Final Report to VMRC-Recreational Fishing Advisory Board

Project Title: Connecting Productivity in Eelgrass Beds to Recreationally Important Finfishes in Chesapeake Bay: Forage Fishes as Trophic Conduits

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Introduction

Structured habitats, such as oyster reefs and seagrass beds, have been shown to support a greater diversity and abundance of fishes and invertebrates than nearby unstructured habitats (Orth 1977, Orth et al. 1984, Mattila et al. 1999, Heck et al. 2003). Of these structured habitats, seagrass is of primary importance in estuarine and shallow near-coastal areas for providing ecosystem services, including habitat provisioning (Orth et al. 2006). Along the Atlantic coast of the United States, eelgrass (*Zostera marina* L.) is the dominant seagrass species, typically growing as a fringe in the shallow sub-tidal zone. Eelgrass exhibits high levels of primary production, including serving as a substrate for epiphytic algae that grow on the leaf blades (Borowitzka et al. 2006). In turn, eelgrass has been shown to support an abundance of invertebrate consumers (Nelson 1979, Stoner 1980, van Montfrans et al. 1984, Fredette et al. 1990, Douglass et al. 2010). While primary and secondary productivity associated with seagrasses, and eelgrass specifically, have been well documented, less attention has been given to biomass transfer to higher trophic levels and the subsequent movement of eelgrass-derived energy to neighboring and distant habitats (Valentine et al. 2002, Heck et. al. 2008). While this function has been widely assumed, it has not been well documented, and therefore, a gap remains in the understanding of seagrass systems related to transfer to higher trophic levels and export to other habitats.

Numerous studies in recent decades have shown that the primary food sources of fishes associated with submerged vegetation are small crustaceans, including amphipods, isopods, shrimp, and small crabs (e.g., Adams 1976, Klumpp et al. 1989). Valentine and Heck (1993) showed that the abundance and production of small seagrass-associated invertebrates and fishes in the Gulf of Mexico are some of the highest values reported among all types of marine communities. Complex, dense seagrass beds are likely to support higher abundances of both predators and prey (Wyda et al. 2002). The ability to support higher abundances of fauna at multiple trophic levels suggests both a foraging and refuge advantage for species using these habitats. Recent studies have shown that foraging success rates do not necessarily increase with increasing complexity, but are species- and foraging strategy-dependent (Boström and Mattila 1999, Canion and Heck 2009, Hourinouchi et al. 2009). These studies support the hypothesis of the value of seagrasses as both structural refuge and superior foraging habitat. And, while predation is well documented for fishes using seagrass habitats, quantitative data showing the value of seagrasses in terms of export from the seagrass beds themselves to the adjacent marine system are lacking (Heck et al. 2008).

In lower Chesapeake Bay, many fish species, including several of the sciaenids (i.e. spot, croaker, silver perch, Family Sciaenidae), are seasonally abundant in seagrass habitats, exhibiting considerable growth rates over short periods of time during the warm summer months. These fishes often recruit to eelgrass habitats as early-stage juveniles, rear for a period of time, and outmigrate to deeper waters as ontogeny forces a switch to larger prey items or as water temperature declines seasonally. In some cases the use of seagrass habitats may be opportunistic, while for other species it is considered critical rearing habitat. As these organisms move to other habitats and offshore, much of the production gained from seasonal growth may be transferred to higher-trophic levels, in essence producing a cross-habitat subsidy from benthically-driven eelgrass beds to the broader coastal marine ecosystem.

The production and consumption of eelgrass bed-derived biomass via fishes was the focus of this study. Fish and invertebrate abundance can be variable in space and time, and while previous work has focused on the habitat provisioning function of eelgrass in lower Chesapeake Bay, it is necessary to understand current patterns of fish distribution and habitat utilization. Additionally, patterns of eelgrass distribution and areal coverage have varied considerably over the past thirty years (Orth et al. 2010) and understanding current patterns of fish distribution in light of changing eelgrass coverage is essential to understanding the functioning of this ecosystem.

The main objectives of this study were to describe and quantify community composition and fish diets collected from eelgrass beds in lower Chesapeake Bay. Using a combination of collection methods, including trawl and trammel nets for fishes and benthic samplers for invertebrates, we collected data on the abundance, distribution, size, and timing of fishes using eelgrass habitats and diet data for both resident fishes and those species periodically using eelgrass habitats.

Methods

Study Site

All work was conducted in lower Chesapeake Bay, USA, specifically in the polyhaline region of the Bay at the mouth of the York River, Virginia (Figure 1). The focus was on sites within the Mobjack Bay/York River Mouth area, as the closer proximity allowed for more frequent sampling, and thus, documentation of seasonal changes on a finer time scale. We selected three sites for our sampling efforts: the northeast side of Goodwin Islands at the mouth of the York River, Browns Bay on the western shore of Mobjack Bay, and Pepper Creek on the eastern shore of Mobjack Bay (Figure 1). The Goodwin Islands site is within the Chesapeake Bay National Estuarine Research Reserve and was selected for the availability of complementary data from ongoing research there. All sites were chosen for their high seagrass coverage, as documented on the Virginia Institute of Marine Science (VIMS) Submerged Aquatic Vegetation Program (SAV Program) interactive maps (http://web.vims.edu/bio/sav/maps.html). All sites were similar in that seagrass coverage is >70% over the majority of the site, diminishing toward the seaward edge. All sites were predominantly eelgrass, *Zostera marina*, with varying amounts of widgeon grass, *Ruppia maritima*, toward the landward/marsh edge. We used the VIMS SAV Program eelgrass maps to determine coverage for the years sampled.

Field Sampling

To describe the distribution and abundance of fishes in lower Chesapeake Bay eelgrass beds, fishes were collected using an otter trawl and a trammel net. The trawl survey was designed to capture mostly eelgrass resident species, while the trammel net sampling was designed to capture larger predators that may be using the seagrass beds more intermittently for foraging. As different usage patterns can occur during the day and at night, we sampled during both diel periods throughout the months of April-October. Intermittent winter samples were collected; however, catches were typically very low.

Trawl sampling was conducted every other week. The 4.9-m otter trawl (2.5-cm mesh wings, with 0.6-cm liner) was towed from a shallow-draft vessel through eelgrass habitats. Each haul was two-minutes in duration and each set was non-overlapping. Boat speed over ground and direction were recorded with a high precision GPS unit (Trimble GeoXT 2005 Series). Fishes were brought onboard and identified, enumerated, and measured (length) in the field. Individuals (mostly juveniles) that could not be field-identified were taken back to the lab for further analysis.

A 185-m trammel net (~2.5 m in height) with 35 cm outer panels and a 6.35 cm inner panel was used for capturing larger, more mobile predators. This sampling was done monthly on high daytime tides, with additional samples being conducted at night several times during the sampling season (also at high tide). The net was deployed by small vessel in a horseshoe shape, beginning on the marsh adjacent to the seagrass bed; the net was deployed out across the seagrass bed and the fishable area was closed by bringing the net to shore. The deployment of the trammel net was similar to the deployment of a beach seine; however, the extensive length of the monofilament trammel net allowed for greater area swept. A high precision GPS was used to draw the area enclosed as the net was being deployed, so that accurate measurements of area swept were available. Fishes were removed from the net as it was pulled onto shore and were processed in the same manner as in the trawl sampling. Two net-sets were conducted at each site per sampling period over the period of highest tide, unless conditions were unfavorable.

Invertebrates were collected from the eelgrass beds monthly to describe relative abundance of invertebrate prey over the sampling season. A combination of invertebrate sampling methods—Virnstein sampler (modified from Virnstein and Howard 1987), plankton tows, and suction samples—were used to account for epifaunal and pelagic invertebrate prey.

Water quality—temperature, salinity, and dissolved oxygen—were measured once (from mid-water) in between trawls or trammel net sets at a given site on a sampling day. Additionally, because *in situ* temperature collection in shallow waters can be highly variable by time of day, seawater temperatures collected from the VIMS/VECOS (Virginia Estuarine and Coastal Observing System) Goodwin Island continuous monitoring station were also downloaded for the sampling periods.

