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The influence of marsh edge and seagrass habitat on summer fish and macroinvertebrate recruitment to a northern Gulf of Mexico coastal system

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Marshes and seagrass beds have been widely recognized as important habitat for estuarine species, but less has been done on how these habitats interact and function together, thereby limiting understanding of the variability of juvenile recruitment to coastal systems. Therefore, the objective of this study was to assess the interaction between fringing marsh and adjacent seagrass for the provision of habitat for juvenile nekton. Weekly seine net and benthic seagrass core sampling from June to November 2020 determine the relationship between nekton and marsh-edge and seagrass habitat. This study shows disparate results, in terms of the effects of proximity to marsh edge and seagrass biomass on nekton abundance and size, pointing to different selectivity of marsh edge versus seagrass by different species. In addition, there are no effects of proximity to marsh edge and seagrass biomass on community composition, but an interactive effect on community dispersion.

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CHAPTER I

INTRODUCTION

Coastal areas are comprised of a myriad of diverse habitats that provide numerous ecosystem services essential to the economic and ecological preservation of coastal communities. Coastal habitats such as mangroves, oyster reefs, marshes, and seagrass beds have been well documented as essential reproductive habitat, nursery grounds, and shelter for a multitude of organisms (Beck et al., 2001; Boesch & Turner, 1984). Numerous studies suggest that the structural complexity associated with these habitats provides excellent refuge and food resources for the recruitment of juveniles of estuarine-dependent species, (species that require estuaries during their lifecycle), making these habitats ideal nurseries in addition to full-time habitat for resident species (Boesch & Turner, 1984; Briggs & O'Connor, 1971; Heck Jr et al., 1997; Heck Jr & Wetstone, 1977; Orth et al., 1984; Orth & VANMONTFRANS, 1987; Pattillo et al., 1997; Penry, 1982; Stoner, 1980; Virnstein et al., 1983; Zimmerman & Minello, 1984).

Many studies demonstrate the tendency for greater densities of estuarine-dependent species in structured habitat such as, fringing marshes, oyster reefs, seagrass beds, and mangroves compared to non-structured habitat, owing to the enhanced refuge and food availability associated with structurally complex habitats (Heck et al., 2003; Hollweg et al., 2020; Minello et al., 2003). The diversity of habitats within coastal ecosystems allows for preferential utilization of one habitat over another for refuge and food provision depending on the species physiological requirements and behavioral traits (Baltz et al., 1993). For instance, some species may find suitable refugia and provision of food in the flexible, soft leaf canopies of seagrass beds, while others may prefer hard substrate such as oyster reefs (Heck & Thoman, 1984; Hollweg et al., 2020; Shervette & Gelwick, 2008). In addition, these habitats support prolific food webs maintained by high primary productivity, in turn sustaining several trophic levels occupied by estuarine-dependent species (Boesch & Turner, 1984; Cebrian, 2002).

Estuarine-dependent species can be further described by their temporal utilization of estuarian habitats as permanent or transient residents (Hettler, 1989). Permanent residents inhabit shallow coastal systems throughout their entire life cycles. Examples of permanent residents include Gulf killifish (*Fundulus grandis*), striped mullet (*Mugil cephalus*) and silversides (*Menidia* sp.). These species are commercially and ecologically important species in the nGOM that complete their entire lifecycle in inshore waters and are commonly found along emergent marsh vegetation and seagrass beds (Pattillo et al., 1997; Wagner, 1973). Species that require estuarine habitats for only a portion of their lifecycle are coined the term "transient" residents. For these species, spawning usually occurs offshore from coastlines and eggs and/or larvae will immigrate to estuaries (Pattillo et al., 1997). Post-larvae and small juveniles recruit to shallow vegetated inshore habitats and will utilize these habitats until they are large enough to move into deeper waters to repeat the cycle (Able, 2005; Sheaves et al., 2015). Transient residents support some of the largest commercial and recreational fisheries such as brown shrimp (*Farfantepenaeus aztecus*), white shrimp (*Litopenaeus setiferus*), and blue crab (*Callinectes sapidus*) (Lellis-Dibble et al., 2008).

Salt marshes and seagrasses provide essential habitat to coastal ecosystems and are often found in close proximity to each other. Salt marshes in the nGOM constitute the majority of the total area of U.S coastal marshes and is dominated by *Juncus roemerianus* and *Spartina* *alterniflora* grass species (Heard & Lutz, 1982; Macy et al., 2019). When these habitats are inundated over a tidal cycle, their fringing edges provide an ideal foraging environment with ample food resources and protection from predators (Boesch & Turner, 1984; McIvor & Rozas, 1996). Seagrasses in the nGOM are subtidal and beds are typically "patchy" and sparse due to physical disturbances such as extended periods of depressed salinity and decreased light availability in combination with anthropogenetic stressors (Heck Jr & Orth, 1980; Moncreiff, 1940). The most common species of seagrass in the nGOM include paddle grass (*Halophila decipiens*), star grass (*Halophila engelmannii),* turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), and wigeon grass (*Ruppia maritima*) (Christiaen et al., 2016; Moncreiff, 1940). Despite the ephemeral nature of seagrasses in the nGOM, they provide essential habitat for transient and resident estuarine-dependent species (Heck et al., 1997; Raposa & Oviatt, 2000).

The population density of juvenile nekton reflects the cumulative response of recruitment, mortality, and emigration; thus, density can be an important indicator of nursery habitat value (Minello, 1999). Juvenile nekton species are found in abundance in a variety of coastal habitats and utilize them for various purposes. Focusing specifically on marsh-edge (the interface between marsh and open water) and seagrass habitat, the combination of the two habitats may interact in a way that influences juvenile nekton abundance (Glancy et al., 2003; Heck Jr et al., 1993; Heck Jr et al., 2003; Irlandi & Crawford, 1997; Rozas et al., 2012; Rozas & Odum, 1987).

Although both saltmarsh and seagrass beds frequently co-occur in the northern GOM and are considered important juvenile habitats, studies comparing juvenile utilization of these estuarine habitats are rare (Heck et al., 1993; Rozas & Minello, 1998; Thomas et al., 1990).

Quantifying how fisheries species' recruitment to coastal systems changes over short distances and periods of time is essential to understanding habitat value on a larger scale. The goal of this project is to achieve an enhanced comprehension of nekton abundance patterns by assessing the importance of marsh-edge and seagrass, separately or interactively as habitat for juvenile nekton. Weekly seine net and benthic seagrass core sampling from June to November 2020 allowed us to determine the relationship between nekton and marsh-edge and seagrass habitat.

CHAPTER II

METHODS

2.1 Study Site

Point aux Pins (30.3705° N, 88.3158° W), is a shallow, microtidal, protected saline marsh consisting of fringing marsh vegetation and patches of adjacent seagrass beds in Mississippi Sound (Figure 2.1). Marsh species are dominated by *Juncus roemerianus* and *Spartina alterniflora* and seagrass beds consist of shoal (*Halodule wrightii*) and widgeon grass (*Ruppia maritima*). Point aux Pins is a microtidal system with a relatively consistent salinity regime, in this study ranging from 15.7- 24.6 ppt (Table A.1).

Figure 2.1 Location of the five sampling locations at study site in Point aux Pins, Alabama

Each block number corresponds to a specific GPS location where sampling was performed within that location +/- a few meters for each sampling date. Block 1: 30°22'21.96"N 88°18'49.72"W. Block 2: 30°22'31.75"N 88°18'43.01"W. Block 3: 30°22'37.52"N 88°18'39.52"W. Block 4: 30°22'42.25"N 88°18'38.13"W. Block 5: 30°23'3.18"N 88°18'44.51"W.

2.2 Study Design

Weekly sampling occurred from June -November 2020 to ensure most of the recruitment period of structurally associated species was captured, which is defined as one that actively selects structured over non-structured habitat (Glancy et al., 2003; Irlandi & Crawford, 1997; Minello & Rozas, 2002; Rozas & Minello, 1998). Within the approximate 1.5 km study area, five sampling blocks were chosen randomly to conduct nekton and benthic core sampling. Within each sampling block one sampling transect was established along the marsh-edge and the second, hereafter referred to as non-edge, was about 40 meters seaward, from the marsh-edge transect.

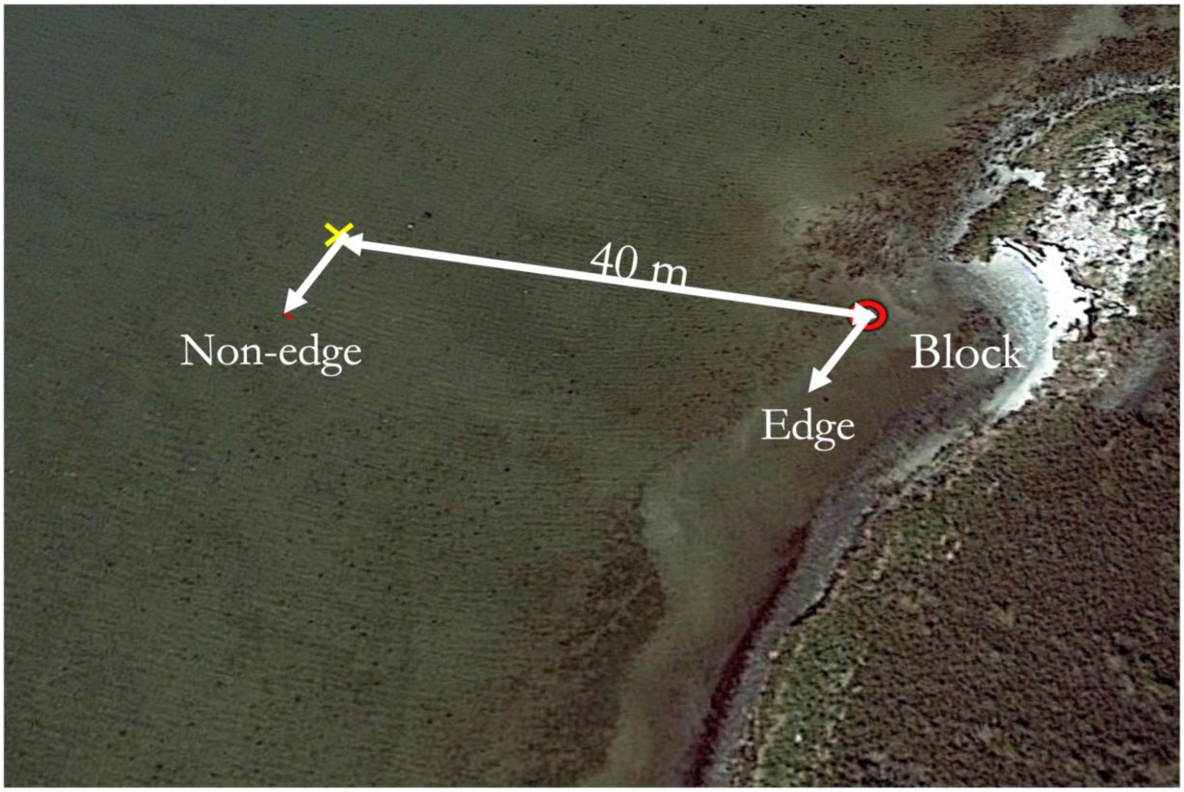

Figure 2.2 Locations of seine net sampling within each sampling block

Two seine net samples were executed within each sampling block. One along the marsh edge and the other forty meters seaward perpendicular to the marsh edge transect.

2.3 Environmental Characterization

Environmental measurement including salinity (ppt), temperature (°C) dissolved oxygen (mg/L) were recorded within each sampling block with a YSI ProSolo Digital Water Quality Meter (Table A.1). Water depth measurements were recorded within each sampling block at both edge and non-edge transect locations (Table A.2). In addition to water depth measurements, the frequency at which the marsh edge was inundated more than five centimeters throughout the study period was calculated. A HOBO U20L logger was deployed on the piling of a dock within block five of our study area to record water depth every thirty minutes. Also, for every sampling date five marsh edge measurements from each block were recorded, taking note of the time of measurement. By subtracting the average marsh edge depth from the corresponding depths on the logger, the value on the logger at which the marsh edge would have zero centimeters of water, or depth at which the marsh edge floods and or drains within each block was determined. This value, adding five cm to ensure nekton had access to the marsh vegetation, was compared to all other values recorded from the depth logger to see how often and for how long the marsh edge was accessible to juvenile nekton (Minello et al., 2012). Because the depth logger was not deployed for the entire study period, the same method was used with depth logger data from Alabama's Real-Time Coastal Observing System (ARCOS) Bon Secour station for dates 6/30/2020 to 9/25/2020. Although the Bon Secour station is one of the furthest stations in the ARCOS system from our site, it was the only one functioning during the period of the study. The Point aux Pins depth readings were plotted against Bon Secour for the dates the Point aux Pins logger was deployed, 9/26/21-11/12/2021, and the depth gauges showed a strong correlation ($r = 0.91$).

2.4 Nekton and seagrass collection

Seining was chosen as the sampling technique to capture macroinvertebrates and small individuals of fish species associated with seagrass structure (Rozas & Minello, 1998). The seine net was 1.8 meters tall x 15.24 meters wide with 0.64-cm mesh size and was pulled 10 meters against the current at each sampling location. Within each sampling block, one pull was executed parallel along the continuous emergent marsh-edge, with one end of the net pulled as close to the vegetation as possible, and the second was pulled approximately 40 meters seaward of the edge transect, parallel to the shoreline, resulting in 10 (2 per block x 5 blocks) total seine pulls for each sampling date. To standardize the area sampled by each replicate seine haul, a head rope was attached to the top of the seine net to ensure the personnel hauling it were exactly 10 meters apart. Once an initial 10-meter distance was set, the seine net was pulled perpendicular to the shoreline 10 meters, then closed off to complete a square enclosing for a total sampled area of 100 square meters.

To assess the relationship between nekton and above ground seagrass biomass, the amount of seagrass was quantified along the central axis of the of the 10-meter transect using a corer (10-cm diameter) to collect benthic cores every two meters, resulting in up to six cores per transect. Only cores with seagrass present (containing leaf, rhizome, and root structures) were taken from the field for further processing.

2.5 Nekton and seagrass processing

Nekton from each seine pull were identified and counted. For each species identified in every seine sample, a random sample of up to 20 individuals were measured to the nearest mm, weighed to the nearest 0.1 g wet weight, and sexed if possible. Seagrass cores were sieved to isolate seagrass. A razor blade was used to cut the leaves of the seagrass at the node to separate the above ground structure from below ground structure. The leaves of each core were then dried in a drying oven at 70 °C for 48 hours before being weighed to obtain above-ground biomass as grams of dry weight per square meter. Only above-ground biomass was processed because that portion of the seagrass is what provides juvenile nekton with usable structured habitat.

2.6 Statistical Analyses

2.6.1 Total and Specific Species Abundance

The statistical analyses were done with R version 4.2.1. Generalized linear mixed models using the glmmTMB package (Brooks et al., 2017) were used to analyze data for total abundance and the six most abundant structurally associated species caught during the study: white shrimp (*Litopenaeus setiferus*), blue crab (*Callinectes sapidus*), brown shrimp (*Farfantepenaeus* spp.), spotted seatrout (*Cynoscion nebulosus*), American silver perch (*Bairdiella chrysoura*) and pinfish (*Lagodon rhomboides*). Model selection was performed following recommendations by Zuur et al. (2009) using the distributions that best fit the data and based on maximum likelihood criteria, using Akaike information criterion (AIC), for the random variable portion of the model. That is, the distributions that best fit the data were identified, data was transformed to better fit that distribution if necessary and the significance of the random factors within the model were evaluated using AIC. Final *p*-values for main factors and their interactions were obtained using Wald chisquare tests (Anova function, car package). Model assumptions for all variables were examined using the DHARMa package (Hartig, 2020). In some cases, even with data transformations and adjusting the distribution, it was not possible to meet all model assumptions. If assumptions of the model were met, results were significant at an alpha of 0.05; however, if assumptions were not met the alpha was reduced to 0.001 (Antón et al., 2011).

The fixed portion of the model included the main effects of seagrass biomass (continuous variable), proximity to marsh-edge (categorical variable: edge/non-edge), time (categorical variable), the two-way interaction between seagrass biomass and time, marsh-edge proximity and time and seagrass biomass and marsh-edge proximity and the triple interaction between seagrass biomass, marsh-edge proximity, and time. Block, repeated measures (seine pull), and temporal autocorrelation were included as random factors and a zero-inflation parameter was also included if the dataset contained too many zeros. Final models for each dependent variable varied in the type of distribution family, data transformation, and inclusion/ exclusion of random factors (Table A.3).

2.6.2 Individual Species Size

For individual size analyses of the six most abundant species, each combination of date and seine pull, the average length of all individuals was used as the dependent variable. Unlike abundance where all eighteen dates were used for the analyses, for individual species size only sixteen dates, June 30th through October 20th, are considered for analysis due to insufficient data the last two weeks of the study (November 5 and 12). General linear mixed models were applied using the glmmTMB package (Brooks et al., 2017). Model selection was performed in the same way as described for total and species-specific abundance. Final models for each dependent variables varied in the type of data transformation, and inclusion/ exclusion of random factors (Table A.4).

2.6.3 Non-metric multi-dimensional scaling ordination analysis

An analysis of marsh edge proximity and seagrass effects on species assemblages was performed using non-metric multi-dimensional scaling ordination based on the Bray–Curtis similarity index (Warwick & Clarke, 1991) on fourth-root-transformed data. The NMDS ordination patterns were obtained using the metaMDS function of the vegan package (v.2.0-4; (Oksanen et al., 2013) for the R statistical software.

To evaluate the effects of marsh proximity and seagrass abundance on total community assembly, a permutational analysis of variance using the Bray-Curtis dissimilarity index based on fourth root-transformed data was performed. The homogeneity of group dispersions, was checked using the same distance matrix (Anderson et al., 2006). This analysis used the betadisper and permutest functions from vegan package for R. For both analyses the permutations were restricted (1999 permutations for each test) according to account for our experimental design. Thus, different sampling dates were permuted first with a cyclic design (i.e., subsequent years always remain together), not allowing permutations between sampling units. Then, permutations between marsh proximities were performed but only for those belonging to the same block. The model accounted for the random factors of block, location, time, and temporal autocorrelation, and the fixed factors of proximity to marsh edge and seagrass biomass to test for differences in composition and dispersion due to proximity to marsh edge and seagrass biomass. Seagrass biomass is a continuous variable in this study, but high seagrass biomass is defined as values greater than the median biomass of 2.5 grams of biomass per square meter, and low seagrass biomass as values less than the median.

