropical species decrease while the temperate and polar species increase. This results in the rejection of the null hypothesis: H_{05} = The sub-region with the greatest Δ S/A ratio with Δ latitude does not exhibit a significantly higher diversity value than all other sub-regions.

Decadal comparisons of the average S/A ratio for region 3 were found to be significant by an ANOVA ($p < 0.05$). Tukey's tests found the 1980s and 2000s S/A ratios significantly different ($p < 0.05$). The average S/A ratio values for the 1980s and 1990s were almost found significantly different ($p = 0.07$). These findings result in the rejection of the null hypothesis: H_{06} = The average S/A ratios for region 3 are not significantly different among the 1980s, 1990s, and 2000s. A warming trend is suggested by an increase in the average S/A ratio which are as follows 1980s = 0.29, 1990s = 0.38, and 2000s = 0.42.

4. Discussion

Characterization of the marine realm into biogeographical regions and examination of latitudinal patterns in diversity (Ekman, 1953; Pielou, 1979) has been based largely on presence absence data sets for particular taxa (Blanchette, 2008). While demersal finfish are just one of the many groups whose distribution defines biogeographical provinces, they have long been relied on for endemism estimates as they are the most widely studied vertebrate (Briggs, 2012). In this study, assessments of their distribution provided insight into the effects of Cape Cod as a zoographic barrier, a well-defined boundary between the Acadian and Virginian provinces, and the identification and description of associated characteristics for a discrete transitional zone between the two provinces.

The first study hypothesis investigated whether the S/A ratio would decrease with increasing latitude across the five inshore regions of Massachusetts. The index value decreased with increasing latitude among regions (Table 3). The higher S/A ratio in Region 2 as compared to region 1 is explained by a lower average latitude and higher average bottom temperature. The decrease in S/A ratio with both increasing latitude and decreasing bottom temperature are consistent, as latitude is often used as a proxy for temperature in biogeographical studies (Rose, 2005), providing evidence of the reliability of the ratio. ANOSIM results are consistent with the regional S/A values as dissimilarity between regions also increased with increasing differences in water temperature. As temperature is well accepted as a dominant factor in determining organism distributions, the boundaries identified here for finfish will likely apply to other marine organisms, as they coincide with abrupt changes in oceanic conditions including temperature. For example, Blanchette (2008) examined the spatial structure of the rocky intertidal community using similarity measures and report that similarity was consistent with geographic distance and highly correlated with sea surface temperature.

To identify the area of the transitional zone, the presence of larger scale differences in the community assemblage were first investigated by use of similarity measures. ANOSIM results demonstrated the effects of Cape Cod as a zoographic boundary identifying multiple discrete assemblages among the five regions. Similarity between species assemblages has been shown to decrease with increasing distance, which is controlled by two factors: niche relationships and dispersal processes (Nekola and White, 1999). These regions are in close proximity, relative to their size, and the discontinuities in fish distribution identified by similarity analysis strongly suggest the presence of a zoographic barrier. This is demonstrated by the ANOSIM results, for any pair of regions, where average between groups similarity is less than within group similarity (Table 2).

Previous investigators have defined the elbow of the Cape as the TZ between two biographical regions where species from both provinces could exist (Ayvazian et al., 1992). This coincides with our selection of region 3 as the transitional zone between the Acadian and Virginian province as the S/A ratio dropped abruptly from 0.52 (region 2) to 0.37 (region 3). For this research purpose our definition of the TZ is the definable area where the S/A ratio is < 0.50. The transitional zone's location is dependent on our selection of a sample size of 20, which allowed for even comparisons while minimizing variability. While the latitude values for each haul were averaged, relatively high sampling effort in the area of the TZ permitted the comparison of relatively small sub-regions, ~8 kilometers. This location is south of the vicinity of the estuarine environment transitional zone hypothesized by Ayvazian et al. (1992). It is important to note our results are for the near shore marine finfish assemblage rather than the estuarine, which are similar but not identical environments. As the estuarine environment is warmer in the fall months it is plausible that the transitional zone, under the S/A ratio definition provided here, for the estuarine finfish lies north of that for the near shore demersal finfish. Additionally, the data utilized in this analysis is more spatially intense than that of Ayvazian et al. (1992) which investigated three sample sites from Maine to lower Cape Cod. For these reasons it is not surprising that the locations of these transitional zones are similar yet not identical.

Results show the S/A ratio as quantitative tool capable of identifying the boundaries between adjacent provinces. Depending on the definition of boundary, the S/A ratio allows for easy adjustment. This is important in an area where the seasonal fluctuations in fish distributions due to temperature variability complicate defining consistent biogeographical boundaries (Ekman, 1953). For these reasons, the study identifies the transitional zone during a period of time that marks the northern limit of the transitional zone on the Virginian / Acadian border.

In terms of species richness, region 3 is the least diverse of all regions (1 = 14.63, 2 = 12.07, 3 = 11.69, 4 = 13.80, and 5 = 12.90). However, within this region the sub-region defined as the transitional zone was significantly higher in diversity than all other sub-regions within region 3. So while at the broad scale region 3 is relatively low in diversity, the sub-area identified as the transitional zone (sub-region C), combines a location and habitat that leads to enhanced diversity. While a direct comparison is not possible due to differences in sample size (ex. region 2: n = 275 and TZ: n = 20), the average species richness of the sub-area of the TZ is 13.65 which is higher than that of regions 2, 3, and 5 suggesting it provides habitat suitable for animals on the fringe of both provinces.

The location of the TZ was identified (41º25.00’ N) by the dramatic increase in species richness and the decrease in the S/A ratio. The TZ is identified as the area where finfish from both provinces coexist, leading to a sub-region of enhanced species richness. This coincides with a decline in the S/A ratio which signals the addition of temperate and polar species rather than solely an increase in subtropical species. The concept and location of this transitional zone is further supported with the highest rate of change of the S/A ratio with latitude occurring in this same area of increased species richness. This demonstrates that diversity peaks in the area of overlap between regions where the highest rate of change of the S/A ratio occurs.

Global mean surface temperature is projected to increase throughout the 21st century (Meehl et al., 2007). While the effects of climate change on the marine system are well documented, climate variability and change may not be uniform over the North Atlantic (Rose, 2005), complicating the prediction of species responses. Multiple responses of the near shore demersal fish community to warming in Narragansett Bay, RI (Collie et al., 2008) have been identified. Responses include a shift from fish to invertebrates, demersal to pelagic fish, larger to smaller body size, and the community composition becoming increasingly similar to that of southerly estuaries. The average decadal S/A ratios from region 3 (1980s = 0.29, 1990s = 0.38, and 2000s = 0.42) show evidence of this fish community becoming increasingly similar to that of its southerly regions.

Sea surface temperature (SST) trends along the Northeast U.S. East Coast from 1875 to 2007 show warming in the Gulf of Maine [1.0° ± 0.3°C $(100\ \mathrm{yr})^{-1}$] and Middle Atlantic Bight [0.7° ± 0.3°C $(100\ \mathrm{yr})^{-1}$](Shearman, 2010). Over time the coasts warm 1.8 to 2.5 times the rate of the regional atmospheric rate, with coastal currents controlling long term climate control rather than air-sea based heat (Shearman, 2010). Surprisingly, little change is associated with the location of the border, which is relatively stable as water currents are influenced by the presence of Cape Cod as a zoographic barrier.

With continued warming, the role of Cape Cod as a zoographic barrier will likely change throughout all the regions of Massachusetts waters. Briggs (1974) notes that marine zoography must primarily be the zoography of the various waters and secondarily the zoography of the various coastal regions. The S/A ratio calculated for the near shore marine demersal finfish community proved useful in multiple comparisons. It is convenient as it allows for comparisons across studies which likely have different sampling methods. As the coastal waters vary in Massachusetts the combination of the MADMF trawl survey and the S/A ratio are capable of investigating and understanding the varying effects of Cape Cod as a zoographic boundary to the near shore marine finfish distribution.

Table 1. Scientific name, common name, and coding of fish species detected in stratum 17 as subtropical, temperate, or polar.

Scientific name	Common name	Code
Alosa pseudoharengus	alewife	temperate
Aspidophoroides monopterygius	alligatorfish	temperate
Anguilla rostrata	American eel	subtropical
Hippoglossoides platessoides	American plaice	temperate
Alosa sapidissima	American shad	temperate
Gadus morhua	Atlantic cod	temperate
Clupea harengus	Atlantic herring	temperate
Scomber scombrus	Atlantic mackerel	temperate
Brevoortia tyrannus	Atlantic menhaden	subtropical
Selene setapinnis	Atlantic moonfish	subtropical
Menidia menidia	Atlantic silverside	temperate
Microgadus tomcod	Atlantic tomcod	temperate
Torpedo nobiliana	Atlantic torpedo	subtropical
Anchoa mitchilli	bay anchovy	subtropical
Selar crumenophthalmus	bigeye scad	subtropical
Centropristis striata	black sea bass	temperate
Alosa aestivalis	blueback herring	subtropical
Peprilus triacanthus	butterfish	subtropical
Tautogolabrus adspersus	cunner	temperate
Rhinonemus cimbrius	fourbeard rockling	temperate
Paralichthys oblongus	fourspot flounder	temperate
Lophius americanus	goosefish	temperate
Myoxocephalus aenaeus	grubby	temperate
Citharichthys arctifrons	gulf stream flounder	subtropical
Leucoraja erinacea	little skate	temperate
Myoxocephalus ocotodecemspinosus	longhorn sculpin	temperate
Selene vomer	lookdown	subtropical
Cyclopterus lumpus	lumpfish	polar
Decapterus macarellus	mackerel scad	subtropical
Menticirrhus saxatalis	northern kingfish	subtropical
Syngnathus fuscus	northern pipefish	subtropical
Sphoeroides maculatus	northern puffer	temperate
Ammodytes dubius	northern sand lance	polar
Prionotus carolinus	northern searobin	temperate
Macrozoarces americanus	ocean pout	temperate
Opsanus tau	oyster toadfish	subtropical
Pollachius virens	polluck	temperate

Osmerus mordax	rainbow smelt	temperate
Urophycis chuss	red hake	temperate
Pholis gunnellus	rock gunnel	polar
Trachurus lathami	rough scad	subtropical
Selar crumenophthalmus	round scad	subtropical
Stenotomus chrysops	scup	subtropical
Hemitripterus americanus	sea raven	temperate
Pristigenys alta	short bigeye	subtropical
Merluccius bilinearis	silver hake	temperate
Ariomma bondi	silver rag	subtropical
Etropus microstomus	smallmouth flounder	subtropical
Mustelus canis	smooth dogfish	subtropical
Epinephelus niveatus	snowy grouper	subtropical
Squalus acanthias	spiny dogfish	temperate
Urophycis regia	spotted hake	subtropical
Anchoa hepsetus	striped anchovy	subtropical
Morone saxatalis	striped bass	temperate
Prionotus evolans	striped searobin	temperate
Paralichthys dentatus	summer flounder	temperate
Tautoga onitis	tautog	subtropical
Urophycis tenuis	white hake	temperate
Scophthalmus aquosus	windowpane	temperate
Pseudopleuronectes americanus	winter flounder	temperate
Leucoraja ocellata	winter skate	temperate
Limanda ferruginea	yellowtail flounder	temperate

Table 2. ANOSIM results of finfish assemblages for regions 1-5.
Results indicate that all regions have significantly differing finfish assemblages.

Regions	R Statistic	Significance
5 vs 2	0.919	0.01
5 vs 1	0.706	0.01
4 vs 2	0.600	0.01
5 vs 3	0.481	0.01
2 vs 3	0.476	0.01
4 vs 1	0.321	0.01
1 vs 3	0.312	0.01
5 vs 4	0.304	0.01
1 vs 2	0.260	0.01
4 vs 3	0.243	0.01

Table 3. S/A ratios and fall bottom temperatures for five regions of Massachusetts waters.

Region	S/A Ratio	N	Temp C°
1	0.51	136	18.70
2	0.53	275	19.35
3	0.36	123	16.13
4	0.29	85	15.88
5	0.20	75	14.21

Table 4. Average latitude, S/A ratios, sample size, species richness (S), and species richness standard error for sub-regions A-F (located within region 3).

Sub-Region	Average Latitude	S/A Ratio	N	Average (S)	(S.E.) Standard Error
F	42º04.19’	0.27	20	10.90	0.48
E	41º55.37’	0.26	20	11.00	0.71
D	41º33.45’	0.32	20	12.20	0.70
C	41º23.29’	0.37	20	13.65	0.75
B	41º18.67’	0.51	20	10.60	0.83
A	41º14.57’	0.51	20	11.65	0.77

Figure 1. The study area of Cape Cod and the surrounding inshore waters of Massachusetts. Included are: Regions 1-5 (in bold) as described by the Massachusetts Division of Marine Fisheries Trawl Survey and region 3 sub-regions A-F.

