Environmental Assessment
Appendix E:
Essential Fish Habitat

U.S. Army Corps of Engineers
New York District

January 2004

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APPENDIX E1

ESSENTIAL FISH HABITAT ASSESSMENT

NEW YORK AND NEW JERSEY HARBOR DEEPENING PROJECT

ESSENTIAL FISH HABITAT ASSESSMENT

JANUARY 2004

U.S. Army Corps of Engineers – New York District
Environmental Analysis Branch
Jacob K. Javits Federal Building
26 Federal Plaza
New York, New York 10278

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1 INTRODUCTION

Based on data collected during recent aquatic biological sampling programs (USACE 2002a, 2002b, 2002c) the U.S. Army Corps of Engineers (USACE), New York District (the District) has reinitiated Essential Fish Habitat (EFH) consultation with the National Marine Fisheries Service (NMFS) to determine what, if any, seasonal restrictions should be placed on New York and New Jersey Harbor (the Harbor) deepening activities to minimize potential adverse impacts during construction of the authorized navigation channel improvement projects.

EFH is defined under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (PL 94-265), as amended by the Sustainable Fisheries Act (SFA) of 1996 (PL 104-267), as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The SFA requires that EFH be identified for those species actively managed under Federal fishery management plans (FMPs). This includes species managed by the eight regional Fishery Management Councils (FMCs), established under the MSFCMA, as well as those managed by NMFS under FMPs developed by the Secretary of Commerce.

The National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service Guide to Essential Fish Habitat Designations in the Northeastern United States, Volume III: Connecticut and New York, March 1999 (NMFS 1999) and the agencies associated website Guide to Essential Fish Habitat Designations in the Northeastern United States (http://www.nero.noaa.gov/ro/doc/webintro.html) provides a geographic guide to "the species and life stages of fish, shellfish, and mollusks for which EFH has been designated in a particular area" (NMFS 2003).

EFH designations emphasize the importance of habitat protection to healthy fisheries and serve to protect and conserve the habitat of marine, estuarine, and anadromous finfish; mollusks; and crustaceans. EFH embodies both the water column (including its physical, chemical, and biological growth properties) and its underlying substrate (including sediment, hard bottom, and other submerged structures). Under the EFH definition, necessary habitat is that which is required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. EFH is designated for a species' complete life cycle, including spawning, feeding, and growth to maturity, and may be specific for each life stage (eggs, larvae, juvenile and adult).

EFH designations are based on various levels of information available for a species' life stage distribution, abundance, and habitat-productivity relationships. Information levels include: presence/absence (Level 1); habitat-related densities (Level 2); growth, reproduction, and survival rates within habitats (Level 3); and production rates by habitat types (Level 4). Several long-standing and comprehensive sources of information are available to develop EFH designations, including the NMFS bottom trawl survey (1963-97), the NMFS Marine Resources Monitoring, Assessment and Prediction (MARMAP) ichthyoplankton survey (1977-87), the NOAA Estuarine Living Marine Resources (ELMR) program, and state or regional surveys (e.g., Connecticut Trawl Survey of Long Island Sound). For most species, the primary source of information currently used to designate EFH within the Hudson-Raritan River and Sandy Hook Bay estuary was the ELMR program (NEFMC 1998, MAFMC 1998 a, b). Conducted jointly by NOAA's Strategic Environmental Assessment (SEA) Division, the Office of Ocean Resources Conservation and Assessment (ORCA), the ELMR program used both quantitative and qualitative information to develop a consistent database on the life history, relative abundance, and distribution of fish and invertebrates in estuaries throughout the nation (Stone, et al. 1994). Species information contained in the ELMR database is reported as a monthly relative abundance of each species' life stage by estuary for three salinity zones (seawater, mixing, and tidal freshwater). ELMR relative abundance was based on both quantitative studies and the professional and personal knowledge of regional, state, and local scientists and managers familiar with the species and estuaries considered. For EFH designation purposes, ELMR information is considered Level 1 (presence/absence).

NMFS (1999a) has summarized EFH in ten-minute squares of latitude and longitude in the waters along the Atlantic coast, including inshore estuaries. A summary of EFH identified in these latitude and longitude squares within or adjacent to the project area is provided in Table E1-1. Figure E1-1 provides the square locations and ELMR salinity zones within the Hudson-Raritan estuary and Sandy Hook Bay. Because the boundaries of the estuaries do not coincide exactly with the latitude and longitude coordinates for each square, a life-stage inclusion for a given species in the summary table may not correspond with its inclusion in the individual squares (NMFS 1999a).

EFH that is judged to be particularly important to the long-term productivity of populations of one or more managed species, or to be particularly vulnerable to degradation, may also be identified by Fisheries Management Councils (FMC) and NMFS as habitat areas of particular concern (HAPC). Areas of EFH considered HAPC must be proven to be important to the ecological function provided by the habitat for managed species. The extent to which the habitat is sensitive to human-induced environmental degradation, including development activities that stress the habitat and the rarity of the habitat are considered (NEFMC 1998).

The only managed species in the project area for which HAPC has been identified is summer flounder. NMFS identifies HAPC for juvenile and adult summer flounder across its entire range as: all native species of macroalgae, seagrasses, and freshwater and tidal macrophytes in any size bed, as well as loose aggregations, within adult and juvenile summer flounder EFH is HAPC. The remainder of the EFH species in the project area have no HAPC identified anywhere in their range (NMFS 2003).

2 EFH DESIGNATIONS WITHIN THE PROJECT AREA

A summary of those species for which EFH has been designated in the Hudson-Raritan estuary and Sandy Hook Bay is provided in Table E1-2 (NMFS 1999a, NMFS 2003). EFH has been designated for specific life stages based on their occurrence in tidal freshwater, estuarine (i.e., mixing/brackish salinity zone), or marine (i.e., seawater salinity zone) waters. EFH for most species includes both the estuarine and marine waters within and surrounding the project area. Exceptions include butterfish larvae (estuarine waters only), Atlantic mackerel juveniles and adults (marine waters only), summer flounder larvae (estuarine, marine, and tidal freshwater), and scup (marine waters only for all life stages).

Of the EFH species listed, only winter flounder, windowpane flounder, and scup have EFH designated in the project area for each stage of their life cycle. Red hake, Atlantic sea herring (*Clupea harengus*), Atlantic butterfish, and summer flounder have EFH designated for larval to adult stages. Bluefish, Atlantic mackerel, and black sea bass have had EFH designated for juvenile and adult stages.

EFH has been designated in the project area for several finfish species and life stages, and is identified by channel below. Note that this information is based solely on the designation of species and life stages in the 10-minute by 10-minute squares provided for use in determining the presence of EFH by the National Marine Fisheries Service on their website. Because the limits of these squares do not coincide with channel or estuarine boundaries, a species or life stage identified in a square may not be present in a particular channel or estuary. Fortunately, the data from several fish sampling programs conducted in the project area over the past several years can be used to assist in accurately determining the presence of EFH.

Ambrose Channel EFH has been designated for the following species in the vicinity of the Ambrose Channel: red hake (eggs, larvae, juveniles, and adults); winter flounder (eggs, larvae, juveniles, and adults); windowpane flounder (eggs, larvae, juveniles, and adults); Atlantic herring (larvae, juveniles, and adults); bluefish (eggs, larvae, juveniles, and adults); butterfish (juveniles and adults); Atlantic mackerel (juveniles and adults); summer flounder (larvae, juveniles, and adults); scup (eggs, larvae, juveniles, and adults); black sea bass (juveniles and adults); king mackerel (*Scomberomorus cavalla*) (eggs, larvae, juveniles, and adults); Spanish mackerel (*S. maculatus*) (eggs, larvae, juveniles, and adults); cobia (*Rachycentron canadus*) (eggs, larvae, juveniles, and adults); sand tiger shark (*Odontaspis taurus*) (larvae); dusky shark (Carcharhinus obscurus) (larvae and juveniles); and sandbar shark (C. plumbeus) (larvae, juveniles, and adults).

Anchorage Channel EFH has been designated for the following species in the vicinity of the Anchorage Channel: red hake (eggs, larvae, and juveniles); winter flounder (eggs, larvae, juveniles, and adults); windowpane flounder (eggs, larvae, juveniles, and adults); Atlantic herring (larvae, juveniles, and adults); bluefish (juveniles and adults); butterfish (larvae, juveniles, and adults); summer flounder (larvae, juveniles, and adults); scup (eggs, larvae, juveniles, and adults); black sea bass (juveniles and adults); king mackerel (eggs, larvae, juveniles, and adults); Spanish mackerel (eggs, larvae, juveniles, and adults); cobia (eggs, larvae, juveniles, and adults); sand tiger shark (larvae); dusky shark (larvae and juveniles); and sandbar shark (larvae and adults).

Kill Van Kull Channel EFH has been designated for the following species in the vicinity of the Kill Van Kull Channel: red hake (eggs, larvae, and juveniles); winter flounder (eggs, larvae, juveniles, and adults); windowpane flounder (eggs, larvae, juveniles, and adults); Atlantic herring (larvae, juveniles, and adults); bluefish (juveniles and adults); butterfish (larvae, juveniles, and adults); summer flounder (larvae, juveniles, and adults); scup (eggs, larvae, juveniles, and adults); black sea bass (juveniles and adults); king mackerel (eggs, larvae, juveniles, and adults); Spanish mackerel (eggs, larvae, juveniles, and adults); cobia (eggs, larvae, juveniles, and adults); sand tiger shark (larvae); dusky shark (larvae and juveniles); and sandbar shark (larvae and adults).

Arthur Kill to Howland Hook Channel EFH has been designated for the following species in the vicinity of the Arthur Kill Channel to Howland Hook: red hake (eggs, larvae, and juveniles); winter flounder (eggs, larvae, juveniles, and adults); windowpane flounder (eggs, larvae, juveniles, and adults); Atlantic herring (larvae, juveniles, and adults); bluefish (juveniles and adults); butterfish (larvae, juveniles, and adults); summer flounder (larvae, juveniles, and adults); scup (eggs, larvae, juveniles, and adults); king mackerel (eggs, larvae, juveniles, and adults); Spanish mackerel (eggs, larvae, juveniles, and adults); cobia (eggs, larvae, juveniles, and adults); and sandbar shark (larvae and adults).

