Below the Surface of the Bay

Marine Ecosystem Assessment of Pleasant Bay, Cape Cod, Massachusetts

by the Center for Coastal Studies

funded by
Friends of Pleasant Bay

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Introduction

Pleasant Bay on Cape Cod is protected from the Atlantic Ocean by the Nauset Beach - barrier spit - barrier island system. The bay is surrounded by approximately 42.9 miles of coastline, and its watershed includes the towns of Orleans, Chatham, Harwich and Brewster. A highly valued regional resource, it is designated by the state and recognized by the surrounding towns as an Area of Critical Environmental Concern (ACEC). This valuable **ecosystem** (bolded terms are in glossary), a collection of both living and nonliving components, is at risk from development within its watershed and from human activities within the bay.

The Friends of Pleasant Bay (FOPB) funded the Center for Coastal Studies (CCS) to conduct an ecosystem assessment of Pleasant Bay between 2014 and 2017. The goal of this research was to:

develop a dataset of baseline information that assesses the present status of the natural resources of Pleasant Bay and that can be used to develop a long-term habitat monitoring program.

Habitats, ecological or environmental areas inhabited by a particular species or group of species, are made up of both physical or abiotic factors (e.g. grain size, temperature, light, salinity) and living or biotic factors (e.g. food availability, presence of predators) and can be created by ecosystem engineers (e.g. eelgrass, oysters, tube building worms). Adequately describing and defining habitats is challenging, as they change over time and are made up of numerous components, all gradients of one another. Data collected within the same area varies based on season as well as mapping resolution and the habitat being quantified. Therefore, ecosystem-based management requires spatial and temporal data sets that encompass a variety of living and nonliving factors. The establishment of a baseline and its assessment is the first step in understanding an ecosystem. The second is to explore the connection of the inhabitants, fishes, shellfishes and predators, to the resources available.

The goals of this assessment were to:

- Collect bay-wide physical, chemical and biological data sets that would be used in understanding bay evolution and developing high-resolution benthic habitat maps. These data included vessel-based acoustic surveys of the bay, seismic reflection profiling, sediment coring, bottom grab samples and videos to classify sediment and identify micro-invertebrates by sediment type.
- Determine the distribution and relative abundance of individual shellfish and finfish species using a variety of sampling methods.
- Describe the seasonal distribution and numbers for gray and harbor seals at haul-outs inside Pleasant Bay during 2014 and 2015 through monthly aerial surveys.
- Provide additional information on the diet of gray and harbor seals though otolith and hard part identification in collected scat samples.
- Provide an initial representation of the interrelationships among the bay's biological and physical features.

Benthic Habitat Mapping of Pleasant Bay

Pleasant Bay is relatively shallow, so not all of the bay was accessible by boat to collect sidescan sonar imagery. For this study we were able to map approximately 60% of the bay, and the average depth of the mapped area was 6.6 feet. **Bathymetry** and information on depths within the bay were collected for over 40% (6.78 km^2) of the area mapped. To determine the biological and physical structures of these areas, we conducted field surveys to collect **micro-invertebrate** and sediment samples, as well as video imagery and information on water column components, at 48 locations throughout Pleasant Bay. Of these, 15 were selected to overlap with benthic stations sampled by the Massachusetts Estuaries Project (MEP) study conducted in 2003.

These data, together with **seismic reflection profiling** and sediment coring, were used to better understand the historical evolution of the bay over the last 6000 years and its current state, as well as to develop submerged marine (or benthic) habitat maps using the Coastal and Marine Ecological Classification Standard (**CMECS**). CMECS is composed of four components: (1) "**geoform**", as determined by sidescan sonar and bathymetry, (2) "**substrate**", reflecting on sediment grain size, (3) "**water column**", incorporating physical and chemical parameters of the water column and (4) "**biotic**", relating to the flora and fauna of the area.

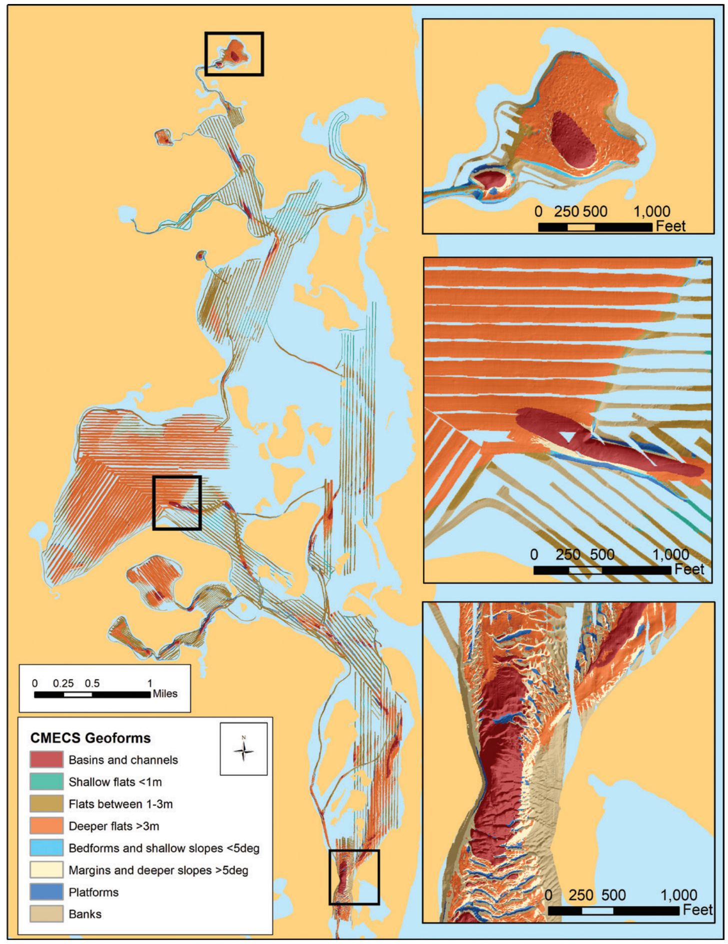


Figure 1: Geoforms of Pleasant Bay as determined by sidescan sonar and bathymetry, with special focus on Meeting House Pond, navigational channel in Big Bay and the southern Inlet to Chatham Harbor. Data were classified according to CMECS standards.

Geoforms

Based on CMECS, we identified eight "geoforms" (such as "shallow flats", "basins and channels") and used them to create a map (Figure 1) showing, for example, "deeper flats" in Big Bay, "Channels" south of Tern Island and "Basins" in Meeting House Pond. While these terms are not commonly used, they are central to the transferability and future applicability of this study's findings.

Substrate

We analyzed sediment grain size samples from 48 stations and created a "substrate" map (Figure 2); another way of showing the changing habitats within Pleasant Bay. The sediment in highly dynamic areas, such as close to the inlets, is characterized by larger grain size corresponding to coarse sand, while more protected and/or deeper areas and areas with high eelgrass cover are muddier. Future changes in grain size would be a clear sign that real changes, rather than perceived ones, are occurring in the bay.

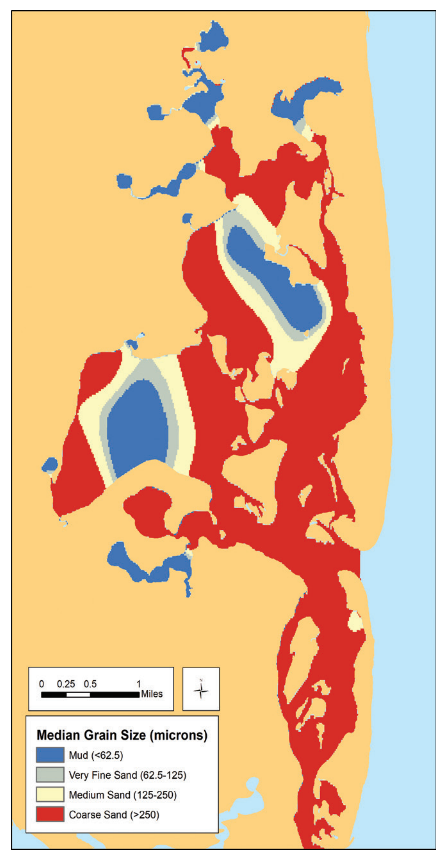


Figure 2: Substrate components of Pleasant Bay as described by grain size of sediment with sample stations as black circles. Grain sizes are indicated in µm and range from mud (smaller than 62.5 microns) to coarse sand (larger than 250 microns).

Water Column

To fulfill the "water column" component, we measured salinity and temperature. Salinity data show euhaline, or truly marine, conditions throughout Pleasant Bay. Temperatures shift from cool (close to the inlets) to very warm (in the northern ponds). The consistent salinity values and the highly seasonal aspect of water temperatures yielded no area of special interest.

Flora and Fauna

To define the biotic components of Pleasant Bay, we used micro-invertebrate data. In our field study, we found a total of 67,167 individuals belonging to 148 different species. The most abundant species in Pleasant Bay was the Amethyst Gem Clam (***Gemma gemma***), with 18,659 individuals, followed by a side-swimmer or **Amphipod** species (*Ampelisca sp*), with 16,658 individuals. The top 95% of species were used to determine assemblages with similar species composition called clusters. The information about the most abundant species of each cluster enables CMECS to determine **biotic groups** (Figure 3).

Biotopes

These biotic groups, in combination with geoform and substrate classifications, determine **biotopes**. The biotopes of Pleasant Bay were defined by 3 substrate factors regarding grain size and distribution, which are directly related to energy levels within the bay. Together, these factors explained 22% of species distribution. We were able to determine three **indicator species** (Side-swimmer (*Ampelisca sp*), northern dwarf tellin (*Tellina agilis*) and the worm capitellids (**Capitellidae**), which were also the most dominant species in several clusters in the benthic community cluster analysis, suggesting that they play an important role in the overall composition of benthic communities in the bay (Figure 4). In potential future studies, given the extensive work done in the bay for this project, monitoring these species and corresponding sample locations could be a critical component in documenting the evolving ecosystem state in Pleasant Bay.