Data were entered on field data sheets and input into a spreadsheet once in the lab; count data were checked by a second researcher.

Data Analysis

Data storage, manipulation, and summary analyses were performed in Microsoft Excel and all statistical analyses were performed in R (R Development Core Team 2011) and Primer (Clarke and Gorley 2006). Summary statistics on distribution, timing, and abundance are provided, as data were mostly observational in nature.

Individual species abundances, for selected common species, were analyzed in R using generalized linear models (GLM, McCullagh and Nelder 1989, R functions *glm* and *glm.nb*). Abundance data were assumed to follow the negative binomial distribution, as suggested for count data with overdispersion, and the log link function was used to relate the observed data to the predictive model.

The categorical factors *month* (calendar month) and *site* (three sampling sites), as well as the continuous variables, *temperature, dissolved oxygen, and salinity*, were used in the analysis. The three water quality parameters were collected in the field at each site/sampling date; in cases where values were missing, data from the Goodwin Island continuous monitoring station (http://www3.vims.edu/vecos/) were used.

Candidate models were evaluated using Akaike's Information Criterion (AIC), where AIC=*-2*log-likelihood + k*npar*, where *npar* is the number of parameters in the fitted model, and $k = 2$. Analysis of deviance was used to validate the model selection.

Community analysis was approached using multivariate non-metric multidimensional scaling (NMDS), an ordination technique, in Primer. Input data were means from replicate hauls on each sampling date at each site. The Bray-Curtis similarity measure was used to generate the resemblance matrix; to account for samples with zero catches, a dummy variable was added to the data matrix to maintain these (mostly winter-time) samples in the analysis. To generate the NMDS plots, 100 random starts were used and 2-d solutions were considered. The analysis of similarity (ANOSIM) procedure was used to test for differences among groups (*data set, month, site*).

Diet data were summarized by species and size class within a species. Biomass data were used for all calculations (as opposed to numeric diet composition). Means for each species/size-class were calculated from full stomachs only.

Results and Discussion

Trawl Surveys

From July 2009 to August 2011, 322 trawl hauls were taken. We measured the distance over ground for each haul using a high precision GPS (Trimble GeoXT 2005 Series); data were post-processed using the "calculate geometry" tool in ArcGIS and we estimated the average area distance swept to be 123.5 m (standard deviation=18.9 m). Thus, the mean area swept was approximately 605 m^2. We collected a total of ~19,000 individual fish from 38 species (Table 1). Additionally, invertebrates such as blue crab (*Callinectes sapidus*), and the shrimps *Crangon septemspinosa* and *Palaemonetes* spp., were collected in the trawl survey. The most commonly occurring and most abundant (based on mean catch per unit effort) fish species were: spot (*Leiostomus xanthurus*), silver perch (*Bairdiella chrysoura*), northern pipefish (*Syngnathus fuscus*), dusky pipefish (*S. floridae*), bay anchovy (*Anchoa mitchilli*), and Atlantic silverside (*Menidia menidia*). These six species made up 94.8% of the total catch. Spot was the most abundant species, comprising 40% of the catch and silver perch accounted for 20.3% of the catch. The only other species contributing to 10% or more of the total catch were bay anchovy (16.5%) and dusky pipefish (10%). The majority of the fish species (32 species) each made up less than 1% of the total catch, indicating that many species were present in low abundances or were not readily captured by our gear. We collected over 2,300 blue crabs; this species had a mean of 7.2 animals per trawl and was collected in over 80% of the trawls performed. It should be noted that a subset of fishes were saved for diet analysis as part of this research; however, over 80% of the animals collected were returned to the water. Incidental mortality tended to be highest during the hot summer months when abundances were high and the catch was primarily small juvenile fishes. We made every attempt to process the catch quickly and return animals to the water alive.

When percent occurrence (the percentage of trawls a species was captured in) was calculated, spot were the most common species, occurring in over 80% of the samples taken, with the two pipefish species (*S. fuscus* and *S. floridae*) the next most commonly occurring species (~62% occurrence for both species). 26 species occurred in less than 1% of the samples collected, again suggesting that the majority of species occur in such low abundances that they are not commonly encountered and/or collected by this gear type in this habitat.

Species richness (SR) was 5.01 (+/- 2.5, range 0-12) for the all samples, and 5.5 for the summer months when SR was highest; variance around SR was greatest in late summer when species that are warm-water visitors to the Bay were collected in the samples. Several species occurred more commonly during particular seasons. For example, spotted hake (*Urophycis regia*) were collected only during months with cold water (e.g. March) and Atlantic spadefish (*Chaetodipterus faber)* were common only during the late summer, when the juveniles occupied seagrass habitats. These patterns of distribution likely reflect preferred water temperatures, but other species may be opportunistically using seagrass beds when prey is abundant or for some other reason.

There were distinct seasonal patterns to fish abundance as well, with peak abundance occurring during the mid-summer months (Figure 2). Young-of-the-year (YOY) spot typically began migrating into the seagrass beds in May or early June, followed by YOY silver perch in July and August, greatly increasing the number of individuals in our trawls. Pipefish (both species) were most abundant during mid-summer when YOY and adult fish were collected in the samples. Despite the general nature of this pattern, there was inter-annual variability for total fish abundance among years (Figure 3, note total abundances for July and August which were sampled in all three years) and within species for the three sampling years as well. Other common species, like bay anchovy and Atlantic silversides showed no distinct recruitment events, like the sciaenids, but were mostly cosmopolitan in their distributions; peak abundance for bay anchovy appears toward the end of the summer and in June for Atlantic silversides.

To better understand the factors driving the distributions of the most common species, we developed a series of generalized linear models for spot, silver perch, dusky pipefish, and northern pipefish. These models were built as described in the methods and included categorical factors (site and month) and water quality parameters (water temperature, salinity, and dissolved oxygen, the latter of which was dropped from all models due to the diel variability of this measurement in these well-mixed, photosynthesizing, shallow habitats). In general, all of the species modeled were at peak abundance in the summer. Thus, we were not surprised that calendar month had more explanatory power than any other variable in the models (Table 2). While temperature added additional explanatory power, it was not as strong as month in explaining variance within the dataset for all species modeled. This finding suggests that life-history strategy may determine timing of fishes in seagrass beds in lower Chesapeake Bay as much as water temperature does, if not more so. It should be noted that the combination of month and temperature did universally explain more variance than month alone. In most cases, the site factor only contributed negligibly to the overall explanation of abundance, suggesting that differences in abundance among sites are minor. Salinity did appear to be an important factor for spot distribution, but not as powerful of an explanatory variable for the other species. While the model showed spot abundance to increase with increasing salinity, a plot of spot abundance versus salinity showed a dome shaped response, with greatest abundances between 16-19 ppt.; thus, the linearized model may not be capturing the true relationship between spot and salinity.

Because YOY fish are such an important component of seagrass beds, which many species use for rearing, we looked at growth over the sampling period by estimating weight from length-weight regressions for select species. Spot, which were the earliest recruits to seagrass habitats and also the most abundant, began appearing in our gear when they were approximately 25 mm or about 0.15 grams in April and May. These fish grew throughout the summer (Figure 4), reaching weights of 15-20 grams by the end of October, when most individuals began exiting the habitat. This growth (~20 g in 175 d) represents daily growth of ~0.1 g per individual). In Figure 4, the mean growth drops from July to August at both Browns Bay and Goodwin Island; the sample sizes for these dates were low (e.g. at Goodwin Island <35 individuals) and only smaller individuals may have been encountered, leading to a smaller mean size during these periods. Alternately, the data may represent two different cohorts, one group of early recruits (those first seen in early May) that were over 100 mm (75 g) at that time period and another group that recruited later (in June) and were less than 100 mm in length (50 g) at that time period. Our observations of spot timing and growth are similar to what was reported by Murdy et al. 1997.