CHAPTER III

RESULTS

3.1 Habitat structure and overall community

For the duration of the study period, the marsh-edge at each block was inundated greater than five centimeters for at least 95% of the time. Therefore, both habitats were available to juvenile nekton, for most of the study. Seagrass biomass was variable throughout the 18-week study and differed overall between marsh edge (4.5 +/- 0.46 grams DW per square meter) and non-edge (3.5 +/- 0.43 grams DW per square meter) transects. A total of 10,598 individuals encompassing 70 taxa were captured in nekton samples across the entire project (Table A.5). The six most abundant structurally associated species found in this study were: white shrimp (*Litopenaeus setiferus*), blue crab (*Callinectes sapidus*), brown shrimp (*Farfantepenaeus* spp.), spotted seatrout (*Cynoscion nebulosus*), American silver perch (*Bairdiella chrysoura*) and pinfish (*Lagodon rhomboides*). Therefore, along with total abundance these species are the focus of the remainder of this study. Individuals from these six species captured in this study were mostly juveniles based on total length and carapace width described in Pattillo et al. (1997) (Table A.6).

3.2 Total and specific species abundance

Total, white shrimp, brown shrimp, blue crab, and speckled seatrout abundance resulted in a significant triple interaction between proximity to marsh edge, seagrass biomass, and time (Table 3.1). Looking at the effect of seagrass biomass in relation to marsh edge proximity on nekton abundance first, total abundance, white shrimp and brown shrimp abundance data followed a negative binomial distribution and, thus, adjusted least squares curvilinear regressions between juvenile abundance and seagrass biomass to the five values within each combination of proximity to marsh edge and time. To determine whether the curve denoted a significant relationship between abundance and seagrass biomass, the confidence intervals at the beginning and end of the curve were compared. That is, if overlap existed between the confidence intervals, no significant relationship occurred, but otherwise if overlap did not exist. Following this criterion, the results revealed three significant relationships for total abundance, i.e., a positive relationship between abundance and seagrass biomass in the marsh edge on June 30, along the non-marsh edge on August 6, and a negative relationship between abundance and seagrass biomass along the marsh edge on October 20 (Figure 3.1). For white shrimp the results showed a positive relationship between abundance and seagrass biomass along the marsh edge on June 30 and August 14, and a negative relationship between abundance and seagrass biomass on October 20 (Figure 3.2). For brown shrimp, findings showed a positive relationship between abundance and seagrass biomass in marsh edge locations on August 14, and in non-marsh edge locations on August 6, September 3, September 30, October 7, and November 5 (Figure 3.3).

Blue crab and speckled seatrout abundance data were log 10 and square root-transformed, respectively to improve model assumptions, and fit to a gaussian distribution for analysis. Least-squares linear regressions were adjusted between abundance and seagrass biomass for marsh edge and non-marsh edge separately on each sampling date. To determine whether the regression had a significant relationship between abundance and seagrass biomass the slope of the regression was compared to a slope of zero. That is, if the slope of a regression was not significantly different than zero, no significant relationship occurred. The results revealed two significant regressions where a positive relationship between abundance and seagrass biomass occurred on July 14 and August 14 for blue crab (Figure 3.4, Table 3.2) and nine significant relationships of a positive relationship with seagrass biomass, four of them for marsh edge on August 6, August 28, September 10, and October 7 and five of them for non-marsh edge on August 28, September 3, September 10, October 7, and October 20 (Figure 3.5, Table 3.3). For speckled seatrout only dates in August through October were included in the analysis due to very low abundances in other months.

For total abundance, white shrimp, blue crab, and brown shrimp graphically comparing abundance between marsh edge and non-marsh edge, showed the highest abundances were found in marsh edge in relation to non- marsh edge locations on most sampling dates. Highest abundances in marsh edge locations occurred at relatively low seagrass biomass on some dates, and at relatively high seagrass biomass on others (Figure 3.6, 3.7, 3.9 and 3.8). Speckled seatrout abundances were highest along the marsh edge in relation to non-marsh edge locations on most sampling dates, with those highest abundances typically corresponding to relatively high seagrass biomass (Figure 3.10).

Silver perch and pinfish abundance showed a significant double interaction between seagrass biomass and time (Table 3.1). These data were log 10-transformed to improve model assumptions and fit to a gaussian distribution, and thus least squares linear regressions were adjusted between abundance and seagrass biomass for each sampling date (Figure 3.11 and 3.12). The results showed significantly higher abundance with higher biomass on July 21 and August 19 for silver perch (Table 3.4), and one significant relationship of higher abundance with higher biomass on June 30 for pinfish (Table 3.5). There was no significant effect of marsh edge proximity on silver perch or pinfish abundance (Table 3.1).

Table 3.1 Wald chisquare test *p-values* for abundance model

Dependent variable	Seagrass biomass	Marsh-edge proximity	Time	Seagrass biomass x Marsh-edge proximity	Seagrass biomass x Time	Marsh-edge proximity x Time	Seagrass biomass x Marsh-edge proximity x Time
Total	3.882×10^{-5}	9.659×10^{-11}	2.2×10^{-6}	0.072	0.021	0.0001	**0.001***
White shrimp	0.816	1.934×10^{-11}	1.141×10^{-10}	0.869	1.016×10^{-5}	0.005	**0.008***
Blue crab	0.941	1.652×10^{-9}	0.0004	0.510	0.001	0.598	**3.592×10^{-7}***
Brown Shrimp	9.393×10^{-15}	0.003	3.684×10^{-9}	0.118	0.465	0.028	**0.026***
Speckled seatrout	7.521×10^{-16}	0.038	7.185×10^{-9}	0.107	0.006	0.038	**0.027***
Silver perch	6.13×10^{-10}	0.938	4.249×10^{-13}	0.012	**2.235×10^{-7}***	0.007	0.400
Pinfish	0.009	0.056	4.647×10^{-16}	0.050	**7.146×10^{-5}***	0.009	0.019

P-values of main effects, double interactions, and triple-interaction of abundance models for dependent variables. Bolded *p-values* with (*) indicates the significant *p*-value discussed in the results section.

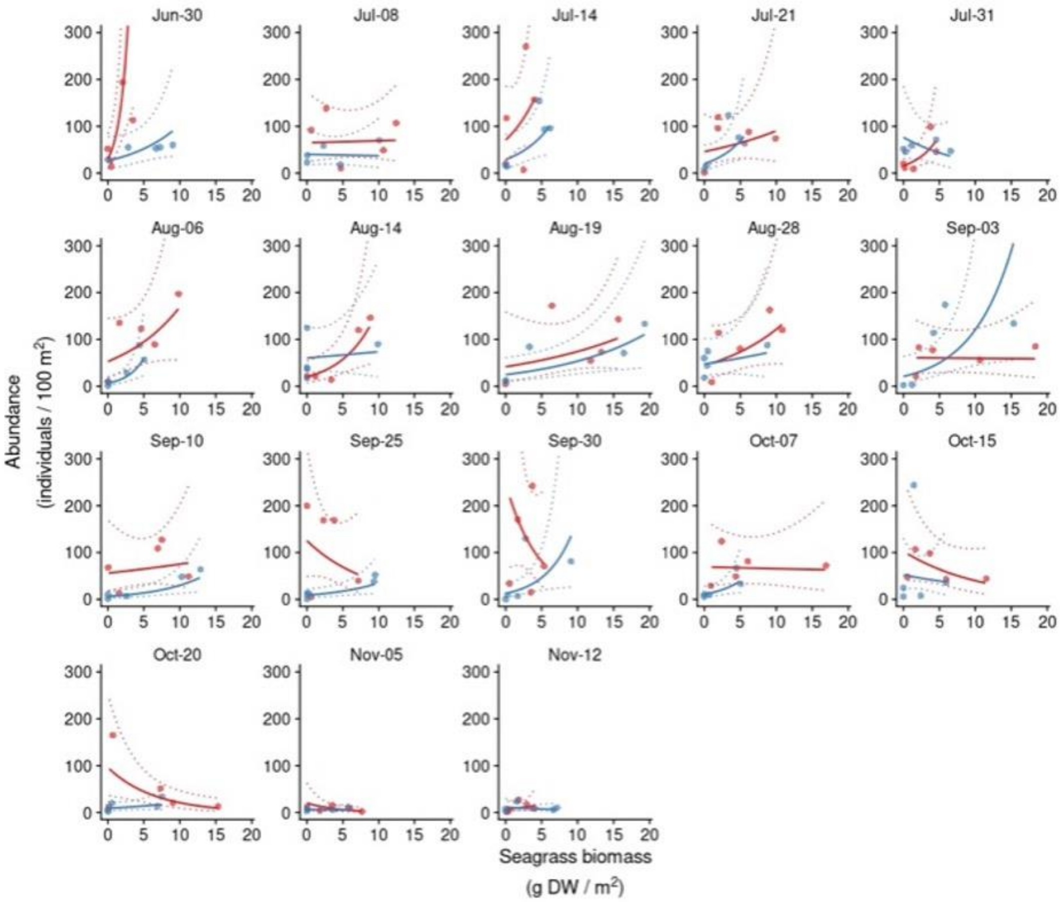

Figure 3.1 Total abundance regression plots

Curvilinear regressions between total abundance and seagrass biomass in relation to marsh edge proximity, red regression lines indicate marsh edge and blue non-edge. Significant relationships occurred on June 30, August 6, and October 20.

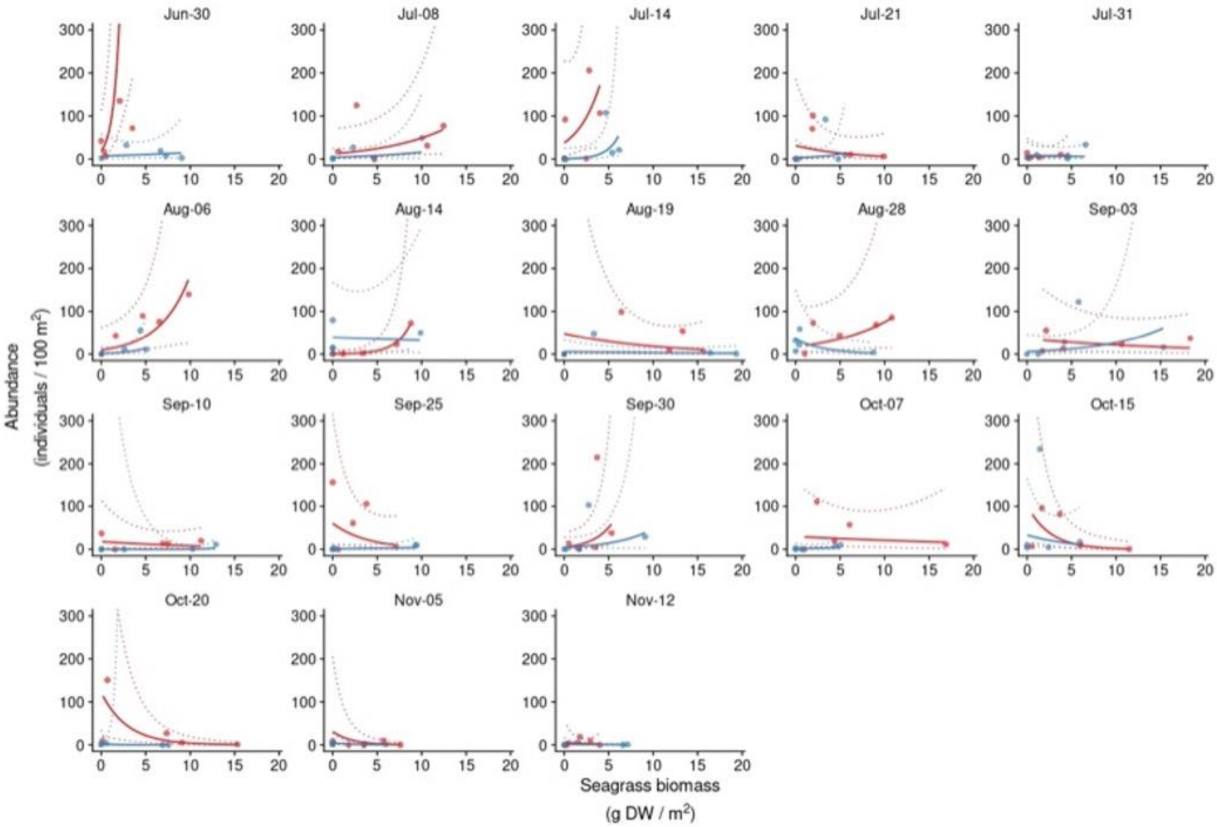

Figure 3.2 White shrimp regression plots

Curvilinear regressions between white shrimp abundance and seagrass biomass in relation to marsh edge proximity, red regression lines indicate marsh-edge and blue non-edge. Significant relationships occurred on June 30, August 14, and October 20.

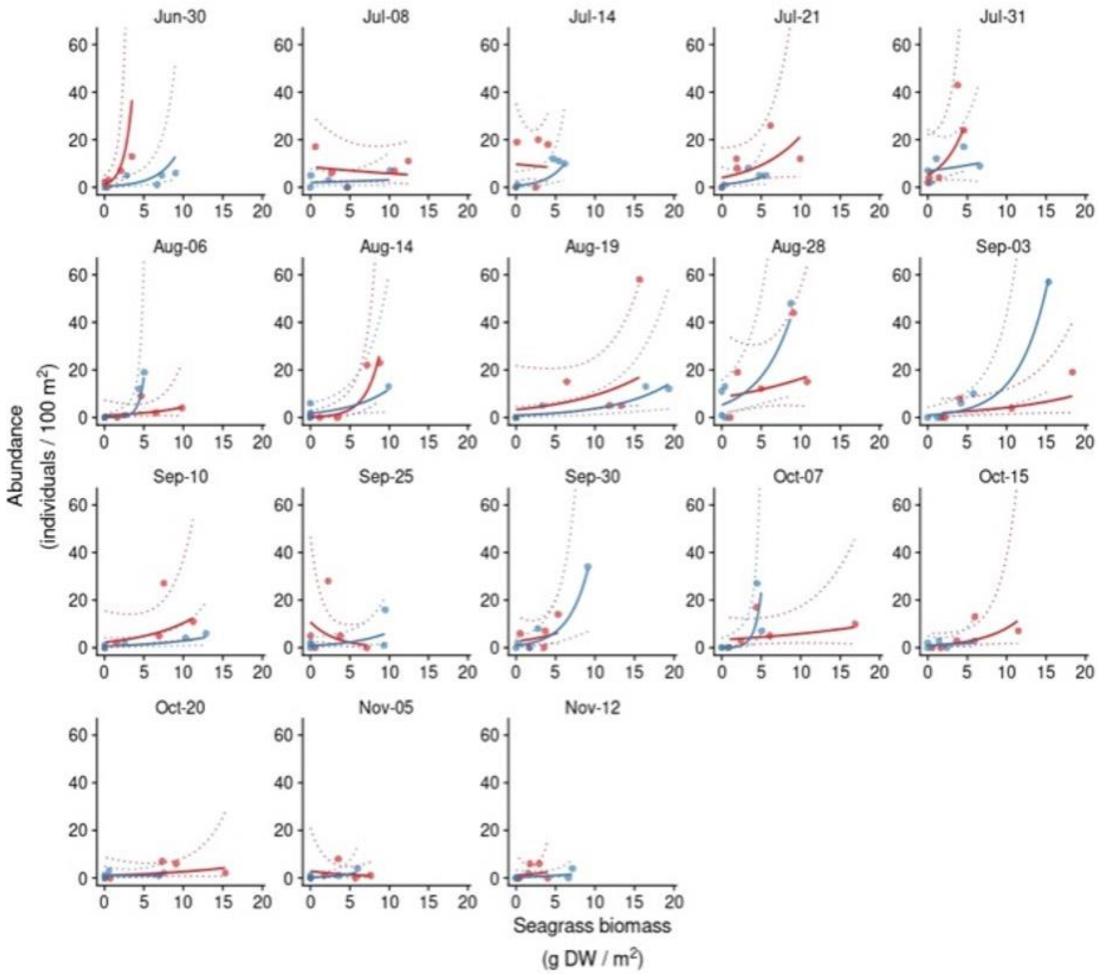

Figure 3.3 Brown shrimp regression plots

Curvilinear regressions between brown shrimp abundance and seagrass biomass in relation to marsh edge proximity, red regression lines indicate marsh-edge and blue non-edge. Significant relationships occurred on August 6, August 14, September 3, September 30, October 7 and November 5.