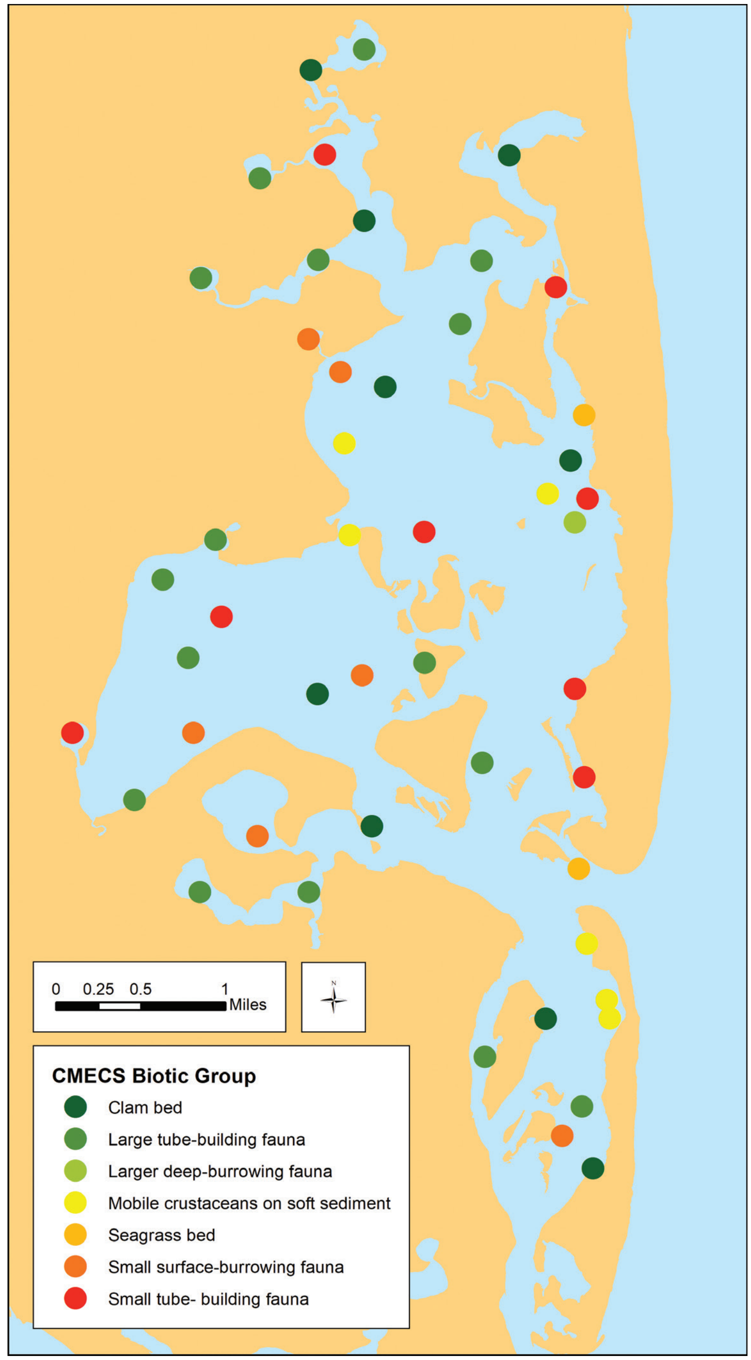


Figure 3: Biotic groups of micro-invertebrates at each sampling station: clam beds (amethyst gem clams (Gemma gemma)), large tube-building fauna (Ampelisca amphipods), large deep-burrowing fauna (Nephtys polychaeta worms), mobile crustaceans on soft sediment (skeleton shrimp (Caprellidae) and Haustoriidae amphipods), seagrass beds (dexiospira worms and idotea), small surface-burrowing fauna (Acetocina snail, capitellidae worms and Tellina bivalves) and small tube-building fauna (Streblospio benedictii worms, Cirratulidae worms and Spionidae worms). The biotic groups were classified according to CMECS standards.

Figure 4: Micro-invertebrates most abundant in biotic groups according to CMECS: (from top to bottom, left to right): Dexiospira worm, Haustorridae side swimmer, *Gemma gemma* clam, Nephtys worm, Spionidae worm, *Acetocina canaliculate* snail, Ampelisca side swimmer, Capitellidae worm, *Tellina agilis* clam, *Streblospio benedictii* worm, *Idotea balthica*, Cirratulidae worm, Caprellidae side swimmer

Acoustic Surveys

The acoustic surveys and subsequent map production identified natural geological processes, as well as human-induced impacts on the seafloor. For example, sediment transported into an area near the deepest basin in Pleasant Bay ("Big Bay") provided eelgrass with a shallow water environment where it was able to grow. Less than 2 km away, an existing eelgrass bed was being buried by the natural movement of sediment into the area (Figure 5). Both these areas are close to the tidal inlet that formed in 2007 ('07 Inlet). The surveys also documented the presence of coir logs on the seafloor that had been "eroded" from erosion control structures along the shore of the bay.

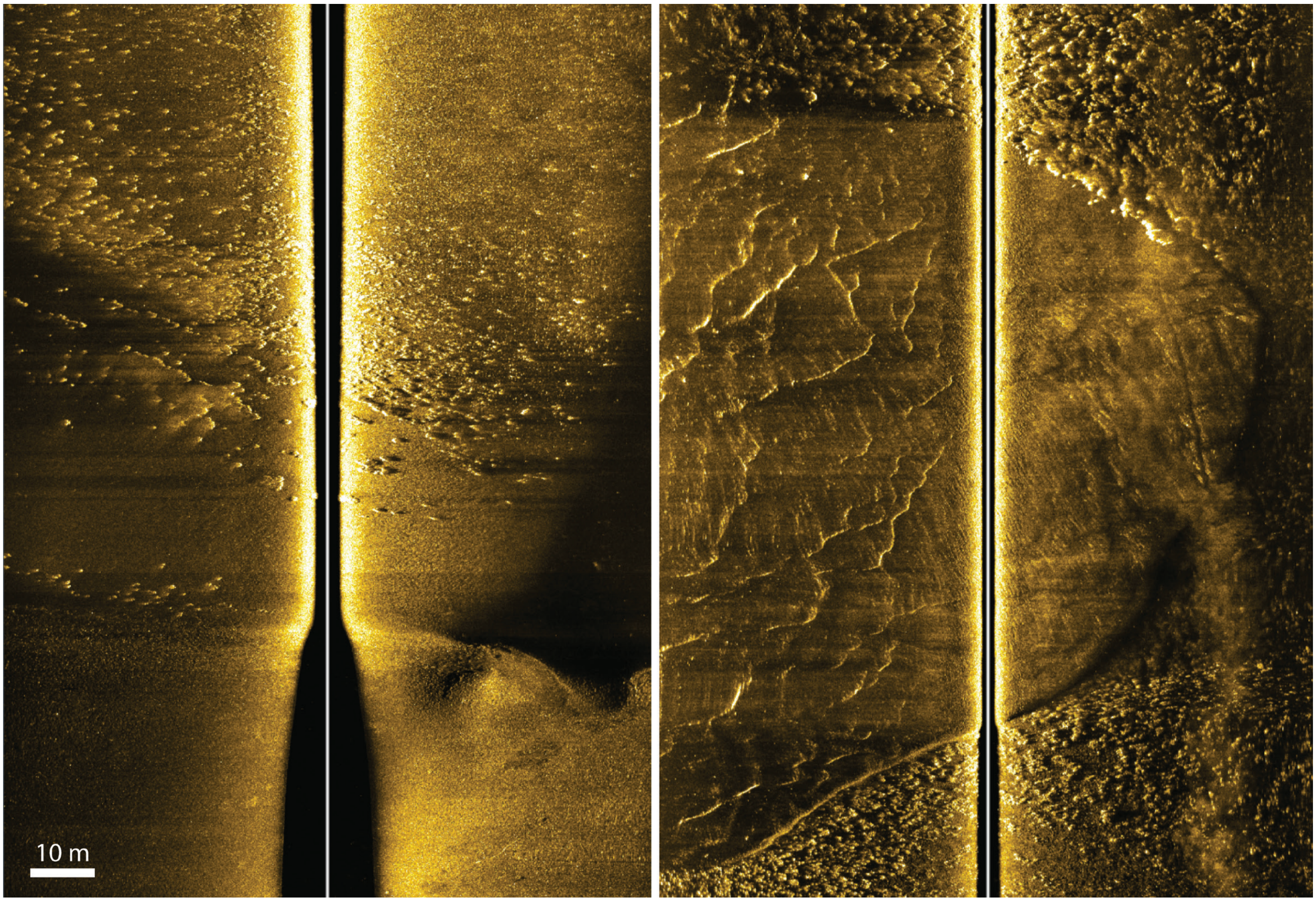


Figure 5: Raw sidescan sonar images from Pleasant Bay. Left: An area in Pleasant Bay where sediment being transported into a deeper basin is providing habitat for eelgrass to grow in. Right: An area within the same embayment where the natural movement of sediment is burying eelgrass beds. If these data did not capture this 'snapshot' in time the loss of eelgrass may havebeen wrongly attributed to other phenomena, whether natural or anthropogenic.

Sediment Coring and Seismic Profiling

The sediment coring and seismic profiling together provide a better understanding of basin evolution over the last 6000 years, when sea levels rose and Pleasant Bay became partially enclosed by the precursor form of the Nauset Beach - barrier spit-barrier island system. The sediment core data illustrate the sedimentation rates and patterns as sea level rises and the bay becomes a lower energy basin. Late in the core, closer to the surface, industrial age inputs are clearly seen and signal a change in bay chemistry and energy regime. Seismic profiling surveys send acoustic energy into the subsurface and that reflected energy comes back to the surface and gives us a 2-dimensional picture of the "sub-bottom". These data provide quantitative information on basin evolution as well as sediment thickness, all within a regime of historical and current sea level rise. However, in Pleasant Bay the inlets are the main drivers of change, and they will continue to be into the fore-seeable future. Management actions can help to mitigate and minimize negative impacts or can exacerbate them. These maps and accompanying data provide an important baseline inventory, a snapshot in time, to rigorously and quantitatively measure future natural change and the impacts of human alterations.