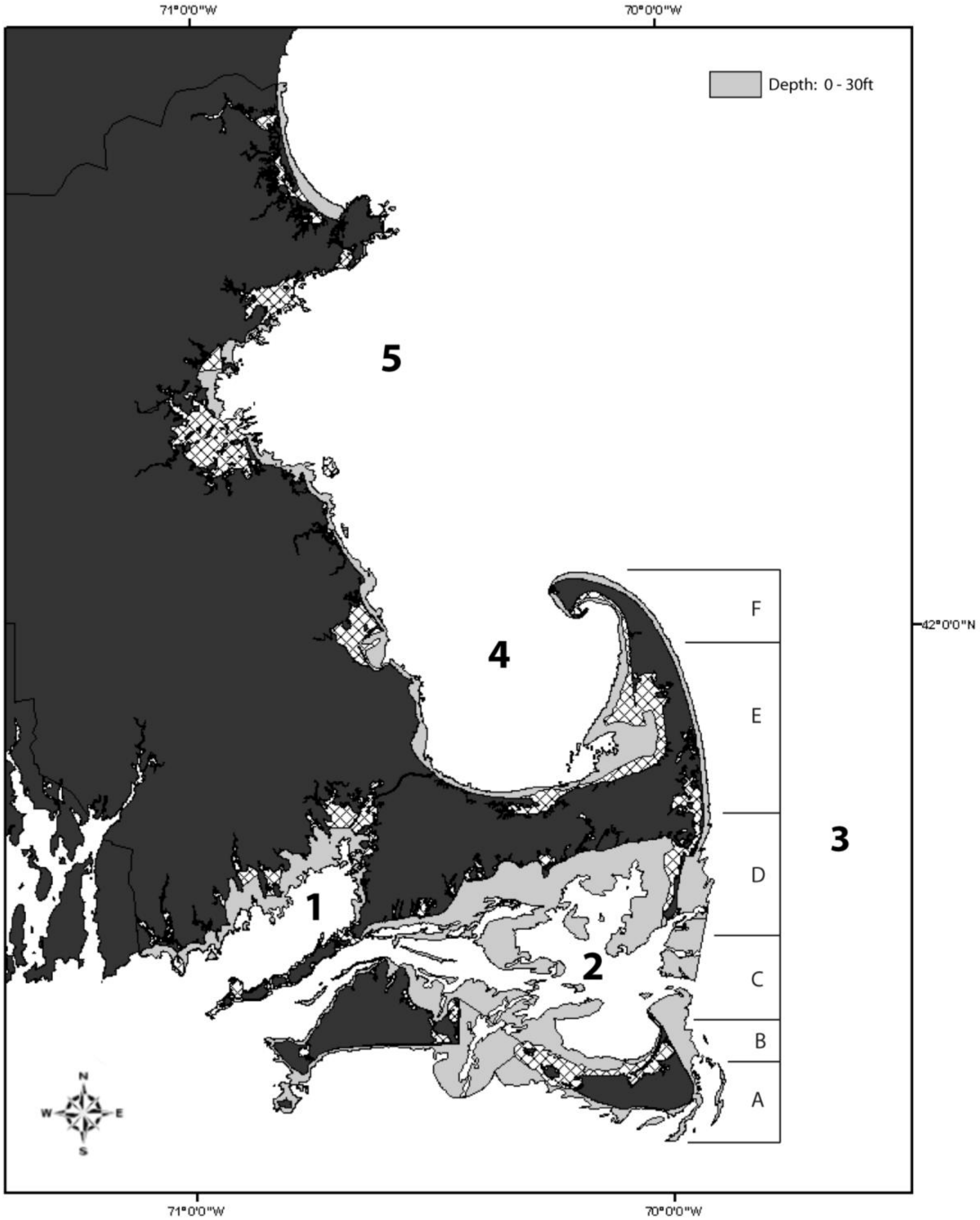


Figure 2. Multi-dimensional scaling of finfish assemblages of Massachusetts waters for regions 1-5.

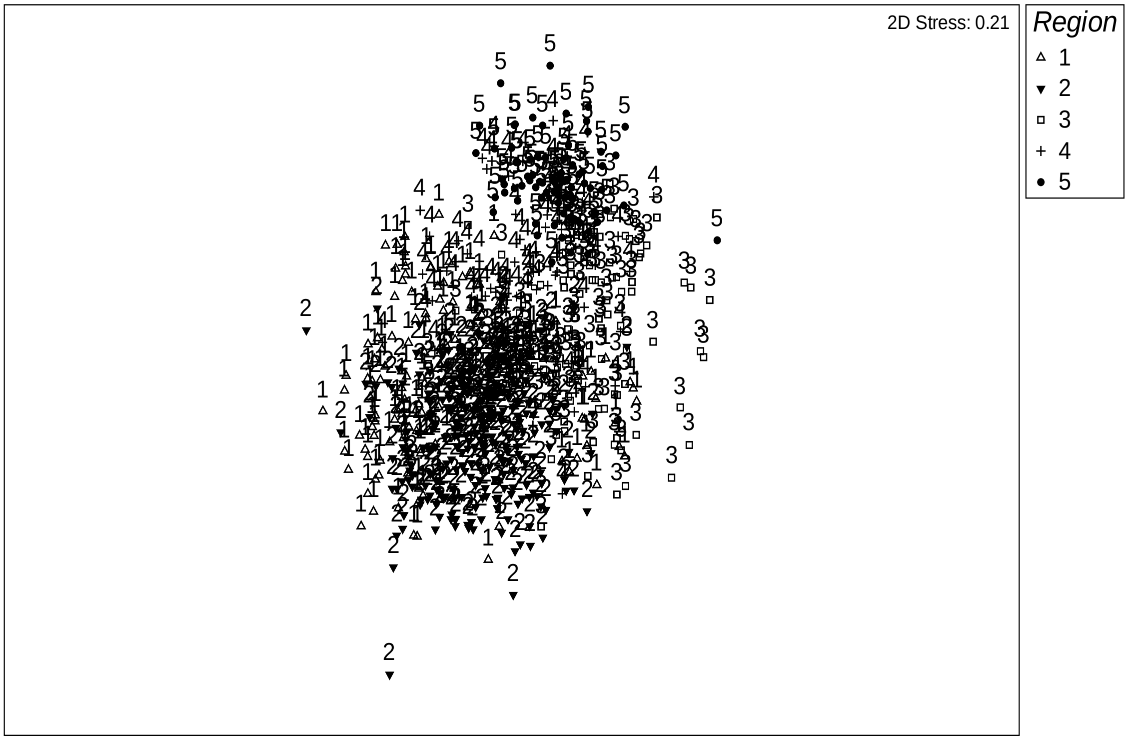


Figure 3. Diversity and S/A ratio values by latitude for region 3. Data points represent sub-regions A-F.

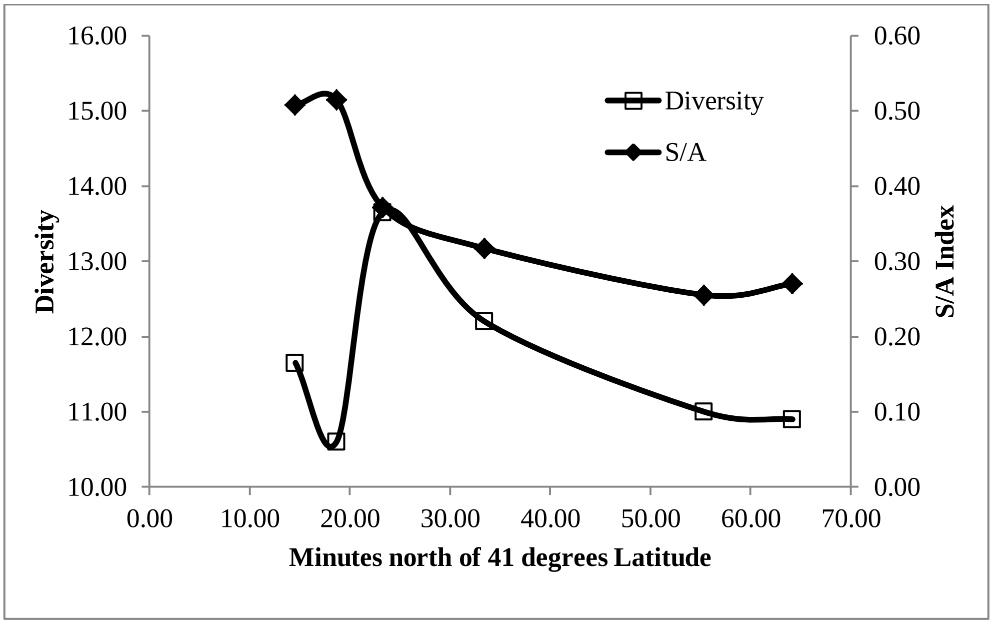
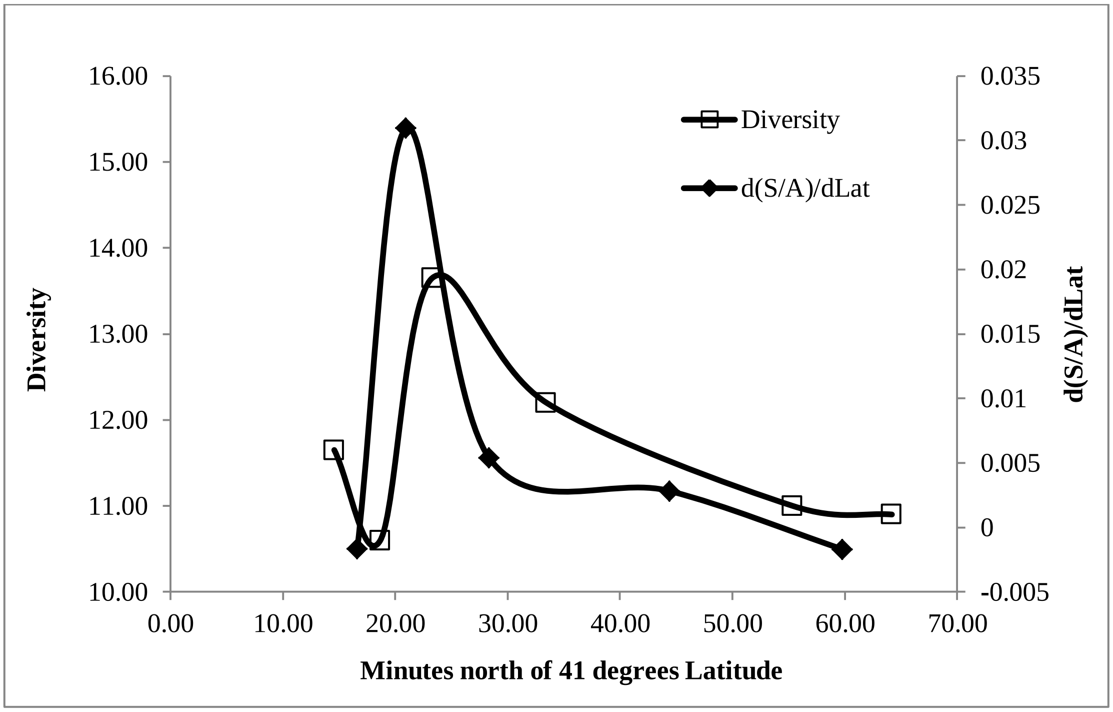


Figure 4. Diversity and rate of change of S/A ratio with change in latitude for region 3. Data points represent sub-regions A-F.



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MANUSCRIPT – III

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Effects of Tidal Stage and Short Term Variability on the Surf Zone Finfish Assemblage at East Matunuck Beach, Rhode Island

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Abstract

This study investigated aspects of the surf zone finfish assemblage at Matunuck Beach, Rhode Island during August 19, August 27, and September 19, 2004. The goals were to determine the potential to evaluate changes in the finfish distribution with tidal stage, provide a measure of the short term variability associated with this finfish distribution, evaluate the influence of tidal stage relative to that of short term variability, and provide recommendations for future sampling of both the dominant finfish species and the total finfish community. Overall, 18 finfish species were identified with four species comprising 99% of the total catch (Atlantic menhaden, bay anchovy, Atlantic silverside, and alewife). When viewed separately, each sampling event was dominated by three finfish species which accounted for 99% of a day's total catch. Sampling was stratified by tidal stage across events and ANOVA results revealed no effect of tidal stage on the number of species present among or within sampling events ($F = 1.18$, $p > 0.05$). Additionally, ANOSIM results did not identify distinct finfish assemblages associated with tidal stage among or within sampling events. This effort served as a pilot study to investigate the potential to evaluate changes in the finfish distribution with tidal stage. Sample size calculations identified between 56 – 2,767 samples necessary to determine differences in species richness among tidal stages. Pairwise comparisons between sampling dates with ANOSIM revealed three distinct finfish assemblages identified within a one month period ($p < 0.01$): Aug 19 vs. Aug 27; $r = 0.381$, Aug 19 vs. Sept 19; $r = 0.507$, and Aug 27 vs. Sept 19; $r = 0.300$. The influence of the distribution variability on species composition associated with these short term assemblages (Global $R = 0.398$, $p <$

0.01) exceeded that of tidal stage (Global $R = 0.041$, $p > 0.05$) which likely confounded tidal stage analyses. Results of species accumulation curve analysis reveal that a 50% reduction in daily effort, across sampling events, would identify 100% of the dominant species and 85% of the total species detected. Since ANOSIM detected no differences in species assemblages based on tidal stage and sampling at low rising tide detected the dominant species with the least amount of effort (eight hauls) future sampling events should be conducted during low rising tide. At present, there is no singular definition for the area comprising the surf zone among studies. Additionally, there is no commonly accepted temporal criterion for a surf zone community member. Until standard spatial and temporal surf zone community definitions exist, surf zone studies will have limited comparative ability.

