Macrofaunal assemblages on oyster aquaculture and rock reef habitat in Long Island Sound

Renee Mercaldo-Allen[1]*, Paul Clark[1], Yuan Liu[1, 2], Shannon Meseck[1],
Lisa Milke[1], Dylan Redman[1]

[1]NOAA Fisheries, Northeast Fisheries Science Center,
Milford Laboratory, 212 Rogers Avenue, Milford CT 06460, USA

[2]Integrated Statistics, 16 Sumner Street, Woods Hole, Massachusetts 02543, USA

RUNNING PAGE HEAD: macrofauna within oyster aquaculture and reef habitats

Abstract

Trap sampling was used to survey relative abundance of juvenile fish and invertebrates near three habitats including an off-bottom oyster cage farm (cage farm), a traditional on-bottom oyster culture area (shell bottom), and a natural cobble and boulder reef (rock reef) in a coastal embayment in Long Island Sound near Milford, CT. Ten traps, deployed on two subsites within each habitat (20/habitat), were allowed to soak for ~24 hours, 2-3 times per week, from June through September 2016. Juvenile finfish assemblages appeared similar on the cage farm and rock reef while composition of the invertebrate community was more variable among the three habitats. These preliminary observations suggest that oyster cage farms may provide functional habitat populated by structure-oriented finfish communities similar to those found on natural rock reefs in Long Island Sound.

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* Corresponding author: renee.mercaldo-allen@noaa.gov

Aquaculture of the Eastern Oyster *Crassostrea virginica* in coastal Connecticut is conducted primarily using traditional on-bottom culture on leased shellfish beds, where live shellfish and shell cultch are distributed on sediments for grow-out and spat collection. Oysters and shell on substrate add complexity to low relief areas and create a hard bottom irregular surface on otherwise featureless seafloor (Dumbauld et al. 2009). Many species of juvenile fish associate with the cover provided by shell bottom (e.g., Auster et al. 1991; Able et al. 1995), where spaces among and between oysters and empty shell valves may provide respite from current and wave action (Meyer and Townsend 2000). Shellfish that serve as attachment surfaces for sessile invertebrates may enhance prey resources for ecologically important fish and crustacean predators (Arve 1960; Ozbay et al. 2014; Lehnert and Allen 2002). Some adult fish that mature at smaller sizes are known to spawn on subtidal shell bottom (Crabtree and Middaugh 1982). Habitat afforded by oysters and shell may provide critical refuge and resources for small organisms and young fish in areas where biogenic features are otherwise limited.

More recently, use of three-dimensional off-bottom aquaculture cages has increased in popularity, allowing growers to raise more oysters on a smaller footprint. Composed of a wire framework and containing mesh bags or trays of oysters, these cages add vertical structure and surface area to low relief seafloor. Anecdotal observations by shellfish growers have reported fish interacting with the structure provided by submerged oyster aquaculture cages. Over time, the surface of multi-tiered cages become colonized by epibenthic, emergent, and encrusting organisms, which may provide fish with camouflage and shelter, refuge from predation, respite from high current flow, and a food source (Shumway et al. 2003; DeAlteris et al. 2004; Dumbauld et al. 2009; Ozbay et al. 2014). Microenvironments created by cage farms may concentrate prey resources for foraging fish (Ozbay et al. 2014) and serve as nurseries for new recruits (Erbland and Ozbay 2008). Aquaculture gear, which remains on the seafloor for extended periods, may increase carrying capacity within an ecosystem (DeAlteris et al. 2004). Single oyster cages represent discrete and highly localized sources of structure (Erbland and Ozbay 2008) that may be important in areas with little natural seafloor relief. Clusters of cages on shellfish farms augment existing habitat and may boost abundance and diversity of commercially and recreationally important fish species (e.g., DeAlteris et al. 2004; Erbland and Ozbay 2008; Marenghi et al. 2010).