Fisheries Investigations in Pleasant Bay 2014-2017

We conducted an inventory of shellfish and finfish in Pleasant Bay, with a focus on commercially and recreationally important species. Intertidal and subtidal fish and invertebrate sampling was conducted in Pleasant Bay from June 2015 through June 2016. Fifteen subtidal sampling stations were chosen as a random subset of sites chosen for benthic habitat sampling. A survey for postlarval lobsters was conducted in 2014 and opportunistic sampling was conducted from July 2015 through October 2017. We used a variety of sampling methods, including beach seines, trawls, dredges, ventless lobster traps, passive collectors, and gillnets. Where practical, we conducted sampling efforts using methods and gears similar to previous studies conducted in the same area, particularly the 1965-66 Massachusetts Division of Marine Fisheries (MADMF) assessment (Fiske et al 1967). During meetings with stakeholders and natural resource managers, we learned that focused shellfish surveys targeting specific species and areas would be a useful complement to the random survey design described above.

Figure 6: Young-of-the-Year sea herring (*Clupea harengus*)

Fish and Invertebrate Species

Atlantic silversides, mummichogs and striped killifish were among the dominant fish species observed. Species that are food for larger fishes and animals (e.g. sand lance, silversides, sea herring, and longfin squid) were well-represented in trawl surveys (Figure 6). Winter flounder were among the most abundant species at stations sampled in 1965-66 but were comparably less abundant in the present study. While the greatest species diversity was observed in trawls, dredges towed at the same stations revealed species that were not caught by the trawl at all, or greater relative abundances of species that live on or near the bottom and hide in crevices or are camouflaged, such as the seaboard goby. Fish species captured by passive collectors were not present in other gears (e.g. juvenile spotfin butterflyfish, snowy grouper and black sea bass). The incorporation of a third year of opportunistic trawl survey data added several new species to our inventory, including pelagic species such as mackerel and butterfish that had not previously been reported in the bay.

Many fish and invertebrate species were found in the bay in juvenile stages, but rarely at larger sizes (e.g. winter flounder; Figure 7). All of the winter flounder captured in trawls were most likely ≤ 1 year. It is unclear what has caused the decline in abundance of winter flounder, particularly large fish in spawning condition, relative to the 1965-66 MADMF study. Longfin squid are among the species that apparently spawn in the bay, as evidenced by the presence of eggs and small juveniles, although it is most likely that only the largest squid captured in trawls were sexually mature (Figure 8). It is notable that two of the four most abundant organisms captured in bay-wide dredge sampling were specialist shellfish predators (sea stars and oyster drills).

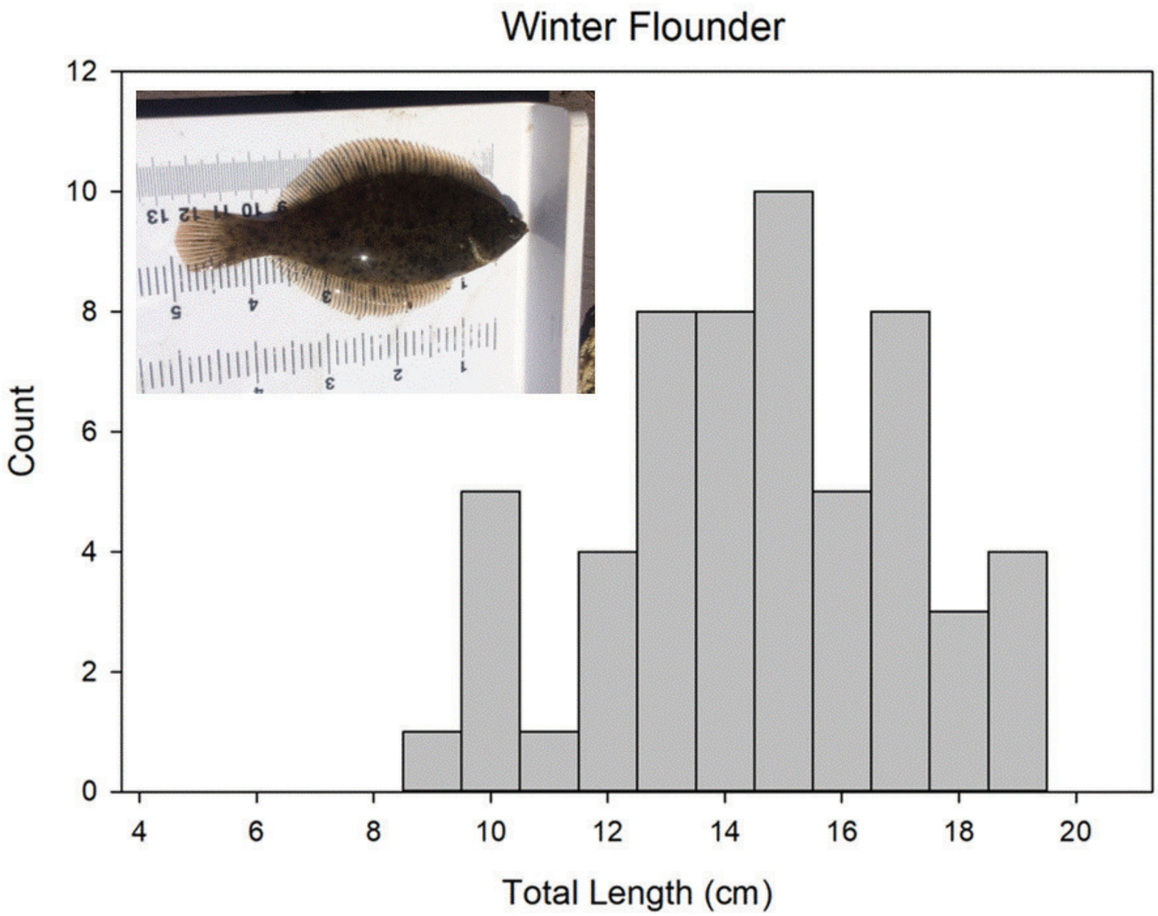


Figure 7: Length frequency of winter flounder (*Pseudopleuronectes americanus*) captured in trawls, June 2015-June 2016

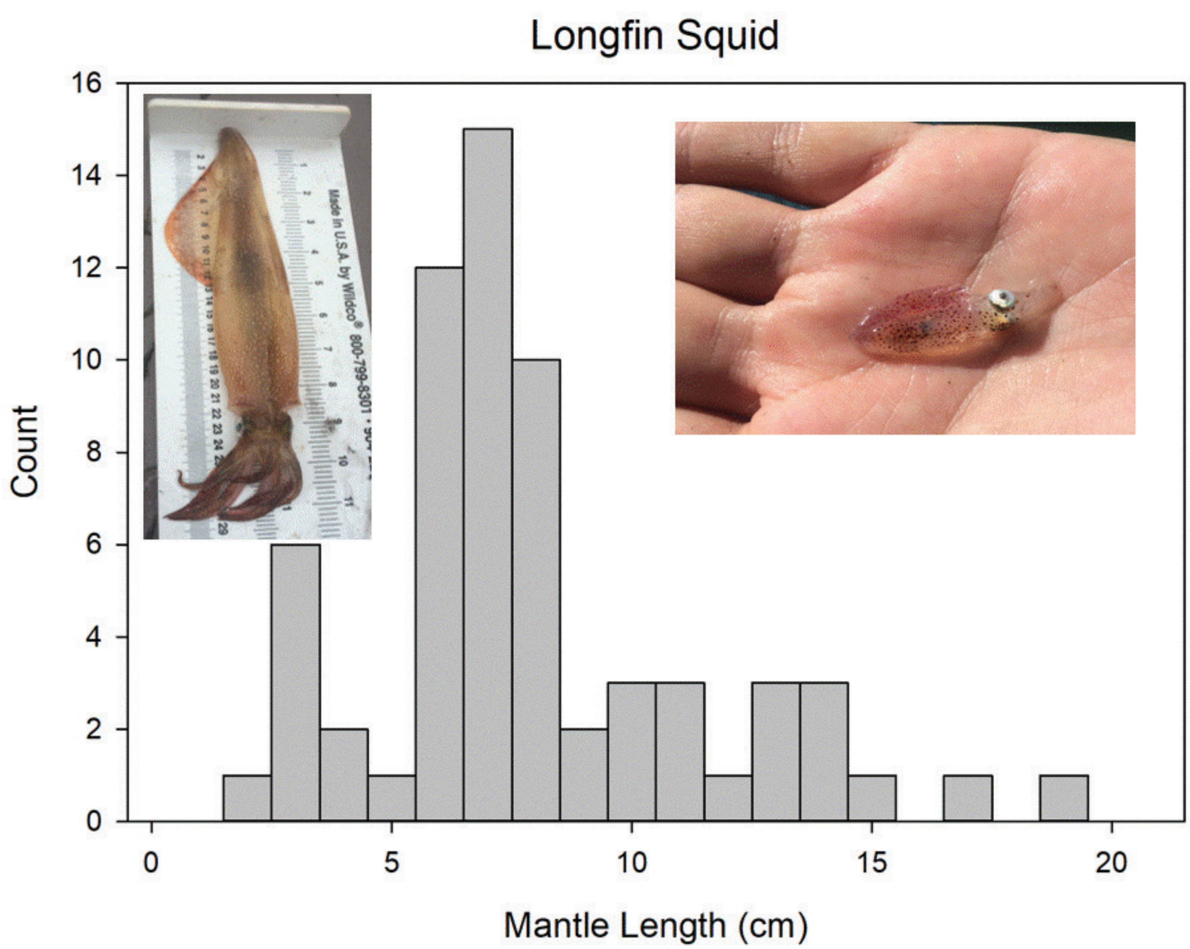


Figure 8: Length frequency of longfin squid (*Doryteuthis pealeii*) captured in trawls, June 2015-June 2016

Shellfish Surveys

Targeted shellfish surveys established a baseline of shellfish abundance at select areas identified by natural resource management agencies. Mussel beds changed in distribution during this investigation. Bay scallops were essentially absent from areas identified by natural resource managers and local fishermen. A dredge survey captured primarily large, presumably old quahogs (Figure 9) in relatively low abundance when compared to catches with the same dredge in Cape Cod Bay.