The ability to track growth of species like spot and silver perch—which migrate into seagrass habitats as YOY fish, use the habitat for a period of time, and then migrate out to deeper waters—differs from that for resident species, like the pipefishes, which occupy seagrass habitats continually. While mid-summer recruitment events are evident in our data for these species (e.g., dusky pipefish, Figure 5, black oval), the pattern of growth over the course of the study is less clear, given the lack of sudden cohort recruitment. Additionally, due to the shape of the syngnathiform fishes (long and slender), recruitment to the gear happens at a much larger size

(~60 mm) than for the sciaenids and other species. While we were seeing many syngnathid larvae in our catch bucket during mid-summer, these were individuals that had undergone parturition from the brooding males while in the net, not animals that had recruited to the gear on their own. To better understand the patterns in biomass in these habitats, we evaluated mean biomass at each site over time (e.g., northern pipefish, Figure 6). In Figure 2, we showed that the peak abundance (number of fish) for this species occurred in mid-summer (June-July); in Figure 6, we see that the mean weight drops considerably during this time, indicating the presence of a large proportion of YOY fish in the sample. By utilizing both abundance and biomass data we will better understand the functioning of these systems in terms of production.

While much analysis can be done on individual species from the samples we have taken, we were also interested in community composition at the eelgrass sites. We analyzed community composition across the three sites using non-metric multidimensional scaling, a multivariate ordination procedure, with the main objective being to determine if there were differences among sites. This procedure is advantageous for being able to include full community composition data in the analysis, including rare species, which comprise a large portion of our data. To test for differences between the three sampling sites and across months, geometric means from each sampling date were used as input data. The resulting NMDS analysis (from 100 random starts) had a stress (measure of model fit) of 0.15, considered a reasonably good model fit for the data (Figure 7). Analysis of similarity (ANOSIM) was used to test for differences among sites (Global R=-0.031, significance=0.78) and dates (Global R=0.584, significance=0.001). As would be expected from the summary plots alone, there was a significant difference between sampling months. However, there was no significant difference in community assemblage across the three sites. We also conducted a nested ANOSIM analysis (Site within Month) to account for the monthly variation and found that the results were the same: no differences among sites (Global R=-0.071, significance=0.749), suggesting that fish communities (as sampled by small trawl) are similar across the three lower Chesapeake Bay eelgrass beds in our study, even when seasonality is accounted for.

While not one of our primary objectives for this project, the robustness of our trawl data allowed for comparison to similar data which were collected in the late 1970s (Orth and Heck 1980). A manuscript with complete methods of analytical procedures and results is currently in preparation. In short, we found that there were significant community changes over time

(ANOSIM results showed dataset—1970s or present—to be a significant factor and species richness declined over the 30+ year period, when modeled using general linear models. Additionally, species abundances were different between the two data sets, with the prevalence of the two pipefish species changing over time (northern pipefish more commonly occurring and abundant in the historical survey and dusky pipefish more commonly occurring and abundant in our survey). Some species, which were formerly regularly caught (e.g., winter flounder, *Pseudopleuronectes americanus*), were not seen at all in our survey, despite more robust sample size; conversely, species such as kingfish (*Menticirrhus* spp.) and Atlantic spadefish were very common in our survey (see Table 1), but were not collected in the previous survey. Interestingly, an analysis of eelgrass areal coverage showed that the density and coverage of eelgrass within the study area was largely unchanged from the late 1970s to present, despite loss from some of the deeper regions; it should be noted that the interim period (1990s) had more extensive eelgrass coverage than either study period and we have seen declines in coverage in recent years. Also, while we detected changes over time in the fish community, the same six species that made up the majority of the catch in our present survey dominated the historical survey as well, indicating that there may be some stability among the more dominant species, despite changes in Chesapeake Bay as a whole.

Trammel Net Surveys

Trammel net collections were undertaken twice monthly during the 2010 summer sampling season. When conditions allowed, two consecutive but non-overlapping sets were made. On several occasions, we were only able to make one set due to weather conditions, processing time, or gear fouling. We analyzed the sites/dates where two sets had been made (n=6) using NMDS with ANOSIM to test for differences between hauls (first or second) to determine if there was a significant difference in community composition between the two sets (we hypothesized that catch in the second set may be reduced due to disturbance from the first set; NMDS stress=0.10 indicating a good model fit, ANOSIM Global R=-0.056, significance=0.608). Because there was no set effect, we used means from the two sets in our analysis. We measured the area swept for each haul using a high precision GPS (Trimble GeoXT 2005 Series) and estimated the average area encompassed to be 255 m.

We collected a total of 1600 individuals of 26 species in 21 unique net sets. Croaker (*Micropogonias undulates*), spot, hogchoker (*Trinectes maculatus*), and gizzard shad (*Dorosoma cepedianum*) were the predominant fish species, with summer flounder (*Paralichthys dentatus*), bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*), and striped mullet (*Mugil cephalus*) also caught frequently, but in lower abundances (Table 2). Only 5 species occurred in more than 50% of the samples, 12 occurred in more than 25% of the samples, and 8 were rare, occurring in less than 10% of the samples (Table 3). In addition, we captured a number of blue crab and diamondback terrapin (*Malaclemys terrapin*); while not the target species, these animals often got caught in the monofilament line of the net and were released alive.

Net sets were performed during the day and at night. While daytime (n=15) and nighttime (n=6) samples showed similar species occurrence and similar species richness (day mean=8.6, night mean=10.0), it appeared that nighttime samples had higher abundances (mean abundance across all samples, day=68.1 individuals and night=106.5 individuals); however, when tested with a two-sample *t*-test, there was no significant difference between diel periods ($p<0.1195$). In general, mean abundances were highly variable (min=9 individuals caught, max=253 individuals, mean=79.1) and additional samples may elucidate diel patterns.

Mean species richness was higher in the trammel net survey than in the trawl survey, despite the lesser area swept. There was a mean of 9.0 species per haul compared to a mean of 5.5 species (summer months only) in the trawl survey; the minimum number of species was 4 (Browns Bay in June) and the maximum 15 (Goodwin Island at night in September). There was no significant difference in species richness between sites (ANOVA, $p<0.798$). The deployment technique for the net, where we enclosed an area, allowed us to capture species that would have escaped from or evaded a trawl. Despite the difficulties with gear setting and retrieval, the method did prove successful for capturing larger fish and some species that were not encountered by the trawl.

Fish distribution and abundance from trammel net collections at all three sites was compared using NMDS (Bray-Curtis similarity). A two-dimensional solution with final stress of 0.13 was the best model fit (Fig. 8). Community composition among sites and months was compared using the ANOSIM procedure. As with the trawl data, no difference in community composition was found among the three sites (Global R=0.012, significance=0.438). Additionally, there was no difference in community composition across the months sampled

(June-October, Global R=0.201, significance=0.103). This result is different than that for the trawl survey, which did show seasonal (monthly) differences in community composition. Perhaps because there were fewer rare species in the trammel net survey, community composition appeared largely stable over time using the Bray-Curtis distance measure (which tends to accentuate rare species and down-weight common species) in the NMDS procedure (Clarke and Gorley 2006).

In the trawl survey, we were able to observe recruitment and growth of some species over the sampling season. The trammel net sampling was not as frequent, but even so, there did not appear to be much variation in the size of the fish caught across the summer months (e.g. croaker, Figure 9). In part, the gear is selecting for specific sized individuals, but additionally, the larger fishes collected by this gear type may not be using this habitat specifically for rearing; it is likely that seagrass habitats are just one of many habitat types these animals encounter and inhabit.

Diet Analysis

To date, we have analyzed over 500 stomach samples from 34 species of fish, with several hundred more still to analyze. Fish gut samples were collected from both trawl and trammel net surveys, so for several species, such as spot and summer flounder, a wide range of sizes are included in the data base.

While stomach contents are highly variable by species, there are some generalities to be made. Prey diversity was very high with over 85 taxa represented in the samples. However, most of these taxa occurred very rarely, with over half appearing in less than 1% of the samples collected. One of the largest components in the fish guts was unidentified material; this is common in fish diet analysis because the material within the stomach has been subjected to digestion for differing periods of time, and the more digested the contents are, the more difficult identification is. While only appearing in a small proportion of stomachs (~10%) bivalve clams and their siphons were abundant (by biomass). The mysid shrimp, *Americamysis bigelowi* and *Neomysis americana* were common by percent occurrence and biomass. Where identification was possible, *A. bigelowi* was the dominant species. The isopods *Erichsonella attenuata* and *Idotea baltica* and gammarid and caprellid amphipods were also important prey items.