Newark Bay Channel EFH has been designated for the following species in the vicinity of the Newark Bay Channel to the Elizabeth Port Authority Marine Terminal: red hake (eggs, larvae, juveniles, and adults); winter flounder (eggs, larvae, juveniles, and adults); windowpane flounder (eggs, larvae, juveniles, and adults); Atlantic herring (larvae, juveniles, and adults); bluefish (eggs, larvae, juveniles, and adults); butterfish (larvae, juveniles, and adults); summer flounder (larvae, juveniles, and adults); scup (eggs, larvae, juveniles, and adults); black sea bass (juveniles and adults); king mackerel (eggs, larvae, juveniles, and adults); Spanish mackerel (eggs, larvae, juveniles, and adults); cobia (eggs, larvae, juveniles, and adults); sand tiger shark (larvae); dusky shark (larvae and juveniles); and sandbar shark (larvae, juveniles, and adults).

Port Jersey Channel EFH has been designated for the following species in the vicinity of the Port Jersey Channel: red hake (eggs, larvae, juveniles, and adults); winter flounder (eggs, larvae, juveniles, and adults); windowpane flounder (eggs, larvae, juveniles, and adults); Atlantic herring (larvae, juveniles, and adults); bluefish (eggs, larvae, juveniles, and adults); butterfish (larvae, juveniles, and adults); summer flounder (larvae, juveniles, and adults); scup (eggs, larvae, juveniles, and adults); black sea bass (juveniles and adults); king mackerel (eggs, larvae, juveniles, and adults); Spanish mackerel (eggs, larvae, juveniles, and adults); cobia (eggs, larvae, juveniles, and adults); sand tiger shark (larvae); dusky shark (larvae and juveniles); and sandbar shark (larvae, juveniles, and adults).

Bay Ridge Channel EFH has been designated for the following species in the vicinity of the Bay Ridge Channel: red hake (eggs, larvae, and juveniles); winter flounder (eggs, larvae, juveniles, and adults); windowpane flounder (eggs, larvae, juveniles, and adults); Atlantic herring (larvae, juveniles, and adults); bluefish (juveniles and adults); butterfish (larvae, juveniles, and adults); summer flounder (larvae, juveniles, and adults); scup (eggs, larvae, juveniles, and adults); black sea bass (juveniles and adults); king mackerel (eggs, larvae, juveniles, and adults); Spanish mackerel (eggs, larvae, juveniles, and adults); cobia (eggs, larvae, juveniles, and adults); sand tiger shark (larvae); dusky shark (larvae and juveniles); and sandbar shark (larvae and adults).

Table E1-1

Summarized Locations of EFH within the Project Area
Life Stage and EFH Location (10' x 10' latitude and longitude square)

	Eggs							Larvae						
Species	**42**	**56**	**57**	**58**	**72**	**73**	**74**	**42**	**56**	**57**	**58**	**72**	**73**	**74**
Red hake		X	X	X			X	X	X	X	X	X	X	X
Winter flounder	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Windowpane Flounder	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic herring								X	X	X		X	X	
Bluefish							X							X
Butterfish								X	X	X	X	X	X	
Atlantic mackerel														
Summer flounder								X	X	X	X	X	X	
Scup	X	X	X	X	X			X	X	X	X	X		
Black sea bass	n/a													
King mackerel	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spanish mackerel	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cobia	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sand tiger shark								X		X	X			X
Dusky shark										X	X		X	X
Sandbar shark								X	X	X	X	X	X	X

Table E1-1

Summarized Locations of EFH within the Project Area
Life Stage and EFH Location (10’ x 10’ latitude and longitude square)

	Juveniles							Adults						
Species	**42**	**56**	**57**	**58**	**72**	**73**	**74**	**42**	**56**	**57**	**58**	**72**	**73**	**74**
Red hake	X	X	X	X	X	X	X	X				X	X	
Winter flounder	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Windowpane Flounder	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic herring	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bluefish	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Butterfish	X	X	X	X	X	X	X	X	X	X	X	X	X	
Atlantic mackerel	X	X	X	X	X	X	X	X	X	X	X	X	X	
Summer flounder	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Scup	X	X	X	X	X	X	X		X	X	X	X	X	X
Black sea bass	X	X	X	X	X	X	X	X		X	X	X	X	X
King mackerel	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spanish mackerel	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cobia	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sand tiger shark														
Dusky shark			X				X							
Sandbar shark	X			X			X	X	X	X	X		X	X

Table E1-2

Summary of Federally Managed Species with EFH Designations in the Hudson-Raritan Estuary and Sandy Hook Bay

Species	**Life Stage**				
	Eggs	**Larvae**	**Juveniles**	**Adults**	**Spawning Adults**
Red hake (*Urophycis tenuis*)		M,S	M,S	M,S	
Winter flounder (*Pseudopleuronectes americanus*)	M,S	M,S	M,S	M,S	M,S
Windowpane flounder (*Scopthalmus aquosus*)	M,S	M,S	M,S	M,S	M,S
Atlantic sea herring (*Clupea harengus*)		M,S	M,S	M,S	
Bluefish (*Pomatomus saltatrix*)			M,S	M,S	
Long finned squid (*Loligo pealei*)	n/a	n/a			
Short finned squid (*Illex illecebrosus*)	n/a	n/a			
Butterfish (*Peprilus triacanthus*)		M	M,S	M,S	
Atlantic mackerel (*Scomber scombrus*)			S	S	
Summer flounder (*Paralicthys dentatus*)		F,M,S	M,S	M,S	
Scup (*Stenotomus chrysops*)	S	S	S	S	
Black sea bass (*Centropristus striata*)			M,S	M,S	
Surf clam (*Spisula solidissima*)	n/a	n/a			
Ocean quahog (*Artica islandica*)	n/a	n/a			
Spiny dogfish (*Squalus acanthias*)	n/a	n/a			
King mackerel (*Scomberomorus cavalla*)	X	X	X	X	
Spanish mackerel (*Scomberomorus maculatus*)	X	X	X	X	
Cobia (*Rachycentron canadum*)	X	X	X	X	

S = Includes the seawater salinity zone (salinity $\geq$ 25.0 ‰)
M = Includes mixing water / brackish salinity zone (0.5‰ < salinity < 25.0‰)
F = Includes tidal freshwater salinity zone (0.0‰ $\leq$ salinity $\geq$ 0.5‰)

n/a = No EFH designated for this lifestage (squids, surf clam, ocean quahog). With regard to the squids, the surf clam, and the ocean quahog, juvenile corresponds to pre-recruits, and adult corresponds to recruits in these species' life histories.

Source: NMFS (1999)

3 EFH ASSESSMENT

The EFH assessments for the ten identified species are based on the potential direct, indirect and cumulative impacts resulting from both short and long term changes to aquatic habitats as a result of the proposed consolidation of separately authorized navigation improvement projects[1] (Predecessor Projects) with the New York and New Jersey Harbor Navigation Project (Recommended Plan), the combination of which to be hereinafter known as consolidated implementation. For the purpose of this assessment, the three types of impacts are defined as follows:

- Direct impacts are those that would directly affect the habitat of the ten species, or cause direct mortality. These impacts include physical alterations to the useable habitat for each species.

- Indirect impacts include potential direct impacts to the forage species of the ten designated species in the form of displacement, temporary loss of forage species habitat and/or temporary loss of forage species individuals.

- Cumulative impacts, for the purpose of this EFH assessment, are considered to be those impacts on the habitat of the ten species resulting from the simultaneous dredging of more than one channel at any given time or other channels undergoing maintenance dredging at the time of the deepening. These impacts would be a combination of the direct and indirect impacts to habitat associated with each dredging effort.

Potential effects attributable to the Recommended Plan are those short-term and long-term impacts associated with deepening the channels to the authorized 50 ft depth. Direct, indirect and cumulative impacts associated with unconsolidated implementation of the Predecessor Projects and the Recommended Plan are documented in various National Environmental Policy Act (NEPA) and feasibility documents, the most recent being the *New York and New Jersey Harbor Navigation Study Feasibility Report* and its accompanying Final Environmental Impact Statement – *December 1999* (the *Feasibility Report*)[2]. These impacts are being re-evaluated in this EFH assessment. Potential

[1] Specifically, the Arthur Kill Channel, Howland Hook Marine Terminal, New York and New Jersey; the Kill Van Kull and Newark Bay Channels, New York and New Jersey; and the New York and Adjacent Channels, Port Jersey Channel, New Jersey. They are designated AK-41/40, KVK/NB-45, and PJ-41, respectively, and hereinafter referred collectively to as the "Predecessor Projects". They are Predecessor Projects in the sense that their complete implementation was assumed as part of the most likely without-project future condition for the New York and New Jersey Harbor Navigation Study.

[2] U.S. Army Corps of Engineers, *New York and New Jersey Harbor Navigation Study Feasibility Report*, (December, 1999). Hereinafter the shorthand reference "*Feasibility Report*" will be used to refer to this document and "Recommended Plan" to refer to the plan recommended in the

impacts associated with consolidated implementation of the of the Predecessor Projects and the Recommended Plan (i.e., direct dredging and rock-blasting to authorized depths) are evaluated in the *Environmental Assessment (EA) on the Consolidated Implementation of the New York and New Jersey Harbor Deepening Project*.

Potential impacts to EFH include: changes in physical or chemical properties (e.g., water temperature, salinity) of the water column; changes in underlying substrate, including sediment type and presence/absence of aquatic vegetation; and changes in water depth. These potential impacts may occur temporarily (short-term impact) during construction of the proposed project, or permanently (long-term impact) due to ultimate changes in bathymetry, sedimentation, and hydraulic patterns (e.g., estuarine mixing).

Short-term water quality impacts to EFH due to project construction would most likely be limited to changes in turbidity levels and suspended solids in the immediate construction areas. Some change in dissolved oxygen (DO) may also occur, concomitant with sediment re-suspension.