This comprehensive inventory indicated that Pleasant Bay is home to a diverse assemblage of marine animals. The standardized, replicable methods employed during this study established baseline data on distribution and relative abundance of a wide variety of animals, including those of commercial, recreational, and ecological importance.

Figure 9: Quahogs (*Mercenaria mercenaria*) captured during dredge survey, December 2017

Harbor and Gray Seal Distribution, Counts and Prey

CCS flew monthly aerial seal surveys to determine seal distribution at haul-outs inside Pleasant Bay in 2014 and 2015 and collected scat to determine seal diet between January 2016 and March 2017.

Seasonal Distribution and Counts

Aerial surveys showed that harbor seals inhabit Pleasant Bay seasonally in winter and spring, while gray seals utilize the bay in summer and fall. The only overlap of the two species observed during our investigation was in December of 2015. The maximum daily counts for harbor seals inside Pleasant Bay were 936 in February 2014 and 753 in March 2015. The highest daily counts for gray seals were 1,276 in June 2014 and 2,379 in August 2015 (Figure 10).

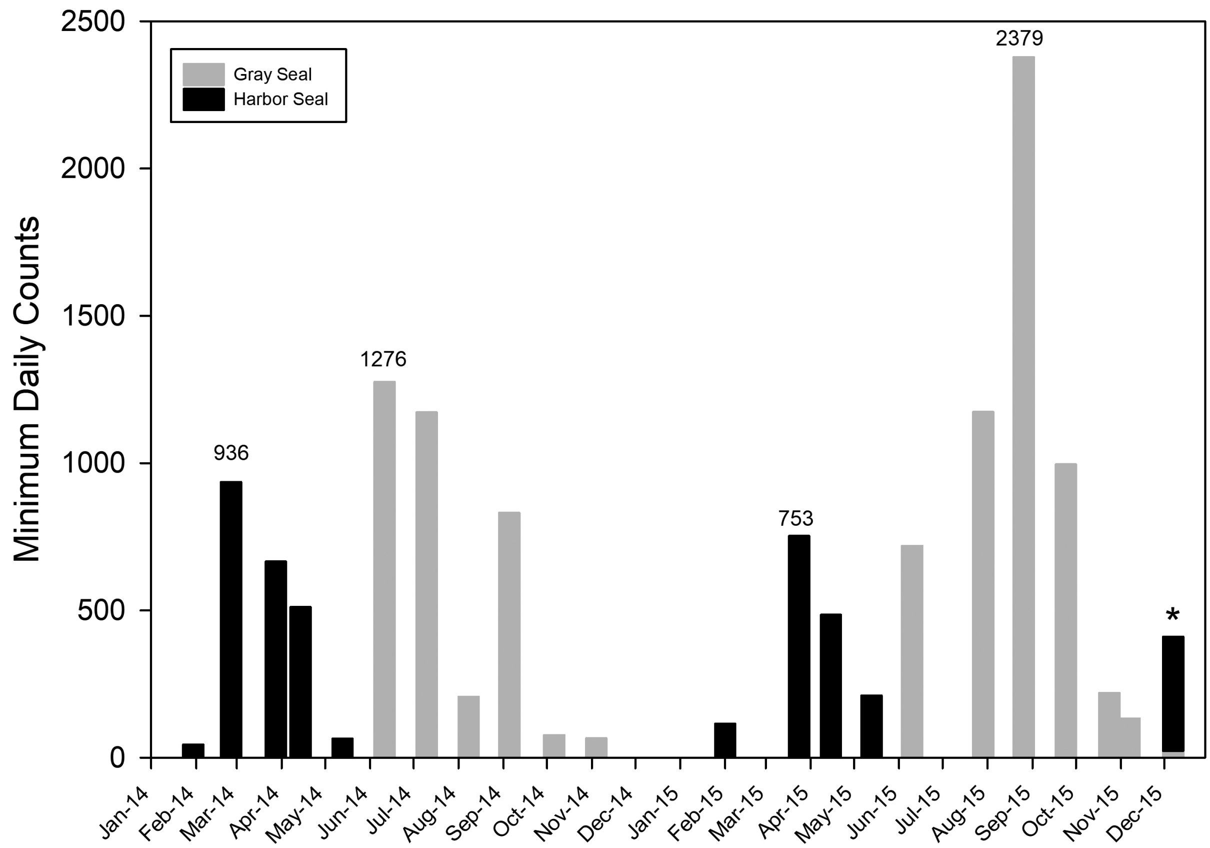


Figure 10: Minimum daily counts for harbor seals (in black) and gray seals (in grey) at haul-outs inside Pleasant Bay between January 2014 and December 2015. Asterisk (*) indicates months in which harbor and gray seals overlap.

We identified nine haul-out sites (Figures 11&15) during the course of this study. They were all confined to Chatham Harbor/Aunt Lydia's Cove and the shoals between the '07 Inlet and Strong Island. Harbor and gray seals both utilized tidal sand bars in Chatham Harbor in 2014 and 2015. However, in 2015, we observed gray seal numbers increase inside the bay. That year, their distribution shifted north to include a series of developing tidal sand bars southeast of Strong Island.

Figure 11: UAS image of gray seal haul-out west of Nauset Beach and Southeast of Strong Island in June 2017. The image was taken by Dr. Michael Moore under NOAA Permit.18786. The drone was flown in support of IFAW's seal disentanglement efforts inside Pleasant Bay. This image shows that the observed shift in gray seal distribution has persisted through summer 2017.

Scat Sample Findings

Between January 2016 and March 2017, we collected and analyzed 25 harbor seal and 63 gray seal scat samples from Pleasant Bay. Diet was estimated based on the recovery and identification of hard parts such as: fish otoliths, cephalopod beaks, dermal denticles (modified scales) from cartilaginous fish (such as skates), crab carapaces, clam shells, snail shells, bones and teeth (Figure 12). We used frequency of occurrence analysis to calculate prey species detected in scat samples.

Figure 12: Selection of hard parts and fish otoliths found in seal scat samples. From upper left to lower right: otolith of sandlance, otolith of herring, otolith of flounder, marine snail species, dermal denticle of skate, shell fragment of blue mussel, fragment of crustacean carapace, otolith of cod, beak of longfin squid

Sand lance was the most frequently recovered prey (93% winter, 83% spring) in harbor seals. Herring species and cod species were present in 33% of winter scat samples and in 17% of spring scat samples. Blue mussels and ocean pout were found only in winter scat samples (13% and 7% respectively). As was the case in harbor seals, sand lance was the most frequently recovered prey species in gray seal scat samples, 67% of summer scat samples and 89% of fall scat samples. Longfin squid was recovered in 28% of summer samples and 26% of fall samples, followed by blue mussel shells (summer: 28%, fall: 7%), and other species (Figure 13). Blue mussels, snails and crustaceans were included in the analysis; however, it is not known if these are secondary prey items (prey of species that were consumed) for harbor and gray seals or targeted prey species in the seals' diet.