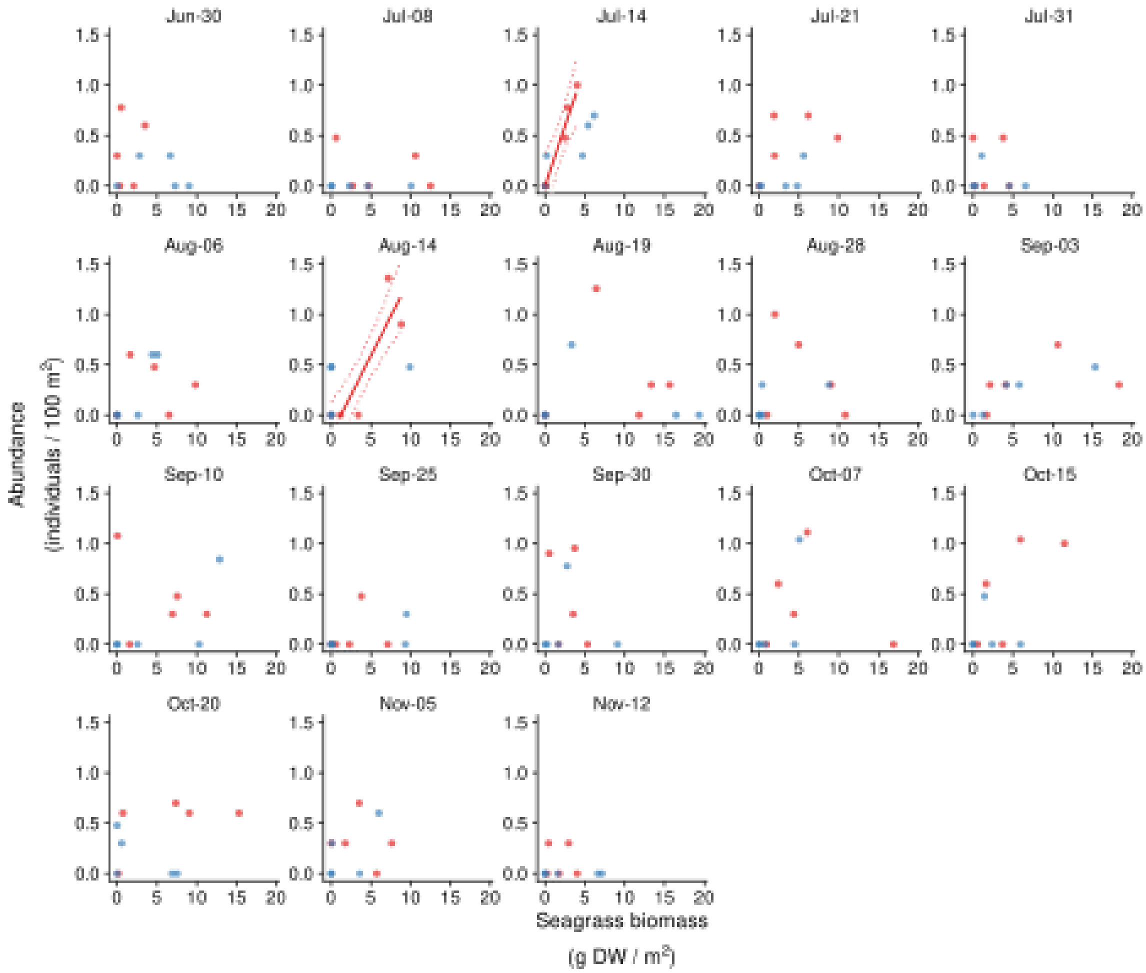

Figure 3.4 Blue crab regression plots

Least squares linear regression between blue crab abundance and seagrass biomass in relation to marsh edge proximity, red regression lines indicating marsh edge and blue non-edge. Significant relationships occurred on July 14 and August 14.

Table 3.2 Slopes +/- SE and *P*-values of blue crab abundance regression lines

Date	Edge		Non-edge	
	Slope (+/- SE)	P-value	Slope (+/- SE)	P-value
6/30/20	0.04 (0.08)	0.589	-0.01 (0.02)	0.583
7/8/20	0.003 (0.02)	0.901	-0.03 (0.02)	0.187
7/14/20	0.24 (0.07)	**p<0.001**	0.04 (0.03)	0.209
7/21/20	0.03 (0.03)	0.361	-0.002 (0.03)	0.942
7/31/20	0.02 (0.06)	0.736	-0.06 (0.03)	0.027
8/6/20	-0.01 (0.03)	0.703	0.07 (0.04)	0.065
8/14/20	0.16 (0.03)	**p<0.001**	0.01 (0.02)	0.432
8/19/20	-0.02 (0.02)	0.354	-0.01 (0.01)	0.273
8/28/20	-0.04 (0.03)	0.163	0.02 (0.02)	0.491
9/3/20	0.01 (0.02)	0.605	0.03 (0.01)	0.034
9/10/20	-0.05 (0.03)	0.056	0.02 (0.01)	0.156
9/25/20	0.01 (0.04)	0.750	-0.01 (0.02)	0.503
9/30/20	-0.09 (0.06)	0.136	-0.02 (0.02)	0.337
10/7/20	-0.02 (0.02)	0.371	0.07 (0.03)	0.050
10/15/20	0.08 (0.03)	0.003	-0.04 (0.03)	0.264
10/20/20	0.01 (0.02)	0.634	-0.07 (0.02)	0.001
11/5/20	-0.02 (0.04)	0.595	0.01 (0.03)	0.794
11/12/20	-0.04 (0.07)	0.620	-0.04 (0.02)	0.085

Blue crab regression line slopes are compared to a slope of zero and are significant at an alpha < 0.001.

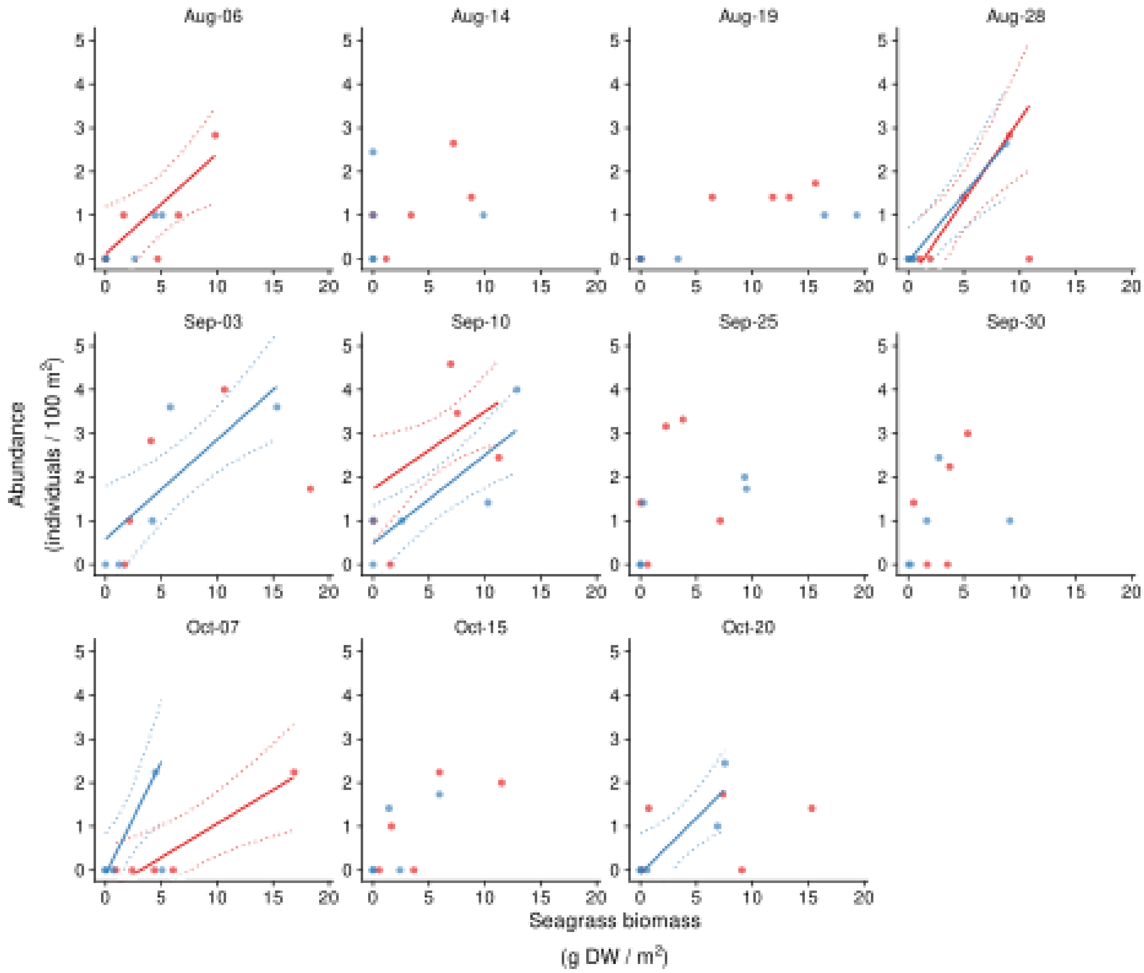

Figure 3.5 Speckled seatrout regression plots

Least squares linear regression between speckled seatrout abundance and seagrass biomass in relation to marsh edge proximity, red regression lines indicate marsh-edge and blue non-edge. Significant relationships occurred on August 6, August 28, September 10 and October 7 for edge and August 28, September 3, September 10, and October 20 for non-marsh edge.

Table 3.3 Slopes +/- SE and *P*-values of speckled seatrout abundance regression lines

Date	Edge		Non-edge	
	Slope (+/- SE)	P-value	Slope (+/- SE)	P-value
8/6/20	0.23 (0.85)	**p<0.05**	0.21 (0.15)	0.15
8/14/20	0.15 (0.09)	0.12	-0.06 (0.08)	0.46
8/19/20	0.09 (0.06)	0.14	0.06 (0.04)	0.12
8/28/20	0.37 (0.11)	**p<0.05**	0.31 (0.09)	**p<0.05**
9/3/20	0.02 (0.05)	0.62	0.23 (0.07)	**p<0.05**
9/10/20	0.18 (0.08)	**p<0.05**	0.20 (0.05)	**p<0.05**
9/25/20	-0.09 (0.12)	0.45	0.13 (0.07)	0.08
9/30/20	0.33 (0.18)	0.08	-0.05 (0.15)	0.73
10/7/20	0.15 (0.05)	**p<0.05**	0.52 (0.18)	**p<0.05**
10/15/20	0.15 (0.08)	0.07	0.25 (0.14)	0.08
10/20/20	0.02 (0.07)	0.84	0.25 (0.09)	**p<0.05**

Speckled seatrout regression line slopes are compared to a slope of zero and are significant at an alpha < 0.05.

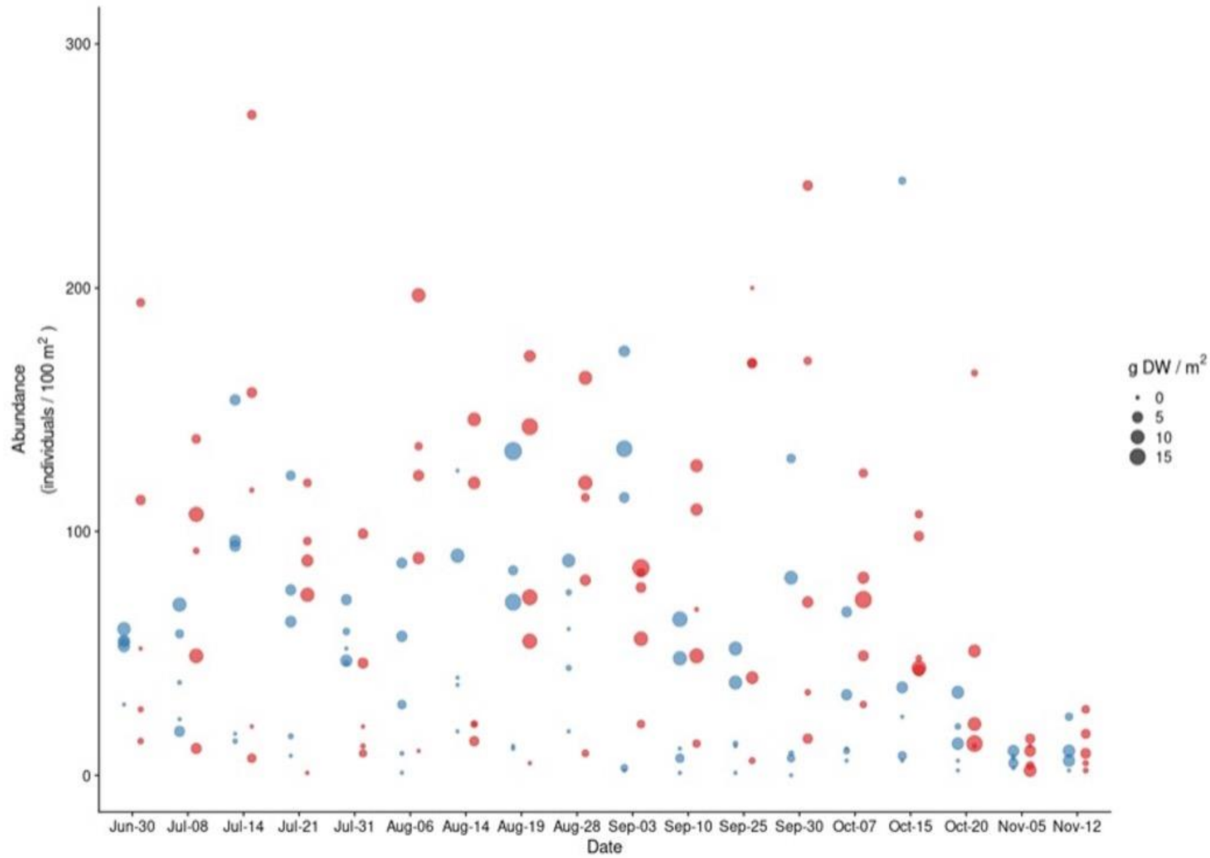

Figure 3.6 Total abundance in edge and non-edge habitat with respect to seagrass biomass

Differences in total abundance between marsh edge, red, and non-marsh edge, blue, across different levels of seagrass biomass, denoted by different sizes of bubbles, on each of the sampling dates.

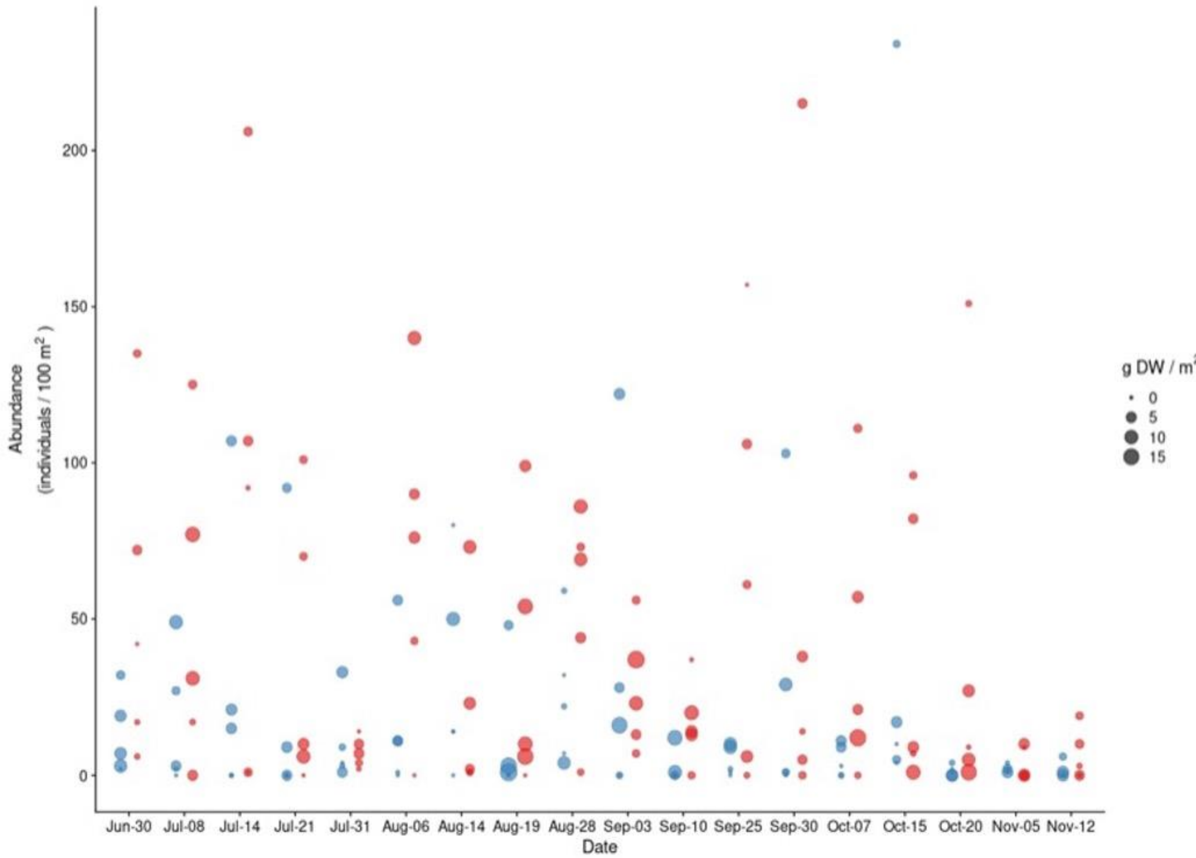

Figure 3.7 White shrimp abundance in edge and non-edge habitat with respect to seagrass biomass

Differences in white shrimp abundance between marsh edge, red, and non-marsh edge, blue, across different levels of seagrass biomass, denoted by different sizes of bubbles, on each of the sampling dates.

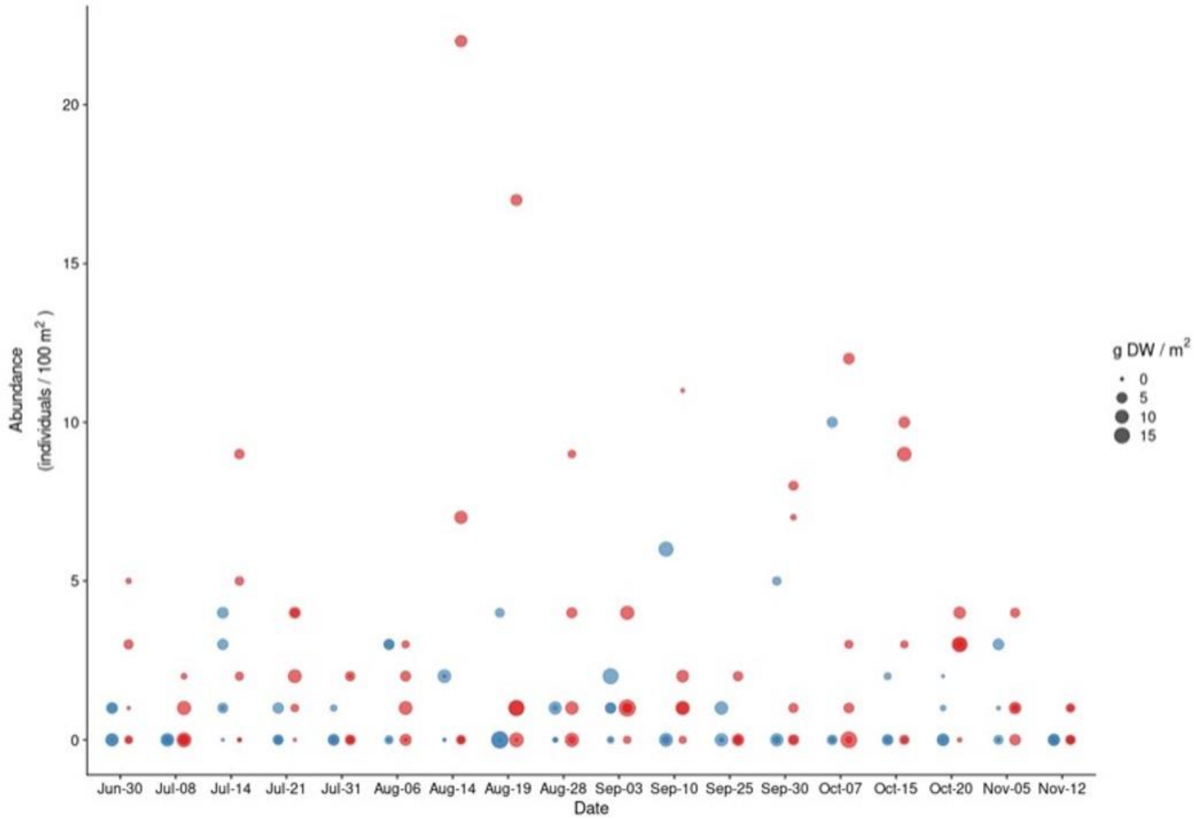

Figure 3.8 Blue crab abundance in edge and non-edge habitat with respect to seagrass biomass

Differences in blue crab abundance between marsh edge, red, and non-marsh edge, blue, across different levels of seagrass biomass, denoted by different sizes of bubbles, on each of the sampling dates.