No significant impact related to short-term sediment disturbance is supported by recent modeling efforts using SSFATE (Suspended Sediment FATE), which estimated the strength of sediment release and sediment transport based on dredging and sediment characteristics specific to the Arthur Kill Channel (USACE 2003) and total suspended solids (TSS) monitoring during dredging operations in Newark Bay, Arthur Kill/ Kill van Kull and Port Jersey (USACE 2002e). SSFATE model estimates predicted that suspended sediment concentrations are highly dependent on grain size distribution of the sediment dredged, and that the majority of sedimentation will occur within the channel with some sedimentation on the shoals adjacent to the channel. Sedimentation on the shoals will likely be in the range 0.002 – 0.016 mm/day depending on the source strength of the dredging plant. Even at the maximum deposition rate, this is equivalent to only 5.8 mm after one year of 24 dredging operations, which is well below ambient sedimentation rates. TSS monitoring indicated bottom TSS values were elevated in the immediate vicinity of the dredge, but returned to ambient levels within 100 ft down current of the dredge plant.

Potential increases in suspended solids and turbidity would be minimized by using approved equipment and techniques for sediment dredging and rock removal (e.g., sealed-bucket dredge, controlled hoist speeds), with this equipment and these techniques to be specified in state water quality certifications. For these reasons, no appreciable impact is expected.

The proposed in-water work would potentially disturb mobile life stages of managed fish species, some individuals would avoid the immediate construction area opting for other

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Feasibility Report with the modifications that have occurred since the 1999 release of the *Feasibility Report.*

useable habitat within the harbor thereby reducing available water column habitat. This avoidance would occur only in those areas where active dredging/blasting is underway. Other similar habitats within the harbor would remain available during the proposed deepening. In-water work would be seasonal and once completed, the local habitats would again be available to all fish species and their prey.

Existing sediments in the channel areas support a benthic community which is dominated by polychaete worms living on the substrate, and a variety of amphipods and shrimp living on the surface of the substrata (epibenthos). Benthic studies conducted throughout the Harbor in channel and shoal areas have shown that this type of benthic community is common where fine-grained sediments (e.g., silts, clays) predominate. This community is an important food resource for fish, particularly the epibenthos. Impacts to EFH sediment type would be short-term, since natural sedimentation and subsequent recolonization of benthic invertebrates is expected to occur rapidly, within months following construction activities. Because of its widespread occurrence and rapid recovery after disturbance, the short-term loss of the benthic community to deepening activities would not be a significant adverse impact to EFH.

Changes in water depth and bathymetry would result in long-term impacts, since both channel and shoal habitat will have been excavated during the deepening. Construction of the proposed project would impact littoral zone (i.e., shallow water 0 to 6 ft below MLW) and intertidal habitat. A portion of this area would be permanently lost or be made deeper than its current depth. The largest changes are projected for the Arthur Kill/Howland Hook vicinity, followed by the Newark Bay Channel, the flats area on the western side of Newark Bay south of Port Elizabeth Channel, and the Kill Van Kull (See Environmental Assessment – Pre-Construction Engineering and Design Modifications for a description of projected areas impacted).

Other potential impacts due to the proposed project include changes in underlying substrate and changes in water depth. Impacts to sediment type would result from the removal of fine-grained sand and mud from channel areas. Sediment removal impacts would be realized most in areas requiring channel excavation below bedrock (Arthur Kill Channel, Kill Van Kull Channel, and Newark Bay Entrance Channel). Only minor impacts to sediment type would occur in other project areas, since sediment type below existing bottom sediments is expected to be similar to the bottom sediments.

Deepening would also disturb 42.03 acres of sublittoral (i.e., depths >6 to 15 ft MLW) habitat. Some of this habitat would be permanently altered from existing physical conditions to channel sideslope and channel bottom habitat. Some portion of the 42.03 acres would become permanently deeper than 15 ft below MLW, and thus would no longer meet the definition of sublittoral zone habitat.

Modeling of salinity, water temperature, and DO under the proposed project conditions shows that no detectable changes in water quality are likely to occur in the future due to channel deepening. This includes no appreciable changes in salinity regime, location and persistence of the salt wedge, nor changes in tidal flows or height (USACE 1999a). Therefore, no impacts to EFH physical water quality parameters are expected due to construction of the proposed project.

Both short- and long-term potential impacts to EFH would differ from species to species, depending upon life history, habitat use (demersal vs. pelagic), distribution, and abundance. Potential EFH impacts in the project area would be limited primarily to demersal (i.e., bottom-oriented) species and life-stages. Pelagic species and life-stages are expected to continue using portions of the water column during and following channel excavation and construction. During construction, pelagic species might experience disturbance to a small portion of EFH due to a need to avoid the active project area. Most of the project area, however, would remain available for foraging, spawning and growth. Pelagic larval and egg life stages (i.e., those life stages with limited motility) would be carried through the active project area with prevailing tides and currents, resulting in limited exposure to construction-related disturbance.

Data Review

A review of biological sampling data was conducted to provide information on the seasonal occurrence and abundance of the EFH listed species in distinct project areas or water bodies of the project area (USACE 1999, USACE 2002, USACE 2002a). The 1998-1999 baseline-sampling program (USACE 1999) was conducted in the New York/New Jersey Harbor (Harbor) to obtain information on seasonal occurrence of fish in deep water areas (i.e. navigation channels and approach channels), shallow water areas (i.e. flats or shoals) and interpier areas. Twenty (20) stations were sampled throughout the Upper Bay, Newark Bay, Arthur Kill, Kill Van Kull and Lower Bay to target adult and early lifestages of demersal fish species. Epibenthic sled surveys were conducted monthly from February 1999 through June 1999. Bottom trawl surveys were conducted from October 1998 through September 1999.

In 2000-2001, twenty-four (24) stations were sampled as part of the Supplemental Sampling Program. This program maintained the concept of sampling channel and shallow areas throughout the Harbor, but only focused on the Upper Bay, Arthur Kill and Newark Bay. The overall program goals were modified to obtain data and information specific to the distribution patterns of the egg and larval stages of demersal species, with an emphasis on early life stage winter flounder. Ichthyoplankton surveys were conducted over a 7-month period beginning in December 2000 and continuing through June 2001. The sampling schedule was selected to bracket the seasonal occurrence of winter flounder eggs and larvae in the Harbor. Bottom trawl surveys were not conducted during the 2000-2001 Supplemental Sampling Program.

Twenty-six (26) stations were sampled in 2001-2002. The objective of the 2001-2002 sampling program was to determine the utilization and significance of habitat designated as essential fish habitat (EFH) for adult and early life-stages (eggs and larvae) of winter flounder. Six Lower Bay stations were added in 2000-2001 to provide better spatial coverage of the Harbor. Epibenthic sled tows were conducted from February 2002 through July 2002. Bottom trawl surveys were conducted from December 2001 to June 2002.

Sampling techniques and gear were the same for all three sampling programs described above. Results from the annual epibenthic surveys indicated that eggs were collected in lower densities than larval lifestages. In most aquatic populations, eggs when present typically represent the dominant lifestage by number. Winter flounder early life-stages are strongly demersal, thus sampling closer to the bottom or disturbing the bottom, may "improve" catches. As a result, modifications to the epibenthic sled (i.e. decreased net height above substrate and the addition of a tickler chain) were tested in a gear comparison study conducted during February and March 2002 (USACE 2002c), by towing paired epibenthic sleds. Results from the study did not indicate that incorporating a lower net height or tickler chain would especially for eggs result in repeatedly higher or lower numbers of winter flounder eggs and larvae collected.

Data analysis was conducted to determine the temporal and spatial distribution patterns of fish in the Harbor using statistics as a tool for analyzing the fish, habitat, and water quality data collected during 1998-1999, 2000-2001, and 2001-2002 (USACE 2002d). Understanding the spatial and temporal distribution of fish in the Harbor over multiple years helps to provide the necessary information required for determining the potential impact associated with deepening the Harbor. The specific objectives of the analysis was to determine for early life-stages (egg, yolk-sac, post yolk-sac and juveniles) and adults of winter flounder spatial patterns in distribution in the Harbor, temporal patterns in distribution in the Harbor, distribution patterns in the Harbor related to biotic and abiotic habitat variables, and the distribution pattern related to depth (i.e. channel vs. shallow/shoal).

Potential direct and indirect impacts to EFH due to short-term changes in habitat for each managed species are identified in the project area based on the aforementioned studies and existing literature. Unfortunately some of the EFH species, based on their life histories, were not common in the study area during months that sampling was conducted. As a result, the descriptions of these species are limited. Data on pelagic species were reviewed with caution because pelagic species can be underrepresented in the benthic oriented gear (i.e. epibenthic sled and trawl) used in these studies. Cumulative impacts are summarized below.

Managed species overview

EFH has been designated for sixteen species of finfish in the 10' x 10' squares covering and adjacent to the project area. For this assessment, the presence of EFH and the potential seasonal occurrence of managed species in the vicinity of the project area were based on known habitat characteristics (e.g., water depth and salinity) and data from previous sampling programs conducted in the area. Based on this information, EFH for a total of ten managed species is believed to exist in the project area. These are red hake, winter flounder, windowpane flounder, Atlantic herring, bluefish, butterfish, Atlantic mackerel, summer flounder, scup and black sea bass. The remaining six managed species with designated habitat in 10' x 10' squares in or adjacent to the proposed project area (king and Spanish mackerel, cobia and the sand tiger, dusky and sandbar shark) have not been collected during recent sampling programs or in other surveys evaluated and are therefore not considered in this assessment.

3.1 Red hake (*Urophycis chuss*)

EFH is designated within the project area for larval, juvenile, and adult red hake, in both estuarine and marine waters (NMFS 1999). Red hake make seasonal migrations in response to changing water temperatures, inhabiting shallow water in the spring and summer but move to deep offshore water to over-winter. Eggs and larvae are more common east and north of the Harbor, though juveniles may be found in most estuaries (Able and Fahay 1998).