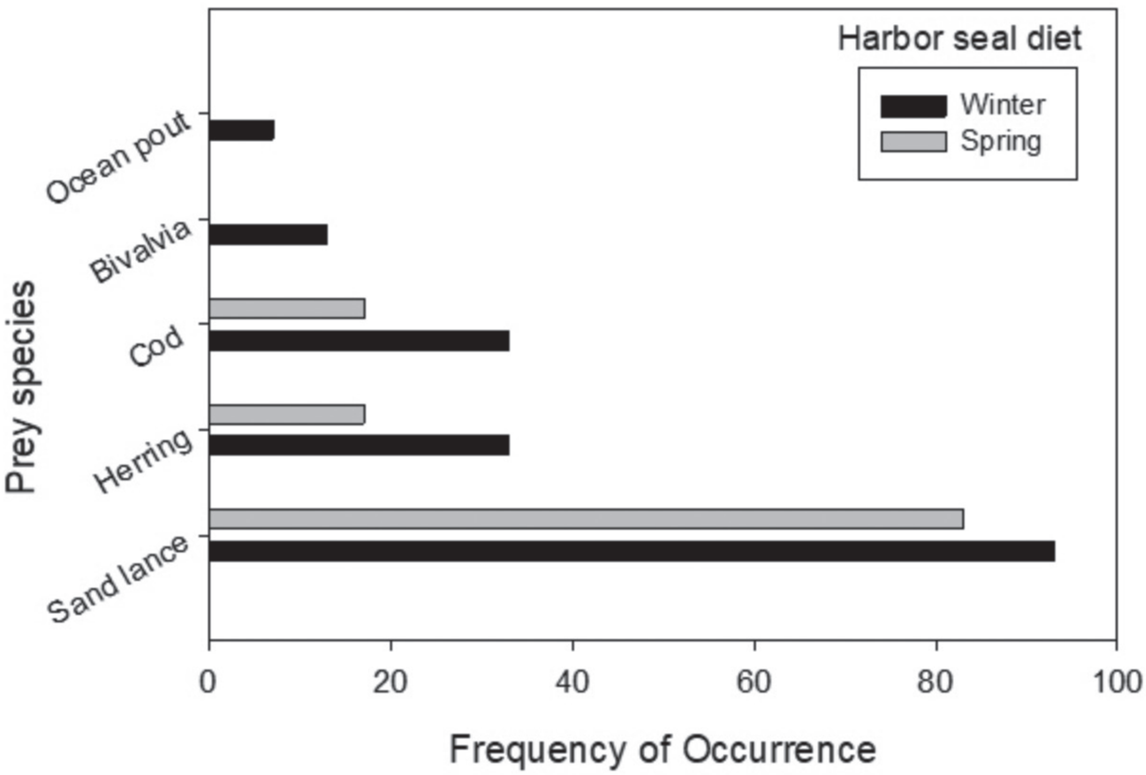
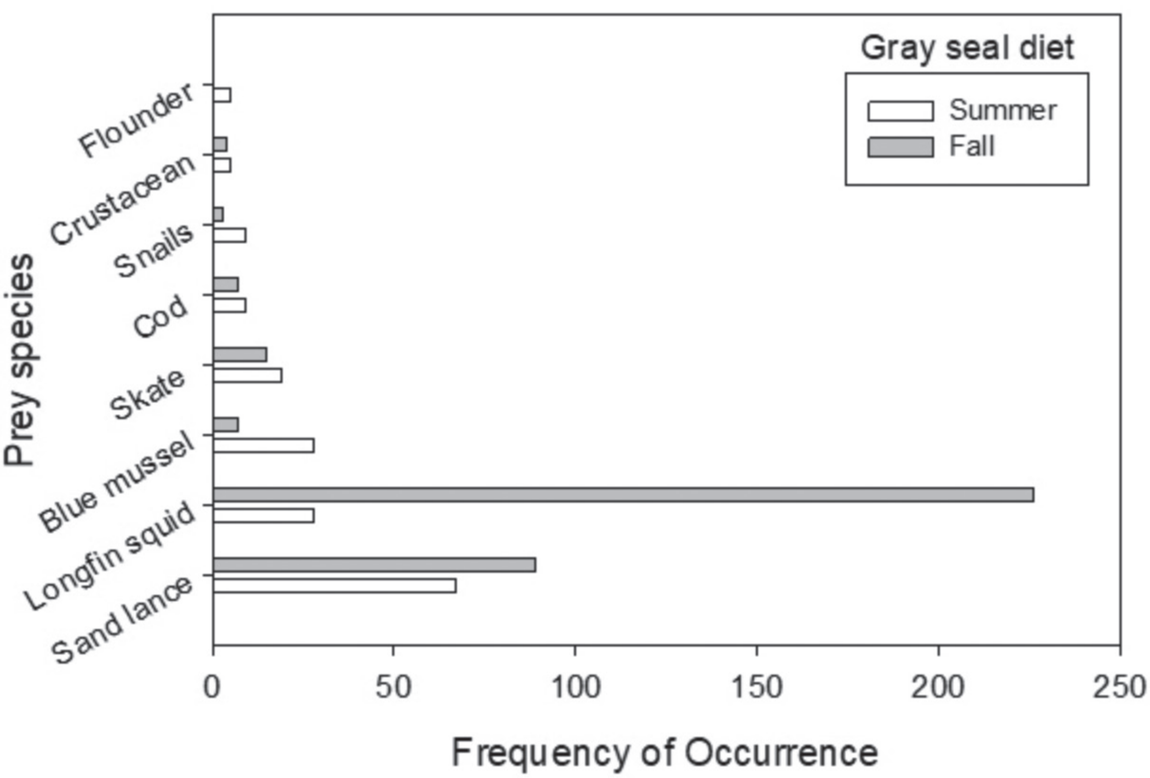


Figure 13: Occurrence of prey species in harbor seal scat samples (top) and gray seal scat samples (bottom) by season.



Interrelationships Among the Bay's Physical and Biological Features

The abundance and distribution of commercially, recreationally, and ecologically important species of fish and shellfish are influenced by the habitat type, habitat quality, and resource availability. Benthic micro-invertebrate communities are indicative of both the health of the system and the habitat present. Benthic micro-invertebrate species found in the bay range from hardy-resilient opportunists, with the ability to handle great changes to the environment, to specialized organisms that require specific substrate and salinity regimes, making them ideal for long-term monitoring and trends. Benthic micro-invertebrates are often food sources utilized by fish and shellfish. For example, horseshoe crabs are known to consume amethyst-gem clams (*Gemma gemma*) and may move according to their abundance (Botton 1984). The polychaete worms, Capitellidae, are known to be an indicator of disturbance as they are highly **opportunistic** (Blake et al. 2009). Sticklebacks, silversides and mummichogs are all known to fill **niches** within marsh systems by adapting to different food availabilities (Deegan and Garret 1997). These fish act as an important food source for predators such as winter flounder and squid, which are, along with sand lance, an important part of the diet of top predators such as the harbor and gray seal.

In a final step of our analysis, we linked data from the invertebrate surveys, fisheries independent data and seal surveys. Advances in analytical techniques have made it possible to examine habitats and their constituents as interactive communities and draw conclusions to describe the community assemblages and their health. The approach integrated both information gained from video and pictures and information from sediment analysis (Figure 14). As the habitat characteristics and benthic micro-invertebrate communities are a snapshot in time, this presents itself as an opportunity to test how useful these characteristics are when measured with a sampling design disregarding temporal aspects.

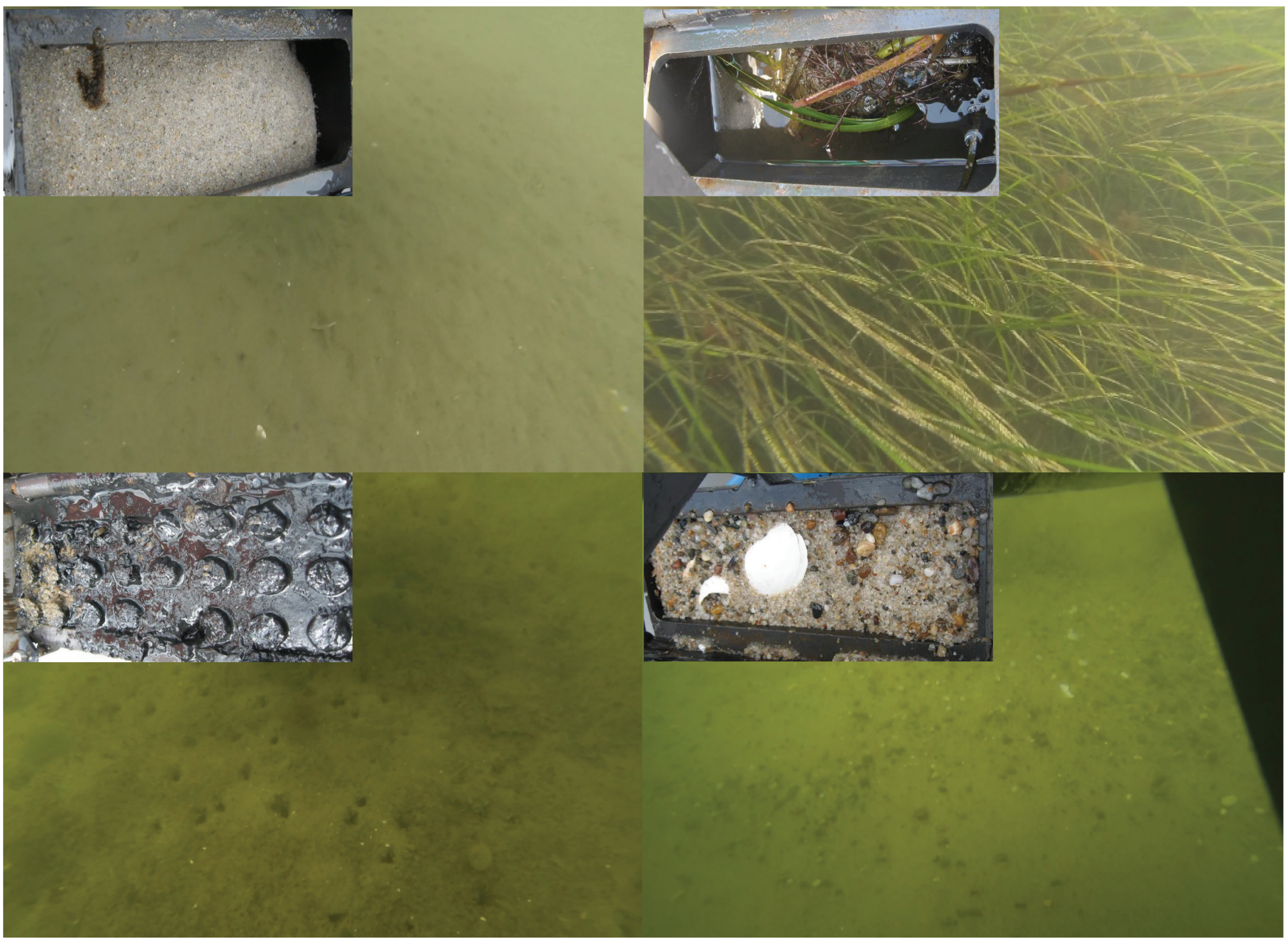


Figure 14: Video stills of in-situ sediment and pictures corresponding grab samples at four different stations in Pleasant Bay collected in the summer of 2014

Fish and shellfish communities were examined for temporal trends. Fish communities from trawl sampling were represented by six species (Figure 15), including Atlantic silverside, four spine stickleback, cunner, sand lance and mummichogs. Longfin squid represented the 6th species of fish communities. Due to their behavioral characteristics and their catchability, squid were examined in conjunction with the fish communities and not the shellfish communities.