Studies suggest that oyster cages may offer attractive habitat to fish species associated with hard bottom environments (e.g., Tallman and Forrester 2007; Erbland and Ozbay 2008; Ozbay et al. 2014). Two studies in New England estuaries have compared aquaculture gear to natural seafloor as habitat for fish and other organisms. In Point Judith Bay, Rhode Island, DeAlteris et al. (2004) used a combination of lift-nets, quadrat sampling of sessile invertebrates, drop-nets, and a suction dredge to assess organisms associated with oyster cages, submerged aquatic vegetation, and non-vegetated seabed. They reported species richness and abundance near oyster cages similar to that of submerged aquatic vegetation and greater than that of non-vegetated seabed. Another Rhode Island study by Tallman and Forrester (2007) used trapping to evaluate relative fish density among oyster cages, natural rock reefs and an artificial reef in Narragansett Bay. These authors found that oyster cages, while providing suitable habitat for reef fish, contained fish assemblages that differed in composition from rock reef communities.

In Connecticut, the value of oyster aquaculture as habitat for fish and invertebrate assemblages, relative to natural structured habitat, is not well studied. This is of particular interest where structured habitat is relatively sparse, such as leased bottom in the central basin of Long Island Sound (LIS). We used trapping to collect preliminary data on composition and relative abundance of juvenile finfish and invertebrate assemblages associated with habitat created by off-bottom oyster cage culture (cage farm) and traditional on-bottom oyster culture (shell bottom) and a naturally occurring rock and cobble reef (rock reef).

METHOD

Study sites.—This field study was conducted within a single embayment west of Charles Island near Milford, CT in the central basin of Long Island Sound and was located around a midpoint of 41°11.249 N and -73° 04.185 W (Figure 1). The three study habitats included an off-bottom oyster cage farm (cage farm), traditional on-bottom oyster culture area (shell bottom) and a natural cobble and boulder reef (rock reef). Each habitat was divided into 2 subsites (A and B) for sampling.

. Distances between habitat sampling areas measured from 745 to 1537 meters. Topography on inshore shellfish beds in this embayment (in the absence of shellfish or cages) is known to be generally uniform with low seafloor relief (e.g., Goldberg et al. 2012, 2014; Meseck et al. 2014; Mercaldo-Allen et al. 2016) and little benthoscape variation (Zajac et al. 2000).

In Connecticut, much of the seafloor in the inshore coastal zone is leased to shellfish growers and shellfish beds and periodically cultivated for hydraulic harvest of the Northern Quahog *Mercenaria mercenaria* and/or collection of eastern oysters using dragged metal cages. Two active shellfish lease areas, one containing bottom cages and the other supporting traditional on-bottom oyster culture, were chosen as study sites based on permission by leaseholders to access shellfish areas while creating minimal disruption to ongoing aquaculture operations.

The cage farm was located on a 0.11 km^2 shellfish lease (12M), approved for up to 200 cages (each 91 long x 122 wide x 61 cm high) within a 0.014 km^2 gear area. We focused our sampling effort adjacent to four large novel cages situated within the northeast quadrant (Figure 2). These cages measured 132 cm high, 183 cm deep, and 121.9 cm wide and were composed of twenty 91.4 x 121 cm trays holding a total of 300,000 oysters (Figure 2). The large cages were located in close proximity to a second shellfish farm (L385), approved for up to 250 cages (each 38 cm high and 61 cm wide) within a 0.25 km^2 area. Sampling subsites (A and B) were placed 134.4 meters apart at opposite sides of the large cage array and adjacent to the second farm. Cages were not disturbed for maintenance during the study.

The mixed shell bottom habitat was located within an active traditional on-bottom culture area, where live oysters and empty shell valves are found together on the seafloor. Subsites (A and B) were placed 332.8 meters apart along the delineation between two shellfish leases L305 and L392. These leases, which measured 0.20 km^2 in size, were bordered by additional shellfish leases where on-bottom oyster culture was practiced.

The rock reef is horseshoe-shaped, covers approximately 0.25 km^2, and varies in rock density and size, with boulders up to 1 meter high. The two subsites (A & B) were situated 198.4 meters apart, in areas where dive surveys indicated 70% or greater boulder coverage (Mercaldo-Allen et al. 2011). Although located on shellfish lease L386, the presence of hard substrate on the reef precludes active shellfish harvesting here.