Adults

EFH for adult red hake includes bottom habitats of sand, muddy sand, and mud substrate. Adult red hake can be found in the water column; however, they are typically found in depressions within soft sediments or shell beds (Steimle et al. 1999). General water conditions that make up EFH for adults of this species include depths of 5m to less than 300m (preferred depths are 30 to 130m), salinity between 20 and 33ppt, temperatures of 2 and 20ºC, and dissolved oxygen (DO) concentrations in the Hudson-Raritan estuary of less than 6mg/L (Steimle et al. 1999). Adult red hake are seasonally common in the Hudson-Raritan estuary between November and May (Stone et al. 1994). The diet of red hake consists of crustaceans, squid and demersal and pelagic fish (Steimle et al. 1999).

Spawning

Spawning occurs on the continental shelf, at temperatures between 5 and 10oC and is most abundant in May and June in the New York Bight (Steimle et al. 1999).

Eggs

Red hake eggs are pelagic and are approximately 0.6 to 1.0mm in diameter (Steimle et al. 1999). Eggs tend to be restricted to the deeper marine (seawater zone) area (Able and Fahay 1998). Eggs are found in temperatures below 10oC and salinities of 25ppt or less, are most often observed from May to November (NMFS 2003), and are most abundant during June and July (Steimle et al. 1999). Red hake eggs are not typically separated from eggs of Urophycis or Phycis species as they occur together; therefore, habitat characteristics in which red hake eggs are found may be generally uncertain (Steimle et al. 1999).

Larvae

Red hake larvae are pelagic and have been collected from the mid- to outer-continental shelf of the Middle Atlantic Bight at temperatures between 8 and 23oC and in water depths of 200m or less (Steimle et al. 1999). Larvae prefer salinities ranging up from 0.5ppt (NMFS 2003). Larvae are often found from May through December, and peak abundance is during September and October (Steimle et al. 1999). Dietary components of red hake larvae include copepods and microcrustaceans (Steimle et al. 1999).

Juveniles

Red hake juveniles are pelagic until they reach approximately 25mm TL or greater at which time they become demersal seeking shelter along the continental shelf bottom within depressions in the sediment or among live sea scallop beds (Steimle et al. 1999). Juveniles also may associate with other forms of shelter including debris and artificial reefs (Steimle et al. 1999). In the Hudson-Raritan estuary, red hake juveniles have been collected at temperatures between 2oC and 22oC, at depths between 5m and greater than 50m when salinities range from 22ppt to 28ppt, and feeding on small epibenthic crustaceans (Steimle et al. 1999).

Occurrence in Project Area

Red hake have been collected in most biological sampling programs conducted in the study area (Table E1-3). Juvenile red hake have been reported as abundant in Sandy Hook Bay during March and April (Pacheco 1983). NMFS (1998) also reported red hake present in bottom trawl samples collected in the Hudson-Raritan Estuary. Red hake occurred in 17% of all trawl samples collected in Raritan Bay, Lower Bay, Sandy Hook Bay and Graves End Bay from January 1992 through December 1997. Red hake (the majority being juveniles less that 260mm in length) were found primarily in channel areas and were abundant during December and January, and again from April through July (Steimle et al. 1998).

No red hake were collected at shoal stations sampled in Newark Bay during 1995-1996 (LMS 1996); however, they were present at channel stations during 1993-1994 (NMFS 1994). Although red hake was not among the most abundant species collected in Newark Bay, it was collected at channel stations during May through June, and again in December, January, March and April (NMFS 1994). Abundance was highest during May and June, with most individuals between 100 and 170mm in length (NMFS 1994). Similar to studies conducted in 1995-1996 (LMS 1996), no red hake were collected at shoal stations. No red hake eggs, larvae, or juveniles were collected in plankton net samples (NMFS 1994).

Spatial distribution and relative/seasonal abundance data used in the ELMR program, suggest that both juvenile and adult red hake are common in the Hudson-Raritan estuary from November through May, and that larvae are common in June (Stone et al. 1994). Data reliability for the Hudson-Raritan estuary, however, was classified as that of reasonable inference, indicating that little or no sampling data was available (Stone et al. 1994). Data from past sampling programs indicate that red hake is not among the dominant species collected in the study area. May and June are the months of highest juvenile red hake abundance. However relative abundance is low compared to other species and areas (Steimle et al. 1998). No adult or larval red hake were collected in the Newark Bay sampling program (NMFS 1994). Red hake larvae were also absent from ichthyoplankton samples collected during entrainment monitoring programs in the Arthur Kill (LMS 1993).

Red hake were collected infrequently during the 1998-1999 Biological Monitoring Program (USACE 1999). Juveniles (all fish collected <220mm in length) were collected in bottom trawl samples at one location during November, March, June and August. Average CPUE (catch per unit effort defined as number of individuals per 10-minute trawl tow) was never greater than 3.0 during any month. The highest number of fish was collected at the Port Jersey approach channel during June. Red hake were not collected in the Arthur Kill, Kill Van Kull, Newark Bay, Red Hook, or Lower Harbor areas. No red hake eggs, larvae or juveniles were collected in epibenthic sled ichthyoplankton samples during this monitoring program.

During the seven month (December 2000 through June 2001) Supplemental Sampling Program (USACE 2002), no early life stages (eggs, larvae, and juveniles) of red hake were identified in the ichthyoplankton samples collected.

In the 2001–2002 Aquatic Biological Sampling Program (USACE 2002a) trawl samples collected in December through May (program ran from December through June) contained red hake. Highest CPUEs were at stations located in the Lower Bay channels for the months of December through April and at channel stations in the Upper Bay in the month of May. Samples that were gathered at the Arthur Kill/Newark Bay channel stations yielded individuals in March and April only. Trawls in the shoal/shallows produced red hake in December and February in the Upper Bay and in March in the Lower Bay. No red hake were collected in trawls at the Arthur Kill/Newark Bay shoal/shallows and no early life stage red hake were identified in any of the ichthyoplankton samples collected during the program.

Potential Impacts

EFH requirements for red hake are met throughout the project area for all three life stages identified above. However, in the most recent three years of sampling conducted in the project area Red hake larvae were not collected, indicating that spawning is not likely occurring in the Harbor. Due to the lack of egg and larvae and low occurrence of juveniles and adults, the navigation channel improvements associated with the Recommended Plan are expected to have minimal impact to designated EFH for this species. Juvenile red hake, which prefer deep-water areas, may actually benefit from long-term changes in littoral and sublittoral habitat.

For those juvenile and adult red hake that use the project area, potential direct impacts to EFH would be limited primarily to the short-term disruption of juvenile and adult bottom habitats in deep-water channels of the Lower Bay. For early juveniles (scallop stage), these potential impacts would be further limited to those areas primarily associated with scallop beds or other protective structures. Scallop beds within the project area would be found only in the deep-water areas of Lower New York Bay. These potential short-term impacts would be seasonal, primarily during May and June, when juvenile red hake are most common in the estuary, and would be limited to the immediate construction area. Increased turbidity and disturbance of benthic habitat is the most likely potential short-term impact on individuals of this species. In the long term, both juvenile and adult red hake, which prefer deep-water areas, may benefit from the permanent deepening of the channels and increased habitat from dredging of littoral and sublittoral habitat.

Indirect impacts are those resulting from disturbance or temporary loss of forage organisms and/or forage habitat related to the construction and operation of the proposed project. Impacts to red hake forage species and their habitat would occur as a result of the authorized project. Alteration of benthic habitat, in both the near and long-term, would cause the displacement or temporary loss of benthic crustacean forage species preferred by the larval, juvenile and, to a lesser extent, adult life stages. Benthic invertebrates could be impacted through burial from settling of suspended sediments and through loss of individuals due to physical removal of the substrate. Red hake would therefore need to find other acceptable benthic foraging habitat within the harbor during and immediately following dredging related to the project, until the benthic community reestablishes itself in the disturbed areas. Recolonization is expected to occur within a few months to a year.

Adult red hake, which also prey on mobile demersal and pelagic fish and squid, would need to follow these species to other suitable areas as some prey species may avoid the active in-water work areas. All indirect impacts would be limited to the work area(s) and the adjacent habitat, primarily in the Lower Bay.

3.2 Winter flounder (*Pseudopleuronectes americanus*)

EFH for winter flounder has been identified in the seawater and mixing zones of the project area for all life stages (NMFS 2003). Preferred habitat includes shallow-water shoals and subtidal areas (< 6 meters) over bottom habitats of sand, muddy sand, mud, and gravel substrate. Found throughout the estuarine and marine portions of the project area, these habitats provide EFH for spawning winter flounder adults, and for eggs, and larvae. EFH for early juvenile (i.e., young-of-year) and juvenile winter flounder also includes shallow water, as well as deep water, estuarine, and marine waters of the project area. Although found in the project area throughout the year, abundance of these life stages varies with season.

Adults

During summer months, adult winter flounder reside in nearshore coastal waters, with the distance offshore dependent upon water temperature, i.e., the warmer the water temperature the further offshore adults move. Adults of this species frequent water with temperatures below 25°C, salinities ranging from 15 to 33ppt and depths anywhere from 1 to 100 meters (NMFS 2003). They begin an inshore migration moving into shallow bays and estuaries in the early fall in preparation for spring spawning. By July, mature adults have left the inshore waters for offshore areas with lower water temperatures. Major prey of winter flounder were found to be bivalves, amphipods and polychaete worms (NMFS 2003). Bowman et al. (2000) documented that adults of this species feed primarily on polychaetes, anthozoans, and amphipods.

Spawning

Spawning in the mid-Atlantic Bight (and the study area) occurs between February and April in estuaries and bays (Howe et al. 1976). Preferred water characteristics include water temperatures below 15°C, salinities between 10 and 32ppt (Pereira et al. 1998) over sand, mud and gravel substrates in depths less than 6 meters (NMFS 2003)

Eggs

Winter flounder eggs are demersal and, adhesive. They range from 0.6 to 1.0mm in diameter, with an average diameter of 0.6mm (Topp 1968, Klein-MacPhee 1978, Buckley 1989). The optimal salinity for egg development and survival is 15 to 30ppt (Buckley 1989), with 100% mortality at low salinities (5 to 10ppt), and high mortality and a high percentage of deformed larvae reported at water salinities of 35 to 40ppt (Klein-MacPhee 1978). Eggs are typically found in water with temperatures less than 10°C and depths less than 5 meters over sand muddy sand mud and gravel substrates (NMFS 2003)

Larvae

Larvae are non-buoyant and have a strong benthic orientation, often resting on the bottom between swimming efforts (Pearcy 1962). Since the early life stages of this species are non-dispersive, the spawning grounds and the nursery grounds are essentially the same (Pearcy 1962). Howell et al. (1992) indicate that the nursery habitat for larvae and juveniles includes littoral and sublittoral saltwater coves, coastal salt ponds, estuaries, and protected embayments. Winter flounder larvae prefer water with temperatures less than 15°C, depths less than 6 meters, and a salinity range of 4 to 40ppt (NMFS 2003).