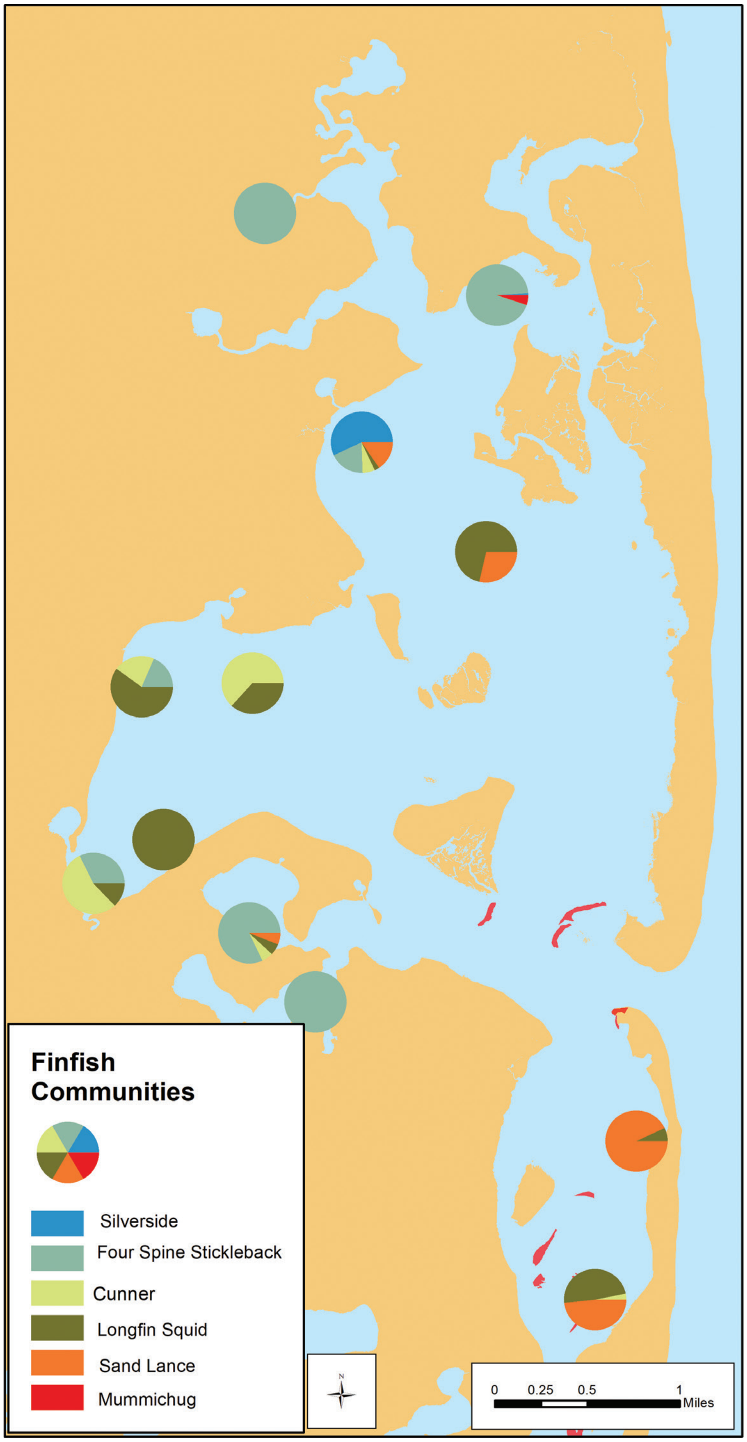


Figure 15: Six finfish species (silverside, four spine stickleback, cunner, longfin squid, sand lance, mummichog) sampled by trawl at 12 stations in Pleasant Bay (pie charts). Seal haul-outs are indicated in red. Due to their behavioral characteristics and their catchability, longfin squid were examined in conjunction with fish communities instead of shellfish communities.

Shellfish communities captured in dredge sampling showed that six species were representatives of different communities across Pleasant Bay (Figure 16): bay scallop, green crab, rock crab, common periwinkle, sea star and oyster drill. Each of these species forms a niche in the ecosystem and is associated with specific habitats. Shellfish communities captured in trawl sampling showed that five species represent the community assemblages across the bay (Figure 17, following page): bay scallop, bubble shell, common periwinkle, sea star and surf clam.

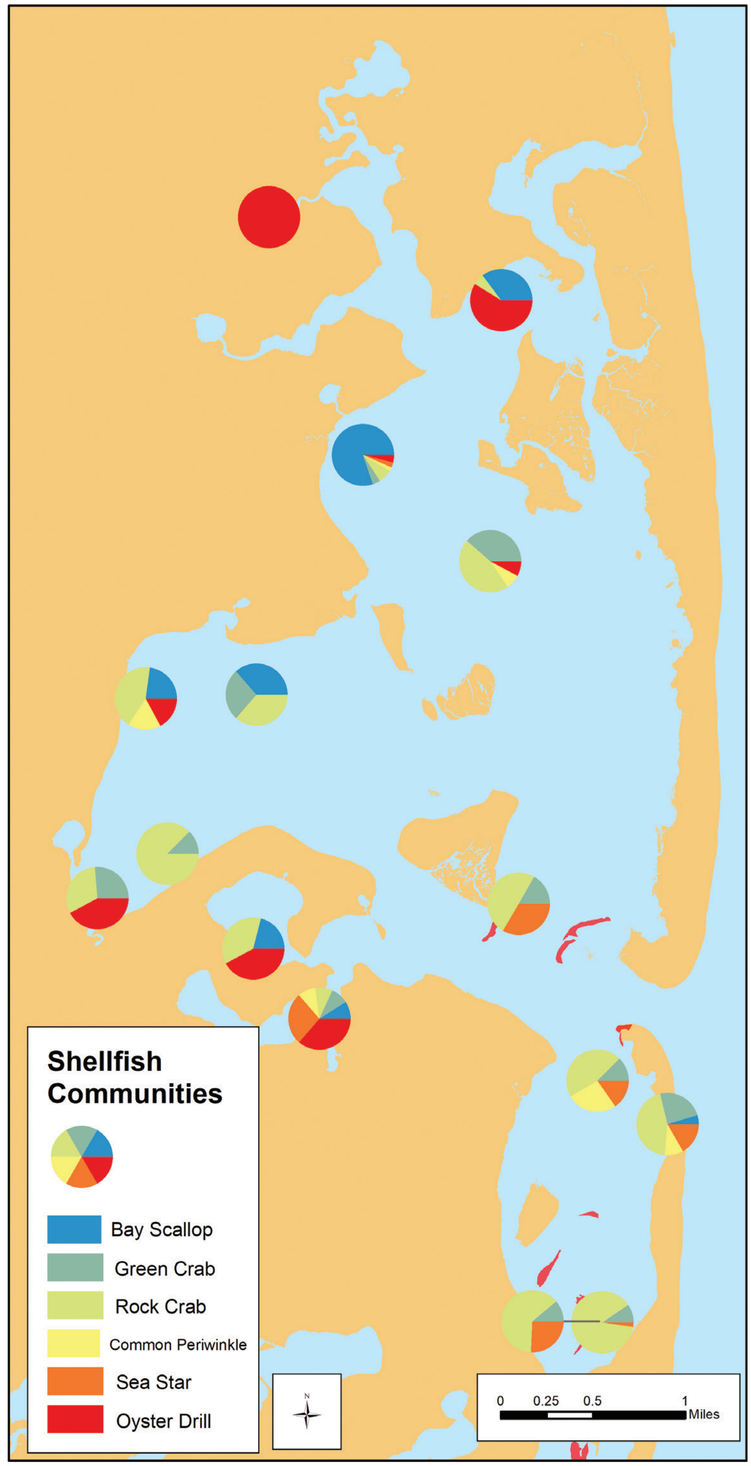


Figure 16: Six shellfish species (bay scallop, green crab, rock crab, common periwinkle, sea star, oyster drill) sampled by trawl at 15 stations in Pleasant Bay (pie charts). Seal haul-outs are indicated in red.

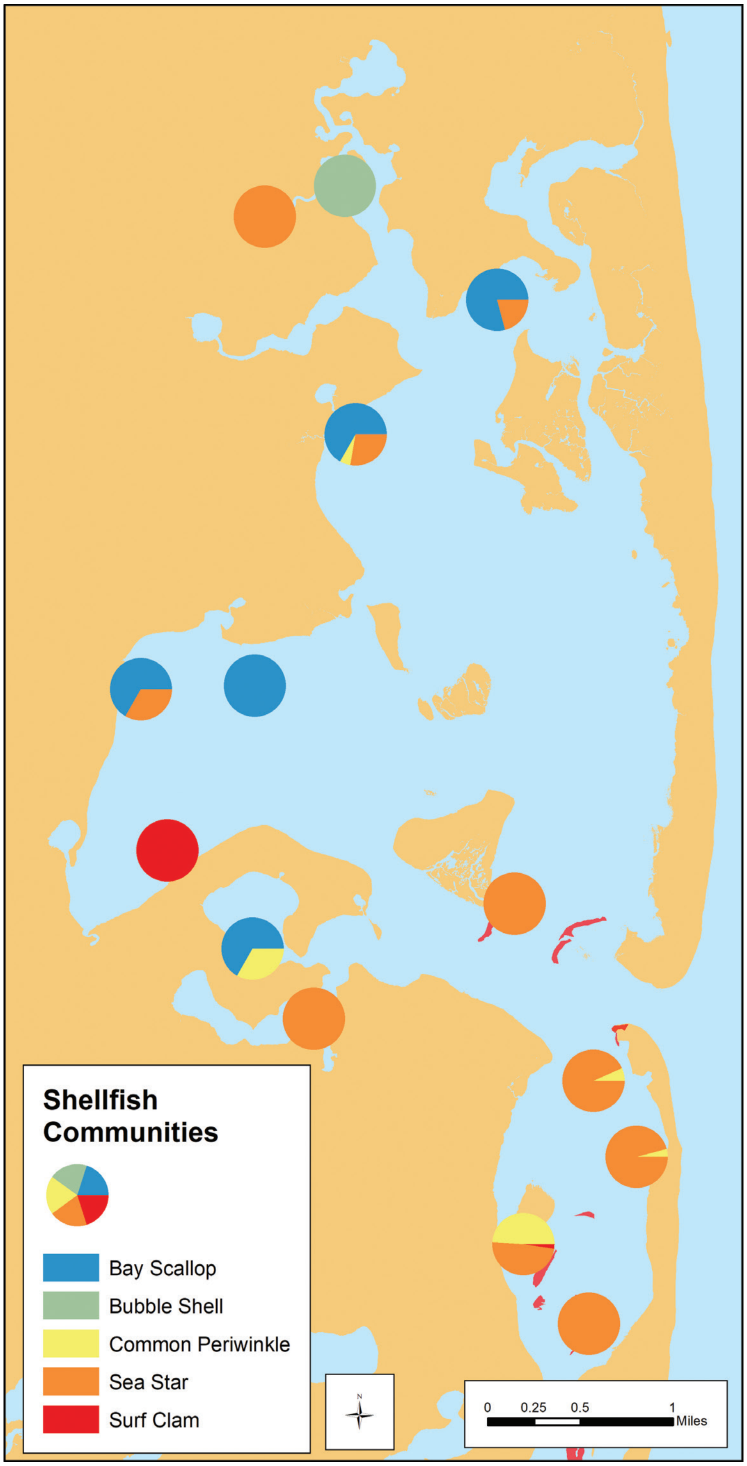


Figure 17: Five shellfish species (bay scallop, bubble shell, common periwinkle, sea star, surf clam) sampled by dredge at 14 stations in Pleasant Bay (pie charts). Seal haul-outs are indicated in red.