Diets for individual species are summarized in Table 4. For each species/size-class the total number of stomachs analyzed and the number of empty stomachs are provided. Many species are not included because the sample sizes are too low for meaningful analysis. For some species, like the pipefishes, there was little difference in diet across size classes, so the mean percent biomass was used across all data. Other species showed ontogentic shifts in diet (summer flounder and croaker) and diets were summarized by size classes. Not all size classes have been processed for all species; however, work is ongoing and we hope to have a full diet matrix for the species collected at the culmination of the analysis.

Mysids were an important prey item across species. Most of the diet samples were collected in the trawl gear, which resulted in small sized fishes (<150 mm). While larval or juvenile fishes were present in some diets, most of these smaller fish were eating mysids and other crustaceans, such as amphipods, isopods, and shrimps. The larger fishes, which were collected in the trammel net, were much more piscivorous. Bivalves and bivalve siphons were also important prey items, especially among the sciaenids. Only bay anchovy preyed extensively on zooplankton, including copepods and diatoms. In evaluating diets, it's important to keep in mind that there is wide variation in diet, even within a species/size-class. In some cases, one fish was full of a given prey, but the other samples from that pool were not eating that prey; even so, that prey will have a high mean percent biomass among the whole sample pool. The remaining samples will help elucidate the primary prey species; additionally, we hope to tease out prey switching due to diel periods or time of the year as the data allow.

Tagging Studies

In both 2010 and 2011, we conducted tagging studies to evaluate survival and growth of silver perch. This species was selected because of its use of seagrass habitats for rearing for a finite period of time in the mid-summer. A pilot study was initiated in 2010 where silver perch young-of-the-year (YOY, beginning at 35 mm) were marked with sequential individual coded wire tags (Northwest Marine Technology, Shaw Island, WA) weekly beginning in July, when YOY recruited to the Goodwin Island eelgrass bed. We marked about 600 fish, hoping for a recovery rate of about 2% (previously shown by Miller and Able 2002). We planned to use a Cormack-Jolly-Seber model (Pledger et al. 2003, Lebreton et al. 1992, Pollock et al. 1990), designed for open populations (but where the scientist acts as the fisher) to model apparent survival (Pine et al. 2003). We also used individual coded wire tags on a subset of fish at Browns Bay measure growth (change in length over time) in individual fish during the fish's time at-large (due to tag constraints for small (< 75 mm) juvenile fish, two separate tagging studies were necessary: one for survival and one for growth). We based the timing of the tagging study on our 2009 data, which showed silver perch recruiting to seagrass habitats in July, rearing for several months, and leaving the habitats as the water cooled in September and October. Unfortunately, 2010 was a very warm summer (with water temperatures routinely around 32°C in these shallow areas) and silver perch abundances began falling off in late July; by mid-August there were very few silver perch remaining in the seagrass beds and we failed to recapture any of our marked fish.

In 2011, we again tried a tagging study, but switched technologies to a batch-mark using visible implant elastomer tags (Northwest Marine Technologies, Shaw Island, WA), with the sole objective of estimating survival. These tags are essentially a colored, two-part epoxy-like material that is injected into the dorsal area of a fish. We aimed to tag about 2000 individuals and again conducted this study at the Goodwin Islands site. We began tagging the early recruits in late-June and continued through July, tagging approximately 700 fish over 5 weeks; silver perch catch-per-unit-effort (i.e., number of fish in each trawl) was much lower than in the previous two years and we had difficulty tagging the number of fish we hoped. Additionally, as in 2010, silver perch abundances rapidly declined, perhaps owing to warm water temperatures or some other factor (Figure 10). We recaptured only three fish, each of which had been at large one week or less, which is insufficient for generating the survival model. We may attempt this type of study again in 2012 if conditions seem favorable, but daily tagging and recovery efforts may be necessary.

Conclusions

The data collected as part of this study provides insight into patterns of use, occurrence, and abundance of the small mobile fishes using seagrass beds in lower Chesapeake Bay. Many of these species have been documented as prey items for commercially and recreationally important species like summer flounder (*Paralichthys dentatus*) and speckled trout (*Cynoscion nebulosus*). In fact, silver perch, one of the most abundant fishes in our surveys, was observed as prey for both of these species. Most of the fish stomachs we have analyzed to date were from smaller fishes captured in the trawl gear; they show mysids, amphipods, bivalve siphons, and isopods, as well as hydroids, to be important prey items. While mysids are common in many habitats, juvenile blue crabs and amphipods and isopods are particularly tied to seagrass habitats and provide an important trophic link to fishes. The sand shrimp (*Crangon septemspinosa*) is a common eelgrass inhabitant and appeared as an important diet item for several species.

In terms of abundance and distribution, the patterns we observed were similar to studies done previously (Orth and Heck 1980), with spot, silver perch, dusky pipefish, northern pipefish, bay anchovy and Atlantic silverside as the most common species, making up over 90% of the total catch. However, some species, like Atlantic spadefish and kingfish appear to be found in greater abundances now than in the past. Whether these species are taking advantage of warming water (and prolonged periods where water temperatures are favorable) or if there increased abundances reflect variability remains to be seen. Similarly, it appears the dominant pipefish species may be changing, with dusky pipefish (*Syngnathus floridae*) more prevalent now than in the past, when northern pipefish (*S. fuscus*) was the more abundant species. It is these types of observations that validate the importance of periodic monitoring in lower Chesapeake Bay seagrass habitats.

The data from this study will be used in other on-going explorations of trophic transfer in seagrass systems. For example, a food-web model, specific to these habitat types will be constructed from the occurrence and abundance data, as well as the diet matrix that will result from the gut content analysis. While the samples were collected as part of this project, the laboratory and data analysis is ongoing. The food-web model will be used to simulate if changing eelgrass coverage (and the associated prey fauna) has impacts to fishes that use these habitats for rearing or as primary habitat.

The data produced from this study provide a much-needed update of information about basic use of shallow-water vegetated habitats. These habitats are inaccessible to larger vessels conducting long-term monitoring of fishes in Chesapeake Bay, yet their high levels of primary and secondary productivity and general decrease in areal coverage in recent years suggests that an understanding of how fishes using these systems are impacted by changes is necessary to fully understand fisheries in Chesapeake Bay.

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Table 1. Species, total numbers collected, and percent occurrence by trawl gear.

Species Common Name	Species Scientific Name	Total Catch	Percent Occurrence
American Eel	*Angullia rostrata*	15	0.03
Atlantic Silverside	*Menidia menidia*	239	0.20
Atlantic Spadefish	*Chaetodipterus faber*	54	0.10
Bay Anchovy	*Anchoa mitchilli*	3148	0.47
Black Sea Bass	*Centropristis striata*	11	0.03
Bluefish	*Pomatomus saltatrix*	1	0.00
Chain Pipefish	*Syngnathus louisianae*	10	0.03
Croaker	*Micropogonias undulatus*	42	0.07
Dusky Pipefish	*Syngnathus floridae*	1915	0.62
Feather Blenny	*Hypsoblennius hentz*	12	0.04
Florida Pompano	*Apeltis quadricus*	1	0.00
Gag Grouper	*Mycteroperca microlepis*	1	0.00
Gray Snapper	*Lutjanus griseus*	1	0.00
Hogchoker	*Trinectes maculatus*	92	0.17
Kingfish	*Menticirrhus saxatilis*	154	0.21
Lined Seahorse	*Hippocampus erectus*	13	0.03
Mummichog	*Fundulus heteroclitus*	125	0.09
Naked Goby	*Gobiosoma bosc*	20	0.06
Northern Pipefish	*Syngnathus fuscus*	1294	0.62
Northern Puffer	*Sphoeroides maculates*	97	0.21
Northern Searobin	*Prionotus carolinus*	2	0.01
Northern Stargazer	*Astroscopus guttatus*	1	0.00
Oyster Toadfish	*Opsanus tau*	1	0.00
Pigfish	*Orthopristis chrysoptera*	14	0.04
Pinfish	*Lagodon rhomboides*	12	0.03
Rainwater Killifish	*Lucania parva*	5	0.01
Red Drum	*Sciaenops ocellatus*	23	0.03
Silver Perch	*Bairdiella chrysoura*	3889	0.55
Skilletfish	*Gobiesox strumosus*	33	0.05
Southern Stingray	*Dasyatis americana*	4	0.01
Speckled Trout	*Cynoscion nebulosus*	49	0.10
Spot	*Leiostomus xanthurus*	7640	0.78
Spotted Hake	*Urophycis regia*	17	0.03
Striped Bass	*Morone saxatilis*	16	0.03
Striped Blenny	*Chasmodes bosquianus*	25	0.08
Striped Burrfish	*Chilomycterus schoepfii*	20	0.07
Summer Flounder	*Paralichthys dentatus*	45	0.14
Weakfish	*Cynoscion regalis*	76	0.04

Table 2. GLM model comparison for common species in the trawl survey. Bolded models are considered the best candidate model(s) for each species.