1. Introduction

Little attention has been paid to the surf zone environment when compared to the deeper water ocean habitats. This effort will investigate the fishery resources in the surf zone portion of the near shore environment (Figure 1). This near shore area encompasses the breaker zone, the area in which arriving waves reach instability and break; the surf zone, where transition waves occur following breaking waves; and the swash zone, the shoreward portion where the beach face is alternatively covered and exposed by water. The presence and width of a surf zone is primarily a function of tidal stage and wave height (Komar, 1976).

Studies have documented that the surf zone is occupied by a wide variety of species (Wilber et al., 2003b; Lasiak, 1984a), but dominated by relatively few species (Ross et al., 1987; Romer, 1990), usually with less than 10 species, mostly juveniles (Machado and Araujo, 2003), making up greater than 90% of the catch (Schaeffer, 1967; Lasiak, 1984a; Machado and Araujo, 2003). Even more depauperate are the shallows of the surf zone (<0.4 m) where as few as three species have been shown to comprise 94% of the catch (Layman, 2000). Surf zones may be as important as estuaries in providing nursery habitat for juvenile finfish (Bennet, 1989). Additionally, estuarine dependent larval fishes have been shown to outnumber marine species in the surf zone at locations > 5 km from estuaries (Strydon and d'Hotman, 2005). This utilization by juveniles is likely due to accumulation of food resources and protection from predation provided by shallowness, turbidity, and turbulence (Lasiak, 1986).

Factors affecting surf zone finfish distributions in the northeastern U.S.A. can be viewed as hierarchical (Ross et al., 1987). At the broadest scale, climatic events determine the success of a year class for a given species. Next, the variability in seasonal abundances for different species is determined primarily by reproductive and feeding migrations of which temperature appears to be an underlying mechanism (Layman, 2000). Since food webs in surf zone systems are phytoplankton based, the observed seasonal variation in finfish communities may be largely due to the winter decline in phytoplankton productivity due to colder temperatures. This variation in seasonal abundance and species composition is considered to be the primary characteristic of surf zone fish in temperate and high latitudes (Ross et al., 1987).

While at the broader scale the influence of these factors is relatively consistent, smaller scale investigations that evaluate the effects of various habitat characteristics produce many contradictory findings. Still, a number of studies have reported associations between habitat characteristics and finfish distributions. Some factors found to influence distributions include time of day (Lasiak, 1984A; Layman, 2000, Gibson, 1996; Machado and Araujo, 2003), tidal stage (Gibson et al., 1996; Romer, 1990), degree of wave exposure (Clark et al., 1996; Beyst et al. 2001), wind (Warfel and Merriman, 1944; Lasiak, 1984A), aquatic macrophytes (Jenkins and Sutherland, 1997; Crawley et al. 2006), and the presence of rock or other impervious structure (Clark et al., 1990; Peters and Nelson, 1987; Clark et al., 1996; Wilber et al., 2003). It has long been suggested that the small scale migrations within the surf zone environment are a function of the relative quality of the habitat (Sogard et al., 1989) based on factors such as predator avoidance, competition, resource depletion, and mating (Virnstein and Curran, 1986).

Two specific aspects of the surf zone fish assemblages that are important in understanding this environment are: the existence of distinct high and low tide assemblages, and the short term variability associated with this finfish distribution. With the change in tidal stage, the near shore habitat is altered and variations in dominant species, diversity, and abundance have been observed (Lasiak, 1984b), although this relationship is not consistent. Studies have produced conflicting results as to the effects of tidal stage on community parameters. Species richness has been demonstrated to increase during low tide (Gibson et al., 1996), to increase during high tide (Layman, 1999) and to also show no discernible trend between high and low tide (Lasiak, 1984b). It is important to note that these three seminal papers on the effects of tidal stage on surf zone finfish distributions use differing gear types, differing effort, and sample a different area of the surf zone. The lack of standardized approaches complicates improving upon the existing body of knowledge associated with the effects of tidal stage on the surf zone finfish assemblage.

Short-term fluctuations have been shown to exceed long-term fluctuation in the surf zone finfish distribution to the degree of confounding seasonal effects (Lasiak, 1984b). This has been found to be true for a given spatial and temporal sampling effort. Theoretically, if temperature and seasonal migration drive larger scale species movements, then at some higher level of sampling coverage, short-term fluctuations should not exceed the long-term and a series of distinct semi-persistent surf zone finfish communities should be detected.

As previously mentioned, a consistent theme of surf zone studies is that although the surf zone community is comprised of many species it is dominated by just a few which comprise > 90% of the numerical population. Few samples are required to identify the dominant species, yet additional samples are required to detect relatively rare finfish species. This characteristic complicates both the ecological monitoring of this system and defining the surf zone community for a given location. An alternative approach to resolving this problem is to structure sampling around identifying the dominant species present in the surf zone.

This effort will characterize the surf zone finfish assemblage at Matunuck Beach, Rhode Island, by providing a species inventory and relative abundance measures. It will also serve as a pilot study to determine the sampling methods for surf zone finfish in New England with respect to tidal stage. This effect of tidal stage is evaluated relative to the concept of distinct short term finfish assemblages, which leads to an increased understanding in one of the most confounding aspects of the finfish distribution within surf zone, high temporal variability. Additionally, species accumulation curves are constructed to investigate the effort level necessary to identify the dominant species at this location. This effort level is also assessed in terms of the overall percentage of the finfish community detected. From these findings future surf zone finfish sampling recommendations are made with respect to tidal stage and short term effort.

2. Methods

Surf zone sampling took place at Matunuck Beach, Rhode Island, Lat. 41º 22’ 35’’ N, Long. 71º 31’ 43’’ W (Figure 2.), during August 19, August 27, and September 19, 2004. The sampling location was selected in an unsheltered area of moderate wave activity to represent the surf zone environment. The shoreline consists of a mixture of sand and rocks. Varying amounts of aquatic macrophytes were present during the three sampling events. Samples were stratified by tidal stage: low rising, high, high falling, and low (Figure 3). Four replicate samples were taken during each stage for a total of sixteen samples during each sampling event. During August 27, only two hauls were made on the low rising tide, due to extremely high catches, which led to processing time exceeding the length of tidal stage. The sampling schedule is presented in Table 1. Due to safety concerns sampling took place during daylight hours. Water temperatures were consistent, ranging between 21 and 22° C across sampling events. Sampling was conducted with a 30 x 2 m, 3 mm mesh seine net, with 30 m bridles attached to both ends. The net was set parallel to shore in approximately 1.5 m of water, from a small inner tube and hauled ashore with a four person crew. Fish were identified to the species level according to Bailey and Robins (1991) and were measured to the nearest millimeter.

Results from the sampling effort were presented as number of individuals, percent of catch, and rank order. Catch was presented for both the total sampling effort and separately for each individual sampling effort of August 19, August 27, and September 19. Catches were analyzed in terms of total and dominant species, those which comprise greater than 1% of the total catch.

The characteristics of this finfish assemblage were investigated using multidimensional scaling (MDS), cluster analysis, (CLUSTER) and analysis of similarity (ANOSIM) programs found in PRIMER 6.0 statistical package (Clarke and Gorley, 2006). Prior to analysis data were transformed to presence / absence due to the high variability associated with the schooling behavior of these finfish. Similarity matrices were constructed using the Bray Curtis similarity index (Bray and Curtis, 1957). Results were displayed for visual interpretation and grouping patterns were further observed using an ordination plot generated by MDS. Results from CLUSTER were superimposed on MDS results in order to identify the level of similarity between grouped samples. ANOSIM was used to determine if significant temporal differences in the finfish assemblages were detected in the differing tidal stages or among sampling dates. ANOSIM tested the null hypothesis that there is no significant temporal difference among the observed finfish communities. The null hypothesis (H_0) was rejected when the significance level of the R-test statistic was less than $p = 0.05$ (Clark and Green, 1988). Additionally, the effect of tidal stage on this finfish assemblage was tested with a one way ANOVA test. A square root transformation was applied to the data to meet heterogeneity of variance requirements.

The effect of tidal stage on the finfish assemblage was first investigated for each individual sampling event, then for the sampling events combined. ANOSIM was used to test the null hypothesis: H_{01} = The effect of tidal stage does not result in the detection of distinct high, high falling, low, or low rising species assemblages during an individual sampling event. Next, a one-way ANOVA was used to test the null hypothesis: H_{02} =The four tidal stages of high, high falling, low, and low rising do not possess significantly different species richness values during an individual sampling event.

All hauls were then coded by tidal stage and combined. To investigate if detectable differences exist in the observed finfish community among tidal stages the following null hypothesis was tested with ANOSIM: H_{03} = The effect of tidal stage does not result in the detection of distinct high, high falling, low, or low rising species assemblages. When differences exist among varying tidal stages their between sample similarities are less than their within sample similarity. Additionally, the following null hypothesis was tested with a one way ANOVA: H_{04} = The four tidal stages of high, high falling, low, and low rising do not possess significantly different species richness values among sampling events.

Sample sizes necessary to detect differences in species richness among the four tidal stages (Snedecor and Cochran, 1980) were calculated using a preselected power. A test's power is the ability to reject a false null hypothesis. Sample sizes for species richness comparisons between tidal stages were calculated for both 0.80 and 0.90 power at the 95% confidence level. A power of > 0.8 was used as this is the corollary to the Type II error rate where one fails to reject a null hypothesis.

The existence of distinct short term assemblages within the surf zone was investigated with the same hauls used in the tidal stage analysis. Hauls were coded by sampling date: August 19, August 27, and September 19. The following null hypothesis was tested with ANOSIM: H_{05} = The percent similarity for the species assemblages is not significantly different for within than between sampling event comparisons. Results are displayed for visual interpretation with MDS.

The relative effects of tidal stage and short term variability on the finfish assemblage was investigated. First, the results from CLUSTER were overlaid on MDS results representing both tidal stage and short term variability. The relative grouping demonstrated if the short term variability or tidal stage had a stronger effect on the finfish assemblage. Next, ANOSIM was used to test the following null hypothesis: H_{06} = The influence of short term variability on finfish species composition does not significantly differ from the effect of tidal stage.

Species accumulation curves were developed in order to identify the effort necessary to detect the dominant species of this community across all sampling events and for each individual sampling event. Dominant species were identified as those numerically comprising >1% of the total catch over the one month sampling period. Results from both curves were compared to identify what percentage of the overall finfish community was detected at the effort level necessary to identify the dominant species. Additionally, species accumulation curves were constructed to identify the number of hauls necessary to detect the dominant species across differing tidal stages of high, high falling, low, and low rising. Future sampling recommendations for this location were presented in terms of tidal stage and the number of hauls necessary to identify the dominant species during each sampling date.

3. Results

The species detected, number of individuals, percent of catch and rank order of species for the total catch are presented in Table 2. Of the total 18 species detected four species accounted for 99% of the total catch: Atlantic menhaden (*Brevoorita tyrannus*) 42%, bay anchovy (*Anchoa mitchilli*) 38%, Atlantic silverside (*Menidia menidia*) 14%, and alewife (*Alosa pseudoharengus*) 5%). During each sampling event three species accounted for 99% of the total catch: August 19 = alewife 63%, Atlantic silverside 30%, and bluefish (*Pomatomus saltrix*) 6% (Table 3); August 27 = Atlantic menhaden 79%, Atlantic silverside = 19%, and alewife 1% (Table 4); and September 19 = bay anchovy 94%, Atlantic silverside 4%, and Atlantic menhaden 2% (Table 5). The total number of species detected was similar during each sampling event with 13 species detected on August 19, 11 species on August 27, and 11 species on September 19.