For the purposes of our study, the oyster cage farm, on-bottom oyster culture area and rock reef were considered discrete habitats, potentially fulfilling different functional roles for benthic fish and mobile invertebrates. Proximity of cages to one another and location of shellfish farms at shallow water depths limited biological sampling options. Irregular topography on the reef precluded fish collection using nets. For this reason, traps were selected as sampling devices since they could be placed on the reef and near shellfish aquaculture sites without interfering with oyster grow-out or commercial harvesting operations.

Field sampling.—Traps sit on the seafloor and primarily target demersal and epibenthic fish and mobile invertebrates while trap openings and mesh size select for animal size. This method of assessing relative abundance and diversity of juvenile fish has proven useful in describing macrofaunal assemblages in complex environments, where sampling options are limited (e.g, Grabowski et al. 2005; Tallman and Forrester 2007). Our traps were sized to target the juvenile life stage, when fish rely most on structured habitat. Traps were constructed in-house, measured 46 x 23 x 23 cm and consisted of a wire frame lined with 3-mm mesh (Figure 3). Each trap was configured with a single central chamber, double entry, and was fitted with a flexible 25-mm-diameter ring opening at both entrances. A 5-kg steel plate along the base provided ballast and stability. Structure-oriented fish and invertebrates may have little incentive to leave shelter, therefore traps were baited with whole fresh Northern Quahogs, placed in perforated plastic cups, to provide an attractant.

Ten traps were deployed at each subsite for a total of 20 traps per habitat and were spaced 7.6 meters apart. Gear was arranged in two strings of three traps and one string of four traps. Strings were placed in line across the rock reef and shell bottom subsites and clustered near the large cages, reflective of differences in spatial scale of the three habitat types. High cobble and boulder densities at the reef ensured that traps were distributed on or adjacent to natural structure. Traps were placed as close as possible to cages without becoming tangled, < 30 meters. Traps were deployed between 8 and 11 am, soaked for 24-hours and retrieved on the subsequent day. Trapping was conducted 2-3 days per week. During sampling trips, temperature, salinity and dissolved oxygen were measured just above the sediments in bottom waters at each habitat and site in the vicinity of the traps using a handheld Yellow Springs Instrument Co. ProDO optical dissolved oxygen and temperature meter and a Yellow Springs Instrument Co. salinity, conductivity and temperature meter.

A total of 23 sampling trips were conducted from June through early September 2016. Upon retrieval, traps were inspected and all organisms identified, enumerated, and released. Black Sea Bass were measured for standard length (SL) to the nearest 0.1 mm. The number of fish and invertebrates caught per trap hour was used as an index of relative abundance. Catch per unit effort (CPUE) for fish and invertebrates was calculated as number per trap divided by soak time (24 hours). This study presents preliminary and descriptive data on fish and invertebrate abundance on 3 habitat types; access to a single oyster cage farm and rock reef for trap sampling within the study embayment precluded adequate replication for statistical comparison among habitats.

RESULTS AND DISCUSSION

Environmental Data.—Environmental parameters were similar across habitats. Mean seawater temperature (±SD) measured 21.2 ± 3.2 ºC, mean salinity was 27.7 ± 1.4 and mean dissolved oxygen concentrations measured 5.7 ± 1.2 ppm.

Fish Assemblages on Cage Farm, Shell Bottom and Rock Reef.—Fish community composition and abundance data are shown in Figure 4. The eight fish species observed, in order of overall abundance, included Black Sea Bass *Centropristis striata,* Scup *Steotomus chrysops*, Oyster

Toadfish *Opsanus tau*, Cunner *Tautoga adspersus*, Tautog *Tautoga onitus*, Conger Eel *Conger oceanicus*, Bluefish *Pomatomus saltatrix* and Smallmouth Flounder *Etropus microstomus*. A single Smallmouth Flounder, collected on the shell bottom habitat, was not shown in the graph.