Species	Models	# of Parameters	AIC	Δ AIC
Spot	**Y ~ Month + Site + Temp + Sal**	**6**	**1979.9**	
Leiostomus xanthurus	Y ~ Month + Temp + Sal	5	1987.2	7.3
	Y ~ Site + Month + Sal	5	2007.8	27.9
	Y ~ Site + Month + Temp	5	2013.3	33.4
	Y ~ Month + Temp	4	2019.1	39.2
	Y ~ Month	3	2034.6	54.7
	Y ~ Site + Temp + Sal	5	2227.2	247.3
Silver Perch	**Y ~ Month + Temp**	**4**	**1435.4**	
Bairdiella chrysoura	**Y ~ Month + Temp + Sal**	**5**	**1436.3**	**0.9**
	Y ~ Site + Month + Temp	5	1438.9	3.5
	Y ~ Month + Site + Temp + Sal	6	1440	4.6
	Y ~ Month	3	1440.4	5
	Y ~ Site + Month + Sal	5	1441.8	6.4
	Y ~ Site + Temp + Sal	5	1516.7	81.3
Dusky Pipefish	**Y ~ Month + Site + Temp + Sal**	**6**	**1457.6**	
Syngnathus floridae	**Y ~ Month + Temp + Sal**	**5**	**1458.1**	**0.5**
	Y ~ Site + Month + Temp	**5**	**1459.1**	**1.5**
	Y ~ Month + Temp	4	1460	2.4
	Y ~ Month	3	1462	4.4
	Y ~ Site + Month + Sal	5	1462.7	5.1
	Y ~ Site + Temp + Sal	5	1520.8	63.2
Northern Pipefish	**Y ~ Site + Month + Sal**	**5**	**1198.7**	
Syngnathus fuscus	**Y ~ Month + Site + Temp + Sal**	**6**	**1200**	**1.3**
	Y ~ Month + Temp + Sal	5	1203.4	4.7
	Y ~ Site + Month + Temp	5	1204.8	6.1
	Y ~ Month + Temp	4	1208.2	9.5
	Y ~ Month	3	1209.4	10.7
	Y ~ Site + Temp + Sal	5	1312.1	113.4

Table 3. Species, total numbers collected, and percent occurrence by trammel net gear.

Species Common Name	*Species Scientific Name*	*Total Catch*	*Percent Occurrence*
Atlantic Horseshoe Crab	*Limulus polyphemus*	2	0.10
Atlantic Menhanden	*Brevoortia tyrannus*	48	0.24
Atlantic Spadefish	*Chaetodipterus faber*	28	0.24
Atlantic Thread Herring	*Opisthonema oglinum*	16	0.05
Black Drum	*Pogonias cromis*	1	0.05
Blue Crab	*Callinectes sapidus*	380	0.95
Bluefish	*Pomatomus saltatrix*	10	0.33
Butterfish	*Peprilus triacanthus*	2	0.05
Cownose Ray	*Rhinoptera bonasus*	20	0.48
Crevalle Jack	*Caranx hippos*	3	0.05
Croaker	*Micropogonias undulatus*	408	0.71
Diamondback Terrapin	*Malaclemys terrapin*	33	0.48
Gizzard Shad	*Dorosoma cepedianum*	332	0.52
Hogchoker	*Trinectes maculatus*	85	0.62
Houndfish	*Tylosurus crocodilus*	5	0.19
Lookdown	*Selene vomer*	1	0.05
Northern Puffer	*Sphoeroides maculates*	3	0.10
Silver Perch	*Bairdiella chrysoura*	1	0.05
Southern Stingray	*Dasyatis americana*	14	0.33
Speckled Trout	*Cynoscion nebulosus*	11	0.19
Spot	*Leiostomus xanthurus*	194	0.86
Striped Bass	*Morone saxatilis*	15	0.43
Striped Burrfish	*Chilomycterus schoepfii*	2	0.05
Striped Mullet	*Mugil cephalus*	16	0.33
Summer Flounder	*Paralichthys dentatus*	30	0.48
Weakfish	*Cynoscion regalis*	1	0.05

Table 4. Diet summary for selected species and size classes. Values are mean percent biomass for each size bin.

Species	*Length Bins (mm)*	*# Sampled*	*# Empty*	*UID Material*	*Weakfish*	*Spot*	*Silver Perch*	*Killifish*	*Smallmouth Flounder*	*Bay Anchovy*	*Atlantic Silverside*	*UID Fish*	*Mysids*	*Portunid crab*	*Blue Crab*	*Juv. Blue Crab*	*Crustaceans (copepods, cumacenas, other)*	*Amphipods*	*Shrimps (Crangon, Palaemonetes)*	*Bivalves*	*Bivalve Siphons*	*UID Polychaete*	*Vegetation/Hydroids/Other*
Summer Flounder	100-200	7	1		0				0			0	0.5	0	0	0.2	0						0.3
Summer Flounder	200-300	5	1				0.2	0.1				0.2	0.1	0.3									0.2
Summer Flounder	300+	2	0			0.5						0	0.4	0.1									0
Atlantic Croaker	200-250	7	2	0.6																0.2			0.2
Atlantic Croaker	250-300	13	4	0.3																0.5	0.1		0.1
Atlantic Croaker	300-350	7	3																	0.3		0.3	0.4
Atlantic Croaker	350-400	2	0														0.5					0.5	
Northern Puffer	75-150	10	1	0.2										0.1	0.2		0.1						0.5
Weakfish	40-75	30	5	0.2						0			0.7				0					0.1	
Spot	30-80	17	4	0.3													0.2				0.3	0.1	0.1
Spot	80-120	82	12	0.6													0			0	0.1	0	0.1
Spot	180-223	16	6	0.6										0.1						0.1		0	0.3
Speckled Trout	25-35	4	1									0.3	0.7										
Speckled Trout	170	1	0				100																
Bluefish	200-300	4	2								100												
Kingfish	30-55	9	1	0.1									0.8					0.1					0.1
Kingfish	60-90	8	0	0.1									0.2		0		0.1			0.1	0.3		0
Kingfish	110-125	2	0	0.5									0								0.5	0	
Atlantic Spadefish	25-65	13	1	0.7																	0		0.3
Atlantic Spadefish	65-90	18	1	0.5																	0.1		0.1
Atlantic Spadefish	90-120	3	0	0.3																	0.4		0.3
Bay Anchovy	40-80	48	15	0.4									0.1				0.5						0.1
Northern Pipefish	75-185	28	2	0.2													0.3	0.6					
Dusky Pipefish	100-130	24	0	0													0.1	0.6	0.3				
Silver Perch	20-45	18	6										0.7				0.2	0.7					
Silver Perch	50-80	26	0	0.1									0.8					0.1					
Silver Perch	80-120	20	1									0	0.5	0.1			0.2	0.1	0.1			0	
Silver Perch	130-155	10	6	0.2													0.3	0.3	0.3				
Hogchoker	25-30	2	0	0.8																			0.2
Hogchoker	75-135	31	11	0.4																	0.5	0.2	