Separate analyses for individual sampling events failed to identify distinct species assemblages associated with each high, high falling, low, or low rising tidal stage with ANOSIM (August 19: $r = 0.13$, $p > 0.05$; August 27: $r = 0.11$, $p > 0.05$; September 19: $r = 0.13$, $p > 0.05$). This results in the acceptance of the first null hypothesis: H_{01} = The effect of tidal stage does not result in the detection of distinct high, high falling, low, or low rising species assemblages during an individual sampling event. ANOVA tests for each individual sampling event also failed to identify significant differences in species richness across tidal stages (August 19: $F = 2.42$, $p = 0.12$; August 27: $F = 0.08$, $p = 0.97$; and September 19: $F = 1.82$, $p = 0.20$). This resulted in the acceptance of the second null hypothesis: H_{02} =The four tidal stages of high, high falling, low, and low rising do not possess significantly different species richness values during an individual sampling event.

With all sampling events combined, ANOSIM analyses on the effect of tidal stage on the surf zone community also resulted in no significant effects (Global $R = 0.041$, $p > 0.05$). As expected, MDS (Figure 4) showed no evidence of grouping based on tidal stage. This resulted in the acceptance of the null hypothesis: H_{03} = The effect of tidal stage does not result in the detection of distinct high, high falling, low, or low rising species assemblages. Additionally, ANOVA tests found no significant pattern in species richness related to tidal stage when viewing all sampling events in combination (F = 1.18, p = 0.33). This resulted in the acceptance of the null hypothesis: H_{04} = The four tidal stages of high, high falling, low, and low rising do not possess significantly different species richness values among sampling events.

The least amount of sampling effort to determine differences in species richness between tidal stages occurred between high falling and high tide (Figure 5; 0.80 power = 43 samples, 0.90 power = 56 samples). The greatest amount of sampling effort necessary to detect differences in species richness would occur at high falling vs. low (0.80 power = 2,068 samples, 0.90 power = 2,767 samples; not shown on graph). Considerable effort would be needed in order to detect differences in the number of species among any two tidal stages.

Results from investigations of short term variability showed the presence of three differing finfish assemblages (Figure 6). ANOSIM results confirmed the existence of three distinct finfish assemblages with a significant global R value of 0.398 ($p < 0.01$). Pairwise comparisons between sampling events resulted in three significant differences ($p < 0.01$): 1 vs. 2, r = 0.381; 1 vs. 3, r = 0.507; and 2 vs. 3, r = 0.300. This results in the rejection of the fifth null hypothesis: H_{05} = The percent similarity for the species assemblages is not significantly different for within than between sampling event comparisons.

Short term variability of the fish species composition exceeds the effect of tidal stage across all sampling events. This was demonstrated from ANOSIM global R results (tidal effect = 0.04 and short term variability = 0.398). These results were visually displayed in Figure 7 with overlays from cluster analysis (50% similarity) which identified three main groups, each primarily comprised of samples from the same dates. This resulted in the rejection of the null hypothesis: H_{06} = The influence of short term variability on finfish species composition does not significantly differ from the effect of tidal stage.

The species accumulation curve across all sampling events demonstrates that 17 of the total 46 hauls were necessary to identify the four dominant species (alewife, Atlantic menhaden, bay anchovy, and Atlantic silverside), representing 37% of the total effort. This effort level also identified 79% of the total species detected (Figure 8). Across individual sampling events the number of hauls needed to identify finfish species comprising >1% of the total catch and percentage of daily effort were as follows: August 19 = 3 hauls (19% of daily effort), August 27 = 7 hauls (44% of daily effort), and September 19 = 8 hauls (50% of daily effort) (Figure 9). These daily effort levels corresponded to the following percentages of the total catch detected: August 19 = 55% of the total species, August 27 = 85%, and September 19 = 81% (Figure 10). If sampling was based on identifying the dominant species, which would take eight hauls, this would result in 85% (Std. dev. = 3.51%) of the total number of species detected per sampling date. The number of hauls necessary to identify the four dominant species across each tidal stage was as follows: high = 11 hauls, high falling = 11 hauls, low = 10 hauls, low rising = 8 hauls. The number of species detected each tidal stage was as follows: high = 12, high falling = 14, low = 16, and low rising = 12 (Figure 9).

4. Discussion

Eighteen finfish species were identified in the thirty day sampling period (August 19 – September 19) at Matunuck Beach. September has repeatedly been demonstrated as the most diverse month in nearby New England estuaries (Fiske et al., 1967 and Curley et al., 1972) and the number of species identified here is similar to the findings of those studies: Wellfleet Harbor = 15 finfish species (Curley, 1972) and Pleasant Bay = 19 finfish species (Fiske, 1967). This peak in diversity during the late summer is largely due to the temporary influx of southern species. In nearby Narragansett Bay, a trawl survey (1987-2000) has identified 26 warm water species during this time period (Calculated from: Wood et al., 2009). Although numerically few, this effort identified four warm water southern species: crevalle jack, bigeye scad, mullet, and permit (*Trichinotus falcatus*). With the exception of the permit all these warm water species were identified in the Narragansett Bay trawl survey.

The relative abundance findings were consistent with other surf zone studies where few species comprised the majority of the catch. Four species (Atlantic menhaden, bay anchovy, Atlantic silverside, and alewife) accounted for 99% of the total catch. These finfish species are all identified as important forage fish for larger finfish, seabirds, and marine mammals (Bigelow and Schroeder, 1953; Collette and Macphee, 2002) in the Northeastern U.S. When viewing each sampling event individually the same trend on dominance by few species emerged, with three species comprising 99% of the total catch during each sampling event. All events were dominated by the above listed forage fish, with the exception of the bluefish on August 19th which appeared to be feeding on alewives and silversides. While they accounted for 6% of the total catch on this date, bluefish still accounted for <1% of the overall catch.

This study provided a relatively complete picture of the surf zone finfish community when compared to other surf zone finfish studies due to the high level of replicates performed per sampling event: August 19, n = 16; August 27, n = 14; and September 19, n = 16. This led to 46 hauls during a 30 day period at a single location which makes it one of the largest concentrated efforts in surf zone investigations (See Wilber et al. 2003a&b, Table 1 for extensive sampling data on surf zone studies). For this reason, it is likely this investigation accurately described the species composition and relative abundances of the shallow water surf zone at Matunuck Beach during the sampling period.

No significant patterns in species richness were identified with ANOVA across the four tidal stages of high, high falling, low, and low rising for either an individual sampling event or with all events combined. Additionally, ANOSIM was unable to determine a distinct high, high falling, low, or low rising species assemblage for either an individual sampling event or events combined. Tidal stage is often identified in the literature as a likely influence on structuring finfish assemblages. Three main reasons driving tidal migrations have been considered: 1) foraging 2) predator avoidance 3) selection of most suitable environmental conditions (Gibson, 1996). However, due to the interrelation of the many environmental conditions and the highly variable nature of the surf zone finfish assemblage no definitive conclusions have been made as to the effect of tidal stage on finfish distributions and previous investigations have produced conflicting findings. While this effort was unable to identify the trends in species richness across tidal stages, it did permit sample size calculations to investigate the potential to evaluate differences in the surf zone finfish distribution with varying tidal stage. Results of the sample size analysis necessary to detect differences between the species richness associated with tidal stage resulted in extremely large samples. To detect differences between the tidal stages of high falling and high, where the species richness differences were largest, required 43 samples per tidal stage (power = 0.80), while 2,068 samples (power = 0.80) would be required to detect the difference between high falling and low tide. Since the species composition of the surf zone in temperate latitudes varies among seasons, a thorough investigation would require multiple separate large sampling efforts throughout the year to accurately describe tidal differences at a given location. Given the high required sample size it seems unlikely that future investigations, using these sampling methods, will be conducted to evaluate finfish community differences with tidal stage.

Another problem in trying to describe the effect of tidal stage on the finfish distribution is the variability in the volume of water sampled between low and high tide. All surf zones in the northeastern U.S. have a slope from the high tide to low tide line, creating large differences in the size of the sampling unit (i.e. volume of water) due to variability in tidal stage regardless of a standardized circumference of a seine net. It appears that the variability of this assemblage still exceeded this sampling effort as one would expect low tide to have consistently fewer species as the volume of sample area is greatly reduced, which was not observed in this study. This may be a contributing factor to the conflicting results of species richness increasing (Gibson et al., 1996) and decreasing (Layman, 1999) during low tide. This problem is difficult to address, even with a standardized gear, since sampling an equal volume of water from high to low tide leads to sampling an uneven area of bottom habitat. While high tide allows for a greater volume of water to be sampled it also introduces the problem of gear avoidance due to the slope of the beach.

Perhaps the best approach to understanding the effect of tidal stage is to view all factors contributing to the surf zone assemblage as hierarchical in the manner suggested by Ross (1987). Factors such as year class success and seasonal migrations, and interrelated with many other factors such as the type of finfish species present, time of day, wave intensity, wind strength, the presence of aquatic macrophytes, and others. While this concept was suggested over 20 years ago, no models have been developed to relate surf zone finfish distributions to the many habitat characteristics. Due to its interrelation with many other factors and the previously mentioned sample area issues, the influence of tidal stage on the finfish assemblages in the northeastern U.S. could not be determined even with this substantial concentrated effort level.

At Matunuck Beach, the surf zone portion of the near shore marine finfish assemblage was shown to vary considerably in a relatively short period (<1 month). The concept of short term variability exceeding long term variability (Lasiak, 1984b) has long confounded surf zone finfish sampling and has not been addressed when attempting to discern the relative effects of the many habitat characteristics on a finfish assemblage. At Matunuck Beach the finfish assemblages identified on August 19, August 27, and September 19 displayed highly significant differences relative to the variation observed amongst tidal stage. This effect is further substantiated with the overlay of cluster analysis results (Figure 7), which shows three main groups which are primarily composed of samples from the same dates. The presence of these distinct short term assemblages is likely a result from a combination of the previously listed habitat characteristics including time of day, tidal stage, degree of wave exposure, wind, aquatic macrophytes, and the presence of rock or other impervious structure. A possible approach in describing the relationship between habitat characteristics and finfish distribution would be to intensively monitor these discrete short term assemblages, identify the point of community change, and correlate this with a change in some combination of previously listed habitat characteristics.

While there are many finfish species which inhabit the surf zone, this community is numerically dominated by just a few which complicates selecting a universal sampling approach. When combining all sampling events it takes only 37% of the total effort (17 out of 46 hauls) to identify the dominant species, which also identifies 79% of the total species. However, this calculation is misleading due to the nature of the short term assemblages in the surf zone community. Since not all species are present across all sampling dates, sampling needs to be conducted on multiple occasions to ensure that all species are detected. Results from species accumulation curves based on individual sampling events demonstrate that this requires sampling to be spread across multiple dates to ensure that the dominant species are detected: August 19 = 19% of total effort, August 27 = 44% of total effort, and September 19 = 50% of the total effort (Figure 6). Here the low effort level on August 19th is due to only two of the four dominant species detected, which consequently takes many fewer hauls to identify. From these results a standardized number of eight hauls is recommended as this was the greatest number necessary to identify the dominant species during an individual event. This effort would result in the detection of 85% (August 19), 88% (August 27), and 81% (September 19) of the total community which seems reasonable since many of these individuals have relatively rare occurrence (numerically <1% of the total community).

Results from sampling across tidal stages suggest that low rising tide is the most appropriate tidal stage to sample. Although low rising resulted in fewer total species detected than low tide, this was likely due to less overall effort conducted due to the extremely large catches which exceeded sampling time constraints. While comparisons of the number of species detected among tidal stages were insignificant, it did take the fewest hauls (eight), during low rising tide to identify the four dominant species. From these analyses future sampling recommendations at Matunuck Beach are eight daily replicate samples taken during low rising tide. This will result in all dominant species detected and 85% of the total number of species detected with 50% of the total effort.

Perhaps the greatest complication to understanding the ecology of this environment is the lack of standard spatial and temporal definitions of the surf zone finfish community. A spatial definition is complicated as the surf zone is not a discrete habitat as water level and wave activity are inconsistent both among and between beach locations. The surf zone is often vaguely regarded as the area of breaking waves which may vary considerably with wave size, tidal range, tidal stage, or season. By this definition the area defined as the surf zone is ever changing which makes spatial comparisons among surf zone fish community studies difficult. This study makes the recommendation that future sampling efforts at Matunuck Beach with a 30 x 2 m seine net be conducted at low rising tide as sampling at this tidal stage detected the dominant members of the community in the least amount of hauls. This will allow for future comparisons to be made with a standardized sampling unit. However, a definition of the surf zone community in ecology will always be elusive as long as a singular accepted definition of the surf zone area does not exist.

A standard temporal definition of the surf zone finfish community also needs to be established. This study demonstrated that even within a one month period three distinct finfish assemblages were identified. One approach suggested by Lasiak (1984) is to consider the amount of time a species is present in the prescribed area as a basis for defining a surf zone community member. This will be complicated in the northeastern U.S. as most surf zone species are temporary visitors due to seasonal migrations. However, this work was able to identify distinct short term finfish assemblages with a reasonable amount of effort. Perhaps the best way to approach future investigations into the surf zone finfish community in the northeastern U.S. is to identify separate short term assemblages at predetermined times throughout the year. With this approach, future investigations will have usable baseline data to evaluate similarities or dissimilarities in this community (Ex. September 2004 vs. September 2014).