Linkages Among Habitats and Communities

We know that some of these species are linked to certain types of habitats such as bay scallop (eelgrass), surf clam (sandy habitat) and bubble shell (shell habitat), whereas sea stars are indicative of areas with increased salinity and periwinkles are opportunistic snails. When examining the distribution of these fish and shellfish communities, a correlation to sediment type, distance from inlet, and micro-invertebrate clusters within the substrate was found.

Further examination of fish and shellfish distribution indicates that the fish communities adjacent to seal haul-outs are comprised of the same species that are present in seal diet analysis (Figure 18). Analysis of seal scat indicated that both seal species have a high proportion of sand lance and longfin squid in their diet. These two prey species also best describe the fish communities in trawl sampling adjacent to seal haul-outs. The fisheries independent surveys and the seal diet surveys indicate that seals are consuming what is seasonally abundant within and outside the system.

Figure 18 describes fish communities. Each symbol is a different sampling event represented by different constituents. The red symbols happen to be within 200 meters of a seal haul-out and the black symbols are further. A clear difference of fish communities (See how they are separate in space.) is present, and the fishes that are driving the biggest difference are represented by the vectors. The fish communities adjacent to the seal haul-outs happened to contain species that are found in the seal scat diet of Pleasant Bay.

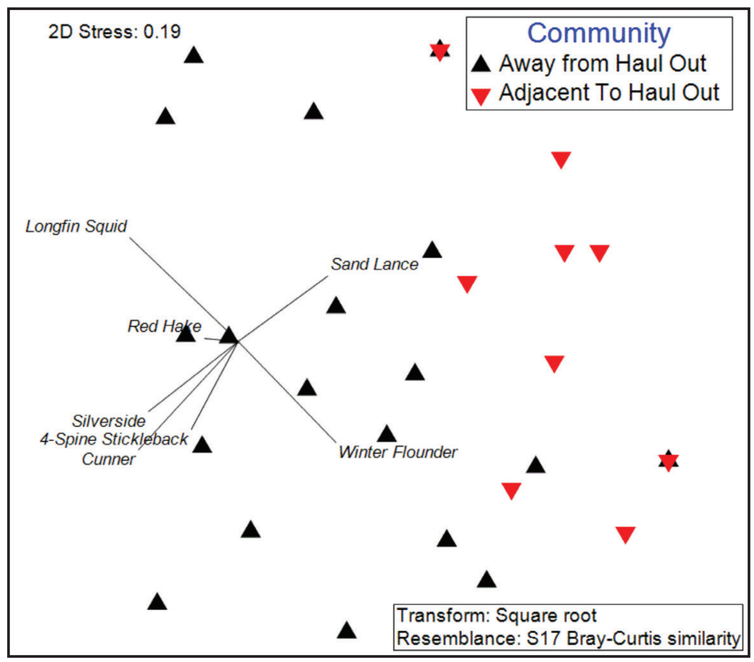


Figure 18: Non-Metric multi-dimensional scaling (nMDS) plot of fish communities adjacent to seal haul outs (red triangles) and away from seal haul outs (black triangles). Each symbol represents different fish communities. Vectors indicate species that are driving the distribution.

The fish and seal communities of Pleasant Bay connect and overlap. The abundances of fishes and shellfishes are influenced by both habitat and resource availability. Analyses showed that micro-invertebrate communities are a significant factor in shellfish distribution within the bay. Analyses also showed that two factors, micro-invertebrate communities and distance from inlet, were significant factors in the distribution of fishes in the bay. In turn, micro-invertebrate distribution correlates with sediment characteristics.

Conclusions and Recommendations

Pleasant Bay is a dynamic and productive coastal system. This study and associated data comprise a critical baseline record of biological and physical characteristics of Pleasant Bay. As habitats change, inlets shift, sea levels rise and temperatures warm, there will be changes in species abundance and composition and in the distribution of habitats. Some of these changes were observed during the course of this study.

The seafloor mapping techniques used in this assessment illuminated natural changes in Pleasant Bay that would not have been known otherwise. In areas close to the '07 Inlet, the tidal currents led to more energetic sediment transport in the area, leading to eelgrass habitat creation in one case and eelgrass burial in another. Without the data from this study, the burial/loss of eelgrass might have been incorrectly linked to another natural or human cause. Mooring chain-scour is another example of a process that is detectable and quantifiable in acoustic datasets. These data provide an important context that may be of use to other researchers and resource managers. The surveys also documented the presence of coir logs that had come free from one or more erosion control structures along the shore of the bay and may be a hazard to navigation and/or degrade the natural habitat.

Analyses of bottom types and associated biological communities highlighted the diversity of habitat types and organisms associated with them. As has been shown in studies of other coastal systems, eelgrass in Pleasant Bay is the most productive habitat, with more than twice the number of individuals and almost twice the number of species as bare sand. Seven hundred and seventeen (717) acres of eelgrass were identified in Pleasant Bay using bathymetric mapping and backscatter imagery.

Atlantic silversides, mummichogs and striped killifish were among the dominant fish species observed in Pleasant Bay. Species that are food for larger fishes and animals (e.g. sand lance, silversides, sea herring, and longfin squid) were well-represented in trawl surveys. Winter flounder were among the most abundant species at stations sampled in 1965-66 but were comparably less abundant in the present study. Many fish and commercially important invertebrate species were found in the bay in juvenile stages, but rarely at larger sizes, indicating important nursery habitats. Targeted shellfish surveys established a baseline of shellfish abundance at select areas identified by natural resource management agencies. Mussel beds changed in distribution during this investigation. Bay scallops were essentially absent from areas identified by natural resource managers and local fishermen.

Aerial surveys showed that harbor seals inhabit Pleasant Bay seasonally in winter and spring, while gray seals utilize the bay in summer and fall. In 2014 and 2015, the only overlap of the two species observed was in December of 2015. However, during the 2016 scat collection trips, CCS observed more overlap of harbor and grays seals in the fall. Nine haul-out sites were identified during 2014 and 2015. Analysis of seal scat revealed that diets of both harbor and gray seals were dominated largely by sand lance. The fisheries independent surveys and the seal diet analysis indicate that seals are consuming what is seasonally abundant within and outside the system.

Integrated analysis of different data sets collected during this study indicates that both micro-invertebrate communities and distance from inlet were significant factors in the distribution of fishes in the bay. In turn, micro-invertebrate distribution correlates with sediment characteristics and habitat type. Further investigation of the fish communities and proximity to seals observed, identifies an overlap in diet and fish abundance that warrants further investigation. The connection of abiotic and biotic factors during this baseline study warrants further investigation into how the inlets, tide and habitat changes of Pleasant Bay affect species that are of commercial, recreational and ecological importance in Pleasant Bay.

- Further investigation into biological and physical factors, such as competition, predation, types of vegetation and water quality will aid in explaining the distribution of invertebrates.
- Fine tuning of sampling equipment (to encompass more fish and shellfish species) and analytical methodologies (like DNA analysis of seal prey species) will lead to an even more comprehensive picture of how the 67,167 individuals or 148 species found in Pleasant Bay utilize this ecosystem.
- The use of pontoon boats and Unmanned Aerial Systems (UAS) will enable acoustic surveys in extreme shallow water. The latter will also facilitate more frequent and cost efficient monitoring of seal populations, given the proper permitting.
- Future seal distribution investigations could include collaboration with organizations interested in satellite tagging gray and harbor seals inside the bay. Pooling resources to maximize the number of seals tagged will increase our understanding of how each species use the entire bay system.
- Any long-term monitoring methodologies (season of field work, sampling locations, sampling equipment used) should be based on this study to ensure the ability to compare results across years.

1Eelgrass was identified only in areas that had sidescan imagery. Eelgrass was included here if it could be identified in patches 100 m2 or larger and within 100 m2 of each other. 717 acres of eelgrass should be considered the minimum amount of eelgrass in Pleasant Bay at the time of acoustic surveys, summer and fall of 2014.

- Engaging the public via citizen science programs could establish a constant stream of supplemental data feeding into seal and fisheries monitoring.

- The presence of tropical fishes (Figure 19) in Pleasant Bay warrants further investigation. This work has begun in Pleasant Bay as an offshoot of this study, in collaboration with the New England Aquarium and the Gulf Stream Orphan Project.

- Analysis of seal scat samples detected micro debris (often referred to as micro plastics). Future studies could research distribution and impact of micro debris in the marine wildlife of Pleasant Bay.

This study and associated data comprise a critical baseline record of biological and physical characteristics of Pleasant Bay. Pleasant Bay is spawning and nursery habitat for a variety of commercially, recreationally, and ecologically important marine animals.