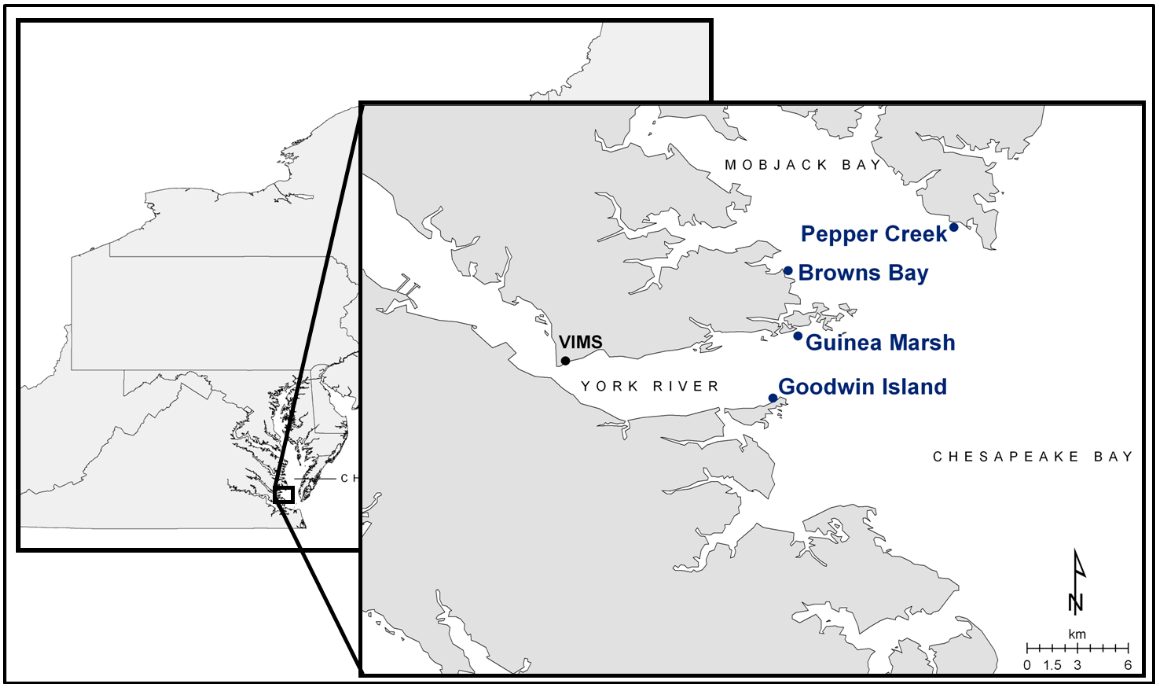

Figure 1. Map of lower Chesapeake Bay, York River mouth and Mobjack Bay study area. Study sites were Browns Bay Pepper Creek, and Goodwin Island. Additional data from Guinea Marsh was used for comparison.

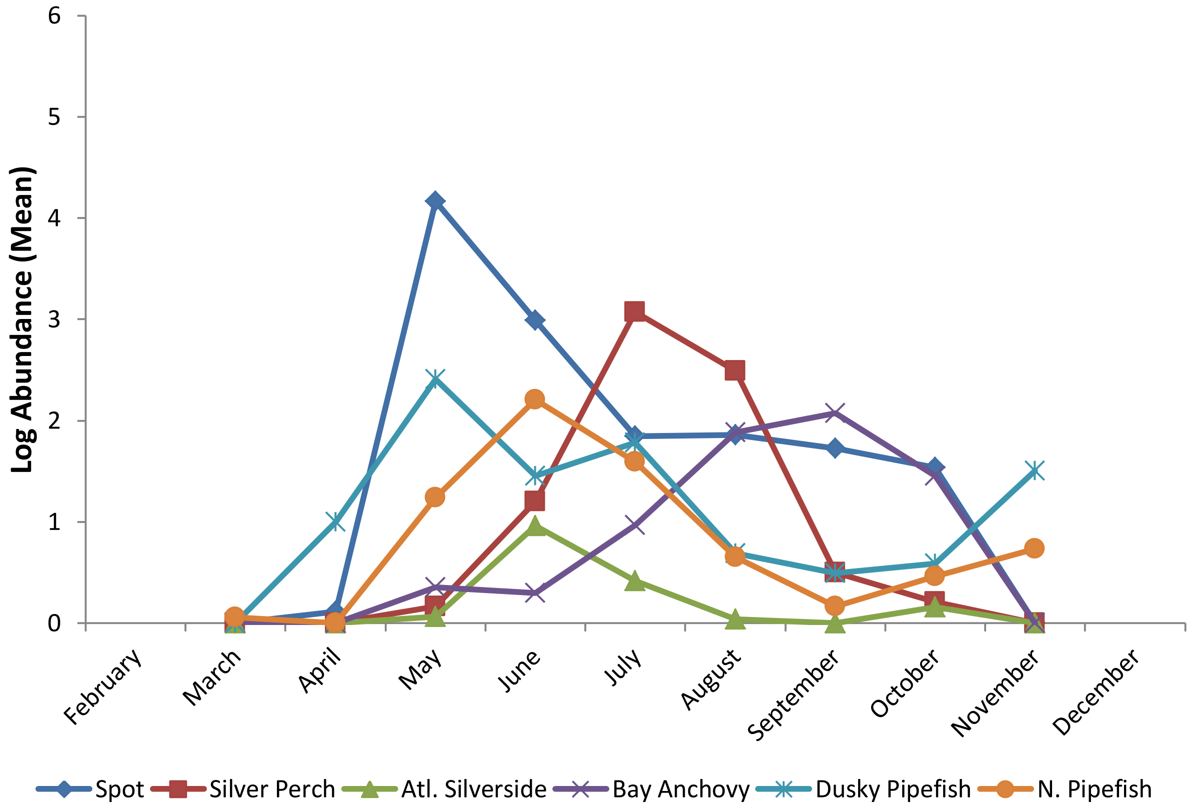

Figure 2. Mean abundances for the most common fish species over the sampling months; all values are means across all sampling years. Abundances are on the log scale.

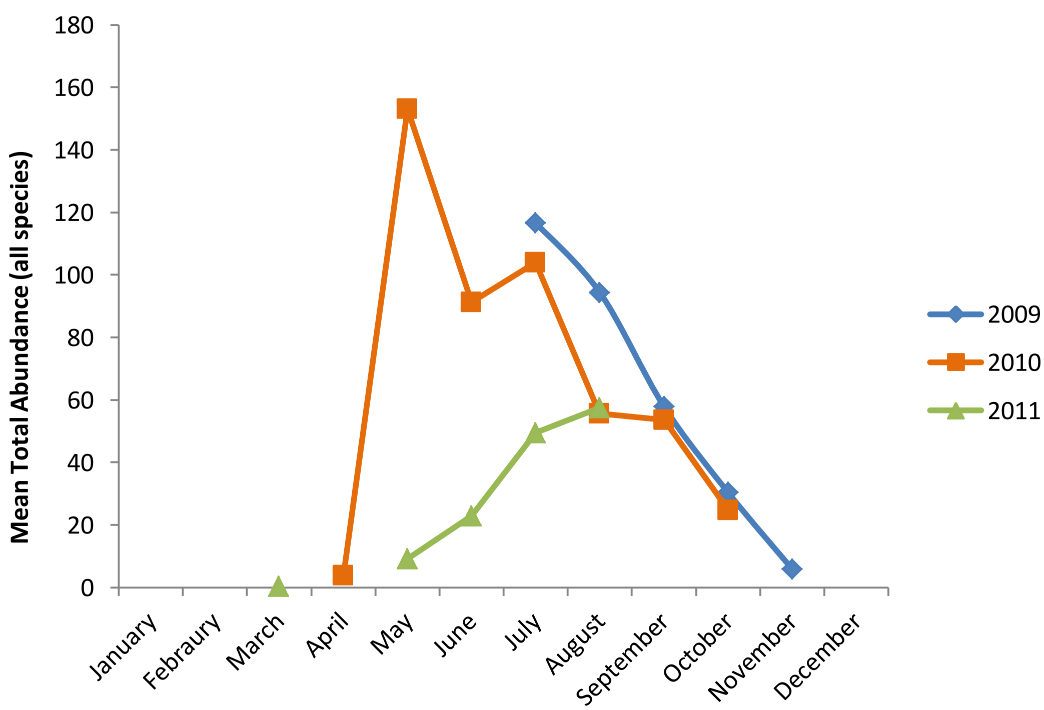

Figure 3. Seasonal changes in abundance (of all species combined) during the three sampling seasons. Note that only July and August were sampled in all three years and that mean total abundance varied considerably.