Table 1. List of sampling information for August 19, August 27, and September 19 including: date, haul number, tidal stage, replicate number, and time of haul.

Date	Haul Number	Tidal Stage	Replicate	Time
19-Aug	1	High	1	955
19-Aug	2	High	2	1025
19-Aug	3	High	3	1050
19-Aug	4	High	4	1125
19-Aug	5	High Falling	1	1235
19-Aug	6	High Falling	2	1250
19-Aug	7	High Falling	3	1335
19-Aug	8	High Falling	4	1350
19-Aug	9	Low	1	1545
19-Aug	10	Low	2	1600
19-Aug	11	Low	3	1630
19-Aug	12	Low	4	1645
19-Aug	13	Low Rising	1	1820
19-Aug	14	Low Rising	2	1850
19-Aug	15	Low Rising	3	1910
19-Aug	16	Low Rising	4	1945
27-Aug	17	High Falling	1	815
27-Aug	18	High Falling	2	840
27-Aug	19	High Falling	3	910
27-Aug	20	High Falling	4	955
27-Aug	21	Low	1	1040
27-Aug	22	Low	2	1110
27-Aug	23	Low	3	1140
27-Aug	24	Low	4	1205
27-Aug	25	Low Rising	1	1400
27-Aug	26	Low Rising	2	1520
27-Aug	27	High	1	1745
27-Aug	28	High	2	1805
27-Aug	29	High	3	1825
27-Aug	30	High	4	1850

Table 1. Continued

Date	Haul Number	Tidal Stage	Replicate	Time
19-Sep	31	Low Rising	1	750
19-Sep	32	Low Rising	2	805
19-Sep	33	Low Rising	3	815
19-Sep	34	Low Rising	4	825
19-Sep	35	High	1	1100
19-Sep	36	High	2	1120
19-Sep	37	High	3	1200
19-Sep	38	High	4	1210
19-Sep	39	Low Rising	1	1346
19-Sep	40	Low Rising	2	1410
19-Sep	41	Low Rising	3	1440
19-Sep	42	Low Rising	4	1515
19-Sep	43	Low	1	1640
19-Sep	44	Low	2	1655
19-Sep	45	Low	3	1725
19-Sep	46	Low	4	1735

Table 2. Number of species detected, number of individuals captured, percent of catch, and rank of finfish collected during sampling conducted at Matunuck Beach on August 19, August 27, and September 19 during 2004.

Species	Common Name	Number of Individuals	% of Catch	Rank
Brevorita tyrannus	Atlantic menhaden	14322	42	1
Anchoa mitchilli	bay anchovy	12900	38	2
Menidia menidia	Atlantic silverside	4732	14	3
Alosa psuedoharengus	alewife	1984	6	4
Pomatomus saltatrix	bluefish	293	<1	5
Syngnathus fuscus	northern pipefish	38	<1	6
Trachinotus falcatus	permit	24	<1	7
Caranx hippos	crevalle jack	14	<1	8
Fundulus heteroclitus	mummichog	13	<1	9
Marone saxatilis	striped bass	7	<1	10
Menticirrhus saxatilis	northern kingfish	7	<1	11
Fundulus majalis	striped killifish	5	<1	12
Mugil sp.	mullet	4	<1	13
Selar crumenophthalmus	bigeye scad	3	<1	14
Tautogolabrus adspersus	cunner	2	<1	15
Sciaenidae sp.	drum	2	<1	16
Clupea harengus	Atlantic herring	1	<1	17
Ammodytes dubius	northern sand lance	1	<1	18

Table 3. Number of species detected, number of individuals captured, percent of catch, and rank of finfish collected during sampling conducted at Matunuck Beach on August 19, 2004.

Species	Common Name	Number of Individuals	% of Catch	Rank
Alosa psuedoharengus	alewife	1800	63	1
Menidia menidia	Atlantic silverside	857	30	2
Pomatomus saltatrix	bluefish	163	6	3
Syngnathus fuscus	northern pipefish	31	<1	4
Brevorita tyrannus	Atlantic menhaden	14	<1	5
Caranx hippos	crevalle jack	5	<1	6
Trachinotus falcatus	permit	5	<1	6
Menticirrhus saxatilis	northern kingfish	4	<1	8
Fundulus heteroclitus	mummichog	3	<1	9
Tautogolabrus adspersus	cunner	2	<1	10
Sciaenidae sp.	drum	2	<1	10
Clupea harengus	Atlantic herring	1	<1	12
Ammodytes dubius	northern sand lance	1	<1	12

Table 4. Number of species detected, number of individuals captured, percent of catch, and rank of finfish collected during sampling conducted at Matunuck Beach on August 27, 2004.

Species	Common Name	Number of Individuals	% of Catch	Rank
Brevorita tyrannus	Atlantic menhaden	14100	79	1
Menidia menidia	Atlantic silverside	3357	19	2
Alosa psuedoharengus	alewife	183	1	3
Pomatomus saltatrix	bluefish	73	<1	4
Trachinotus falcatus	permit	16	<1	5
Fundulus heteroclitus	mummichog	10	<1	6
Caranx hippos	crevalle jack	6	<1	7
Marone saxatilis	striped bass	5	<1	8
Syngnathus fuscus	northern pipefish	5	<1	8
Selar crumenophthalmus	bigeye scad	3	<1	10
Menticirrhus saxatilis	northern kingfish	3	<1	10

Table 5. Number of species detected, number of individuals captured, percent of catch, and rank of finfish collected during sampling conducted at Matunuck Beach on September 19, 2004.

Species	Common Name	Number of Individuals	% of Catch	Rank
Anchoa mitchilli	bay anchovy	12900	94	1
Menidia menidia	Atlantic silverside	518	4	2
Brevorita tyrannus	Atlantic menhaden	208	2	3
Pomatomus saltatrix	bluefish	57	<1	4
Mugil sp.	mullet	4	<1	5
Caranx hippos	crevalle jack	3	<1	6
Trachinotus falcatus	permit	3	<1	6
Marone saxatilis	striped bass	2	<1	8
Syngnathus fuscus	northern pipefish	2	<1	8
Fundulus majalis	striped killifish	2	<1	8
Alosa psuedoharengus	alewife	1	<1	11

Figure 1. Diagram of the near shore area (Komar, 1976).

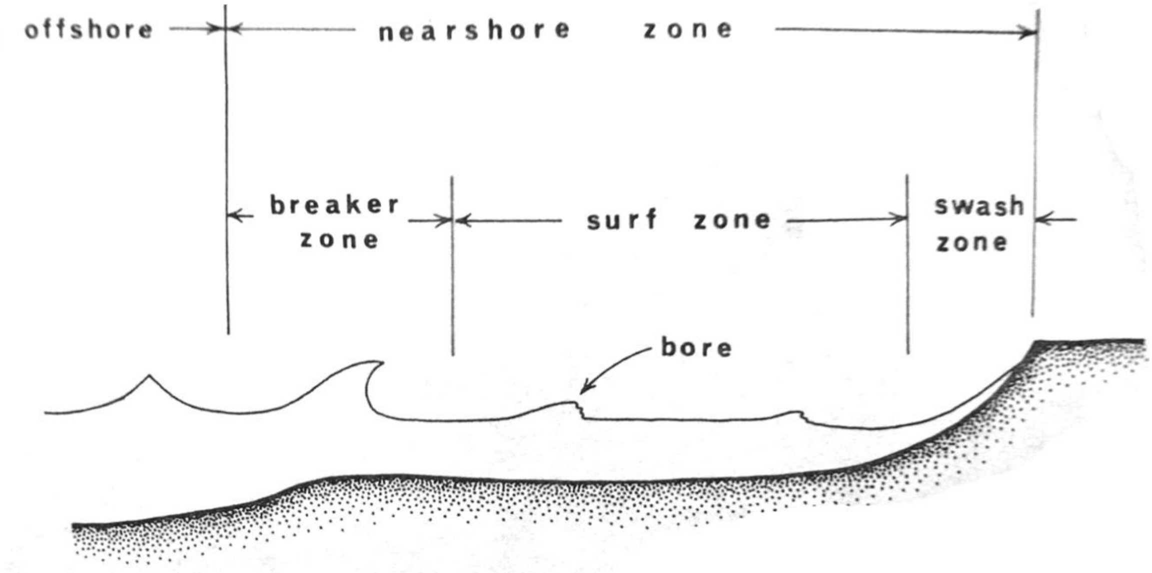


Figure 2. Sampling location of Matunuck Beach, Matunuck RI (A).

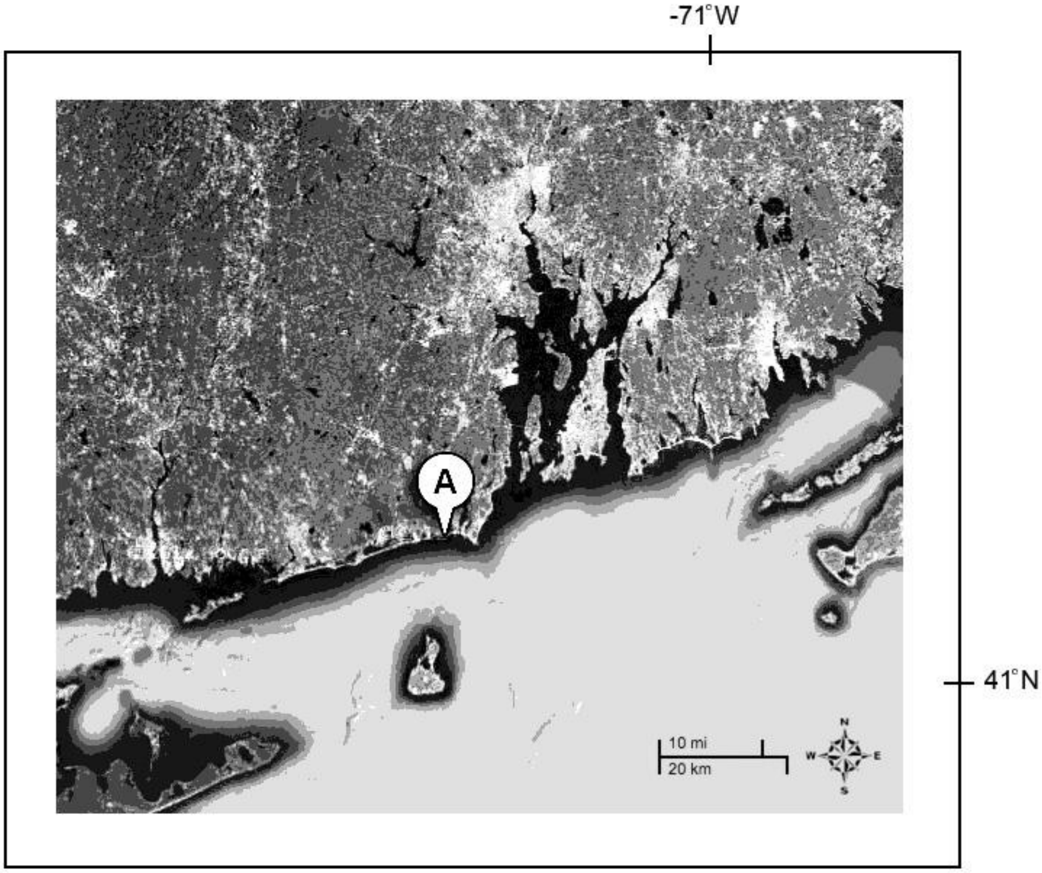


Figure 3. A diagram approximating the timing of the varying tidal stages at Matunuck Beach. With high tide commencing at 3 hours with the high tide interval 1.5 hours before high tide (time 0) and continuing through 1.5 hours after high tide. Time 0 starts at approximately 1.5 hours after mid tide level.