Juveniles

Young-of-year (YOY) and yearlings are tolerant of higher water temperatures and remain in the estuary during the summer (Rose et al. 1996 ESNP). YOY are generally found in areas where the water temperatures are below 28°C, with depths below 10 meters and salinities ranging between 5 and 33ppt. (NMFS 2003).

Following metamorphosis from larvae to juveniles, winter flounder are benthic and seldom lose contact with the substrate (Buckley 1989). The majority of juvenile winter flounder spend most of their first two years in or near shallow, natal waters and on the edge of channels, preferring sand or sand/silt substrate (Topp 1968, Wilkkley 1989). Their preferred habitat is found in waters ranging in temperature from 0 to 25°C, in salinity from 4 to 30ppt and in depths up to 18m (37m in colder weather) (USFWS 1978 CP). Early juveniles (6 to 9cm) have been shown to be photopositive, which, because of generally low light penetration in coastal waters, limits their movements to shallow cove areas, while late juveniles (12 to 18cm) reside in deeper water areas and are photophobic (Howell et al. 1992). Briggs and O'Connor (1971) evaluated shore-zone fish populations in Great South Bay, Long Island, NY and found significantly more juvenile winter flounder over natural bottoms (mixture of sand, clay, mud, and detritus and covered with dense growth of eelgrass [Zostera marina]) compared to open sand-filled bottoms.

Juvenile winter flounder feed on a variety of small organisms with amphipods and polychaetes being the primary food sources (Pearcy 1962 ESNP). NMFS documents that major prey of juveniles are amphipods, copepods, polychaetes and bivalves (NMFS 2003).

Occurrence in Project Area

Winter flounder have been collected in most biological sampling programs conducted in the study area (Table E1-3). Sampling programs in the channel and shallow/shoal areas of Newark Bay provide seasonal abundance information in both deep-water (i.e., channel) and shallow-water habitat (NMFS 1994, LMS 1996). Winter flounder were most abundant in channel areas from July through December, while shallow-water abundance was highest from May through July. Overall abundance was higher in deep-water channel areas. During the summer and fall, adult winter flounder were largely absent from the Upper Bay and Arthur Kill/Newark Bay (USACE 2002d). During late fall and winter, adult flounder catches increased in the inshore areas, especially in the channels.

Winter flounder were collected during every month of the 1998-1999 biological monitoring program, but were most abundant during March, April and again in June (USACE 1999). Limited sampling events (i.e., site-specific stations only) during May likely influenced the drop in winter flounder CPUE during this month. The majority of winter flounder collected during this period appeared to be yearling or older fish, ranging between 100 and 230 mm in length. Young-of-year winter flounder became evident in bottom trawl samples during June, ranging from 20 mm to 70mm. Data from this monitoring program indicates two periods of winter flounder abundance in the study area, one occurring during early-spring to early summer (generally late-March through early August) and one occurring during late-fall to early-winter (generally late-October through December).

Early life stage winter flounder (the focus species of the program) were identified in samples collected from February through June of the Supplemental Sampling Program (USACE 2002), with total densities being highest in April and May. Winter Flounder eggs and yolk-sac larvae were collected from February through April, while post yolk-sac larvae were in samples gathered from February through June. Juveniles of this species were identified only in the month of June.

During this survey, egg densities were highest in March and were collected only at sites in the vicinity of Port Jersey and South Brooklyn. The majority of these eggs were collected at sampling station located in navigation channels as opposed to shoal/shallow areas and no eggs were found at slope locations. Yolk-sac larvae were present throughout the area with the exception of the Newark Bay station. Densities, while relatively low, were highest in April. This life stage was present in samples collected at most navigation channel and shoal/shallow areas, but none were identified in samples from the slope locations. Collected at all sites, post yolk-sac larvae densities peaked in April but were very low throughout the study. Post yolk-sac larvae were in samples collected at stations located in each of the three unique areas. Juvenile densities were the lowest of all early life stages collected being identified at only one sampling station within the study area.

Winter flounder were collected in trawls from December to June (the entire duration of the sampling effort) throughout the New York/New Jersey Harbor during the 2001-2002 Aquatic Biological Sampling Program (USACE December 2002 Final Draft). Winter flounder were more common at channel stations from December through April especially in the Lower Bay, shifting toward shallow/shoal stations later in the sampling program. Peak abundance was recorded at the shallow/shoal stations. Overall, winter flounder were collected in greater densities at the channel stations indicating the importance of this type of habitat to winter flounder adults.

During this study, winter flounder eggs, yolk-sac larvae and post yolk-sac larvae were collected in the Harbor from early-February through early-June. No juvenile winter flounder were collected during the ichthyoplankton sampling program. Winter flounder eggs were collected for a longer duration and in greater densities in the Lower Bay shoal/shallow stations than any other area. The Upper Bay had the second highest percentage of winter flounder eggs and the Arthur Kill/Newark Bay had the lowest.

Winter flounder eggs were collected from mid-February through late April with a peak in mid-February at the Lower Bay shallow/shoal stations. Eggs were most common in shallow/shoal habitats, while in previous years eggs were more common in the channels (USACE 1999; USACE 2002).

Winter flounder yolk-sac larvae were collected from mid-February to late April. The highest densities were recorded in the Lower Bay with a peak at the shallow/shoal stations. This life stage was collected in the lowest densities and over the shortest time frame in the Arthur Kill/Newark Bay. Their preference between channel or shallow/shoal habitat could not be determined as too few winter flounder yolk-sac larvae were collected at the Arthur Kill/Newark Bay stations.

Post yolk-sac larvae were collected from mid-February to mid-May in all areas. Densities were highest in Lower Bay channels where density gradually increased during the sample program to a mid-April peak. Post yolk-sac larvae densities were similar in the Arthur Kill/Newark Bay and the Upper Bay.

Spatial and temporal trends observed in winter flounder abundance patterns suggest that different areas of the Harbor are important to winter flounder at different stages of their life history. Adult winter flounder were most common in the Lower and Upper Bays of the Harbor during January to March, the peak spawning period in the study area (Able and Fahay 1998). Gender specific distribution was also noted during the study with females dominating the samples and males present in the Upper and Lower Bays only.

The 2001-2002 Biological Sampling Program provides additional support to the findings of the Supplemental Study (2000-2001) that winter flounder move or disperse further into the New York-New Jersey Harbor Estuary after hatching. The patterns observed suggest that winter flounder eggs are laid primarily in the Lower Bay and to a lesser degree other areas of the Harbor. Based on the sampling program data collected since 1999, winter flounder eggs occur in greater densities in the Upper Bay than in the Arthur Kill/ Newark Bay area (Figure E1-2). Winter flounder egg data collected in the Lower Bay in 2002-2003 indicated the greatest density of winter flounder eggs may occur in the Lower Bay, as compared to both the Upper Harbor and Arthur Kill/ Newark Bay areas (Figure E1-3). Regardless of sample program year, the Arthur Kill/ Newark Bay area exhibited the lowest winter flounder egg densities (generally < 5 eggs/ 1000 cubic meter on average at each sampling station) among Harbor areas sampled. After hatching and developing into larvae, winter flounder may move from the Lower Bay further into the Harbor.

Potential Impacts

Although distribution of winter flounder varies with location and life stage as noted in recent surveys, EFH for all life stages of winter flounder occurs throughout the project area. Deepening channel reaches in the Arthur Kill, Kill Van Kull, Newark Bay (including the Elizabeth Channel and South Elizabeth Channels), and Port Jersey would disturb just over 40 acres of bottom habitat in the 0 to 15 ft MLW depth range. Potential short term impacts to winter flounder EFH related to this work include temporary disruption of marginal spawning habitat and marginal habitat for early life-stage development (i.e., larval settlement) through increased turbidity and burying or physical removal of substrate and associated loss of demersal eggs. Impacts are considered marginal because the majority of the early life stage winter flounder were collected in the Lower Bay.

Dredging within these shallow areas would have a greater potential impact on juvenile EFH than spawning and larval EFH due to this life stage's prevalence in samples collected further into the estuary. Juveniles were identified regularly in samples collected in the Arthur Kill/ Newark Bay and Upper Bay areas during early summer (June). Juveniles and adults that frequent the Arthur Kill/ Newark Bay and Upper Bay may actively avoid in-water work areas opting for other appropriate habitat within the Harbor.

Work within the channels throughout the project area would have the potential to affect adult winter flounder EFH. Adults and spawning adults were identified in trawls in the channels during recent sampling.

Winter flounder are opportunistic feeders, consuming mostly small invertebrates (e.g. amphipods, polychaetes, anthozoans), and on rare occasions, small fishes. Disturbance of the river bottom and water column habitats occupied by these prey organisms are the primary sources of potential adverse indirect impact to winter flounder. Potential impacts would be localized and both benthic invertebrates and finfish prey species are expected to return to the area immediately following construction.

Short term impacts to forage species would result from disturbance of both demersal and pelagic habitats. Temporary loss or relocation of benthic prey species resulting from physical removal of substrate and burial due to settlement of resuspended sediments would cause winter flounder to locate other feeding habitats within the Harbor. Local benthic invertebrate stock is expected to begin recolonization of impacted areas shortly after deepening activities cease. Water column disturbance and increased turbidity may also displace winter flounder from in-water work areas, forcing some fish to alternative forage areas. These short-term impacts would be limited to the time of the dredging operations. Prey species are expected to return to the area once the deepening is completed.