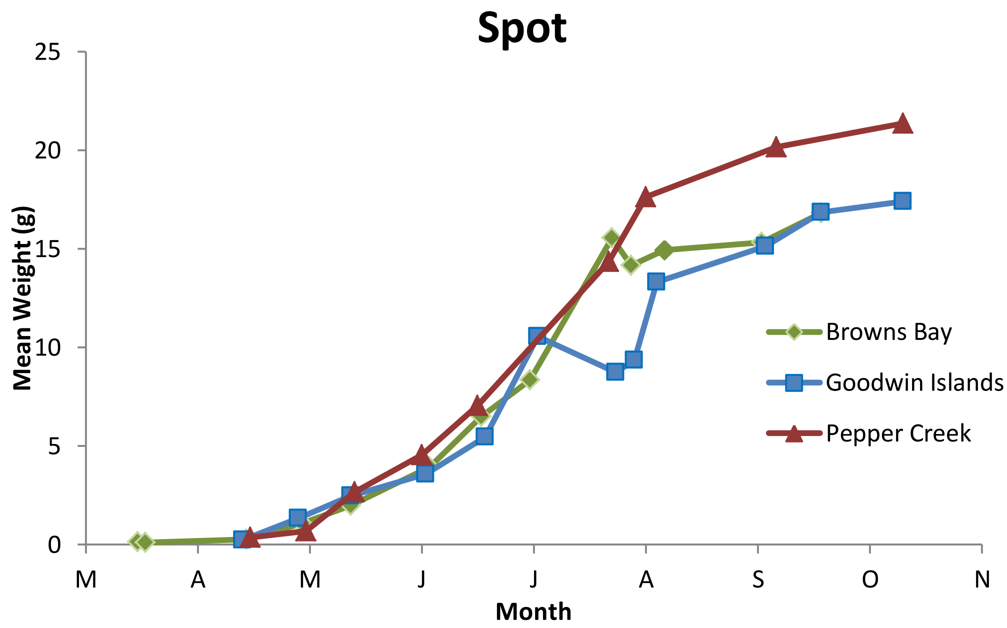

Figure 4. Mean spot weight (g) over the 2010 sampling season. Note that the dips in weight at Goodwin Islands and Browns Bay are likely attributed to a second cohort recruiting to the survey.

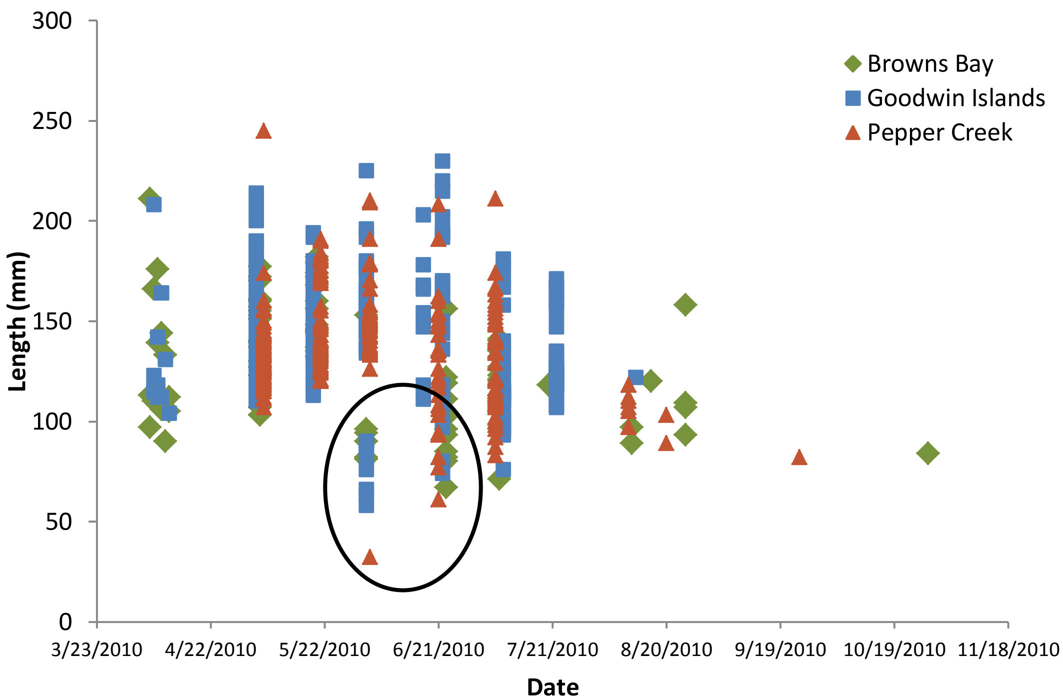

Figure 5. Length frequency of dusky pipefish (*S. floridae*) at the three sampling sites over the 2010 sampling season. The black oval shows a period of recruitment, with smaller sub-adult fish appearing in the samples.

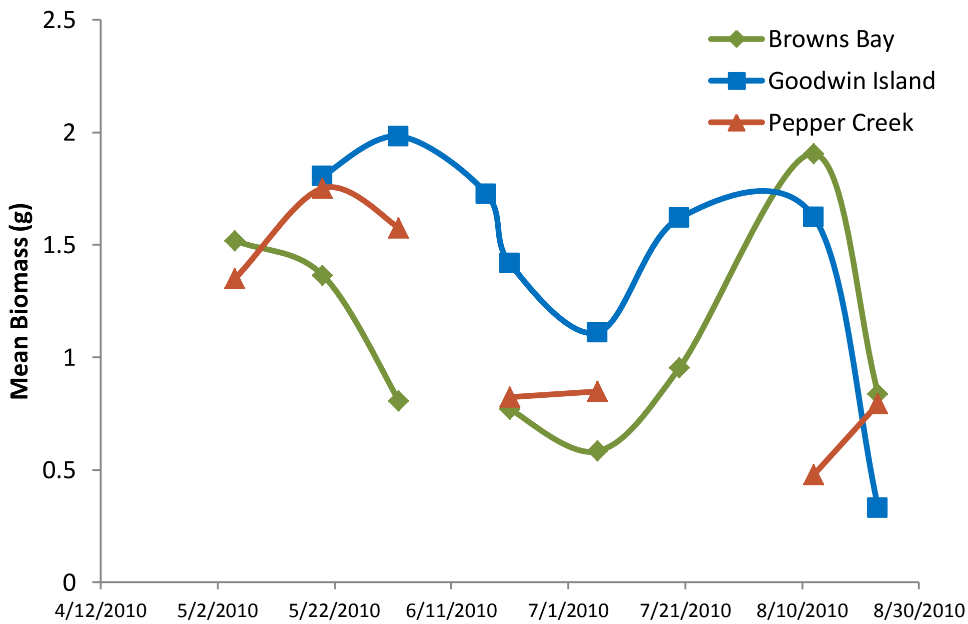

Figure 6. Mean biomass of individual northern pipefish (*S. fuscus*) over time. The lower mean biomass in June and July corresponds with the higher number of individuals during this same period (as seen in Fig. 2), illustrating the influence of YOY individuals during this time.