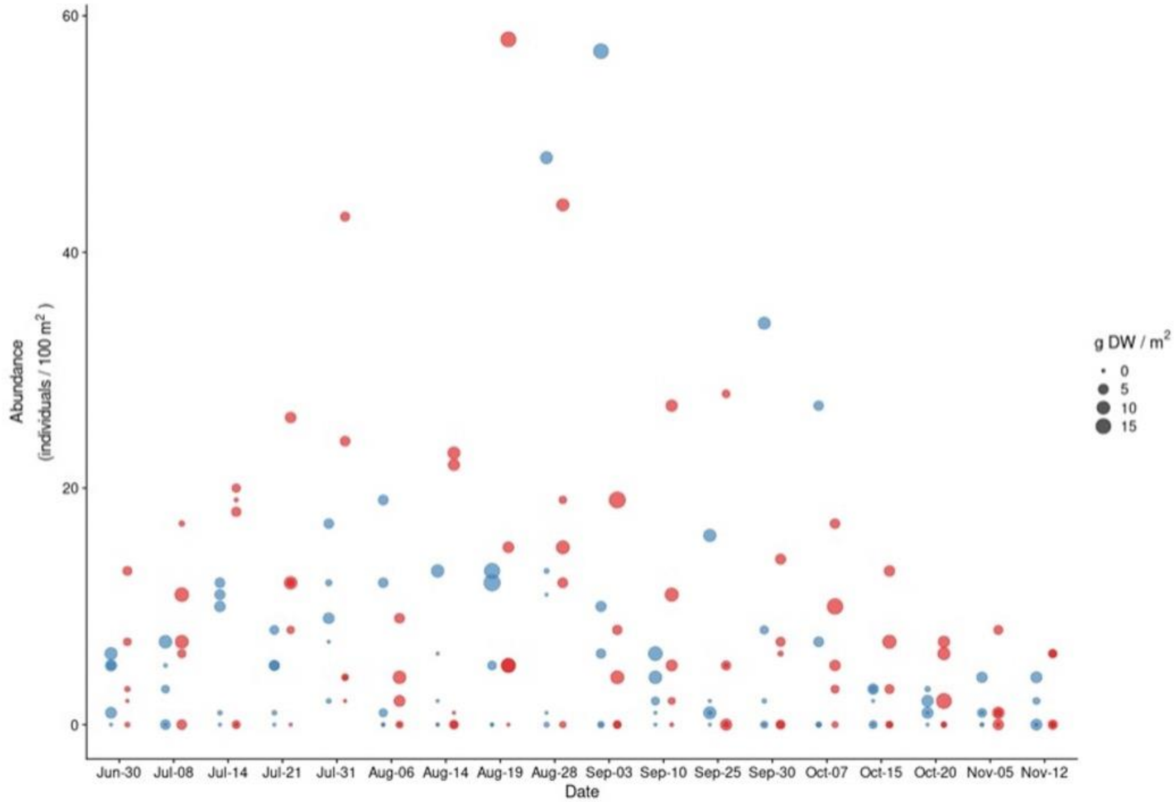

Figure 3.9 Brown shrimp abundance in edge and non-edge habitat with respect to seagrass biomass

Differences in brown shrimp abundance between marsh edge, red, and non-marsh edge, blue, across different levels of seagrass biomass, denoted by different sizes of bubbles, on each of the sampling dates.

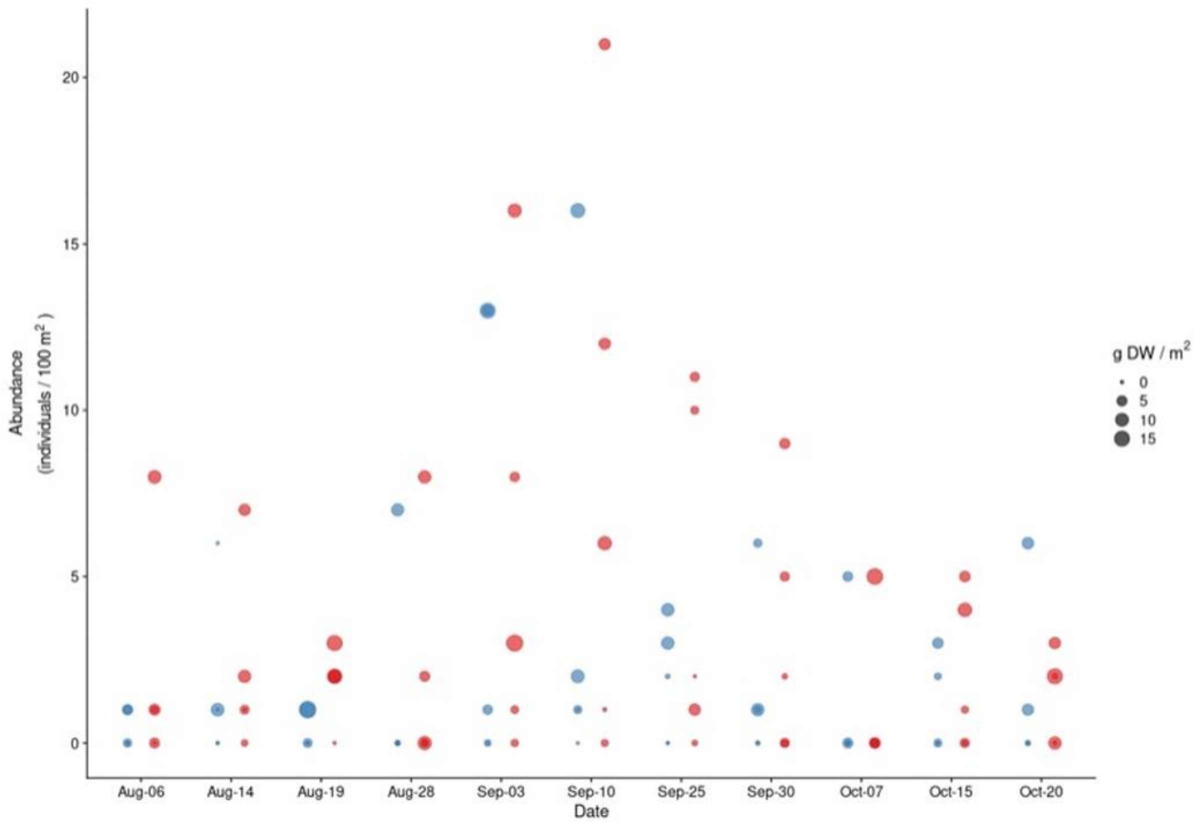

Figure 3.10 Speckled seatrout abundance in edge and non-edge habitat with respect to seagrass biomass

Differences in speckled seatrout abundance between marsh edge, red, and non-marsh edge, blue, across different levels of seagrass biomass, denoted by different sizes of bubbles, on each of the sampling dates.

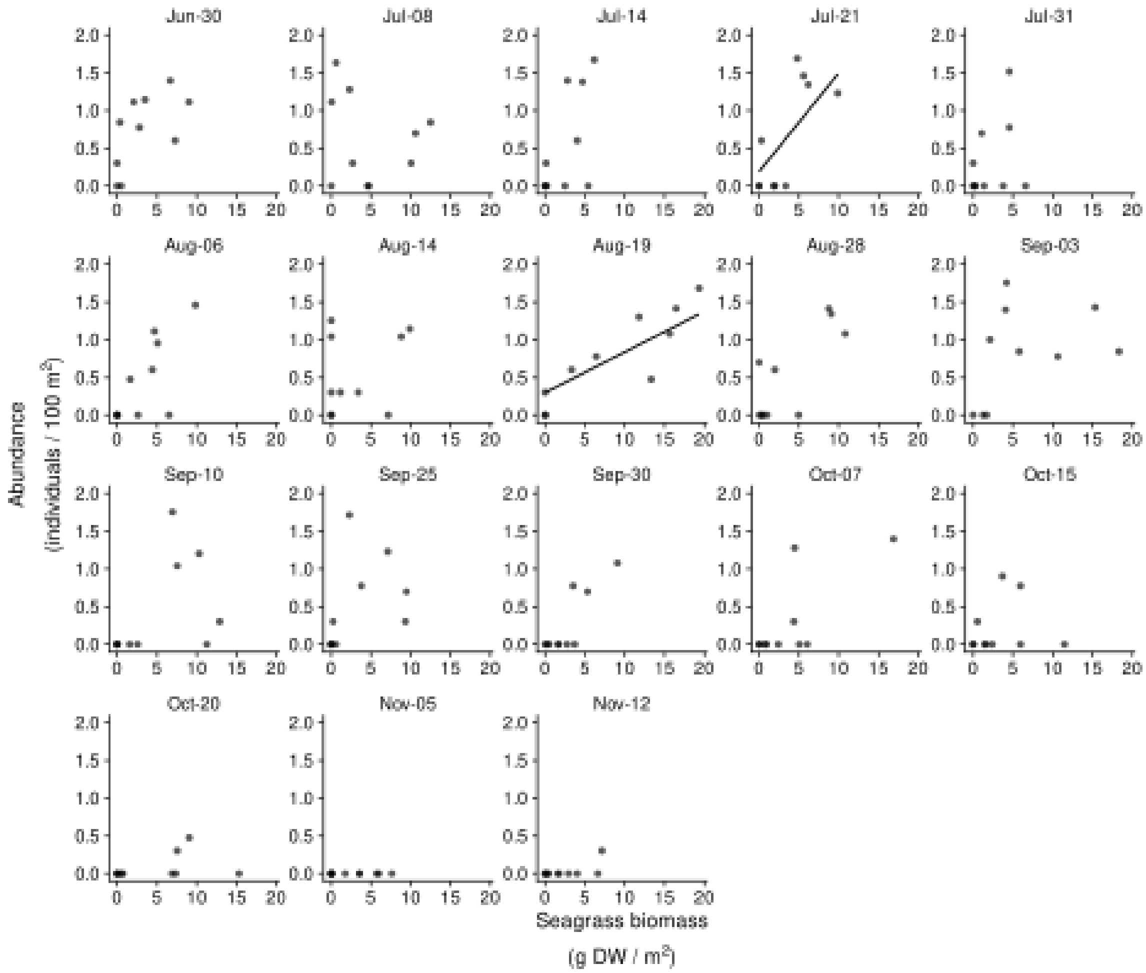

Figure 3.11 Silver perch regression plots

Least squares linear regression between silver perch abundance and seagrass biomass. Significant relationships occurred on July 21 and August 19.

Table 3.4 Slopes +/- SE and *P*-values of silver perch abundance regression lines

Date	Slope (+/- SE)	P-value
6/30/20	0.10 (0.03)	0.004
7/8/20	-0.03 (0.02)	0.206
7/14/20	0.13 (0.05)	0.006
7/21/20	0.13 (0.04)	**p<0.001**
7/31/20	0.03 (0.05)	0.590
8/6/20	0.09 (0.04)	0.014
8/14/20	-0.01 (0.03)	0.638
8/19/20	0.05 (0.02)	**p<0.001**
8/28/20	0.07 (0.03)	0.014
9/3/20	0.04 (0.02)	0.034
9/10/20	0.05 (0.02)	0.025
9/25/20	0.04 (0.03)	0.211
9/30/20	0.07 (0.04)	0.101
10/7/20	0.06 (0.02)	0.013
10/15/20	-0.03 (0.03)	0.396
10/20/20	0.01 (0.02)	0.702
11/5/20	-0.04 (0.04)	0.377
11/12/20	-0.01 (0.04)	0.831

Silver perch regression line slopes are compared to a slope of zero and are significant at an alpha < 0.001.

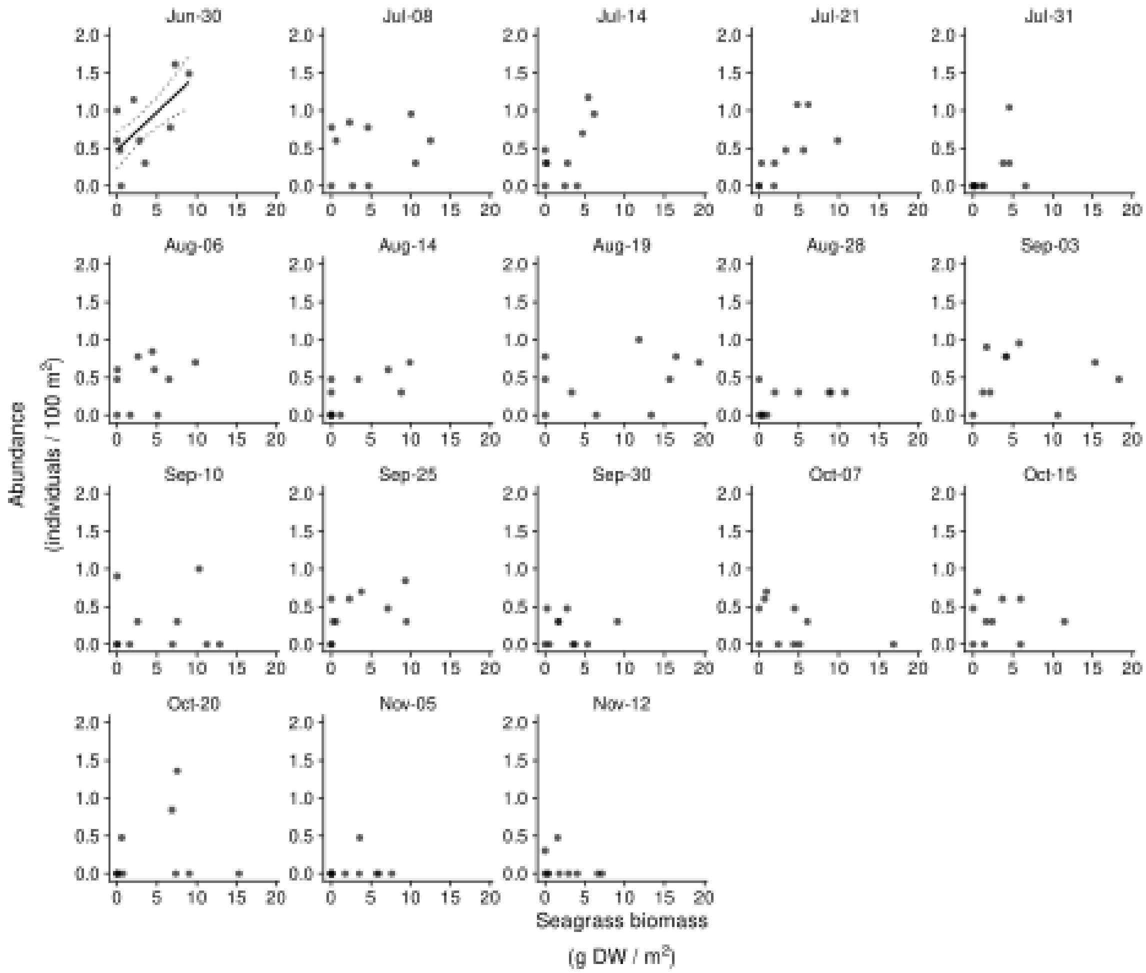

Figure 3.12 Pinfish regression plots

Least squares linear regression between pinfish abundance and seagrass biomass. A significant relationship occurred on June 30.

Table 3.5 Slopes +/- SE and *P*-values of American silver perch abundance regression lines

Date	Slope (+/- SE)	P-value
6/30/20	0.10 (0.03)	**p<0.001**
7/8/20	0.01 (0.02)	0.601
7/14/20	0.07 (0.04)	0.041
7/21/20	0.09 (0.03)	0.001
7/31/20	0.04 (0.04)	0.218
8/6/20	0.03 (0.03)	0.287
8/14/20	0.04 (0.02)	0.068
8/19/20	0.01 (0.01)	0.440
8/28/20	0.02 (0.02)	0.424
9/3/20	0.0001 (0.01)	0.993
9/10/20	-0.01 (0.02)	0.702
9/25/20	0.02 (0.02)	0.413
9/30/20	-0.03 (0.03)	0.403
10/7/20	-0.02 (0.02)	0.154
10/15/20	-0.003 (0.02)	0.884
10/20/20	0.02 (0.02)	0.302
11/5/20	0.001 (0.03)	0.981
11/12/20	-0.04 (0.03)	0.172

Pinfish regression line slopes are compared to a slope of zero and are significant at an alpha < 0.001.

3.3 Individual Size

The model produced no significant interaction or main effects of seagrass biomass and proximity to marsh-edge in relation to length for white shrimp, blue crab, brown shrimp, and silver perch. There was a significant main effect of seagrass biomass on pinfish length and a significant main effect of marsh-edge proximity on speckled seatrout length (Table 3.6). For speckled seatrout, there were significantly larger individuals captured along the marsh-edge compared to non-edge habitat (Figure 3.13). For pinfish, there was a trend of smaller individuals in higher seagrass biomass habitat (Figure 3.14).

Table 3.6 Wald chisquare test *P*-values for individual size model

Factor *P*-value			
Specie	Seagrass Biomass	Marsh-edge proximity	Seagrass biomass x Marsh-edge proximity
White shrimp	0.813	0.232	0.948
Blue crab	0.081	0.395	0.227
Brown shrimp	0.194	0.580	0.603
Speckled seatrout	0.200	**0.020***	0.997
Silver perch	0.265	0.44	0.822
Pinfish	**0.001***	0.775	0.104

P-values of main effects, double interactions, and triple-interaction of individual size models for dependent variables. Bolded *p-values* with (*) indicates the significant *p*-value discussed in the results section.