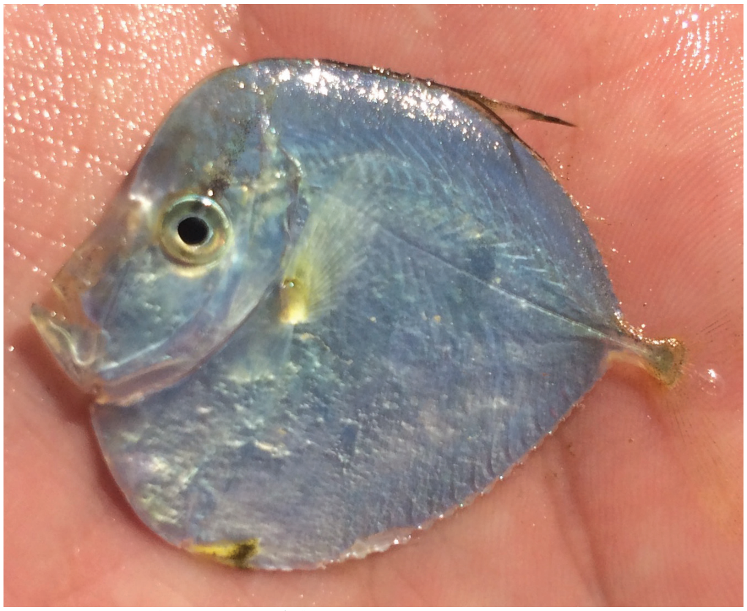


Figure 19. Atlantic moonfish (*Selene setapinnis*)

Future sampling and monitoring will further unlock links between seasons, habitats and abundances and will allow us to connect them to the influences of human actions affecting Pleasant Bay. As the habitat changes, inlets shift, sea levels rise and temperatures warm, both the species composition of Pleasant Bay communities and the distribution of habitats will change. Therefore, and in order to trace and mitigate any impacts, it is necessary to utilize and expand a robust monitoring plan as the basis for strong ecosystem based management.

Acknowledgements

The benthic habitat mapping throughout Pleasant Bay would not have been possible without the significant support from the FOPB. As part of a larger project funded by the National Park Service (NPS) the support of the FOPB allowed the Center to map outside the boundaries of Cape Cod National Seashore (CCNS). This provided the opportunity to map the bay as an entire ecosystem, as it should be, rather than based on an arbitrary boundary. Additional logistical, lab and field support was provided by CCNS for the mapping, The International Fund for Animal Welfare (IFAW) provided two staff members, volunteers and a vessel support for the monthly surveys for the seal diet surveys in 2016. CCS volunteers spent 2,900 hours in the field and at the lab analyzing fishery and benthic samples.

This ecosystem assessment is consistent with the Friends of Pleasant Bay (FOPB) goals of promoting education, research and public awareness; preserving the environmental integrity of the bay and ensuring habitat protection and retention of the bay's rich biological diversity and productivity. It is also consistent with recommendations included in the Pleasant Bay Alliance (PBA) 2013 Pleasant Bay Resource Management Plan (PBRMP). In addition, the results of this assessment, and studies by other investigators working in the bay, can be integrated into an existing digital database, such as that developed by PBA and others for the Coastal Resource Guide for Pleasant Bay/Chatham Harbor, and/or a new database.

Glossary

Amphipod: Amphipods (also known as sideswimmers) are an order of crustacean with no carapace and laterally compressed bodies. Locally they range in size form 0.03 inches to 0.5 inches and are mostly detrivore or scavengers. They are mostly marine animals but are found in almost all aquatic environments. The name Amphipods translates from Greek to “different” “foot” and refers to the two different kinds of legs amphipods have.

Bathymetry: is defined as underwater topography.

Biotope: the term biotope comes from the Greek “bios” life and “topos” place and literally translates to “area where life lives”. A biotope is part of a habitat and is characterized by uniform abiotic features (such as depth or light availability) and associated animal and plant species.

Beach seine: A hand-hauled net for sampling fish in shallow water.

Capitellidae: or threadworms (usually 2 in long), are a family of marine polychaetes, or bristle worms. They are often earthworm-like in color. Members of this family build networks of tubes in mud. They tolerate organic-rich, low oxygen and polluted conditions.

Cartilaginous fish: include sharks, skates and rays. These fish have a skeleton composed of cartilage versus bone which you would typically see in the bony fishes such as cod or herring.

Cephalopod beak: Squid (or cephalopod) beaks are composed primarily of chitin (comparable to crab and lobster shells) and look a lot like the beak of a bird. The function of a squid’s beak is to capture and break up prey that squids then consume.

CMECS: The Coastal and Marine Ecological Classification Standard provides a comprehensive national framework for organizing information about coasts and oceans and their living systems. This information includes the physical, biological, and chemical data that are collectively used to define coastal and marine ecosystems. It is compatible with many existing upland and wetland classification standards and can be used with most if not all data collection technologies. These characteristics allow scientists to more easily use and compare data from various sources and time frames. CMECS was approved by the Federal Geographic Data Committee (FGDC). As an FGDC standard, federally funded projects working with environmental data in the coastal zone should use CMECS as their primary classification system or include CMECS attributes for their data.

Community: In ecology, a community is a group of two or more different species occupying the same geographical area at the same time.

Dermal denticles: Dermal denticles (placoid scales) are modified scales that cover the skin of elasmobranchs (sharks and rays). The denticles act as protection or “armor” against predators. Researchers often find dermal denticles from rays in seal scat studies. Their shapes and coloring are highly variable.

Dredge: An apparatus that is towed along the bottom to capture organisms on or under the seafloor.

Ecosystem: An Ecosystem is made up of living organisms and non-living components such as air, water and sediment. The living (biotic) and non-living (abiotic) components interact through energy flows and nutrient cycles. Ecosystems are controlled by external (e.g. climate and topography) and internal factors, both of which can be influenced by human activity. Ecosystems can be of any size and can encompass multiple habitats, but are usually of limited space. They provide benefits, called ecosystem services, which people depend on. Ecosystem management is generally more efficient than trying to manage individual species.

Fish otolith: The sagittal otoliths (ear bones) are the largest of the three otoliths found in the head of bony fish. They are made up of calcium carbonate and are located behind the brain. Different species of fish have different shaped and sized otoliths. They are commonly used to identify prey species in diet studies of marine animals.

Gemma gemma: the amethyst gem clam is a species of venus clams and grows up to 0.2 inches in size. This clam is common in shallow estuaries, bays and marshes. The species is native to the Atlantic coast of North America but is now found as an invasive species along the Pacific coast.

Geoform: The Geoform component of CMECS captures the geological features of the seascape and describes physical structures of the environment across multiple scales

Gillnet: A net designed to entangle fishes that swim into its mesh.

Habitat: A habitat is the natural environment in which a particular species lives. It is characterized by both physical and biological features. A species’ habitat is those places where it can find food, shelter, protection and mates for reproduction. As opposed to the **niche**, habitats do not include an organism’s interactions with its surroundings.

Micro-invertebrates: Invertebrates is a blanket term that includes all animals that do not posses a spine. This includes giant squid and oysters as well as jellyfish. For the purpose of this study, micro-invertebrates were defined as microscopic animals collected by benthic grabs.

Niche: A niche is the sum of all environmental factors (forming a **habitat**) and biological interactions. The niche of an animal is its place in the environment plus its relations to food and interactions with other species.

Opportunistic: Opportunistic means taking advantage of opportunities as they arise.

In ecology opportunistic organism can live and thrive in variable environmental conditions, and sustain themselves from a number of different food sources, or can rapidly take advantage of favorable conditions when they arise, because the organism is behaviorally sufficiently flexible. Such species can for example postpone reproduction, or stay dormant, until conditions make growth and reproduction possible. Opportunist behavior means that an organism is able to seize and use diverse opportunities in its environment to survive and grow.

In sampling design, opportunistic refers to sampling decisions usually made during field work that generally improve or adapt previous sampling methods or take advantage of opportunities as they arise.

Passive collector: A trap-like device designed to attract and retain fish or invertebrates by creating artificial shelter.

Seismic reflection profiling: is a widely-used technique for using sound waves to image underground rock strata A sound wave is created on the ship and travels down through the water before penetrating into the layers of sediments and rocks of the ocean floor. Some of this sound reflects (echos) off the layers, and travels back up to the surface of the ocean, where it is recorded by a hydrophone (or underwater microphone) trailed behind the ship.

Sidescan Sonar: Sidescan sonar creates a picture or an image of the sea floor. It measures the strength of how “loud” the return echo is and paints a picture. Hard areas of the sea floor like rocks reflect more sound and have a stronger or louder return signal than softer areas like sand. Areas with loud echoes are darker than areas with quiet echoes. Objects or features that rise above the sea floor also cast shadows in the sonar image where no sound hits. The size of the shadow can be used to estimate the size of the feature.

Tellina agilis: the northern dwarf tellin (up to 0.6 in long), has smooth, thin shell and a long siphon for deposit feeding, which are often bitten off by fish. Members of this genus burrow horizontally in silty sands. They often prefer lower salinities.

Trawl: A funnel-shaped net towed through the water to catch fish and invertebrates.

Ventless lobster trap: A modified lobster trap without vents for undersized animals to escape.

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Below the Surface of the Bay

Marine Ecosystem Assessment of Pleasant Bay

Pleasant Bay on Cape Cod is part of the Nauset Beach/Monomoy Island - barrier spit - barrier island system. The bay is surrounded by approximately 42.9 miles of coastline, and its watershed includes the towns of Orleans, Chatham, Harwich and Brewster. A highly valued regional resource, it is designated by the state and recognized by the surrounding towns as an Area of Critical Environmental Concern (ACEC). This valuable ecosystem, a collection of both living and nonliving components, is at risk from development within its watershed and from human activities within the bay.

The Friends of Pleasant Bay (FOPB) funded the Center for Coastal Studies (CCS) to conduct an ecosystem assessment of Pleasant Bay between 2014 and 2017. The goal of this research was to:

Develop a dataset of baseline information that assesses the present status of the natural resources of Pleasant Bay and that can be used to develop a long-term habitat monitoring program.

These are the results of that assessment.

Friends of Pleasant Bay

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