The total aquatic habitat area impacted during the construction phase is a small fraction of the total estuary area adjacent to the project. The majority of this disturbed habitat is expected to undergo natural re-colonization shortly after the construction phase and return to the same productivity levels as currently exists.

Potential impacts due to the permanent loss of intertidal and shallow-water littoral zone areas will be mitigated as described in Appendix D. The acreage of wetland habitat that will be created or restored in the recommended mitigation plan greatly exceeds the requirement to compensate for the littoral zone disturbances. While it is impossible to directly compare the impacts associated with the sublittoral disturbances with the benefits obtained from beneficial use of dredged material and the additional wetland compensation, it is believed that the net beneficial effects resulting from these factors outweigh the disturbances to 42.03 acres of sublittoral habitat. Therefore, no detrimental or unmitigatible impacts to winter flounder EFH are expected to occur.

Beneficial use will be a priority for the management of dredged materials from this project. Given the volume of dredged material likely to be created (approximately 51 million cubic yards from the initial construction alone), the anticipated benefits from the beneficial use of such material are great. The District and NMFS have investigated EFH enhancement opportunities in the New York and New Jersey Harbor for those species with designated EFH occurring in the Harbor. The results of these actions may allow for the implementation of one or more opportunities to enhance EFH throughout New York and New Jersey Harbor while making beneficial use of some dredge material (e.g., rock, sand). Conceptual designs have been developed for several EFH enhancement sites. Details of the conceptual designs are provided in Appendix E.

3.3 Windowpane Flounder (*Scophthalmus aquosus*)

EFH for windowpane flounder is designated in both the estuarine and marine waters of the project area for all life stages (NMFS 1999). Windowpane flounder occur at all depths in the estuary with juveniles and adults seasonally most abundant in deeper channels occurring over bottom habitats of mud or fine-grained sand.

Adults

Adults are found on sandy sediment of the Hudson-Raritan Bay, where preferred temperatures are 0 to 24ºC and salinity ranges from 15 to 33ppt (Chang et al. 1999). In the Hudson-Raritan estuary, adults are more abundant during the summer in deeper channels, and at depths less than 25 meters for all seasons (Chang et al. 1999). Dietary constituents include small crustaceans, such as mysids and decapod shrimp, and tomcod and hake larvae (Chang et al. 1999).

Spawning

Spawning occurs from February through November in coastal, inner continental shelf waters peaking in the mid-Atlantic Bight during May (Able and Fahay 1998). Preferred temperatures for spawning range from 6 to 21ºC (Chang et al. 1999). Some spawning may also occur in the high-salinity portions of estuaries in the mid-Atlantic Bight, including Sandy Hook Bay (Croker 1965). Windowpane flounder spawn in the evening or at night on or near the bottom (Bigelow and Schroeder 1953, Ferraro 1980).

Eggs

Eggs, ranging from 0.9 to 1.4mm in diameter, are typically found in planktonic habitats, less than 70 meters deep and at temperatures between 6 and 14ºC in the spring, 10 and 16ºC in the summer and 14 and 20ºC in autumn (Chang et al. 1999). Eggs are collected in the Middle Atlantic Bight from February to November, with peak densities occurring in May and October (Chang et al. 1999).

Larvae

Larvae, which are pelagic, settle to the bottom at approximately 10 to 20mm total length (TL), and are found throughout the polyhaline portion of estuaries in the spring (Morse and Able 1995), but primarily on the shelf in the autumn (Chang et al. 1999). Larvae occur in the Middle Atlantic Bight from February through July and September through November in planktonic habitats less than 70 meters deep (Chang et al. 1999). Larvae prefer temperatures between 3 and 14ºC in spring, 10ºC and 17 º C in summer and 14 and 20ºC in autumn. Windowpane flounder larvae feed on copepods and zooplankton (Chang et al. 1999).

Juveniles

Bottom trawls in the Hudson-Raritan estuary showed that juveniles were fairly evenly distributed throughout the estuary, but they were most abundant in the deeper channels in winter and summer (Wilk et al. 1998). Windowpane flounder was the third most abundant species collected in bottom trawls in the Hudson-Raritan estuary (Wilk et al. 1998). Juveniles were most abundant at bottom temperatures of 5 to 23°C, at depths of 7 to 17 meters, at salinities of 23 to 30ppt, and at DO levels of 7 to 11 mg/l (Wilk et al. 1998). Bottom trawls in Newark Bay showed a similar depth distribution, with very few juvenile windowpane flounder collected at shoal stations (NMFS 1994, LMS 1996).

Occurrence in Project Area

Although windowpane flounder occur at all depths in the Hudson-Raritan estuary, juveniles and adults are seasonally most abundant in deeper channels. Able and Fahay (1998) considered the habitats of juvenile windowpane flounder not well defined but noted that during extensive collections in estuarine shallows juveniles were never collected in intertidal areas (Able et al. 1996), but occurred frequently along subtidal shores and in a variety of deeper (< 1 to 8 meter) habitats (Szedlmayer and Able 1996). In laboratory studies, early demersal (8 to 18mm standard length [SL]) and larger juveniles (32 to 89mm SL) preferred sand over mud substrate (Neuman and Able in press, see Able and Fahay 1998).

No windowpane flounder eggs were collected in epibenthic ichthyoplankton sampling conducted in the study area as part of the 1998-1999 Biological Monitoring Program (USACE 1999). Windowpane eggs have been collected in ichthyoplankton samples in association with entrainment monitoring at electric generating station cooling water intakes in the project area (LMS 1994).

Larval windowpane flounder were collected in epibenthic ichthyoplankton samples in the study area during May and June (USACE 1999). Windowpane larvae were most common during May, when they were collected in all Harbor areas except Red Hook. Densities were highest in the Upper Harbor. No windowpane flounder larvae were collected in the Port Jersey or South Brooklyn Channels or at shoal stations during June. Very few windowpane flounder larvae were collected in Newark Bay ichthyoplankton sampling (NMFS 1994, LMS 1996).

Bottom trawls in the Hudson-Raritan estuary showed that juveniles were fairly evenly distributed throughout the estuary, but they were most abundant in the deeper channels in winter and summer (Wilk et al. 1998). Windowpane flounder was the third most abundant species collected in bottom trawls in the Hudson-Raritan Estuary; juveniles were most abundant at bottom temperatures of 5 to 23°C, at depths of 7 to 17 meters, at salinities between 23 and 30ppt, and at DO levels of 7 to 11 mg/l (Wilk et al. 1998). Bottom trawls in Newark Bay showed a similar depth distribution, with very few juvenile windowpane flounder collected at shoal stations (NMFS 1994, LMS 1996).

Windowpane flounder were collected during every month of the 1998-1999 Biological Monitoring Program, but were most abundant during April (USACE 1999). A large portion of these were older, possibly mature (> 220mm) (Chang 1998) fish. Bottom trawl catch was highest in the deeper more saline portions of the project area, primarily the Lower Harbor. Juvenile (young-of-year [YOY]) windowpane flounder were evident in bottom trawls from June through October. Older fish were noticeably scarce in late-fall samples.

Windowpane flounder were identified in the months of May and June during the Supplemental Sampling Program (USACE 2002). Eggs of this species, collected in both months, were the most abundant of all species' eggs identified with the highest concentration in June. Windowpane flounder yolk-sac larvae were collected in May only and were the smallest percentage of all species with this life stage present. Post yolk-sac larvae were present in samples from May and June representing a roughly average percent of the total species composition. June was the only month juveniles were identified. All four early life stages were found in samples from stations located in the channels, whereas only eggs and post yolk-sac larvae were found in the shoal/shallow areas. Eggs were the only life stage identified at slope sampling locations.

Windowpane flounder were identified in trawls during the 2001-2002 Aquatic Biological Sampling Program (USACE 2002a) in all months (December through June) in channel habitats and from January through June in shoal/shallow habitats. This species occurred in the Arthur Kill/Newark Bay and Upper Bay areas in each month it was identified in trawls and in all but one month in the Lower Bay. The highest CPUEs for shoal/shallows varied from month to month starting out in the Lower Bay, moving to the Upper Bay with a peak in the Arthur Kill/Newark Bay in April. Channel CPUEs were highest in the Upper Bay for the duration of the sampling with the exception of the April peak in the Arthur Kill/Newark Bay.

Early life stage windowpane flounder were identified in ichthyoplankton samples collected in April, May and June during the January to July Aquatic Biological Sampling Program (USACE 2002a). Eggs were identified in all three of these months in the channel habitats but only in June in the shoal/shallows areas. No yolk-sac larvae were collected in any sample. Post yolk-sac larvae were found in the channel and shoals in the months of May and June with windowpane flounder dominating the species composition in the Lower Bay in May. June was the only month during which juveniles of this species were caught. The few juveniles identified were from samples collected in the channel and shoal/shallows of the Upper Bay and in the channels of the Arthur Kill/Newark Bay.

Potential Impacts

EFH for all life stages of windowpane flounder are represented in the project area. Distribution varies but in recent surveys all life stages of this species has been collected throughout the project area.

Potential direct short term impacts to all windowpane flounder EFH include temporary disruption of bottom habitat during channel deepening/dredging activities along with the associated increased turbidity and disturbance of water column habitat. Potential impacts to spawning adult (limited in the estuary) and egg EFH would likely be limited to deepening activities in Lower New York Bay (i.e., Ambrose Channel). Potential impacts would be seasonal, primarily in April and May when spawning adults and eggs are most likely to be found in the Ambrose Channel. Since windowpane flounder eggs are pelagic, impacts would be limited to disturbances within the water column (e.g., bucket- hoisting operations) and in the immediate construction area.

Potential impacts to juvenile, adult, and spawning adult EFH for windowpane flounder include temporary disruption of bottom habitat during channel deepening/dredging activities as well as disturbance to littoral and sublittoral bottom habitat. Potential impacts to spawning adult and egg EFH would be likely limited to deepening activities in Lower New York Bay (i.e., Ambrose Channel). Potential impacts would be seasonal, primarily in April and May when spawning adults and eggs are most likely to be found in the Ambrose Channel. Since windowpane flounder eggs are pelagic, impacts would be limited to disturbances within the water column (such as i.e., bucket- hoisting operations) and in the immediate construction area. These potential impacts could be easily avoided and mitigated through dredge operation limitations (e.g., hoist speeds).