Juvenile finfish assemblages on the cage farm and rock reef were similar in composition with comparable numbers of Black Sea Bass, Cunner, Oyster Toadfish and Tautog. These species are generally structure-oriented, demonstrate site fidelity and show strong affinity for shelter (e.g. Able et al. 2005). Shelter is a functional requirement influencing abundance of temperate reef fishes, such as the wrasses Cunner and Tautog (Auster 1989; Tupper and Boutilier 1997) and is closely tied to successful recruitment in Black Sea Bass (Drohan et al. 2007). In a Rhode Island study, Tallman & Forrester (2007) found no discernable difference in Black Sea Bass density between reef and cage sites, consistent with the results reported here. However, they report higher numbers of Cunner near rock and artificial reefs while Scup (age 1+) and Tautog were more prevalent near oyster cages. In Delaware, four species of southern reef fish, including Tautog, were observed near shellfish cages but absent from adjacent oyster reef areas (Erbland and Ozbay 2008; Marenghi et al. 2010). Habitats with greater surface area and elevated relief generally support higher numbers of species and individual organisms (Garacía Charton and Ruzafa 1998). Boulder and cobble reefs, while sparse in the central basin of LIS, provide islands of topographically diverse cryptic habitat known to support a variety of fish and invertebrates. The study reef is characterized by a dense growth of hydroids, bryozoans, sponges and seaweeds inhabiting cobble and boulder surfaces (Mercaldo-Allen et al. 2011) providing camouflage and cover to young fish. The presence of sponges has been associated with reduced predation among young Black Sea Bass (Sharf et al. 2006). Although the three-dimensional relief created by aquaculture gear is structurally and functionally different from that of boulders and cobble on natural reefs, oyster cages also support diverse assemblages of fish (Ozbay et al. 2014).

In our study, Black Sea Bass and Scup were more abundant on shell bottom, relative to the other habitats, while relatively fewer Cunner and oyster toadfish were found on shell bottom, and no Tautog were found. The importance of shell bottom as habitat for young Black Sea Bass is well established (Lehnert and Allen 2002; Sharf et al. 2006) and a study in Chincoteague Bay, Maryland found this species to be three times more abundant on shelled bottom versus unplanted seafloor (Arve 1960). In a South Carolina estuary, Lehnert and Allen (2002) noted high numbers of Black Sea Bass on shell bottom during the summer months. Although structure-oriented, Black Sea Bass are known to leave reef areas in pursuit of prey in nearby low relief environments (Lindquest et al. 1994; Steimle and Figley 1996).

Elevated numbers of Black Sea Bass and Scup on shell substrate could represent an artifact of our sampling method. Trapping provides a useful index of relative fish and invertebrate abundance across difficult to sample benthic habitats, but may fish more efficiently in one habitat versus others (Tallman and Forrester 2007), potentially introducing bias into density estimates. Traps placed on low vertical relief seafloor may attract fish in search of shelter as well as food. Higher numbers of fish collected on the shell bottom habitat may also reflect the somewhat larger spatial area covered by this habitat type. Despite these caveats, the high numbers of juvenile Black Sea Bass and Scup we observed substantiate the value of oyster shell bottom as habitat for these species. Higher abundances of bottom feeding fish and associated prey (Plunkett and LaPeyre 2005) and more diverse fish communities (Lehnert and Allen 2002) have been previously documented in shell substrate relative to adjacent featureless bottom. Although cultch and live oysters provide less vertical relief than cages and boulders, our study and others (e.g., Grabowski et al. 2005; Plunkett and LaPeyre 2005; Dumbauld et al. 2009) show that shell bottom provides habitat for a variety of fish and crustacean species.