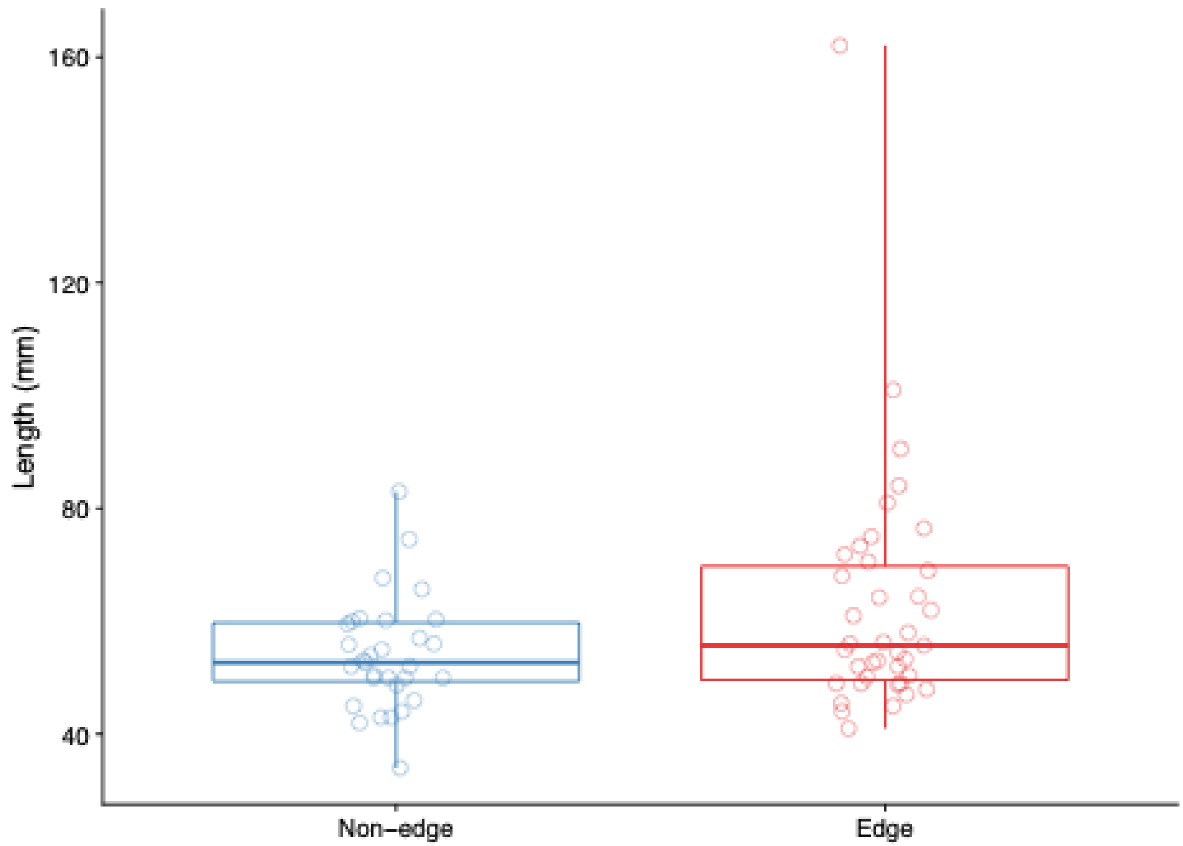

Figure 3.13 Speckled seatrout average length +/- SE in edge and non-edge locations

Average standard lengths +/- SE of speckled seatrout in millimeters caught within the marsh-edge and non-marsh edge habitat from June 30 through October 20.

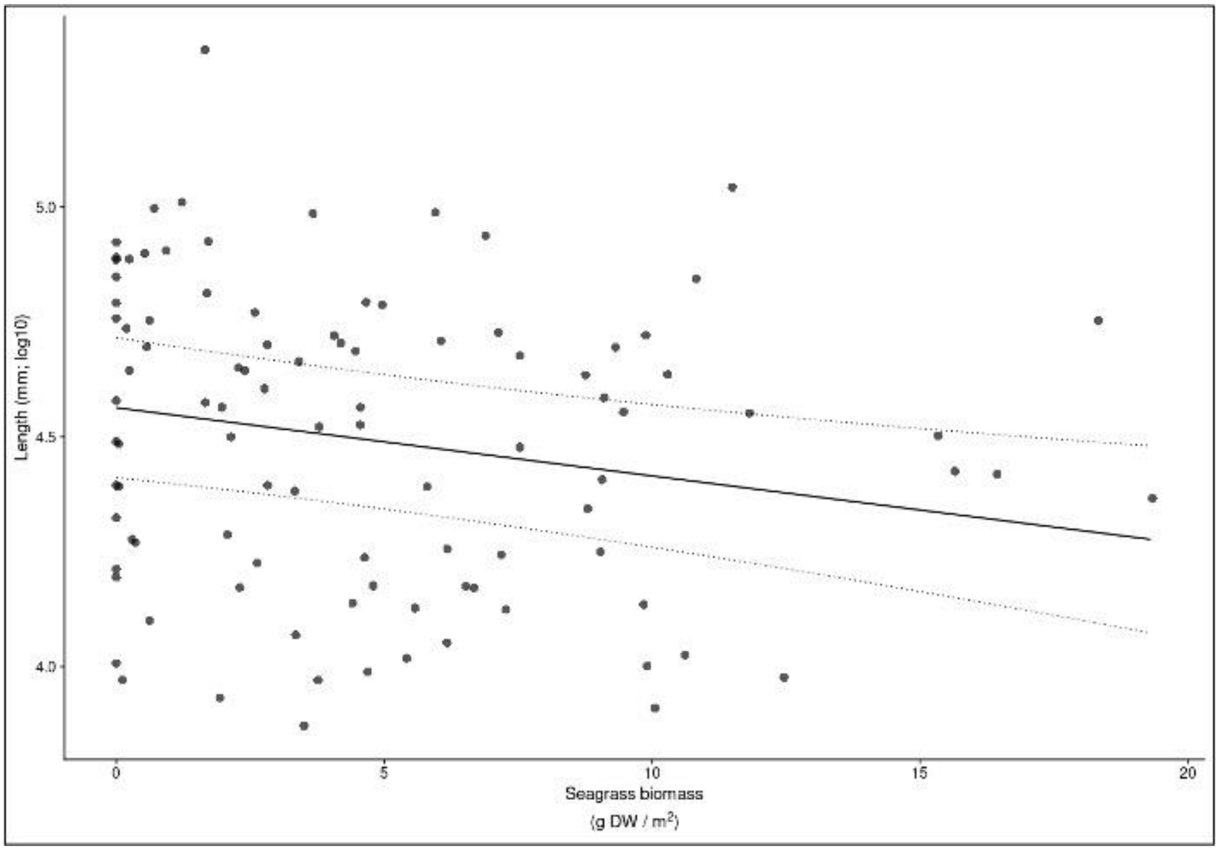

Figure 3.14 Regression of pinfish length versus corresponding seagrass biomass

Pinfish standard lengths in millimeters were log10 transformed and plotted against corresponding seagrass biomass for the period of June 30 through October 20.

3.4 Non-metric multi-dimensional scaling ordination analysis

Looking first at the main effect of marsh edge proximity, composition did not differ between marsh-edge and non-marsh edge habitat and multivariate dispersions were not significantly different between those treatments (Figure 3.15; Table 3.7). For the main effect of seagrass biomass, compositions differed between high and low seagrass, but it is difficult to be conclusive given that multivariate dispersions strongly differed between those treatments (Figure 3.16; Table 3.7). To test for the interaction between proximity to marsh and seagrass biomass on composition the four groups resulting from all combinations of proximity to marsh edge and seagrass biomass, marsh-edge/ high seagrass biomass, marsh-edge/ low seagrass biomass, non-edge/ high seagrass biomass and non-edge/ low seagrass biomass, are compared. This comparison resulted in no differences between any of these groups, implying a non-significant interaction. Similarly, to test for the interactive effects on dispersion the four habitat group combinations are compared, resulting in the non-edge low seagrass biomass group having higher dispersion than the non-edge/ high seagrass biomass group and the marsh-edge/ high seagrass biomass group (Figure 3.17; Table 3.7).

Table 3.7 PERMANOVA analysis results

	Marsh	Seagrass	Interaction	
Composition	0.131	0.008	0.413	
Dispersion	0.260	0.009	0.771	Edge, High v. Non-edge, High
			0.127	Edge, High v. Edge, Low
			0.028*	Edge, High v. Non-edge, Low
			0.079	Non-edge, High v. Edge, Low
			<0.001*	Non-edge, High v. Non-edge, Low
			0.148	Non-edge, Low v. Edge, Low

P-values of main effects and interaction of marsh edge proximity and seagrass biomass on community composition and dispersion from PERMANOVA analysis. Bolded *p-values* with (*) indicates the significant *p*-value discussed in the results section.

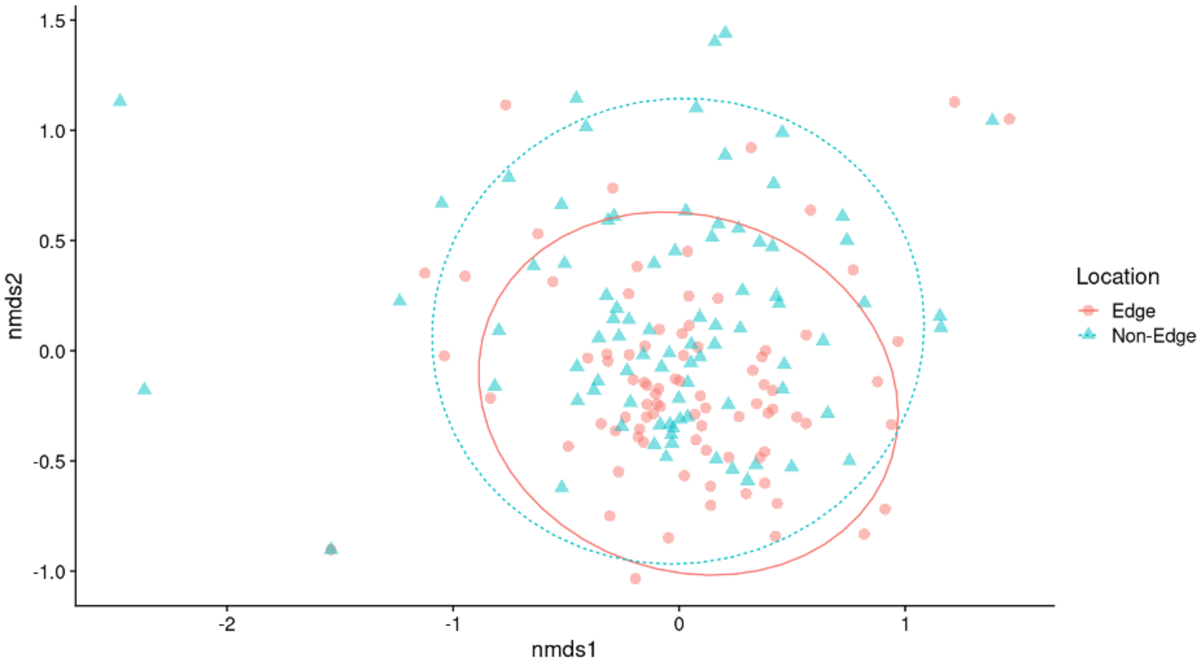

Figure 3.15 Nonmetric multidimensional scaling ordination plot of community assemblages in marsh-edge and non-marsh edge habitat

Nonmetric multidimensional scaling ordination plot of community assemblages in marsh-edge, represented by red circles and the red ellipse, and non-marsh edge habitats, represented by blue triangles and the blue ellipse, in two-dimensional space. Each point represents the species composition in a given time and location, and the distance between any two points represents the difference between those two community assemblages according to the Bray-Curtis dissimilarity index based on fourth root-transformed data. Lines represent the confidence ellipse at the 0.95 level. The larger the ellipse of a given treatment, the greater variability of that treatment.

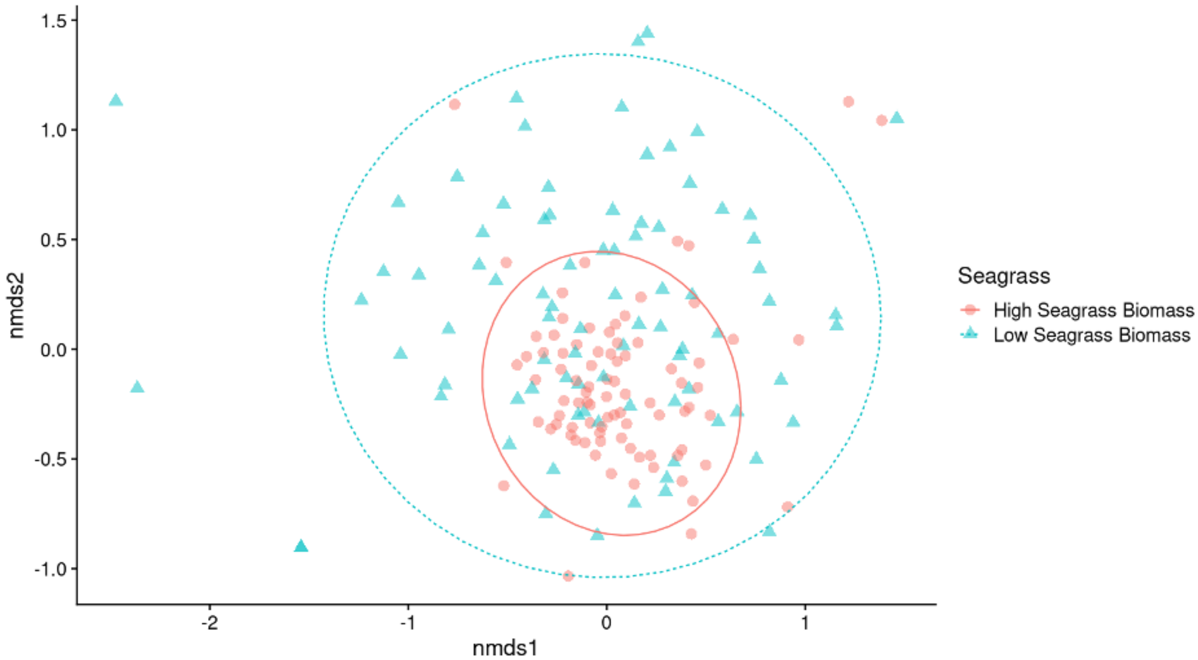

Figure 3.16 Nonmetric multidimensional scaling ordination plot of community assemblages in high seagrass biomass and low seagrass biomass habitat

Nonmetric multidimensional scaling ordination plot of community assemblages in high, represented by red circles and the red ellipse, and low seagrass biomass habitats, represented by blue triangles and the blue ellipse, in two-dimensional space. Each point represents the species composition in a given time and location, and the distance between any two points represents the difference between those two community assemblages according to the Bray-Curtis dissimilarity index based on fourth root-transformed data. Lines represent the confidence ellipse at the 0.95 level. The larger the ellipse of a given treatment, the greater variability of that treatment.

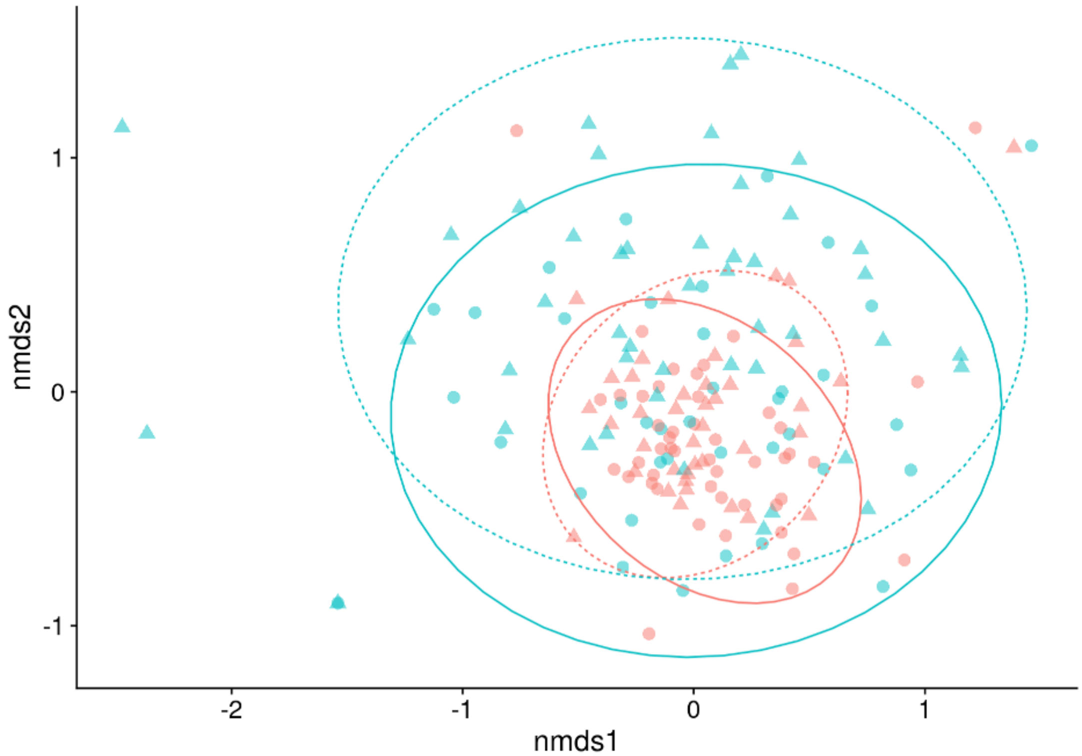

Figure 3.17 Nonmetric multidimensional scaling ordination plot of community assemblages in the four habitat combinations

Nonmetric multidimensional scaling ordination plot of community assemblages of four habitat combinations: marsh-edge/ high seagrass biomass represented by red circles and a solid red ellipse, marsh-edge/ low seagrass biomass represented by blue circles and a solid blue ellipse, non-edge/ high seagrass biomass represented by red triangles and a dashed red ellipse and non-edge/ low seagrass biomass represented by blue triangles and a dashed blue ellipse, in two-dimensional space. Each point represents the species composition in a given time and location, and the distance between any two points represents the difference between those two community assemblages according to the Bray-Curtis dissimilarity index based on fourth root-transformed data. Lines represent the confidence ellipse at the 0.95 level. The larger the ellipse of a given treatment, the greater variability of that treatment.