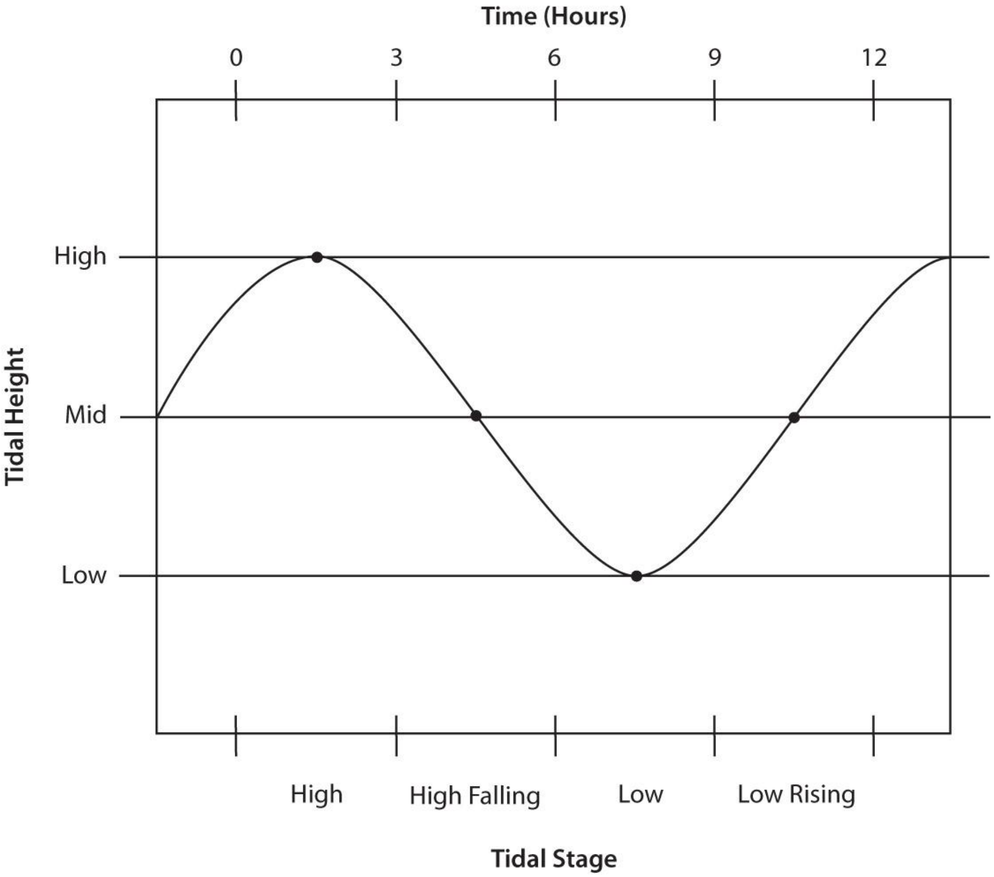


Figure 4. MDS results of tidal stage on the finfish community for sampling events: August 19, August 27, and September 19. (H = High, L = Low, H F = High Falling, LR = Low Rising).

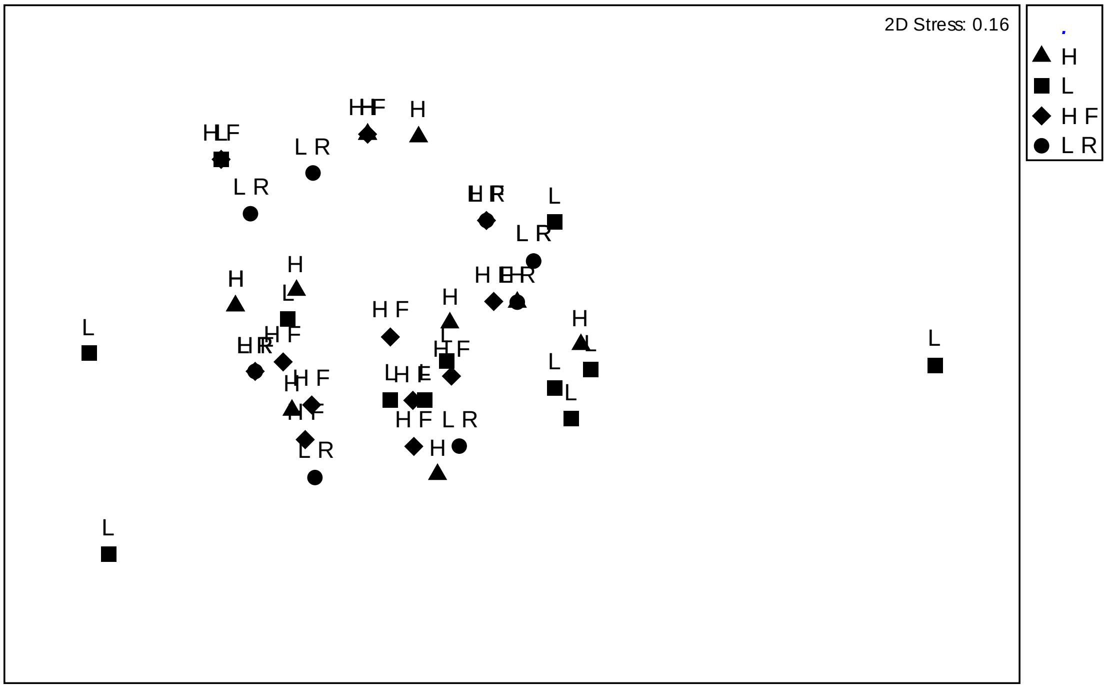


Figure 5. Calculation of sample sizes necessary to detect differences in species richness (S) among tidal stages for both 0.80 and 0.90 power. High falling vs low (0.80 power = 2,068 samples, 0.90 power = 2,767; not shown on graph).

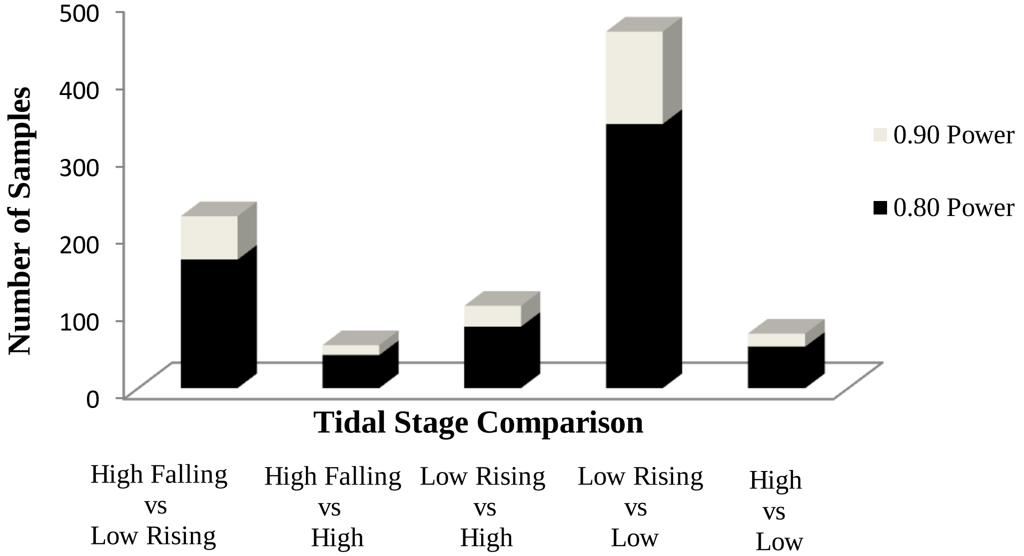


Figure 6. MDS results of short term variability on finfish data collected at Matunuck Beach. Sampling dates are represented as (1) August 19, (2) August 27, and (3) September 19.

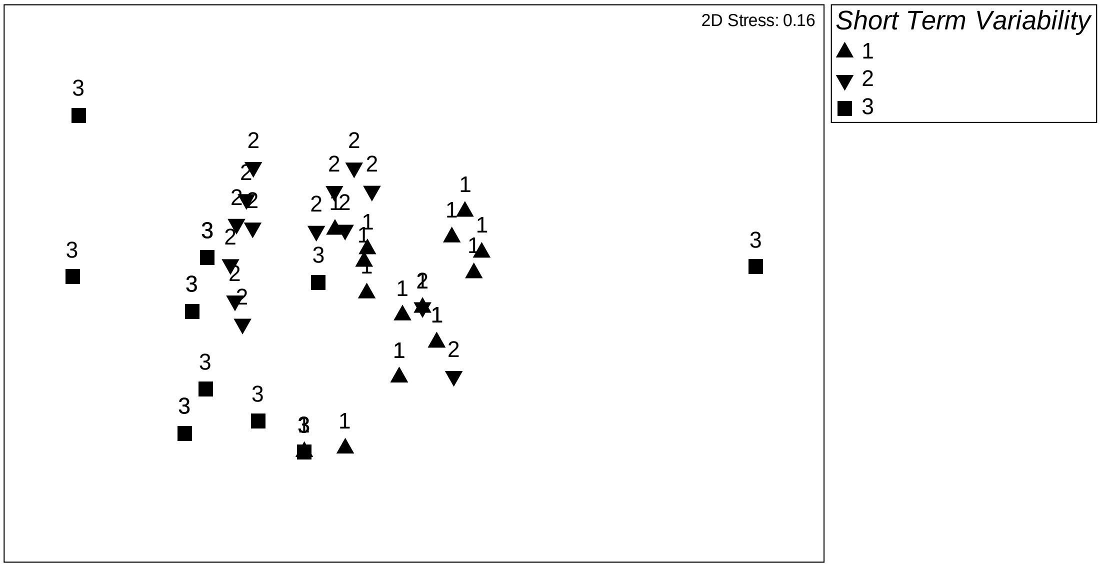


Figure 7. MDS results of both tidal stage and short term variability on finfish data collected at Matunuck Beach. Sampling dates are represented as (1) August 19, (2) August 27, and (3) September 19. Tidal stage is represented as (H) high, (HF) high falling, (L) low, and (LR) low rising. The overlay of cluster analysis identifies three main groups of samples with 50% similarity.

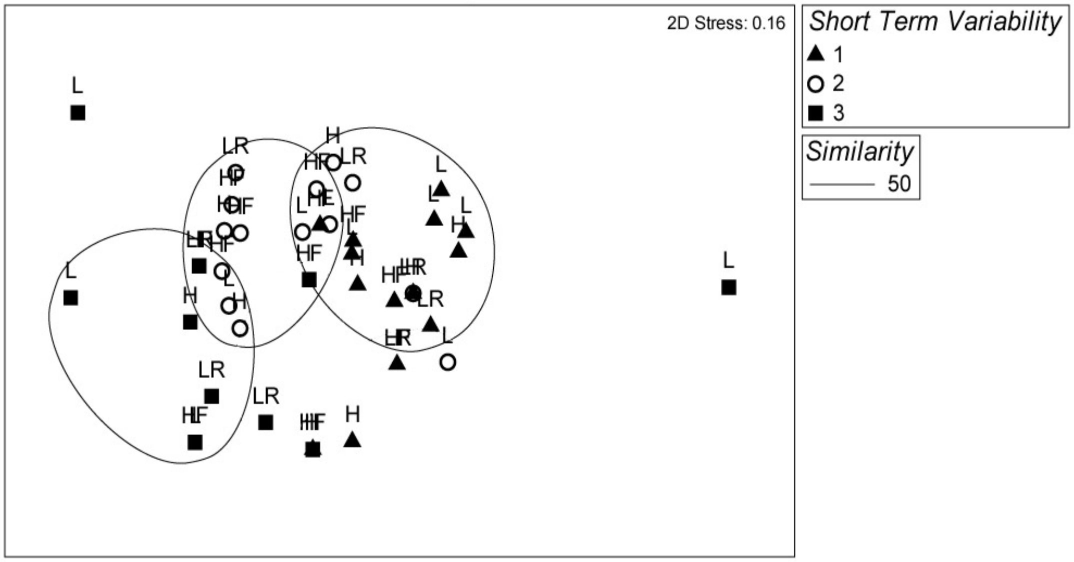


Figure 8. Number of hauls necessary to detect the % of dominant and total species across all sampling events.

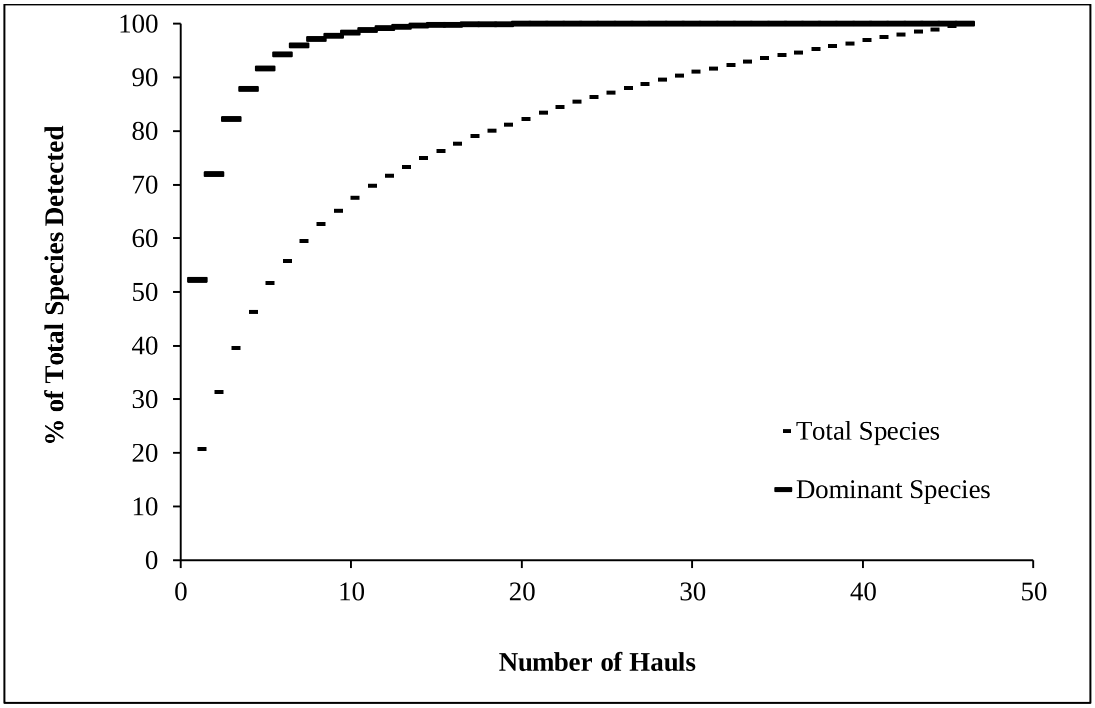


Figure 9. Species accumulation curves for % of dominant species and total species detected per sampling date.