Microhabitats created by live oysters and shell, rock reefs and oysters in cages may confer a variety of benefits to newly settled and juvenile fish. We noted two size classes of juvenile Black Sea Bass present on all 3 habitats in mid-August, when young-of-the-year first appeared in traps, and were easily distinguished by size from the one-year+ population (Figure 5). Interactions between fish and structured habitat are most profound at early life stages (Diaz et al. 2003), when vulnerability to predation make fish reliant on cryptic habitat that contains a ready food source (Scharf et al. 2006). Similar to high relief cobble and boulders, interstitial spaces supplied by wire mesh cages and oyster bags may exclude large-bodied predators, protecting small fish (DeAlteris et al. 2004; Scharf et al. 2006). Higher topographic complexity has been linked to successful recruitment in temperate reef fish, such as Cunner (Tupper and Boutilier 1997). Structure provided by oyster aquaculture may boost fish and invertebrate survival during early life stages, by enhancing availability of nursery habitat, and reducing potential bottlenecks to settlement and recruitment (DeAlteris et al. 2004; Marenghi et al. 2010).

Invertebrate Assemblages on Cage Farm, Shell Bottom and Rock Reef.— Invertebrate community composition and species abundances are shown in Figure 6. Dominant species in order of overall abundance included the Portly Spider Crab *Libinia emarginata*, Atlantic Mud Crab *Panopeus herbstii*, Channeled Whelk *Busycotypus canaliculatus*, Flatclaw Hermit Crab *Pagurus pollicaris*, and American Lobster *Homarus americanus*. Invertebrates present in low abundance (N<3) (not shown in figure) included Purple Sea Urchin *Arbacia punctulata*, Common Sea Star *Asterias forbesi*, Blue Crab *Callinectes sapidus*, Atlantic Rock Crab *Cancer irroratus,* and Green Crab *Carcinus maenas*.

Channeled Whelk, which graze on hard substrate, occurred in high abundance on the reef relative to the other habitats. Interestingly the DeAlteris et al. (2004) study found American Lobsters sheltering inside oyster cages, but we observed them on the reef only. Despite the generally low abundance of American Lobsters in LIS, rock reef environments remain key nursery areas for juveniles (Mercaldo-Allen et al. 2011). Portly Spider Crabs were highly associated with the cage farm and shell bottom and occurred in low numbers on the reef. Long limbs allow these crabs to ascend cages to feed on organisms encrusting surfaces. Flatclaw Hermit Crab occurred in similar numbers on the aquaculture sites and in less abundance on the reef while Atlantic Mud Crabs occurred on all habitats but were most numerous on the cage farm. These two species of predatory crabs are important members of the oyster community where they find refuge and forage among shellfish and empty shell valves (Williams 1983; Day & Lawton 1988; Grabowski and Kimbro 2005). Invertebrate and crustacean species associated with live oysters and shell cultch are prey for resident and transitory predatory fishes (e.g., Lehnert and Allen 2002; Plunket and LaPeyre 2005; Ozbay et al. 2014). Aquaculture of oysters, whether in cages or grown on the seafloor, may represent valuable estuarine habitat (Dumbauld et al. 2009), and a foundation for growth of productive sessile and mobile invertebrate communities (Ozbay et al. 2014).

Conclusion.—Our study found that similar assemblages and abundances of juvenile temperate reef fish on oyster cage farm and rock reef habitats. Relative abundance of species within invertebrate communities were more variable among habitats. Off-bottom oyster cages, rock reef and on-bottom traditional shellfish culture areas provide varying levels of habitat complexity and seafloor relief that each support ecologically valuable finfish and invertebrate communities.

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Figure Captions:

Figure 1: Map shows study sites on shellfish leases located near Milford, CT in Long Island Sound. Habitats include an oyster cage farm (farm), shell bottom (shell) and a rock reef (reef). Box shows location of an adjacent shellfish farm also containing oyster cages. Depths at mean low water indicated in feet (1ft = 0.31m). Black boxes indicate locations of fish trap sampling on subsites (A and B). Black lines represent lease boundaries. Star represents center of large 4 cage array.

Figure 2: Large off-bottom oyster cage style used by the grower at the shellfish farm.

Figure 3: Fish trap style used in field study.