CHAPTER IV

DISCUSSION

This study sought to examine how two widely recognized essential estuarine-dependent nekton habitats, marsh edge and seagrass, determine the abundance of recruiting juveniles to a nGOM coastal system. Few studies have directly compared nekton densities along marsh edge and seagrass habitat together, thereby limiting understanding of the variability in space and time of juvenile recruitment to coastal systems (Rozas et al., 2012). Sampling was focused on a small spatial scale with high temporal frequency in the nGOM to allow for a comprehensive analysis of habitat utilization patterns for the total nekton community and six structurally associated species, i.e., white shrimp, blue crab, brown shrimp, speckled seatrout, silver perch and pinfish.

The abundance analyses focused on determining the effects of proximity to marsh edge and seagrass biomass on juvenile abundance. Following the significance criterion with the curves adjusted, for total abundance there were only two positive significant relationships between abundance and seagrass (Figure 3.1). However, a closer look at the figure reveals six instances where there is very little overlap with the confidence intervals, therefore suggesting a relationship between abundance and seagrass biomass. In addition, the model produced a significant main effect of seagrass (Table 3.1). Altogether, these results suggest that there is a positive effect of seagrass biomass on total abundance mainly at non-edge locations. For the effect of marsh-edge proximity on total abundance, highest abundances were found in marsh edge in relation to non-edge on most dates and that pattern was not consistently associated with a high or low values of seagrass biomass, meaning that the highest abundances in marsh-edge occur at high seagrass biomass sometimes and at low seagrass biomass on other times. Thus, indicating a positive effect of marsh edge occurring at either low or high seagrass biomass (Figure 3.6).

The diversity of the total nekton community captured during this study of more than 10,000 individuals encompassing 70 taxa of residential, transient, non-structure seeking, and schooling nekton, may be influencing the variable habitat utilization patterns within the total nekton abundance analysis. Although the six most abundant structurally associated species were chosen to analyze separately, species that are not highly associated with vegetated habitat were also found in abundance in this study such as *Menidia* spp., *Anchoa mitchilli* and *Brevoortia patronus*. In a meta-analysis done by Hollweg et al. (2018), species like *Brevoortia patronus* and *Anchoa mitchilli* were found in higher densities in open water than in structured marsh-edge habitat. Thus, the relationship of increasing abundance with higher seagrass biomass in non-marsh edge habitat may be influenced by species that prefer offshore habitat types. Conversely, some species like white shrimp and blue crab seem to have a high selectivity for the marsh-edge and are less concerned about the presence of adjacent seagrass habitat. Finding high densities of nekton along the marsh edge, regardless of adjacent substrate, is well documented throughout the northern GOM (Baltz et al., 1993; Minello, 1999; Minello et al., 1994, Peterson & Turner, 1994; Rozas & Zimmerman, 2000).

The six most abundant structurally associated species produced disparate results, in terms of the effects of proximity to marsh edge and seagrass biomass on nekton abundance pointing to different relative selectivity of marsh edge versus seagrass by different species. White shrimp and blue crab showed a high selectivity for marsh edge, regardless of adjacent seagrass biomass.

White shrimp and blue crab show a low association with seagrass denoted by the few significant relationships between abundance and seagrass biomass in respect to marsh-edge proximity (Figure 3.2 and 3.4) and non-significant *p*-values for the main effect of seagrass biomass (Table 3.1). These findings agree with previous studies that have shown that white shrimp and blue crab densities were not significantly different between marsh edge or seagrass habitat (Heck et al., 1994; Rozas & Minello, 1998). However, some studies have shown blue crabs preferentially choose marsh edge habitat with higher abundances in *Spartina alterniflora* edge habitat compared to seagrass beds of *Halodule wrightii*, and adjacent seagrass having no effect of blue crab densities along marsh edge habitat (Rozas & Minello, 1998 & Thomas et at., 1990). Abundance patterns within different geographical locations in the nGOM are variable, but generally the results of this study follow a similar pattern in that white shrimp and blue crabs have a weak association with seagrass and are found in greater abundance in structured habitat compared to non-vegetated bottom habitat and more specifically the marsh edge for blue crabs.

Highest abundances for brown shrimp were found in marsh edge in relation to non-edge on most dates and that pattern was not consistently associated with a high or low value of seagrass biomass, meaning that the highest abundances in marsh-edge occur at high seagrass biomass sometimes and at low seagrass biomass on other times. However, the effect of marsh edge on brown shrimp was smaller than that on white shrimp and blue crab. This is reflected by the smaller differences in abundance between edge and non-edge for brown shrimp in relation to the differences found for white shrimp and blue crab and denoted by the much higher *p*-value, although still significant, for the main effect of marsh edge (Table 3.1). Looking at the effect of seagrass biomass on brown shrimp abundance, there was six significant positive relationships between abundance and seagrass and a significant main effect of seagrass on brown shrimp abundance. Overall, in relation to the other analyzed species, brown shrimp shows a moderate selectivity for marsh edge and seagrass. Previous studies from the nGOM support the study's findings with brown shrimp for having an affinity for both marsh and seagrass and not selectively choosing one habitat over the other (Rozas & Minello, 1998).

Speckled seatrout shows a moderate selectivity for marsh edge, with highest abundances found in marsh edge in relation to non-edge on most dates and those highest abundances were mainly found at high seagrass biomass values, suggesting a positive synergistic effect of seagrass biomass along the marsh edge. Speckled seatrout may preferentially recruit to marsh edge with adjacent seagrass, owing to enhanced habitat provisions and the maintenance of the species requirements for multiple resources (McMichael & Peters, 1989). However, the effect of marsh edge on speckled seatrout was smaller than that on white shrimp and blue crab. This is reflected by the smaller differences in abundance between edge and non-edge for speckled seatrout in relation to the differences found for white shrimp and blue crab and denoted by the much higher *p*-value, but still significant, for the main effect of marsh edge (Table 3.1).

Silver perch showed no preference for marsh edge over non-marsh edge, but high selectivity for seagrass. Following the significance criterion of $p<0.001$, there were only two significant positive relationships between abundance and seagrass; however, there are seven more positive regressions that would be significant an alpha level $p<0.05$, which shows in the probability of the seagrass main effect (Table 3.1). Lastly, pinfish had little selectivity for either habitat (Table 3.1). Life history patterns of juvenile silver perch and pinfish, tend to follow these findings with abundances of these two species commonly found in seagrass beds (Fischer, 1978; Hoese & Lee et al., 1980; Moore, 1977; Sogard et al. 1989). Thus, the results of this study provide a comprehensive view of the differences in the impacts of marsh edge and seagrass biomass on the species examined and, in that regard, the effect of marsh edge is highest for white shrimp and blue crab, intermediate for brown shrimp and speckled seatrout and lowest for pinfish and silver perch. Regarding the effect of seagrass biomass, the effect is highest for speckled seatrout and silver perch intermediate for brown shrimp and lowest for white shrimp blue crab and pinfish.

Although the size analysis of this study only produced two significant results, speckled seatrout and pinfish (Table 3.6), several studies support this study's findings of larger nekton captured in marsh edge, or conversely smaller nekton captured in seagrass and or SAV habitat (Orth & VANMONTFRANS, 1987; Rozas & Minello, 1998, 2015; Thomas et al., 1990). Because the study was focused on juvenile recruitment, in theory most individuals of the same species would be in the same cohort, and therefore size class, following similar habitat utilization patterns, showing no significant interactions or main effects of marsh-edge or seagrass biomass. However, some species have pulses of recruitment throughout the summer to early fall, allowing us to sample cohorts at different stages of growth, and analyze habitat utilization patterns. Smaller nekton species may preferentially choose seagrass or SAV over co-occurring marsh-edge, and as ontogenesis occurs, shift from one habitat to another due to different physiological requirements, prey availability, prey selection, competition, or predation pressures (Baltz et al., 1993).

Next, looking at the effects of proximity to marsh edge and seagrass biomass on community composition and dispersion there was no effect of proximity to marsh and seagrass biomass on community composition. However, there was an interactive effect between proximity to marsh and seagrass biomass on community dispersion. Namely, there was higher dispersion with low seagrass biomass than high seagrass biomass in non-edge locations, and higher dispersion in low seagrass biomass, non-edge locations than high biomass, edge locations. These results suggest that, as the presence of predominant habitat (i.e., high seagrass biomass and marsh edge) is reduced or eliminated, physical heterogeneity among locations may increase, thereby also increasing the number of spatial niches and the variability of the community structure (i.e., dispersion) among locations (Sheaves et al., 2015). In other words, as seagrass biomass in non-edge locations is reduced, or the transition from edge, high seagrass to non-edge, low seagrass biomass locations, there is an increase physical heterogeneity and, thus, find more structurally variable communities among locations. However, the results also show community structure dispersion may not change when predominant habitat is eliminated or reduced. In this study, there was no significant change in dispersion when seagrass biomass is reduced in edge locations, or between edge and non-edge locations with high or low seagrass biomass. Additionally, there was marginally higher dispersion in edge locations with low seagrass in comparison with non-edge locations with high seagrass (Table 3.7). Clearly, it appears there are more factors that can influence community structure dispersion than just the reduction or elimination of structured habitat and corresponding changes in physical heterogeneity among locations.

It is important to consider the implications of the small spatial scale this study was executed relative to the movement patterns of the individuals within the area of interest. Nekton sampled had the opportunity to access and utilize any of the sampling locations; however, lack of differences in community structure may be because nekton were responding to the overall mosaic landscape of fringing marsh and sparse seagrass. A species relationship with one habitat type may be influenced by the distance of other habitat types, therefore, the 40-meter distance between edge and non-edge locations with variable seagrass coverage in this study may have been close enough in proximity for the nekton to utilize the seascape at site scale (Bradley et al., 2020). It is possible that the results observed from this study were due to a single community utilizing marsh edge and seagrass at the whole of site scale, rather than responding to the variable seagrass biomass within the different sampling sites. Although the results from individual species abundances point to species specific habitat selectivity, the scale of this project limits our ability to make general statements about our findings and apply them to larger scale habitat utilization patterns in the nGOM.

Therefore, this study is just a small piece in the larger framework of research that needs to be executed to better inform large-scale restoration efforts. Quantifying how fisheries species recruitment to coastal systems changes over short distances and periods of time is essential to understanding habitat value on a larger scale. For instance, based off previous studies, if marsh habitat adjacent to seagrass beds supports a greater abundance and diversity of commercially important nekton than marsh habitat adjacent to non-vegetated bottom, then management plans can justifiably concentrate on those highly impactful areas (Irlandi & Crawford, 1997). Increased anthropogenic and natural stressors threaten coastal ecosystems, especially seagrass and marsh habitat, in the nGOM (Lellis-Dibble et al., 2008). With a better understanding of how intertidal marshes and adjacent seagrass beds interact and function together, implementation of concerted conservation and management efforts for these crucial nursery habitats could improve their overall quality.

CHAPTER V

CONCLUSONS

This study analyzed in fine detail how the differences or lack of differences between marsh-edge proximity and seagrass biomass depends on the time of sampling in relation to total juvenile nekton abundance and the individual abundances of six ecologically and economically important estuarine-dependent species: white shrimp (*Litopenaeus setiferus*), blue crab (*Callinectes sapidus*), brown shrimp (*Farfantepenaeus* spp.), spotted seatrout (*Cynoscion nebulosus*), American silver perch (*Bairdiella chrysoura*) and pinfish (*Lagodon rhomboides*). This study produces disparate results, in terms of the effects of proximity to marsh edge and seagrass biomass on nekton abundance pointing to different selectivity of marsh edge versus seagrass by different species. Despite the prominent effects of marsh edge and seagrass biomass on nekton abundance, there was little effect of these two habitats on individual size with only speckled seatrout showing selectivity for marsh edge and smaller pinfish selecting for higher seagrass biomass. There were no effects of proximity to marsh edge and seagrass biomass on community composition, despite the prominent effects on total nekton abundance, and there was an interactive effect on community dispersion. These findings contribute to a better characterization of juvenile recruitment to habitats in shallow coastal systems; improve our understanding of how marsh-edge and adjacent seagrass interact as essential nekton habitat; and has the potential to inform policies of coastal habitat protection and conservation. This research is a steppingstone for follow-up studies to be implemented on a greater scale to define coastal habitats of high ecological and commercial impact and implement conservation and or restoration efforts.

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APPENDIX A

SUPPLEMENTARY MATERIALS

Table A.1 Temperature, dissolved oxygen, and salinity measurements

Date	Block	Temperature (°C)	DO (mg/L)	Salinity (ppt)
6/30/2020	1	29.6	4.9	17.5
	2	30.3	6.5	17.4
	3	30.9	6.4	17.4
	4	31.2	8	17.5
	5	32.3	7.7	17.7
7/8/2020	1	27.7	7	19.3
	2	27.5	5.6	18.9
	3	27	5.9	18.8
	4	27.7	7.1	18.8
	5	29	7.7	18.4
7/14/2020	1	26.9	6.1	22.8
	2	30	5.7	21.9
	3	31.2	8.4	21.8
	4	32.2	11.1	21.6
	5	34.9	9.8	22
7/21/2020	1	30.7	5.5	18.9
	2	30.8	5.6	19.2
	3	31	5.5	19.3
	4	31.5	7.1	19.4
	5	32.8	6.9	19.9
7/31/2020	1	28.8	6.2	16.3
	2	28.9	3.4	16.2
	3	29.3	5.7	16.2
	4	29.6	5.8	16.3
	5	30.3	5.6	15.7
8/6/2020	1	28.1	5.6	19.2
	2	28.2	5.8	19.3
	3	28.7	4.9	19.3
	4	29.2	7.1	19.2
	5	30.4	8.5	18.8
8/14/202	1	32.5	6.4	21.6
	2	32.7	6.5	21.8
	3	32.4	6.7	21.8
	4	33.7	9.9	21
	5	30.3	6.6	21.3
8/19/2020	1	29.9	5.6	23.9
	2	30.4	6.4	23.9

Table A.1 (continued)

Date	Block	Temperature (°C)	DO (mg/L)	Salinity (ppt)
	3	30.8	6.4	23.6
	4	31.2	6.4	23.2
	5	30.9	6.3	22.9
8/28/2020	1	31	7.1	21.8
	2	32.3	4.1	21.5
	3	31.9	5.1	21.6
	4	31.9	6.7	21.5
	5	32.8	5.4	20.3
9/3/2020	1	NO YSI	NO YSI	NO YSI
	2	NO YSI	NO YSI	NO YSI
	3	NO YSI	NO YSI	NO YSI
	4	NO YSI	NO YSI	NO YSI
	5	NO YSI	NO YSI	NO YSI
9/10/2020	1	28.1	2.6	19.3
	2	28.8	4.1	19.3
	3	30	6.6	19
	4	31.1	7.7	19.1
	5	31.8	8.2	20.4
9/25/2020	1	24.8	2.4	21.4
	2	25.6	5.1	21.3
	3	26	6.4	21.1
	4	26.5	7.9	21.1
	5	27.6	8.3	21.5
9/30/2020	1	21.5	6.5	21
	2	20.9	7.2	21
	3	22	6.8	21.3
	4	21.5	7.7	21.3
	5	22.1	9.1	21.3
10/7/2020	1	25.9	7.5	23.8
	2	26.5	8.7	24.6
	3	26.5	8.6	24.2
	4	28.5	11.6	24.1
	5	30.7	14.8	22.1
10/15/2020	1	25.1	6.9	22.1
	2	25	7.2	21.9
	3	25.3	7.2	21.8
	4	25.1	8.2	21
	5	25.9	8.4	20.6
10/20/2020	1	25.1	7.4	22.3
	2	25.7	8.3	23.2
	3	26.3	9	23.1
	4	27.7	11.8	22.4

Table A.1 (continued)

Date	Block	Temperature (°C)	DO (mg/L)	Salinity (ppt)
	5	29.6	14.1	22.7
11/5/2020	1	20.9	9	22.3
	2	21.2	8.7	23.2
	3	21.5	8.8	23.3
	4	22.1	10	23.1
	5	23	8.4	23.5
11/12/2020	1	22.1	7.1	18
	2	23.1	7.2	17.8
	3	23.8	7.7	18.1
	4	24.3	7.6	18.2
	5	24.4	8.9	19

Temperature, dissolved oxygen, and salinity measurements taken within each block throughout the study period. There was no YSI meter on 9/3/2020 so data is absent for that sampling date.