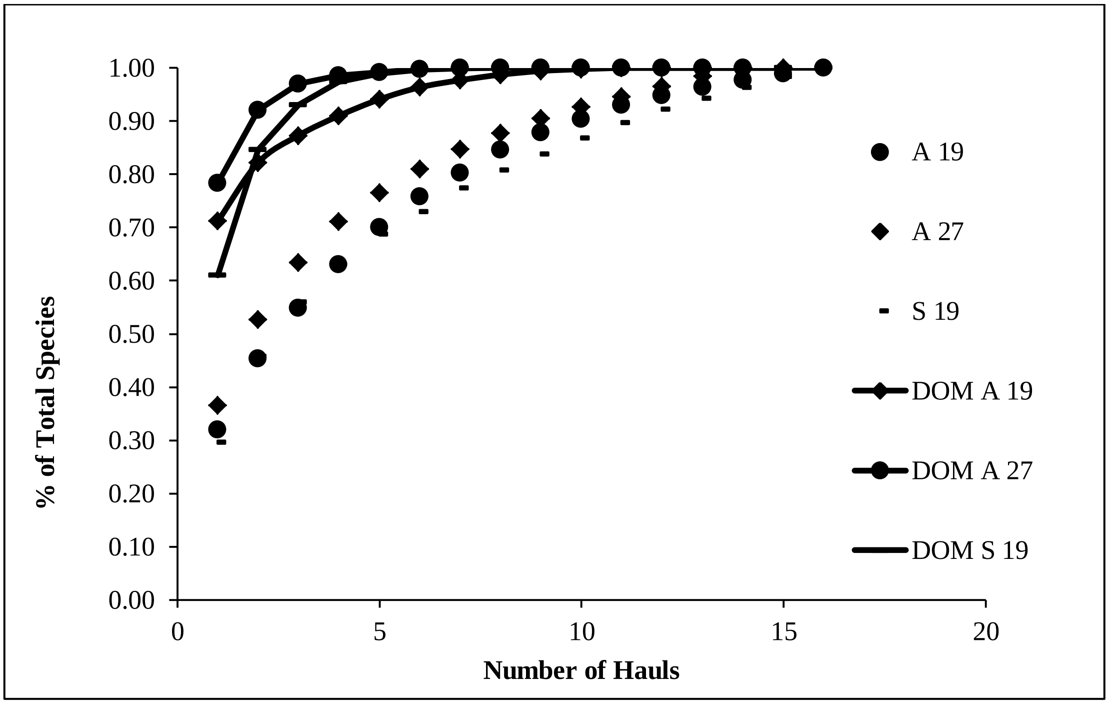
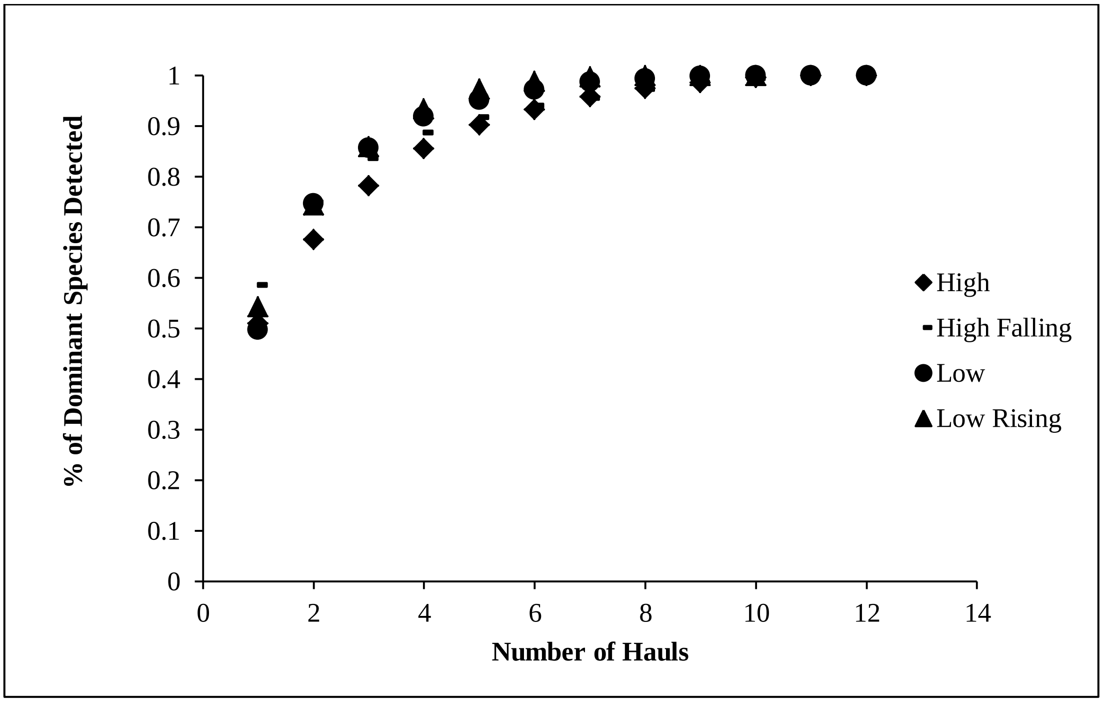


Figure 10. Species accumulation curve for dominant species (alewife, Atlantic menhaden, bay anchovy, and Atlantic silverside) across tidal stages.



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Appendix A. Measured habitat characteristics from 2007 and 2008 sampling season at both Coast Guard (CG) and Fisher Beach (F). Sampling gear types are; haul seine (HS), beach seine (BS), gill net (GN), and long line (LL).

Date	Year	Location	Set	Gear	Time (am)	Tide (high)	Air T (cel)	Water T (cel)	Wind (mph)	SWH (m)	Precip. (cm)
8-Jun	2007	CG	1	HS	7:45	5:34	18.3	12.9	6 ssw	0.61	0.00
8-Jun	2007	CG	2	HS	9:30	5:34	18.3	12.9	6 ssw	0.61	0.00
8-Jun	2007	CG	3	HS	11:15	5:34	18.3	12.9	6 ssw	0.61	0.00
8-Jun	2007	CG	1	BS	12:15	5:34	18.3	12.9	6 ssw	0.61	0.00
8-Jun	2007	CG	2	BS	12:25	5:34	18.3	12.9	6 ssw	0.61	0.00
8-Jun	2007	CG	3	BS	12:35	5:34	18.3	12.9	6 ssw	0.61	0.00
9-Jun	2007	F	1	GN	6:54	6:17	21.6	13.5	8 ssw	0.00	0.00
9-Jun	2007	F	2	GN	8:30	6:17	21.6	13.5	8 ssw	0.00	0.00
9-Jun	2007	F	3	GN	10:00	6:17	21.6	13.5	8 ssw	0.00	0.00
9-Jun	2007	F	1	LL	7:45	6:17	21.6	13.5	8 ssw	0.00	0.00
9-Jun	2007	F	2	LL	9:10	6:17	21.6	13.5	8 ssw	0.00	0.00
9-Jun	2007	F	3	LL	10:45	6:17	21.6	13.5	8 ssw	0.00	0.00
11-Jun	2007	F	1	HS	7:20	8:19	16.6	14.1	6 n	0.00	0.00
11-Jun	2007	F	2	HS	9:00	8:19	16.6	14.1	6 n	0.00	0.00
11-Jun	2007	F	3	HS	10:30	8:19	16.6	14.1	6 n	0.00	0.00
11-Jun	2007	F	1	BS	12:30	8:19	16.6	14.1	6 n	0.00	0.00
11-Jun	2007	F	2	BS	12:35	8:19	16.6	14.1	6 n	0.00	0.00
11-Jun	2007	F	3	BS	12:42	8:19	16.6	14.1	6 n	0.00	0.00
21-Jun	2007	CG	1	GN	6:30	4:51	19.4	12.2	8 wnw	0.91	0.00
21-Jun	2007	CG	2	GN	7:00	4:51	19.4	12.2	8 wnw	0.91	0.00
21-Jun	2007	CG	3	GN	7:30	4:51	19.4	12.2	8 wnw	0.91	0.00
21-Jun	2007	CG	1	LL	8:00	4:51	19.4	12.2	8 wnw	0.91	0.00
21-Jun	2007	CG	2	LL	8:30	4:51	19.4	12.2	8 wnw	0.91	0.00
21-Jun	2007	CG	3	LL	9:00	4:51	19.4	12.2	8 wnw	0.91	0.00

13-Jul	2007	CG	1	HS	8:00	11:18	21.6	17.3	8 ssw	0.91	0.00
13-Jul	2007	CG	2	HS	8:45	11:18	21.6	17.3	8 ssw	0.91	0.00
13-Jul	2007	CG	3	HS	9:35	11:18	21.6	17.3	8 ssw	0.91	0.00
13-Jul	2007	CG	1	BS	10:00	11:18	21.6	17.3	8 ssw	0.91	0.00
13-Jul	2007	CG	2	BS	10:10	11:18	21.6	17.3	8 ssw	0.91	0.00
13-Jul	2007	CG	3	BS	10:20	11:18	21.6	17.3	8 ssw	0.91	0.00
15-Jul	2007	CG	1	GN	7:30	12:23	23.8	16.6	11sw	0.30	0.00
15-Jul	2007	CG	2	GN	8:05	12:23	23.8	16.6	11sw	0.30	0.00
15-Jul	2007	CG	3	GN	8:45	12:23	23.8	16.6	11sw	0.30	0.00
15-Jul	2007	CG	1	LL	9:15	12:23	23.8	16.6	11sw	0.30	0.00
15-Jul	2007	CG	2	LL	9:45	12:23	23.8	16.6	11sw	0.30	0.00
15-Jul	2007	CG	3	LL	10:25	12:23	23.8	16.6	11sw	0.30	0.00
16-Jul	2007	F	1	HS	8:15	12:55	22.7	16.8	8 nw	0.00	0.13
16-Jul	2007	F	2	HS	10:15	12:55	22.7	16.8	8 nw	0.00	0.13
16-Jul	2007	F	3	HS	11:15	12:55	22.7	16.8	8 nw	0.00	0.13
21-Jul	2007	F	1	GN	6:00	4:50	18	15.3	9 nw	0.30	0.00
21-Jul	2007	F	2	GN	7:00	4:50	18	15.3	9 nw	0.30	0.00
21-Jul	2007	F	3	GN	8:00	4:50	18	15.3	9 nw	0.30	0.00
21-Jul	2007	F	1	LL	6:30	4:50	18	15.3	9 nw	0.30	0.00
21-Jul	2007	F	2	LL	7:30	4:50	18	15.3	9 nw	0.30	0.00
21-Jul	2007	F	3	LL	8:30	4:50	18	15.3	9 nw	0.30	0.00
21-Jul	2007	F	1	BS	8:20	4:50	18.8	15.3	9 nw	0.30	0.00
21-Jul	2007	F	2	BS	8:45	4:50	18.8	15.3	9 nw	0.30	0.00
21-Jul	2007	F	3	BS	9:10	4:50	18.8	15.3	9 nw	0.30	0.00
5-Sep	2007	CG	1	HS	9:30	6:50	18	14.5	4 e	1.00	0.00
6-Sep	2007	F	1	HS	9:00	7:40	14.4	16.7	5 s	0.30	0.20
6-Sep	2007	F	2	HS	9:55	7:40	14.4	16.7	5 s	0.30	0.20
6-Sep	2007	F	3	HS	11:00	7:40	14.4	16.7	5 s	0.30	0.20
8-Sep	2007	F	1	GN	7:00	9:48	22.2	19.9	13 ssw	0.30	0.00