Figure 4: Dominant finfish species at the oyster cage farm (farm), shell bottom (shell) and rock reef (reef) habitats during summer 2016. Numbers represent catch per unit effort (±standard error) over the course of the season for each species. The left y-axis indicates total number of individuals collected for all species except Black Sea Bass. The right y-axis indicates abundance of Black Sea Bass.

Figure 5. Time series of Black Sea Bass standard length measurements. Points connected by lines represent mean standard length of all 1+ individuals averaged across each habitat on a single date. Points not connected by lines represent individual YOY Black Sea Bass.

Figure 6: Dominant invertebrate species at the oyster cage farm (farm), shell bottom (shell) and rock reef (reef) habitats during summer 2016. Numbers represent catch per unit effort (±standard error) over the course of the season for each species.

Figure 1

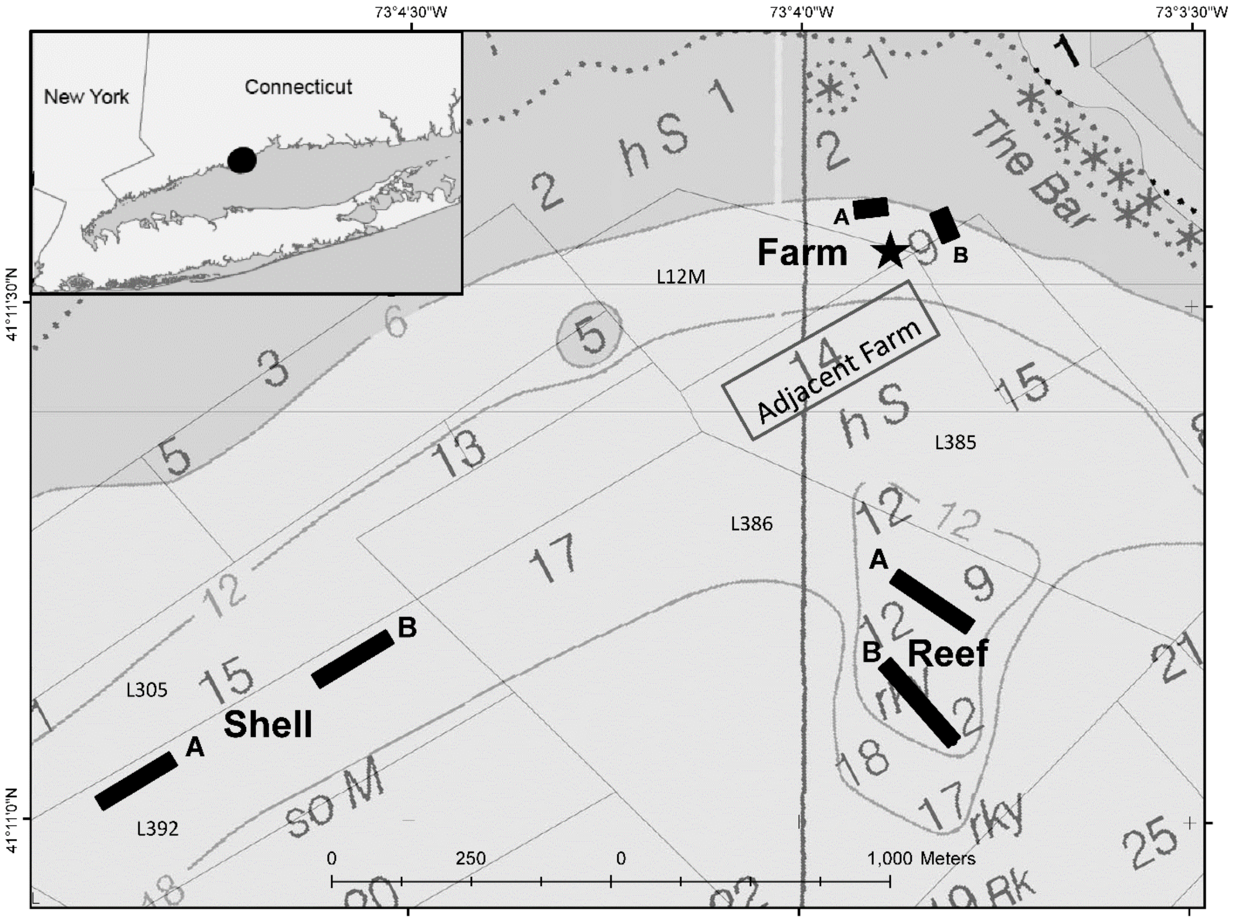

Figure 1 Mercaldo-Allen

Figure 2

Figure 3

438 Figure 4