Table A.2 Water depth point measurements

Date	Marsh Edge Proximity	Block	Depth (m)
6/30/2020	Edge	1	0.53
		2	0.65
		3	0.4
		4	0.6
		5	0.25
	Non-Edge	1	0.55
		2	0.75
		3	0.6
		4	0.55
		5	0.3
7/8/2020	Edge	1	0.8
		2	0.5
		3	0.6
		4	0.7
		5	0.4
	Non-Edge	1	1.0
		2	0.65
		3	0.7
		4	0.9
		5	0.5
7/14/2020	Edge	1	0.5
		2	0.4
		3	0.3
		4	0.3
		5	0.15
	Non-Edge	1	0.7
		2	0.6
		3	0.4
		4	0.4
		5	0.3
7/21/202	Edge	1	1.0
		2	0.9
		3	0.9
		4	0.9
		5	0.6
	Non-Edge	1	1.1
		2	1.0
		3	0.8
		4	0.8

Table A.2 (continued)

Date	Marsh Edge Proximity	Block	Depth (m)
		5	0.6
7/31/2020	Edge	1	0.9
		2	0.7
		3	0.6
		4	0.6
		5	0.5
	Non-Edge	1	1.0
		2	0.9
		3	0.9
		4	0.7
		5	0.5
8/6/2020	Edge	1	0.8
		2	0.5
		3	0.7
		4	0.6
		5	0.5
	Non-Edge	1	1.0
		2	0.7
		3	0.6
		4	0.6
		5	0.5
8/14/2020	Edge	1	0.6
		2	0.5
		3	0.4
		4	0.2
		5	0.2
	Non-Edge	1	0.7
		2	0.5
		3	0.6
		4	0.5
		5	0.4
8/19/2020	Edge	1	0.9
		2	0.8
		3	0.8
		4	0.8
		5	0.7
	Non-Edge	1	1.1
		2	0.8
		3	1.0
		4	1.0
		5	0.5

Table A.2 (continued)

Date	Marsh Edge Proximity	Block	Depth (m)
8/28/2020	Edge	1	0.8
		2	0.6
		3	0.5
		4	0.6
		5	0.4
	Non-Edge	1	1.0
		2	0.8
		3	0.7
		4	0.6
		5	0.3
9/3/2020	Edge	1	0.6
		2	0.4
		3	0.6
		4	0.6
		5	0.5
	Non-Edge	1	0.8
		2	0.6
		3	0.9
		4	0.8
		5	0.4
9/10/2020	Edge	1	0.7
		2	0.5
		3	0.5
		4	0.5
		5	0.3
	Non-Edge	1	0.9
		2	0.7
		3	0.7
		4	0.5
		5	0.3
9/25/2020	Edge	1	1.0
		2	0.8
		3	0.7
		4	0.7
		5	0.4
	Non-Edge	1	1.1
		2	0.9
		3	0.8
		4	0.8
		5	0.4
9/30/2020	Edge	1	0.9

Table A.2 (continued)

Date	Marsh Edge Proximity	Block	Depth (m)
		2	0.6
		3	0.7
		4	0.6
		5	0.4
	Non-Edge	1	1.0
		2	0.8
		3	0.7
		4	0.7
		5	0.4
10/7/2020	Edge	1	0.5
		2	0.3
		3	0.5
		4	0.4
		5	0.3
	Non-Edge	1	0.8
		2	0.6
		3	0.7
		4	0.5
		5	0.3
10/15/2020	Edge	1	0.7
		2	0.8
		3	0.9
		4	0.6
		5	0.5
	Non-Edge	1	1.0
		2	0.6
		3	0.6
		4	0.7
		5	0.5
10/20/2020	Edge	1	0.5
		2	0.3
		3	0.3
		4	0.3
		5	0.3
	Non-Edge	1	0.6
		2	0.6
		3	0.5
		4	0.5
		5	0.4
11/5/2020	Edge	1	0.3
		2	0.2

Table A.2 (continued)

Date	Marsh Edge Proximity	Block	Depth (m)
		3	0.3
		4	0.5
		5	0.2
	Non-Edge	1	0.5
		2	0.6
		3	0.6
		4	0.3
		5	0.3
11/12/2022	Edge	1	1.1
		2	1.0
		3	0.9
		4	0.7
		5	0.4
	Non-Edge	1	0.9
		2	0.7
		3	0.6
		4	0.5
		5	0.5

Water depth measurements taken at both sampling locations, marsh-edge and non-marsh edge, throughout the study period.

Table A.3 Abundance model summary table

Species	Family	Transformation of Dependent variable	Block	Seine Pull	Temporal-autocorrelation	Zero inflation	Assumptions
Total	Nbinom2	none	Y	N	N	N	Met
Blue Crab	Gaussian	log10	Y (fixed)	N	N	Not possible	Not met
Brown Shrimp	Nbinom2	none	Y	N	N	N	Met
White Shrimp	Nbinom2	none	Y	N	N	N	Met
Silver Perch	Gaussian	Log10	N	Y	N	Not possible	Not met
Pinfish	Gaussian	Log10	N	Y	N	N	Not met
Speck	Gaussian	sqrt	N	N	N	Y (~1)	Met

Summary table for each dependent variable including distribution type, dependent variable transformation, inclusion, or exclusion of random variables and if model meets assumptions. Y indicates random variable was included, N indicates random factor was not included and "Not possible" indicates the model could not converge with random variable included.

Table A.4 Individual size summary table

Species	Transformation of Dependent Variable	Block	Time	Seine	Autocorrelation	Assumptions
White Shrimp	N	N	Y	N	N	Met
Brown Shrimp	N	N	N	N	N	Met
Pinfish	log	N	Y	Y	Y	Met
Silver Perch	sqrt	N	Y	Y	Y	Met
Blue Crab	sqrt	N	N	N	N	Not met
Speckled seatrout	sqrt	N	N	N	N	Met

Summary table for each dependent variable including dependent variable transformation, inclusion, or exclusion of random variables and if model meets assumptions. Y indicates random factor was included; N indicates random factor was not included.

Table A.5 Total species abundance

Anchoa hepsetus (Broad striped anchovy)	16
Anchoa lyolepis (Shortfinger anchovy)	1
Anchoa mitchilli (Bay anchovy)	247
Archosargus probatocephalus (Sheepshead)	4
Arius felis (Hardhead catfish)	228
Bagre marinus (Gafftopsail catfish)	1
Bairdiella chrysoura (Silver perch)	1070
Bait Shrimp	105
Bathygobius soporator (Frillfin goby)	4
Brevoortia patronus (Gulf menhaden)	78
Callinectes sapidus (Blue crab)	277
Callinectes similis (Lesser blue crab)	1
Caranx hippos (Crevalle jack)	4
Caranx latus (Horse-eye jack)	1
Chaetodipterus faber (Atlantic spadefish)	13
Chasmodes saburrae (Florida blenny)	1
Chilomycterus schoepfii (Striped burrfish)	9
Chloroscombrus chrysurus (Atlantic bumper)	5
Citharichthys macrops (Spotted whiff)	8
Citharichthys spilopterus (Bay whiff)	23
Citharichthys spp. (Flatfish)	1
Ctenogobius boleosoma (Darter goby)	8
Cynoscion arenarius (Sand seatrout)	103
Cynoscion nebulosus (Speckled trout)	291
Cyprinidon variegatus (Sheepshead minnow)	1
Dasyatis sabina (Atlantic stingray)	24
Dorosoma petenense (Threadfin shad)	15
Elops saurus (Ladyfish)	1
Erotelis smaragdus (Emerald sleeper)	1
Etropus crossotus (Fringed flounder)	1
Eucinostomus spp. (Mojarra)	35
Evorthodus lyricus (Lyre goby)	9
Farfantepenaeus spp. (Brown shrimp)	1227
Fundulus grandis (Gulf killifish)	138
Fundulus similis (Longnose killifish)	1
Gobionellus oceanicus (Highfin goby)	2
Gobiosoma bosc (Naked goby)	2
Gobiosoma robustum (Code goby)	1
Harengula jaguana (Scaled sardine)	93
Hyporhamphus meeki (American halfbeak)	3
Lagodon rhomboides (Pinfish)	425
Larimus fasciatus (Banded drum)	6

Table A.5 (continued)

Leiostomus xanthurus (Spot)	14
Litopenaeus setiferus (White shrimp)	5009
Lobotes surinamensis (Atlantic tripletail)	1
Lucania parva (Rainwater killifish)	1
Lutjanus griseus (Gray snapper)	69
Membras martinica (Rough silverside)	113
Menidia beryllina (Inland silverside)	144
Menidia spp. (Silversides)	375
Menticirrhus americanus (Southern kingfish)	131
Menticirrhus littoralis (Gulf kingcroaker)	1
Menticirrhus spp. (Croaker)	1
Micropogonias undulatus (Atlantic croaker)	14
Mugil cephalus (Grey mullet)	19
Mugil curema (White mullet)	62
Oligoplites saurus (Leatherjacket fish)	92
Paralichthys lethostigma (Southern flounder)	1
Pomatomus saltatrix (Bluefish)	1
Prionotus Tribulus (Bighead searobin)	2
Razor Clam	1
Sciaenops ocellatus (Red drum)	7
Scomberomorous maculatus (Atlantic Spanish mackerel)	2
Selene vomer (Lookdown)	1
Sphoeroides parvus (Least puffer)	19
Stellifer lanceolatus (American stardrum)	1
Stephanolepis hispidus (Planehead filefish)	1
Symphurus spp. (Tonguefish)	30
Syngnathus scovelli (Gulf pipefish)	1
Synodus foetens (Inshore lizardfish)	1

Total number of individual species caught throughout the study period.

Table A.6 Individual species lengths (in mm)

White shrimp

Jun-30: 11, 11, 13, 11, 14, 9, 7, 10, 7, 9, 11, 8, 8, 9, 7, 8, 9, 9, 8, 9, 6, 8, 7, 13, 14, 8, 7, 9, 9, 10, 11, 8, 10, 9, 7, 11, 10, 8, 10, 9, 10, 11, 11, 11, 13, 10, 7, 10, 9, 9, 11, 9, 11, 7, 10, 9, 9, 10, 8, 9, 8, 9, 10, 9, 8, 9, 9, 14, 11, 13, 11, 10, 9, 11, 9, 11, 9, 9, 8, 10, 8, 7, 11, 9, 8, 11, 10, 10, 9, 9, 11, 12, 11, 9, 9, 8, 12, 13, 12, 10, 10, 6, 7, 9, 12, 10, 9, 10, 10, 9, 8, 8, 9, 9, 7, 6, 7, 7, 7, 6, 7, 9, 7, 8, 7, 8, 7, 9, 19, 21, 15, 7, 7, 5

Jul-8: 13, 15, 12, 10, 9, 11, 9, 12, 8, 11, 11, 12, 10, 11, 11, 7, 10, 12, 11, 11, 11, 8, 11, 11, 14, 11, 12, 7,8, 9, 12, 7, 5, 11, 8, 8, 10, 12, 10, 10, 8, 9, 10, 6, 8, 11, 9, 6, 11, 7, 9, 9, 10, 7, 8, 9, 7, 12, 9, 10, 6, 6, 9, 23, 19, 11, 9, 9, 15, 10, 14, 6, 6, 7, 7, 7, 9, 7, 6, 8, 8, 7, 11, 16, 10, 9, 18, 16, 12, 11, 9, 8, 9, 9, 10, 10, 8, 11, 8, 8, 9, 6, 7, 7, 5, 6, 6, 8, 8, 11, 8, 8, 9, 8, 8, 7, 7, 8, 6, 6, 7, 8

Jul-14: 12, 13, 10, 20, 11, 15, 7, 11, 13, 11, 16, 11, 11, 14, 13, 12, 11, 12, 12, 15, 10, 11, 12, 13, 13, 10, 16, 13, 11, 12, 12, 11, 12, 12, 17, 11, 9, 12, 13, 11, 14, 10, 11, 10, 12, 9, 10, 11, 11, 13, 12, 8, 11, 10, 7, 9, 10, 7, 8, 12, 11, 17, 20, 18, 15, 13, 11, 12, 11, 16, 13, 13, 11, 14, 17, 14, 11, 12, 13, 12, 18, 8, 9, 6, 5, 8, 7, 6, 9, 11, 7, 12, 9, 7, 7, 8, 6, 7, 7, 7, 8, 9, 18, 15, 14, 10, 12, 16, 6, 7, 7, 6, 7, 6, 10, 6, 7

Jul-21: 19, 15, 16, 17, 10, 7, 9, 9, 9, 18, 17, 19, 8, 7, 7, 7, 6, 10, 9, 10, 7, 9, 8, 8, 9, 8, 8, 7, 8, 13, 10, 10, 9, 7, 11, 7, 5, 7, 19, 15, 9, 7, 9, 8, 13, 8, 13, 15, 14, 10, 9, 8, 9, 9, 11, 10, 9, 9, 8, 7, 10, 8, 9, 8, 8, 9, 12, 9, 10, 10, 7, 8, 10, 10, 9, 9, 11, 11, 9, 10, 8, 8, 9, 10

Jul-31: 19, 8, 10, 11, 10, 12, 8, 7, 8, 9, 9, 7, 15, 12, 12, 8, 13, 10, 10, 9, 11, 7, 7, 17, 19, 16, 11, 13, 17, 13, 12, 8, 10, 8, 13, 7, 7, 8, 6, 6, 7, 8, 7, 7, 6, 5, 7, 8, 10, 8, 6, 7, 8, 7, 7, 8, 7, 7, 8, 9, 9, 8, 8, 8, 9, 9, 8, 8

Aug-6: 19, 15, 17, 21, 18, 19, 17, 14, 22, 19, 18, 17, 25, 23, 14, 19, 18, 18, 16, 20, 15, 18, 15, 16, 17, 17, 14, 14, 17, 16, 18, 19, 20, 14, 12, 15, 17, 17, 14, 16, 14, 13, 18, 15, 14, 11, 9, 8, 9, 6, 5, 6, 17, 14, 16, 15, 14, 14, 15, 16, 14, 15, 14, 13, 14, 17, 15, 15, 11, 14, 10, 10, 10, 7, 8, 7, 8, 7, 8, 8, 9, 7, 8, 14, 16, 13, 14, 12, 12, 14, 15, 12, 14, 10, 11, 12, 12, 14, 10, 11, 13, 9, 10, 16, 14, 15, 10, 9, 14, 13, 13, 11, 12, 11, 13, 10, 10, 10, 9, 11, 7, 8, 10

Aug-14: 12, 18, 16, 13, 13, 16, 11, 11, 12, 6, 10, 11, 11, 12, 8, 10, 12, 13, 10, 13, 11, 11, 16, 9, 12, 12, 15, 9, 12, 12, 10, 14, 10, 8, 12, 15, 14, 15, 13, 13, 8, 16, 7, 6, 8, 14, 7, 8, 7, 16, 16, 17, 12, 13, 14, 17, 13, 15, 14, 17, 13, 16, 11, 14, 16, 11, 7, 13, 16, 11, 11, 21, 15, 15, 18, 17, 16, 10, 12, 12, 11, 20, 12, 14, 15, 14, 15, 10, 9, 10, 10, 15, 15, 19, 15, 13, 14, 11, 6, 13, 17, 9, 9, 12, 15, 11, 8, 16, 17, 17, 12, 9

Aug-19: 9, 10, 7, 11, 9, 17, 6, 8, 7, 8, 5, 6, 16, 17, 11, 11, 9, 9, 7, 12, 10, 9, 7, 14, 7, 19, 9, 6, 11, 13, 6, 9, 14, 9, 6, 11, 9, 10, 6, 5, 8, 8, 9, 8, 7, 7, 8, 9, 6, 7, 7, 8, 7, 6, 6, 10, 7, 11, 10, 9, 7, 8, 8, 8, 7, 9, 7, 10, 9, 8, 9, 10, 7, 8, 9

Aug-28: 7, 12, 10, 10, 8, 8, 10, 9, 18, 10, 15, 15, 15, 11, 9, 13, 13, 15, 9, 10, 11, 11, 12, 11, 9, 12, 12, 13, 10, 12, 8, 11, 10, 8, 8, 9, 9, 10, 8, 10, 10, 9, 11, 10, 10, 8, 13, 10, 13, 9, 13, 12, 12, 10, 13, 14, 12, 10, 9, 8, 10, 16, 10, 10, 7, 8, 7, 8, 12, 9, 12, 10, 8, 10, 12, 7, 10, 10, 11, 10, 10, 8, 8, 10, 7, 11, 10, 8, 14, 12, 7, 10, 6, 8, 7, 13, 13, 11, 10, 11, 12, 8, 10, 8, 16, 12, 10, 10, 10, 9, 8, 9, 10, 11, 8, 11, 8, 8, 11, 11, 8, 12, 11, 16, 10, 9, 8, 9, 11, 8, 13, 9, 12, 12, 14, 14, 10, 20, 17, 12, 11, 10, 9, 9, 14, 8, 13, 11, 11, 10, 10, 7

Sep-3: 13, 11, 12, 9, 13, 8, 9, 7, 12, 7, 11, 12, 7, 12, 7, 9, 10, 6, 9, 7, 10, 11, 13, 11, 11, 10, 11, 10, 10, 8, 11, 7, 9, 13, 12, 8, 9, 7, 11, 8, 12, 11, 9, 9, 11, 10, 8, 9, 9, 8, 9, 9, 8, 16,

Table A.6 (continued)

14, 12, 17, 11, 10, 12, 8, 8, 12, 9, 11, 10, 11, 10, 8, 11, 9, 9, 7, 13, 12, 13, 15, 11, 9, 8, 10, 8, 9, 10, 9, 11, 7, 8, 8, 11, 17, 7, 18, 8, 19, 9, 8, 9, 13, 15, 9, 9, 9, 9, 10, 7, 7, 9, 7, 7, 16, 15, 7, 11, 12, 7, 8, 13, 15, 9, 13, 9, 10, 9, 14, 11, 7, 17, 16, 12

Sep-10: 16, 11, 11, 12, 13, 13, 10, 10, 11, 7, 8, 9, 8, 8, 12, 10, 9, 9, 9, 6, 10, 17, 12, 9, 8, 15, 10, 14, 8, 14, 14, 14, 8, 13, 9, 11, 10, 11, 10, 7, 7, 13, 21, 11, 13, 13, 11, 15, 15, 13, 19, 10, 10, 15, 12, 17, 13, 15, 14, 11, 15, 13, 16, 16, 14, 11, 13, 12, 15, 9, 12, 11, 14, 12

Sep-25: 7, 7, 7, 15, 15, 16, 8, 12, 13, 14, 9, 10, 12, 14, 14, 12, 11, 12, 10, 12, 15, 11, 11, 15, 10, 12, 11, 15, 11, 10, 10, 11, 12, 9, 9, 8, 11, 9, 7, 13, 9, 13, 10, 10, 10, 8, 11, 6, 8, 6, 8, 8, 6, 14, 13, 7, 14, 9, 11, 13, 11, 16, 11, 8, 13, 6, 14, 10, 11, 9, 7, 11, 12, 13, 8, 9, 9, 8, 6, 10, 10, 7

Sep-30: 17, 16, 8, 12, 15, 13, 14, 10, 14, 16, 15, 7, 16, 15, 13, 14, 8, 15, 9, 15, 7, 8, 9, 8, 7, 7, 13, 16, 11, 16, 14, 15, 12, 9, 10, 7, 7, 6, 7, 5, 5, 6, 14, 14, 7, 13, 16, 12, 20, 5, 13, 17, 13, 7, 8, 18, 13, 11, 10, 11, 8, 13, 14, 8, 16, 12, 15, 10, 7, 9, 16, 9, 15, 16, 13, 9, 14, 6, 16, 7, 16, 18, 11, 15, 17, 14, 10, 14, 18, 14, 15, 17, 14, 12, 10, 13, 13, 12, 10, 11, 14

Oct-7: 14, 16, 18, 8, 9, 13, 15, 7, 15, 9, 9, 17, 15, 15, 14, 9, 14, 8, 16, 8, 16, 13, 12, 16, 17, 15, 16, 6, 16, 16, 16, 9, 13, 13, 8, 10, 16, 13, 12, 9, 14, 14, 13, 14, 14, 8, 16, 14, 12, 11, 10, 9, 13, 15, 10, 8, 8, 9, 9, 8, 15, 13, 13, 21, 10, 9, 10, 13, 10, 17, 13, 18, 18, 13, 8, 16, 12, 8, 8, 10, 13, 10, 10, 9, 13, 11, 8, 11, 9, 9