Potential direct impacts to larvae would result from proposed work in the channels and the shallows as individuals in this life stage are initially pelagic but settle to the bottom after reaching a certain length. This would also be the case for adults and juveniles of this species, both of which prefer deep-water channels but have been collected in shoal/shallow areas as well. These impacts could range from temporary loss of in-water habitat due to the presence of dredging and blasting equipment to temporary increases turbidity.

Potential indirect short-term impacts to windowpane flounder would be primarily related to impacts on forage. The literature shows that the vast majority of this species prey is pelagic. Most pelagic forage species would likely avoid in-water deepening activities, requiring windowpane flounder to follow forage species to other acceptable habitats within the harbor. All of these potential short-term impacts could be easily avoided and mitigated through dredge operation limitations (e.g., hoist speeds).

Long term impacts would be related to windowpane flounder's preference for deepwater higher salinity habitats that favor channel areas to shallows. The conversion of littoral and sublittoral habitats to deeper waters and the further deepening and widening of the existing channel habitats may actually increase juvenile and adult EFH in the study area. Therefore, no detrimental or unmitigatible impacts to windowpane flounder EFH are expected to occur.

3.4 Atlantic herring (*Culpea harengus*)

EFH for larval, juvenile and adult Atlantic herring has been designated for both the estuarine and marine salinity zones of the project area (NMFS 1999). Juveniles and adults are found in the project area during winter months (January through May), when water temperatures are below 10°C, and are most common at mid-water depths in the channels. Individuals from both of these life stages undergo complex north-south and inshore-offshore migrations (Reid et al. 1998). Three general migratory patterns and three distinct spawning stocks are recognized off the northeast Atlantic coast (Sindermann 1979). Juvenile and adult Atlantic herring that occur in the Hudson-Raritan estuary are most likely from the Georges Bank/Nantucket Shoal stock, which spawns over Georges Bank and Nantucket Shoals during September and October, and overwinters south of Cape Cod and along the mid-Atlantic coast (Anthony 1982, Reid et al. 1998).

Adults

EFH for adult Atlantic herring include gravel sea floors where salinities are greater than 28ppt and water temperatures are below 21ºC, while movements become slower at temperatures less than 4ºC (Reid et al. 1999). In the Hudson-Raritan estuary, Atlantic herring catches have been reported most abundant at water temperatures between 3 and 6ºC, depths between 4.5 and 13.5m, salinities greater than 24ppt and at 11mg/L DO (Reid et al. 1999). Adults have been reported to be most common in the Hudson-Raritan estuary during winter and are occasionally collected during spring and fall (Reid et al. 1999). Adult Atlantic herring predominately feed on euphausiids, chaetognath and copepods, and pteropods, amphipods and mysids have also been reported as dietary constituents (Reid et al. 1999).

Spawning

Spawning typically occurs on stone or gravel material in high energy environments (e.g., strong bottom currents) at temperatures between 7 and 15ºC and salinities ranging from 31.9 to 33.0ppt (Reid et al. 1999). The Hudson-Raritan estuary is not considered one of the three historic herring spawning stocks (Reid et al. 1999). Able and Fahay (1998) hypothesized that the resurgence of spawning by Atlantic herring over Georges Bank and Nantucket Shoals has also increased reproductive activity in the northern part of the Middle Atlantic Bight, but sampling data in support of this hypothesis are lacking.

Eggs

Atlantic herring eggs are demersal and often occur in multiple horizontal layers forming egg beds adhered to substrates such as gravel (Reid et al. 1999). In the Georges Bank, egg beds are found at temperatures between 12 and 15ºC, at depths between 40 and 80 meters, and at 32ppt salinity (Reid et al. 1999).

Larvae

Atlantic herring larvae are pelagic and occur in the Gulf of Maine at temperatures between 9 and 16ºC, and salinities around 32ppt (Reid et al. 1999). In the Georges Bank, larvae reside at depths greater than 50 meters (Reid et al. 1999). Atlantic herring larvae in the Georges Bank make vertical migrations, possibly linked to daylight, tidal currents or shifts in prey abundance (Reid et al. 1999). Larval Atlantic herring collected in the study area are most likely from offshore spawning in the northern portion of the Middle Atlantic Bight. Atlantic herring larvae are opportunistic feeders with zooplankton and copepods (Reid et al. 1999) dominating their diet.

Juveniles

Atlantic herring juveniles reside in coastal waters within large schools (Reid et al. 1999). Under laboratory conditions, preferred water temperature is between 8 and 12ºC and preferred salinities range from 26 to 32ppt; salinity preference being temperature dependant. In the Hudson-Raritan estuary, Atlantic herring juvenile were most abundant at 4 to 6ºC and at 15 and 18ºC with occurrence not depicted by depth or salinity (Reid et al. 1999). Juveniles have been reported abundant throughout the lower Hudson-Raritan estuary during the winter and spring (Reid et al. 1999). Juvenile Atlantic herring dominant prey species include copepods, decapod larvae, cirriped larvae and cladocerans (Reid et al. 1999).

Occurrence in Project Area

Very low concentrations of Atlantic herring larvae were collected in the NY/NJ Harbor ichthyoplankton sampling program (USACE 1999).

Atlantic herring were collected in the study area during January through March and again in May and June during the 1998-1999 biological monitoring program (USACE 1999). The majority of Atlantic herring collected from January through March were adults (length > 260mm). Juveniles made up the majority of fish collected in May and June (length < 105mm).

Post yolk-sac larvae Atlantic herring were the only life stage identified during the Supplemental Sampling Program (USACE 2002) and then only during the months of March, April and May. Their densities made up a small portion of the percent composition of post yolk-sac larvae of all species identified. This species was identified variably in samples collected at each of the different station locations.

In the 2001–2002 Aquatic Biological Sampling Program (USACE 2002a) trawl samples collected in January through May (program ran from December through June) contained Atlantic herring. Highest CPUEs were relatively low throughout the survey with peaks in April in the Arthur Kill/Newark Bay channels and during the month of February in the shoal/shallows. Samples gathered at the Arthur Kill/Newark Bay channel stations yielded individuals February through May and in the shoal/shallows in May only. Trawls in the shoal/shallows produced Atlantic Herring in January and May in the Upper Bay and from January through March in the Lower Bay. Individuals were gathered in January in the Lower Bay channels and in April in channels in the Upper Bay. No early life stage Atlantic herring were identified in any of the ichthyoplankton samples taken during the program.

Potential Impacts

Atlantic herring are a pelagic species, not generally associated with bottom habitats or near-shore shallow areas. This is reflected in the relatively low abundance of their occurrence during resent sampling. As a result, impacts to Atlantic herring EFH are expected to be negligible.

Potential short-term impacts would be limited to disturbances within the water column (such as bucket-hoisting operations and turbidity) in the immediate construction area. It is expected that juvenile and adult Atlantic herring that could occur in the project area would actively avoid these disturbances, opting for other pelagic habitats. Long term changes in depth would not negatively impact Atlantic herring and the increased water column to result from the deepening may increase EFH for this species providing a minor benefit to the species.

Potential short-term impacts to Atlantic herring forage species would be the same as those noted above. Some forage species would likely relocate to undisturbed areas during active construction. No potential long-term impacts to forage species have been identified. Upon completion of each segment (i.e., channel contract area) of the project, both Atlantic herring and their prey would likely return to these open water habitats. The potential short-term impacts identified for Atlantic herring EFH would be easily avoided and mitigated through dredge operation limitations (e.g., hoist speeds) and best management practices (BMPs).

3.5 Bluefish (*Pomatomus saltatrix*)

EFH is designated for juvenile and adult bluefish within the project area, including both the estuarine and marine salinity zones (NMFS 1999). This is a pelagic, highly migratory species found in the continental shelf waters in temperate and semi-tropical oceans around the world (Moore 1989). They travel in schools of like-sized individuals and migrate seasonally to be in water of preferred warmer temperatures (Fahay et al., 1999). Bluefish are generally found in estuaries during the juvenile phase and in larger bays and open oceans as adults. This species is most common in the Hudson-Raritan Estuary between May and October (juveniles) and April and October (adults).

While juvenile bluefish have been reported in most estuaries of the Middle Atlantic Bight, eggs and larvae have been recorded in just a few estuaries (Able and Fahay 1998); and are therefore rarely collected in estuarine ichthyoplankton samples. Eggs and larvae are found offshore in the open ocean; while eggs are never found inshore, larvae have been documented in bays (Herman 1963).

Adults

Adults of this species tend to occur in large bays and estuaries, as well as across the continental shelf (Fahay et al. 1999). Adult bluefish tend to prefer ocean salinities and warm water, and have been reported to tolerate temperatures ranging from 11.8 to 30.4ºC (Fahay et al. 1999). Stone et al. (1994) considered adult bluefish common (i.e., frequently encountered but not in large numbers). In the Hudson-Raritan estuary, adult bluefish have been collected at water temperatures greater than 12ºC (most abundant between 21 and 23ºC) and at DO between 5 and 8mg/L (Fahay et al. 1999). Collection depths in the Hudson-Raritan estuary ranged from 5 to 17 meters and most abundant at 6m and salinities ranged from 21 to 30ppt while bluefish were most abundant from 25 to 27ppt (Fahay et al. 1999). The primary food items consumed by New York Bight bluefish were: anchovy, menhaden, round herring, silversides, sand lance, mackerel, butterfish, shrimps, squids, crabs, mysids, and annelid worms (Wilk 1982). According to Wilk (1977) there does not seem to be a preference for particular prey species, however size does appear to be important, with larger sizes being preferred.

Spawning

Spawning takes place offshore over continental shelf waters during a protracted spawning period (March through July) (Fahay et al. 1999).

Eggs

Bluefish eggs occur on the continental shelf (Fahay et al. 1999). Preferred water temperatures are above 18ºC and preferred salinities are greater than 31ppt (NMFS 2003, Fahay et al. 1999). No bluefish egg EFH is designated at any inshore location (NMFS 2003).