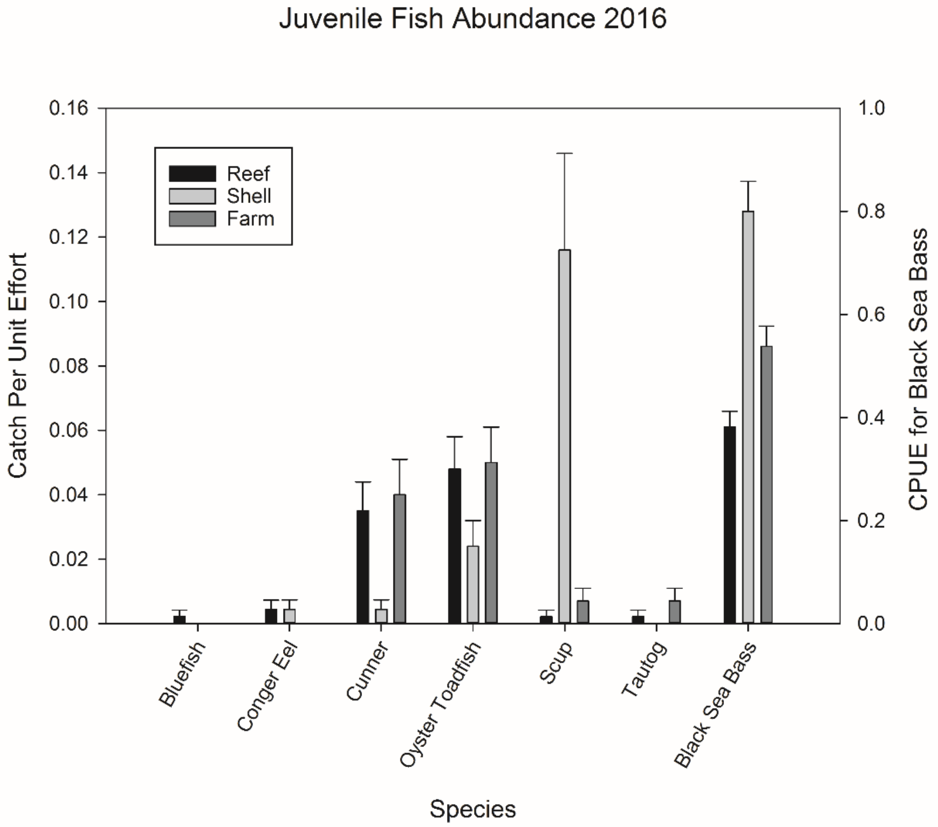

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Figure 5

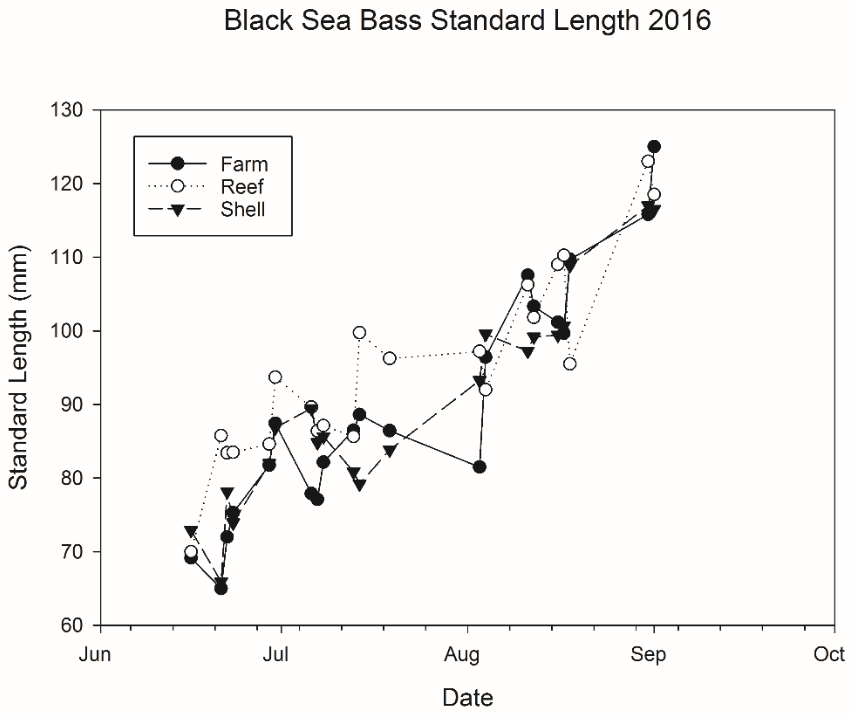
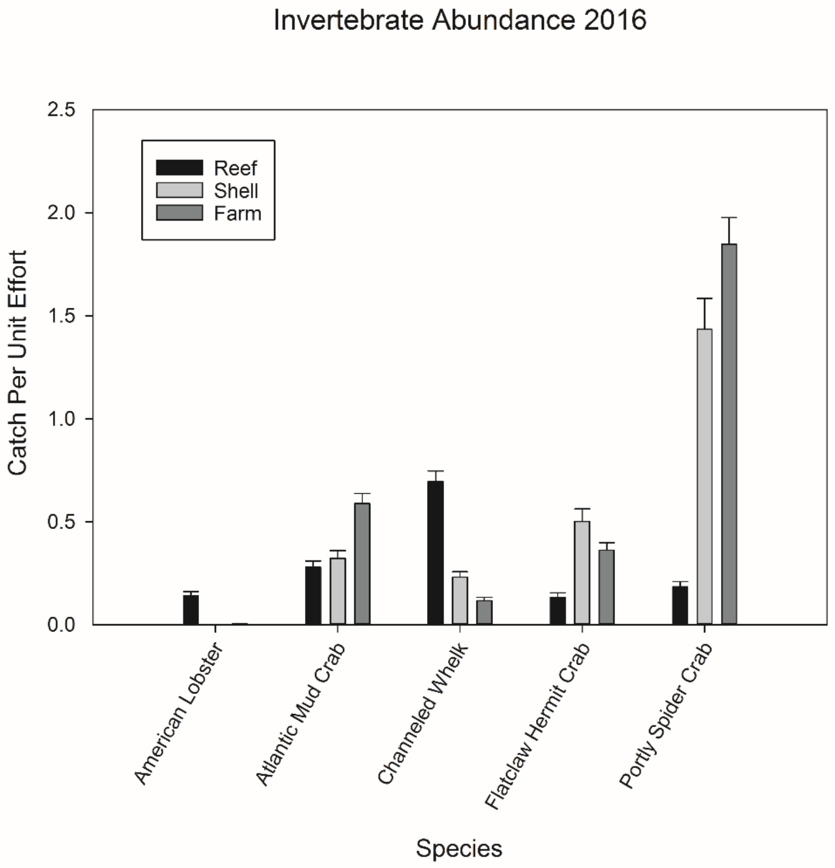

Black Sea Bass Standard Length 2016
Standard Length (mm)
130
120
110
100
90
80
70
60
Farm
Reef
Shell
Jun
Jul
Aug
Sep
Oct
Date

Figure 6


Invertebrate Abundance 2016
Catch Per Unit Effort
2.5
2.0
1.5
1.0
0.5
0.0
Reef
Shell
Farm
American Lobster
Atlantic Mud Crab
Channeled Whelk
Flatclaw Hermit Crab
Portly Spider Crab
Species