Oct-15: 16, 14, 12, 13, 11, 10, 10, 16, 12, 13, 10, 12, 14, 11, 12, 12, 12, 9, 10, 10, 10, 10, 12, 16, 13, 15, 17, 12, 12, 14, 13, 13, 12, 13, 12, 9, 10, 11, 11, 10, 9, 9, 12, 9, 9, 10, 12, 15, 13, 15, 10, 14, 12, 14, 11, 14, 15, 13, 15, 13, 9, 10, 11, 11, 9, 15, 12, 11, 15, 11, 12, 11, 13, 11, 11, 11, 10, 11, 9, 15, 13, 15, 13, 15, 12, 11, 14, 15, 15, 14, 14, 16, 13, 12, 15, 11, 9, 15, 14, 10, 17, 10, 13, 12, 14, 13,

Oct-20: 8, 14, 13, 12, 7, 14, 14, 11, 10, 12, 13, 14, 13, 8, 7, 14, 13, 17, 16, 18, 13, 15, 14, 15, 14, 12, 14, 17, 13, 13, 11, 14, 9, 12, 15, 14, 14, 14, 14, 15, 14, 9, 13, 15, 12, 12, 14, 16, 13, 12, 12, 13, 16, 11, 12, 14, 13, 14, 12, 10, 14, 7

Brown shrimp

Jun-30: 12, 13, 11, 6, 14, 10, 7, 12, 9, 9, 8, 9, 8, 11, 9, 8, 8, 7, 16, 13, 9, 8, 6, 13, 13, 14, 12, 14, 13, 11, 6, 7, 6, 11, 11, 13, 12, 11, 9, 14, 11, 10

Jul-8: 7, 9, 12, 8, 9, 8, 7, 11, 8, 9, 7, 6, 8, 8, 9, 9, 6, 7, 14, 9, 5, 11, 11, 7, 11, 9, 3, 8, 9, 8, 12, 14, 8, 8, 8, 6, 9, 8, 9, 8, 8, 7, 6, 13, 14, 12, 6, 6, 6, 12, 6, 6, 11, 10, 8, 6

Jul-14: 10, 11, 10, 9, 12, 8, 9, 11, 11, 10, 8, 9, 7, 8, 8, 7, 9, 6, 7, 7, 9, 14, 9, 12, 10, 9, 11, 12, 9, 9, 11, 11, 11, 10, 8, 13, 9, 9, 8, 11, 13, 9, 8, 11, 10, 8, 9, 9, 7, 9, 7, 9, 10, 7, 8, 13, 13, 11, 9, 9, 9, 7, 10, 8, 9, 12, 12, 8, 9, 8, 11, 12, 13, 11, 10, 11, 9, 12, 11, 10, 12, 10, 11, 10, 14, 11, 7, 11, 10, 7, 10

Jul-21: 12, 11, 10, 9, 14, 9, 11, 7, 12, 8, 7, 9, 12, 9, 8, 10, 10, 10, 8, 10, 11, 12, 13, 13, 14, 12, 14, 13, 14, 9, 9, 6, 14, 14, 8, 14, 9, 13, 12, 13, 12, 10, 7, 8, 11, 7, 8, 10, 9, 8, 10, 9, 9, 11, 9, 13, 14, 11, 12, 12, 11, 10, 11, 12, 13, 10, 10, 10, 6

Jul-31: 11, 14, 14, 12, 14, 10, 14, 14, 14, 14, 10, 12, 13, 12, 11, 14, 14, 13, 12, 13, 11, 10, 11, 12, 8, 8, 10, 11, 14, 11, 13, 13, 8, 12, 13, 14, 11, 9, 11, 14, 11, 14, 13, 13, 13, 12, 9, 8, 11, 10, 7, 8, 7, 14, 13, 14, 12, 7, 10, 10, 7, 7, 8, 8, 10, 11, 14, 13, 11, 12, 12, 11, 14, 13, 14, 12, 11, 9, 9, 9, 10, 7, 8, 8, 7, 8, 10, 8, 9, 11, 14, 9, 9, 13, 12, 14, 8

Table A.6 (continued)

Aug-6: 12, 8, 9, 13, 12, 12, 13, 11, 10, 11, 10, 12, 8, 12, 11, 14, 13, 13, 10, 12, 13, 11, 9, 12, 10, 10, 8, 9, 8, 8, 8, 7, 8, 14, 10, 11, 14, 11, 12, 12, 12, 10, 12, 10, 10, 14, 12

Aug-14: 14, 14, 11, 10, 7, 10, 9, 10, 11, 8, 9, 9, 7, 8, 7, 8, 8, 8, 9, 8, 7, 9, 8, 11, 8, 16, 7, 7, 11, 12, 14, 14 14, 11, 11, 14, 13, 14, 13, 12, 13, 12, 11, 12, 14, 14, 12, 14, 8, 8, 13, 13, 6, 9, 7, 8, 7, 11, 7, 7, 9, 4

Aug-19: 10, 7, 5, 12, 10, 10, 9, 9, 8, 10, 8, 8, 7, 7, 6, 14, 13, 9, 11, 12, 12, 12, 12, 9, 7, 12, 10, 11, 16, 10, 7, 11, 10, 10, 10, 14, 14, 12, 11, 9, 13, 14, 12, 12, 13, 11, 9, 12, 9, 9, 9, 10, 10, 11, 9, 9, 8, 13, 7, 6, 9, 8, 10, 8, 7, 6

Aug-28: 11, 10, 8, 12, 10, 11, 7, 9, 10, 10, 7, 8, 8, 5, 7, 9, 12, 13, 11, 8, 9, 11, 9, 8, 12, 7, 6, 13, 12, 12, 11, 13, 7, 12, 12, 12, 11, 13, 10, 11, 11, 13, 9, 13, 13, 12, 7, 10, 13, 13, 12, 14, 14, 10, 12, 12, 11, 9, 13, 12, 8, 10, 8, 9, 7, 9, 14, 12, 12, 10, 11, 10, 11, 10, 11, 11, 8, 9, 13, 9, 11, 11, 9, 12, 8, 10, 14, 14, 14, 13, 11, 13, 7, 12, 10, 8, 10, 10, 12, 11, 7, 10, 10, 11, 9, 8, 8, 9, 6, 7, 6

Sep-3: 16, 11, 12, 9, 9, 12, 11, 7, 11, 10, 13, 11, 10, 12, 10, 10, 13, 13, 7, 6, 12, 11, 10, 12, 8, 8, 7, 7, 9, 7, 5, 9, 8, 10, 7, 5, 7, 7, 7, 9, 7, 11, 8, 9, 5, 8, 8, 9, 11, 7, 9, 7, 6, 14, 9, 10, 8, 11, 8, 9, 9, 11, 8

Sep-10: 11, 8, 13, 13, 13, 11, 8, 9, 10, 11, 11, 11, 13, 13, 11, 9, 10, 12, 8, 10, 10, 8, 10, 9, 10, 9, 12, 10, 9, 8,13, 11, 9, 10, 15, 16, 19, 13, 14, 10, 12, 11, 13, 10, 10, 14, 13, 13, 11, 10, 10

Sep-25: 14, 8, 7, 13, 13, 13, 12, 11, 13, 12, 11, 9, 12, 10, 10, 7, 9, 9, 12, 11, 12, 13, 11, 10, 11, 11, 7, 7, 7, 8, 11, 9, 4, 7, 14, 11, 10, 11, 11, 12, 9, 9, 11, 9, 8

Sep-30: 12, 7, 10, 8, 10, 9, 12, 5, 10, 11, 9, 11, 12, 9, 12, 10, 13, 11, 8, 8, 5, 6, 10, 11, 9, 11, 10, 7, 14, 9, 8, 6, 6, 11, 8, 9, 7, 9, 10, 12, 9, 9, 9, 6, 9, 9, 6, 8, 7, 14, 13, 14, 8, 8, 11, 6, 12

Oct-7: 14, 11, 15, 11, 13, 12, 13, 11, 11, 11, 12, 9, 10, 11, 11, 12, 10, 10, 10, 7, 10, 8, 7, 8, 6, 7, 13, 6, 9, 13, 11, 10, 8, 10, 11, 11, 10, 11, 10, 10, 8, 12, 10, 10, 11, 9, 11, 10, 10, 11, 14, 13, 8, 10, 10, 10, 8, 9, 9, 9, 5

Oct-15: 11, 15, 13, 13, 7, 6, 8, 10, 11, 14, 13, 9, 10, 8, 10, 18, 15, 13, 15, 13, 14, 11, 12, 11, 13, 13, 9, 9

Oct-20: 8, 12, 13, 10, 15, 12, 14, 14, 13, 7, 9, 9, 10, 9, 14, 11, 6, 12, 10, 11, 11, 10

Blue crab

Jun-30: 57, 156, 19, 22, 17, 26, 16, 15, 26, 17, 14

Jul-8: 20, 19, 17

Jul-14: 20, 19, 15, 16, 18, 15, 21, 15, 15, 15, 17, 11, 12, 11, 6, 22, 5, 3, 3, 2, 66, 32, 14, 11, 12

Jul-21: 19, 13, 16, 12, 24, 19, 14, 12, 19, 32, 21, 11

Jul-31: 13, 16, 177, 18, 12

Aug-6: 16, 11, 10, 19, 16, 11, 20, 14, 14, 28, 17, 18

Aug-14: 21, 125, 38, 19, 23, 19, 20, 16, 18, 18, 15, 46, 26, 37, 25, 24, 21, 18, 21, 15, 9, 22, 16, 20, 14, 15, 13, 13, 15, 10, 12, 16, 22

Aug-19: 17, 19, 15, 4, 9, 7, 6, 5, 22, 22, 8, 13, 14, 13, 12, 4, 4, 6, 12, 18, 19, 13, 16

Aug-28: 13, 21, 21, 18, 15, 14, 13, 14, 8, 6, 18, 28, 19, 25, 13, 14

Table A.6 (continued)

Sep-3: 200, 15, 16, 28, 21, 188, 41, 30, 14, 14, 15,
Sep-10: 13, 16, 18, 24, 20, 18, 16, 15, 18, 18, 16, 15, 15, 10, 14, 20, 19, 18, 19, 9, 10
Sep-25: 22, 24, 21
Sep-30: 13, 105, 24, 17, 16, 12, 8, 7, 17, 13, 16, 11, 13, 9, 4, 3, 17, 18, 15, 16, 14
Oct-7: 13, 24, 15, 12, 110, 32, 26, 26, 18, 15, 19, 15, 13, 19, 15, 14, 20, 23, 16, 16, 13, 16, 15, 16, 14, 13
Oct-15: 123, 109, 28, 18, 17, 16, 14, 12, 10, 163, 16, 14, 147, 84, 18, 42, 22, 22, 20, 12, 15, 13, 12, 20
Oct-20: 22, 25, 13, 16, 16, 24, 19, 15, 17, 141, 19, 17, 16, 17, 16, 13

American silver perch

Jun-30: 33, 38, 34, 38, 41, 41, 35, 42, 40, 42, 43, 39, 41, 67, 44, 49, 60, 37, 42, 50, 40, 42, 44, 40, 41, 47, 47, 47, 57, 42, 44, 41, 39, 40, 38, 45, 60, 42, 39, 52, 82, 53, 70, 45, 71, 44, 72, 61, 46, 71, 61, 74, 63, 56, 52, 58, 51, 55, 56, 47, 44, 44, 48, 43, 52, 47, 50, 44, 39, 60, 45, 40
Jul-8: 41, 52, 39, 35, 33, 38, 49, 59, 47, 48, 45, 39, 43, 39, 45, 42, 40, 36, 40, 50, 60, 44, 45, 43, 43, 41, 42, 45, 39, 57, 61, 47, 59, 44, 41, 46, 79, 55, 49, 36, 48, 64, 30, 59, 54, 44, 49, 64, 48, 156, 44, 44, 40, 36, 40, 36, 39, 47, 47, 48, 43, 38
Jul-14: 56, 56, 42, 42, 64, 53, 55, 39, 40, 42, 55, 56, 45, 39, 40, 40, 42, 39, 41, 35, 65, 74, 37, 73, 71, 58, 50, 47, 42, 44, 45, 40, 40, 40, 37, 42, 45, 43, 56, 57, 58, 52, 40, 33, 86, 72, 53, 63, 40, 51, 38, 45, 56, 51, 52, 44, 73, 46, 41, 42, 38, 40, 38, 49
Jul-21: 49, 44, 47, 44, 43, 45, 45, 44, 43, 43, 39, 45, 43, 41, 40, 42, 41, 43, 43, 40, 43, 40, 42, 47, 40, 39, 50, 49, 48, 48, 49, 47, 44, 47, 44, 39, 40, 45, 46, 42, 44, 45, 40, 95, 89, 45, 92, 55, 42, 45, 40, 43, 35, 39, 48, 43, 40, 38, 35, 41, 60, 50, 50, 49, 63, 57, 52, 55, 65, 64, 51, 60, 53, 54, 54, 65, 52, 50, 50
Jul-31: 42, 52, 44, 39, 41, 37, 175, 50, 44, 34, 45, 48, 41, 55, 52, 52, 49, 53, 48, 45, 56, 52, 49, 49, 57, 48, 47, 49, 45, 48
Aug-6: 60, 63, 52, 47, 49, 57, 58, 39, 46, 53, 49, 50, 52, 42, 37, 46, 34, 43, 39, 40, 64, 65, 68, 58, 56, 65, 50, 56, 57, 53, 49, 45, 55, 50, 62, 47, 53, 62, 47, 46, 40, 38, 47, 40, 40
Aug-14: 110, 62, 59, 58, 54, 57, 41, 41, 43, 42, 41, 38, 67, 57, 55, 70, 50, 37, 45, 49, 42, 74, 47, 63, 49, 37, 48, 58, 38, 45, 38, 40, 40, 60, 44, 38, 54, 40, 40, 36, 48, 46, 47, 60, 42, 38, 43, 41, 39, 41, 42, 41
Aug-19: 44, 47, 47, 46, 45, 49, 40, 39, 48, 41, 46, 38, 48, 42, 49, 40, 38, 38, 42, 40, 52, 37, 40, 47, 37, 38, 37, 45, 48, 43, 49, 38, 41, 42, 40, 49, 36, 40, 39, 36, 45, 42, 46, 49, 52, 42, 40, 39, 41, 36, 37, 67, 54, 50, 54, 37, 119, 42, 42, 35, 61, 61, 43, 44, 55, 55, 55, 48, 46, 44, 45, 36, 41, 38, 37, 37, 50, 41, 37, 37, 41
Aug-28: 53, 67, 39, 34, 54, 53, 44, 47, 43, 34, 38, 46, 49, 47, 38, 50, 51, 59, 50, 56, 45, 44, 52, 52, 46, 46, 56, 52, 53, 43, 47, 44, 41, 46, 36, 68, 50, 41, 72, 43, 59, 60, 45, 51, 49, 68, 55, 50, 44, 78, 56, 44, 43, 41, 43, 42, 47, 45
Sep-3: 83, 81, 50, 61, 61, 61, 67, 57, 60, 58, 60, 58, 54, 53, 58, 52, 52, 52, 52, 40, 67, 34, 55, 54, 51, 48, 53, 53, 42, 40, 39, 37, 42, 39, 43, 38, 40, 37, 48, 47, 99, 66, 54, 46, 42, 38, 63, 47, 61, 57, 58, 49, 47, 54, 49, 61, 63, 48, 70, 66, 62, 45, 54, 56, 47, 51, 52, 60, 57, 38, 34, 54, 50, 50, 51, 52, 61, 55, 52, 55, 52, 38, 53, 53, 60, 47

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Sep-25: 69, 64, 47, 54, 71, 70, 70, 75, 67, 55, 45, 57, 40, 58, 45, 47, 81, 75, 74, 51, 64, 36, 65, 76, 71, 45, 73, 48, 47, 69, 56, 64, 66, 55, 39, 55, 76, 78, 66, 62, 60, 48, 49, 47, 42, 58, 49
Sep-30: 73, 57, 46, 66, 67, 79, 55, 44, 40, 47, 67, 44, 64, 47, 56, 93, 55, 82, 62, 53
Oct-7: 87, 48, 71, 80, 79, 92, 79, 81, 77, 70, 72, 75, 62, 83, 87, 79, 78, 71, 64, 72, 52, 68, 66, 74, 75, 48, 42, 78, 60, 75, 53, 64, 75, 65, 60, 55, 70, 76, 57
Oct-15: 85, 84, 85, 78, 71, 77, 82, 63, 62, 57, 61, 60, 63
Oct-20: 67, 61, 71

Pinfish
Jun-30: 68, 81, 48, 79, 58, 78, 66, 137, 56, 50, 85, 57, 83, 52, 101, 51, 107, 50, 76, 57, 59, 101, 63, 50, 107, 79, 94, 58, 66, 64, 81, 44, 42, 72, 87, 71, 61, 60, 66, 64, 60, 56, 81, 62, 132, 58, 53, 53, 61, 51, 48, 51, 76, 74, 60, 63, 62, 65, 69, 83, 130, 92, 55, 57, 51, 50, 52, 109, 51, 49, 47, 46, 49, 44, 37, 38
Jul-8: 48, 53, 59, 69, 82, 71, 65, 59, 56, 59, 60, 53, 51, 83, 83, 68, 51, 62, 98, 83, 57, 56, 110, 56, 51, 55, 50, 45, 43, 46, 53
Jul-14: 81, 54, 110, 114, 52, 66, 53, 45, 53, 59, 57, 45, 55, 47, 65, 62, 70, 71, 59, 56, 58, 57, 61, 44, 53, 63, 52, 45, 57, 48, 54
Jul-21: 66, 62, 115, 67, 81, 64, 64, 66, 56, 71, 64, 72, 65, 59, 51, 54, 59, 82, 69, 91, 65, 51, 62, 68, 65, 50, 60, 53, 51, 68, 49
Jul-31: 53, 96, 146, 142, 127, 92, 85, 70, 68, 70, 64, 60
Aug-6: 72, 79, 63, 61, 66, 60, 96, 94, 76, 152, 89, 121, 74, 65, 53, 81, 69, 60, 70, 67, 65, 48, 70, 65, 61
Aug-14: 77, 133, 112, 100, 85, 77, 67, 70, 72, 97, 126, 146, 80
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Fish lengths are reported in standard length, blue crab lengths are reported as carapace width and brown and white shrimp are reported as total length.