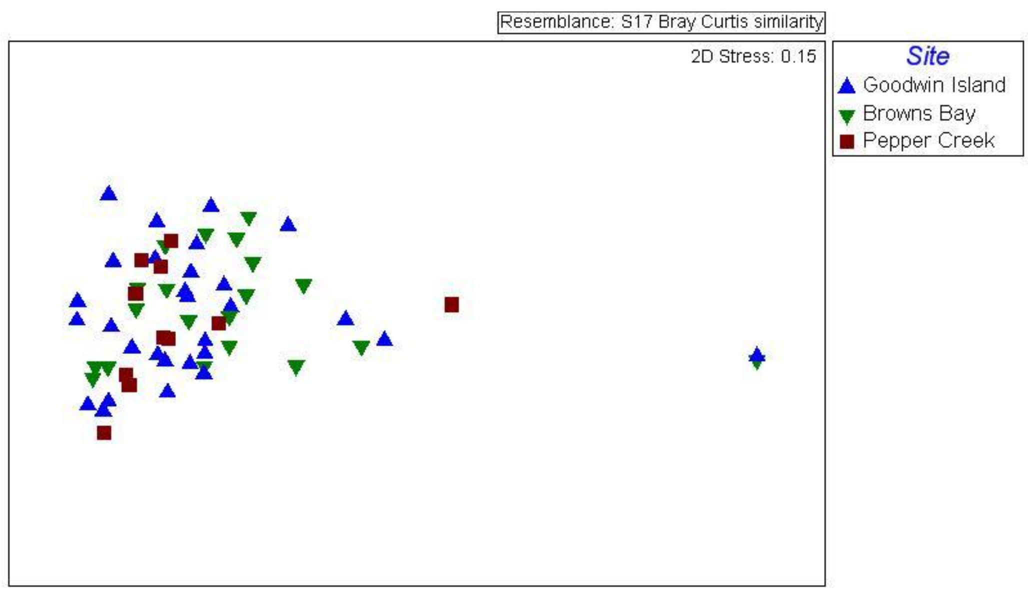

Figure 7. NMDS plot for comparison of fish community structure (trawl data) among sites. ANOSIM showed there to be no significant difference between sites.

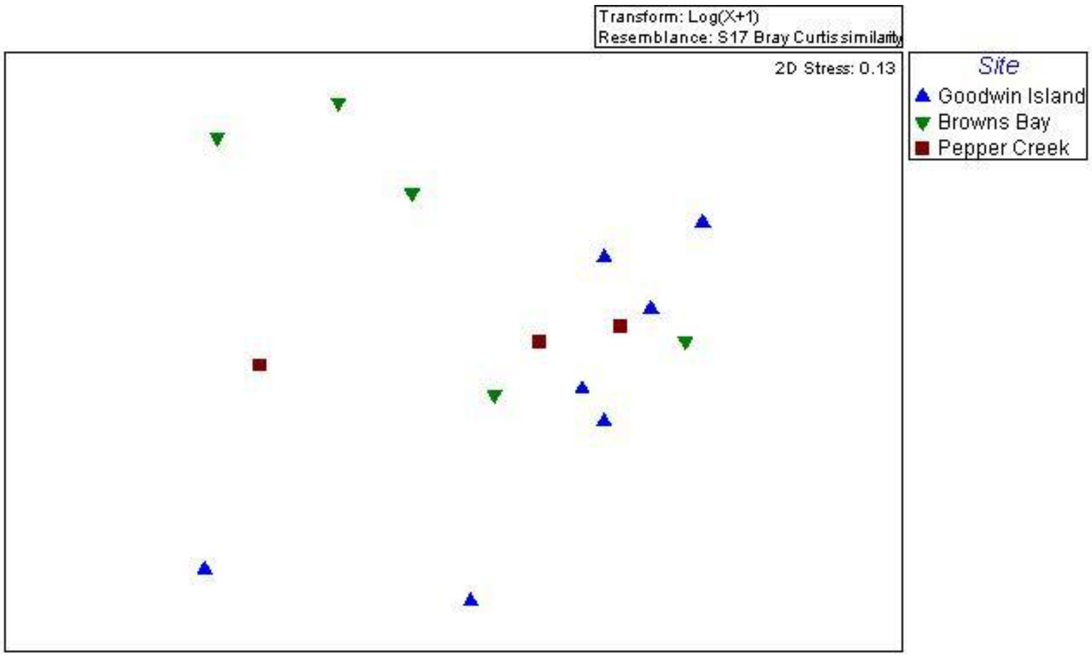

Figure 8. NMDS plot for comparison of fish community structure (trammel net data) among sites. ANOSIM showed there to be no significant difference between sites.

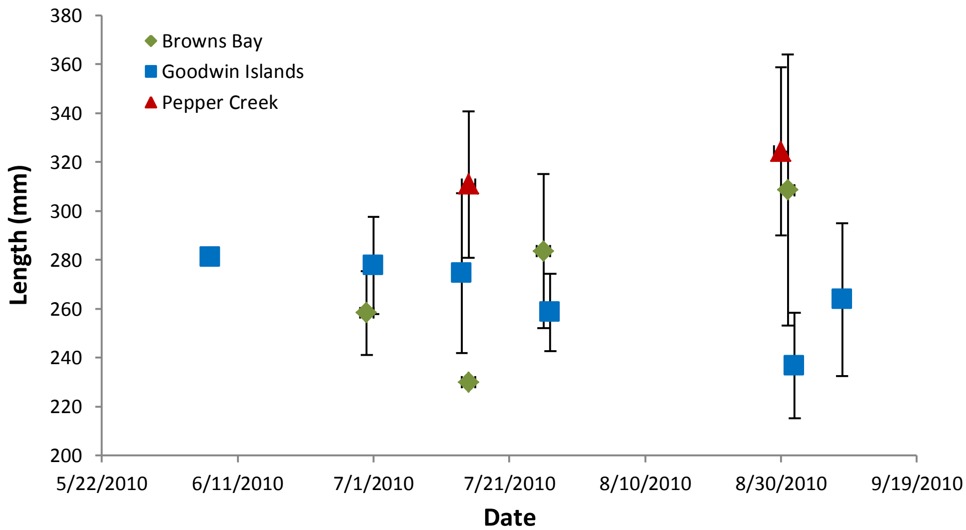

Figure 9. Mean length of croaker across the sampling season at the three sites. Error bars show standard deviation.

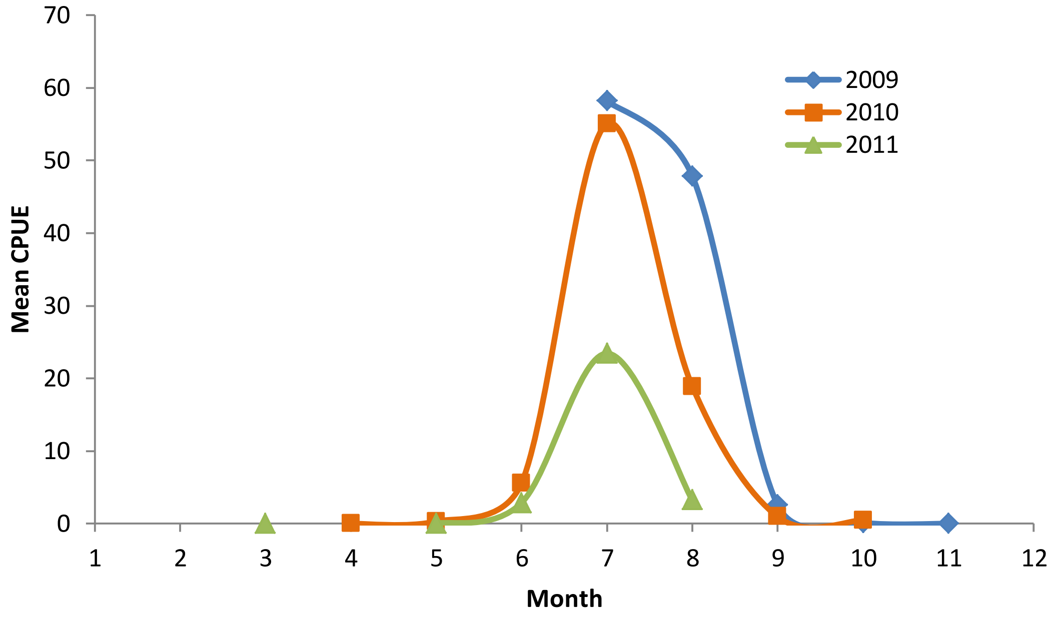

Figure 10. Silver perch mean catch per unit effort for the three sampling years. Note the low abundance in 2011.