8-Sep	2007	F	2	GN	8:00	9:48	22.2	19.9	13 ssw	0.30	0.00
8-Sep	2007	F	3	GN	9:00	9:48	22.2	19.9	13 ssw	0.30	0.00
8-Sep	2007	F	1	LL	7:30	9:48	22.2	19.9	13 ssw	0.30	0.00
8-Sep	2007	F	2	LL	8:30	9:48	22.2	19.9	13 ssw	0.30	0.00
8-Sep	2007	F	3	LL	9:30	9:48	22.2	19.9	13 ssw	0.30	0.00
8-Sep	2007	F	1	BS	9:35	9:48	22.2	19.9	13 ssw	0.30	0.00
8-Sep	2007	F	2	BS	9:45	9:48	22.2	19.9	13 ssw	0.30	0.00
8-Sep	2007	F	3	BS	9:55	9:48	22.2	19.9	13 ssw	0.30	0.00
28-May	2008	F	1	HS	7:00	5:57	13.3	11	14 n	0.30	0.00
28-May	2008	F	2	HS	7:25	5:57	13.3	11	14 n	0.30	0.00
28-May	2008	F	3	HS	7:50	5:57	13.3	11	14 n	0.30	0.00
28-May	2008	F	1	BS	8:35	5:57	13.3	11	14 n	0.30	0.00
28-May	2008	F	2	BS	8:52	5:57	13.3	11	14 n	0.30	0.00
28-May	2008	F	3	BS	9:05	5:57	13.3	11	14 n	0.30	0.00
29-May	2008	CG	1	HS	7:00	7:07	14.4	10	7 sw	0.15	0.00
29-May	2008	CG	2	HS	7:31	7:07	14.4	10	7 sw	0.15	0.00
29-May	2008	CG	3	HS	8:00	7:07	14.4	10	7 sw	0.15	0.00
29-May	2008	CG	1	BS	8:20	7:07	14.4	10	7 sw	0.15	0.00
29-May	2008	CG	2	BS	8:31	7:07	14.4	10	7 sw	0.15	0.00
29-May	2008	CG	3	BS	8:40	7:07	14.4	10	7 sw	0.15	0.00
30-May	2008	CG	1	HS	7:20	8:05	13.8	12	8 ne	0.30	0.00
30-May	2008	CG	2	HS	7:55	8:05	13.8	12	8 ne	0.30	0.00
30-May	2008	CG	3	HS	8:25	8:05	13.8	12	8 ne	0.30	0.00
30-May	2008	CG	1	BS	8:50	8:05	13.8	12	8 ne	0.30	0.00
30-May	2008	CG	2	BS	9:00	8:05	13.8	12	8 ne	0.30	0.00
30-May	2008	CG	3	BS	9:10	8:05	13.8	12	8 ne	0.30	0.00
30-May	2008	CG	4	HS	10:00	8:05	13.8	12	8 ne	0.30	0.00
30-May	2008	CG	5	HS	10:35	8:05	13.8	12	8 ne	0.30	0.00
30-May	2008	CG	6	HS	11:12	8:05	13.8	12	8 ne	0.30	0.00

31-May	2008	F	1	HS	6:00	8:48	16.6	13.5	11 ssw	0.30	0.00
31-May	2008	F	2	HS	6:35	8:48	16.6	13.5	11 ssw	0.30	0.00
31-May	2008	F	3	HS	7:00	8:48	16.6	13.5	11 ssw	0.30	0.00
31-May	2008	F	1	BS	7:14	8:48	16.6	13.5	11 ssw	0.30	0.00
31-May	2008	F	2	BS	7:24	8:48	16.6	13.5	11 ssw	0.30	0.00
31-May	2008	F	3	BS	7:38	8:48	16.6	13.5	11 ssw	0.30	0.00
28-Jun	2008	CG	1	HS	6:00	7:36	18.8	16	7 nne	0.30	0.00
28-Jun	2008	CG	2	HS	6:30	7:36	18.8	16	7 nne	0.30	0.00
28-Jun	2008	CG	3	HS	7:15	7:36	18.8	16	7 nne	0.30	0.00
28-Jun	2008	CG	1	BS	8:00	7:36	18.8	16	7 nne	0.30	0.00
28-Jun	2008	CG	2	BS	8:20	7:36	18.8	16	7 nne	0.30	0.00
28-Jun	2008	CG	3	BS	8:35	7:36	18.8	16	7 nne	0.30	0.00
28-Jun	2008	CG	4	BS	8:45	7:36	18.8	16	7 nne	0.30	0.00
29-Jun	2008	CG	1	HS	7:10	8:36	22.7	15	5 s	0.30	0.20
29-Jun	2008	CG	2	HS	7:45	8:36	22.7	15	5 s	0.30	0.20
29-Jun	2008	CG	3	HS	8:20	8:36	22.7	15	5 s	0.30	0.20
29-Jun	2008	CG	1	BS	9:00	8:36	22.7	15	5 s	0.30	0.20
29-Jun	2008	CG	2	BS	9:14	8:36	22.7	15	5 s	0.30	0.20
29-Jun	2008	CG	3	BS	9:29	8:36	22.7	15	5 s	0.30	0.20
30-Jun	2008	F	1	HS	7:20	9:22	23.3	17.5	12 ssw	0.30	0.28
30-Jun	2008	F	2	HS	8:00	9:22	23.3	17.5	12 ssw	0.30	0.28
30-Jun	2008	F	3	HS	8:30	9:22	23.3	17.5	12 ssw	0.30	0.28
30-Jun	2008	F	1	BS	9:10	9:22	23.3	17.5	12 ssw	0.30	0.28
30-Jun	2008	F	2	BS	9:25	9:22	23.3	17.5	12 ssw	0.30	0.28
30-Jun	2008	F	3	BS	9:40	9:22	23.3	17.5	12 ssw	0.30	0.28
30-Jun	2008	F	4	HS	10:15	9:22	23.3	17.5	12 ssw	0.30	0.00
30-Jun	2008	F	5	HS	10:50	9:22	23.3	17.5	12 ssw	0.30	0.00
30-Jun	2008	F	6	HS	11:15	9:22	23.3	17.5	12 ssw	0.30	0.00
1-Jul	2008	F	1	HS	9:35	10:22	22.7	21	9 ssw	0.00	0.00

1-Jul	2008	F	2	HS	10:00	10:22	22.7	21	9 ssw	0.00	0.00
1-Jul	2008	F	3	HS	10:30	10:22	22.7	21	9 ssw	0.00	0.00
1-Jul	2008	F	1	BS	8:00	10:22	22.7	21	9 ssw	0.00	0.00
1-Jul	2008	F	2	BS	8:20	10:22	22.7	21	9 ssw	0.00	0.00
1-Jul	2008	F	3	BS	8:44	10:22	22.7	21	9 ssw	0.00	0.00
11-Jul	2008	CG	1	HS	7:05	7:00	21.1	18	8 nnw	0.91	0.00
11-Jul	2008	CG	2	HS	7:28	7:00	21.1	18	8 nnw	0.91	0.00
11-Jul	2008	CG	3	HS	8:12	7:00	21.1	18	8 nnw	0.91	0.00
11-Jul	2008	CG	1	BS	9:35	7:00	21.1	18	8 nnw	0.91	0.00
11-Jul	2008	CG	2	BS	9:46	7:00	21.1	18	8 nnw	0.91	0.00
11-Jul	2008	CG	3	BS	10:05	7:00	21.1	18	8 nnw	0.91	0.00
12-Jul	2008	CG	1	HS	6:55	8:02	22.2	16	6 ssw	0.91	0.00
12-Jul	2008	CG	2	HS	7:32	8:02	22.2	16	6 ssw	0.91	0.00
12-Jul	2008	CG	3	HS	8:00	8:02	22.2	16	6 ssw	0.91	0.00
12-Jul	2008	CG	1	BS	8:55	8:02	22.2	16	6 ssw	0.91	0.00
12-Jul	2008	CG	2	BS	9:10	8:02	22.2	16	6 ssw	0.91	0.00
12-Jul	2008	CG	3	BS	9:17	8:02	22.2	16	6 ssw	0.91	0.00
13-Jul	2008	F	1	HS	6:24	8:34	23.3	23	13 s	0.30	0.00
13-Jul	2008	F	2	HS	6:54	8:34	23.3	23	13 s	0.30	0.00
13-Jul	2008	F	3	HS	7:17	8:34	23.3	23	13 s	0.30	0.00
13-Jul	2008	F	4	HS	7:37	8:34	23.3	23	13 s	0.30	0.00
13-Jul	2008	F	1	BS	8:38	8:34	23.3	23	13 s	0.30	0.00
13-Jul	2008	F	2	BS	9:11	8:34	23.3	23	13 s	0.30	0.00
13-Jul	2008	F	3	BS	9:38	8:34	23.3	23	13 s	0.30	0.00
14-Jul	2008	F	1	HS	6:50	9:39	24.4	23	8 ssw	0.15	0.20
14-Jul	2008	F	2	HS	7:22	9:39	24.4	23	8 ssw	0.15	0.20
14-Jul	2008	F	3	HS	7:48	9:39	24.4	23	8 ssw	0.15	0.20
14-Jul	2008	F	4	HS	9:59	9:39	24.4	23	8 ssw	0.15	0.20
14-Jul	2008	F	1	BS	8:41	9:39	24.4	23	8 ssw	0.15	0.20

14-Jul	2008	F	2	BS	9:07	9:39	24.4	23	8 ssw	0.15	0.20
14-Jul	2008	F	3	BS	9:30	9:39	24.4	23	8 ssw	0.15	0.20
19-Sep	2008	F	1	HS	12:45	2:40	12.7	11.5	16 ene	0.00	0.00
19-Sep	2008	F	2	HS	1:20	2:40	12.7	11.5	16 ene	0.00	0.00
19-Sep	2008	F	3	HS	1:55	2:40	12.7	11.5	16 ene	0.00	0.00
19-Sep	2008	F	1	BS	11:10	2:40	12.7	11.5	16 ene	0.00	0.00
19-Sep	2008	F	2	BS	11:40	2:40	12.7	11.5	16 ene	0.00	0.00
19-Sep	2008	F	3	BS	11:58	2:40	12.7	11.5	16 ene	0.00	0.00
20-Sep	2008	F	1	HS	6:20	3:32	14.4	15.5	5 ene	0.15	0.00
20-Sep	2008	F	2	HS	7:15	3:32	14.4	15.5	5 ene	0.15	0.00
20-Sep	2008	F	3	HS	8:00	3:32	14.4	15.5	5 ene	0.15	0.00
20-Sep	2008	F	1	BS	8:15	3:32	14.4	15.5	5 ene	0.15	0.00
20-Sep	2008	F	2	BS	8:45	3:32	14.4	15.5	5 ene	0.15	0.00
20-Sep	2008	F	3	BS	9:04	3:32	14.4	15.5	5 ene	0.15	0.00
21-Sep	2008	F	1	HS	6:25	4:28	13.8	14	3 w	0.30	0.00
21-Sep	2008	F	2	HS	7:00	4:28	13.8	14	3 w	0.30	0.00
21-Sep	2008	F	3	HS	7:40	4:28	13.8	14	3 w	0.30	0.00
21-Sep	2008	F	1	BS	8:00	4:28	13.8	14	3 w	0.30	0.00
21-Sep	2008	F	2	BS	8:40	4:28	13.8	14	3 w	0.30	0.00
21-Sep	2008	F	3	BS	9:00	4:28	13.8	14	3 w	0.30	0.00
22-Sep	2008	F	1	HS	6:30	5:28	15.5	15	6 ene	0.00	0.05
22-Sep	2008	F	2	HS	7:10	5:28	15.5	15	6 ene	0.00	0.05
22-Sep	2008	F	3	HS	7:40	5:28	15.5	15	6 ene	0.00	0.05
22-Sep	2008	F	1	BS	9:00	5:28	15.5	15	6 ene	0.00	0.05
22-Sep	2008	F	2	BS	9:15	5:28	15.5	15	6 ene	0.00	0.05
22-Sep	2008	F	3	BS	9:40	5:28	15.5	15	6 ene	0.00	0.05
25-Oct	2008	F	1	HS	7:00	9:27	12.7	11	8 s	0.00	0.00
25-Oct	2008	F	2	HS	7:35	9:27	12.7	11	8 s	0.00	0.00
25-Oct	2008	F	3	HS	8:17	9:27	12.7	11	8 s	0.00	0.00

25-Oct	2008	F	1	BS	9:00	9:27	12.7	11	8 s	0.00	0.00
25-Oct	2008	F	2	BS	9:20	9:27	12.7	11	8 s	0.00	0.00
25-Oct	2008	F	3	BS	9:40	9:27	12.7	11	8 s	0.00	0.00
28-Oct	2008	F	1	HS	6:20	11:40	11.1	12	4 ese	0.30	0.46
28-Oct	2008	F	2	HS	6:50	11:40	11.1	12	4 ese	0.30	0.46
28-Oct	2008	F	3	HS	7:25	11:40	11.1	12	4 ese	0.30	0.46
28-Oct	2008	F	1	BS	8:00	11:40	11.1	12	4 ese	0.30	0.46
28-Oct	2008	F	2	BS	8:15	11:40	11.1	12	4 ese	0.30	0.46
28-Oct	2008	F	3	BS	8:31	11:40	11.1	12	4 ese	0.30	0.46