Larvae

Bluefish larvae reside over the continental shelf (Fahay et al. 1999) in waters with temperatures greater than 18ºC, salinities above 30ppt and depth more than 15 meters (Fahay et al. 1999). Larvae are considered to be rare in the Hudson-Raritan Estuary (Stone et al 1994). EFH is not designated for bluefish larvae at any location inshore (NMFS 2003).

Juveniles

Stone et al. (1994) considered juvenile bluefish as seasonally abundant in the estuarine and marine areas of the Hudson-Raritan estuary. Juveniles use estuaries during the first summer of their life and move out during the early fall to migrate south. Most of the bluefish population in the New York Bight probably originates from spring-spawned eggs (Chiarella and Conover 1990). Juvenile bluefish produced in the spring travel north with the Gulf Stream (Hare and Cowen 1993) and migrate across the continental shelf to the mid-Atlantic bays and estuaries (which act as productive nursery areas) in early to mid-June, which act as productive nursery areas (McBride and Conover 1991). Preferred temperatures range from 15 to 20ºC and salinities between 36 and 31ppt (Fahay et al. 1999). Bluefish juvenile EFH characteristics include mud, silt, clay and mostly sandy sediments, as well as Ulva and Zostera beds (Fahay et al. 1999). During daytime, juveniles are found near shorelines and in tidal creeks, whereas during night they are found in bays or channels (Fahay et al. 1999). Juveniles can not survive in water temperatures below 10 or above 34ºC (Fahay et al. 1999). Bluefish juveniles are typically found in estuarine water temperatures greater than 20ºC, but not greater than 30 or less than 15ºC (Fahay et al. 1999). Juveniles prefer salinities between 23 and 36ppt, but are reported to tolerate salinities as low as 3ppt (NMFS 2003). Hudson River bluefish juvenile were documented feeding on bay anchovy, white perch, American shad, river herring, and striped bass (Texas Instruments 1976).

Occurrence in Project Area

Bluefish were collected in bottom trawls in Newark Bay in both shoal and channel areas (NMFS 1994, LMS 1996), but were most abundant in experimental gill net samples, reflecting their pelagic behavior (NMFS 1994). Overall, catches were low compared to other species. Abundance was generally highest in September, comprised of mostly young-of-year.

Young-of-year have been collected successfully in nearshore habitats using beach seines, as well as in shallow tidal creeks and shoals using bottom trawls (Able and Fahay 1998). The majority of fish are collected in shallow, high salinity (25.0 to 34.0ppt) areas. Older bluefish, including adults, occasionally enter the lower estuary during summer and feed on a wide variety of available forage fish such as bay anchovy, young menhaden, and river herrings.

Juvenile and adult bluefish were collected in very low numbers in the study area during the 1998-1999 biological monitoring program (USACE 1999). As would be expected, early life stages (i.e., eggs and larvae) were not found in the study area. Bluefish were most common during October when they were collected in the Kill Van Kull, Arthur Kill, Newark Bay and approach channels to Port Jersey and South Brooklyn.

During the seven month (December 2000 through June 2001) Supplemental Sampling Program (USACE 2002), no early life stages of bluefish were identified in the ichthyoplankton samples collected.

Bluefish were rarely identified in the trawl samples taken for the 2001-2002 Aquatic Biological Sampling Program (USACE 2002a). Adults were collected in June in the shoal/shallow habitats of the Arthur Kill/Newark Bay, Upper Bay and Lower Bay areas and in the channels in the Upper bay during June for which CPUEs were very low (0.17 to 0.44). There was no early life stage bluefish collected during the ichthyoplankton portion of this program.

Potential Impacts

Bluefish is a schooling, pelagic species, not generally associated with bottom habitats. Densities within the harbor are relatively low and impacts to EFH for this species, therefore, are expected to be negligible.

Low abundance, and pelagic behavior, greatly limits any potential impact due to deepening activities.

Short-term project effects associated with disruption of pelagic habitat are considered negligible as those individuals frequenting the site will move to other acceptable habitat. Impacts would be limited to actual deepening activities (e.g., blasting) and the associated temporary loss of the volume of the water column occupied by the dredging/blasting equipment and areas of increased turbidity. The volume of water to be impacted at any one time during the project will be only a small portion of open water habitats throughout the harbor. Bluefish would be expected to avoid areas where active dredging and blasting are underway, moving to other suitable habitats in the Harbor.

Long term impacts would be negligible as all pelagic habitats unavailable due to avoidance of in water activities will be open to use upon completion of the project and the volume impacted at any one time would be a small fraction of that available to this species in the region. Bluefish may experience a minor benefit from the increase in pelagic habitat resulting from the deepening and widening of the channel.

Potential indirect impacts are those resulting from disturbance of forage organisms and/or forage habitat related to the channel deepening. Bluefish prefer soft-bodied fishes (e.g. bay anchovy, Atlantic menhaden, river herring, and silversides), and to a lesser extent invertebrates (e.g. shrimp, squids, crabs). Disturbance to water column and river bottom habitats and temporary loss of forage fishes, although limited, have the potential to impact bluefish.

Potential impacts to bluefish forage species could include increases in turbidity and water column disturbance resulting from channel deepening activities; however, these impacts are expected to be minimal as most if not all of these prey species are mobile and would likely avoid in-water work areas. Furthermore, because bluefish consume a number of different prey species and impacts to the forage species would be limited, indirect impacts to bluefish are expected to be insignificant.

Overall, neither short nor long term impacts associated with the project will result in significant impacts to forage organisms or forage habitat of bluefish. Thus minimal adverse indirect impacts to bluefish are expected to occur due to the proposed project.

3.6 Atlantic Butterfish (*Peprilus triacanthus*)

Atlantic butterfish EFH within the project area is designated for larvae, juveniles and adults (NMFS 1999). Juvenile and adult EFH includes both the estuarine and marine salinity zones, while larval EFH includes only estuarine waters (NMFS 1999). Butterfish range along the Atlantic coast is from Nova Scotia to South Carolina and in deeper offshore waters as far south as Florida. Butterfish migrate seasonally moving southward and offshore in the winter to avoid cooler waters and northward and shoreward to feed and spawn during the summer. Larval, juvenile, and adult butterfish are pelagic, occurring in the project area during warmer summer months in both shallow and deeper bay waters. During the summer, butterfish have been reported over shallow flats, sheltered bays, estuaries, and the surf zone. Larger juveniles and adults may congregate near the bottom during the day and move upward at night. Many larger predatory fish including bluefish prey upon this species (LMS March 2001).

Adults

EFH for adult butterfish includes bottom habitats of sandy, sandy-silt and muddy substrates on the continental shelf, coastal bays and estuaries, surf zone and mixed salinity zones (Cross et al. 1999). General water conditions that make up EFH for adult butterfish include water temperatures between 4.4 and 26.0ºC, salinities between 3.8 and 33ppt and DO between 6 and 9mg/L (Cross et al. 1999). In the Hudson-Raritan estuary, adult butterfish have been collected at depths between 3 and 23 meters, water temperatures from 8 to 26ºC, salinities from 19 to 32ppt and DO from 3 to 10mg/L (Cross et al. 1999). Planktonic prey, including thaliaceans, squids, copepods, amphipods, decapods and small fish (Cross et al. 1999), dominates adult butterfish diet.

Spawning

Spawning occurs primarily over continental shelf waters in the middle Atlantic Bight between May and October, although some eggs and larvae have been collected in coastal and estuarine waters (Able and Fahay 1998NAV). Appropriate conditions for spawning include temperatures above 15ºC at depths between 3 and 145 meters (Cross et al. 1999). Butterfish may spawn throughout their annual migration north and inshore as temperatures increase (Cross et al. 1999).

Eggs

Butterfish eggs are pelagic and range in size from approximately 0.68 to 0.82mm in diameter (Cross et al. 1999). Often found in surface waters of the continental shelf and estuaries and bays at depths less than 200 meters and eggs have been collected at depths ranging from 10 to 1250 meters (Cross et al. 1999). Butterfish eggs are reported to be most abundant in water with temperatures between 11 and 17ºC but have been collected in temperatures ranging from 6 to 26ºC (Cross et al. 1999). Favorable salinities for butterfish eggs can range from 25 to 33ppt (Cross et al. 1999).

Larvae

Butterfish larvae are pelagic and have been collected from surface waters at the continental shelf and estuaries and bays in the Middle Atlantic Bight (Cross et al. 1999). Larvae have been collected at salinities ranging from 6.4 to 37.4ppt, water temperatures between 7 and 26ºC (most abundantly found at temperatures between 9 and 19ºC) and varying depths ranging from 10 to 1750 meters (Cross et al. 1999).

Juveniles

Butterfish juveniles reside on the continental shelf, inshore bays and estuaries and are common in inshore areas (Cross 1999). Smaller juveniles have been found under floating objects, while larger juveniles collect over sandy to muddy substrates (Cross et al. 1999). Larger juveniles may congregate near the bottom during the day and move disperse upward at night. Preferred water temperature ranges from 4.4 to 29.7ºC and preferred salinities range from 3.0 to 37.4ppt (Cross et al. 1999). In the Hudson-Raritan estuary, juvenile butterfish have been collected at depths between 3 and 23 meters, water temperatures from 8 to 26ºC, salinities from 19 to 32ppt and DO from 3 to 10mg/L (Cross et al. 1999). Juvenile butterfish diet is similar to adult feeding habits where diet is dominated by planktonic prey (Cross et al. 1999).

Occurrence in Project Area

Data from sampling programs conducted within the study area indicate that butterfish were present in bottom trawls collected at channel stations but were extremely rare in shoal areas (NMFS 1994, LMS 1996). In Newark Bay, no butterfish were collected at shoal stations between May 1993 and April 1994; while only three were collected between April 1995 and March 1996. Butterfish was the most abundant species collected in bottom trawls in the Hudson-Raritan estuary (NMFS 1994).

Butterfish occurred in bottom trawl samples collected during the 1998-1999 biological monitoring program from May through December (USACE 1999). Very few were collected in May and June, with the majority collected during July and August. Butterfish were ubiquitous in the study area during August, collected in all Harbor areas except Red Hook. Catches were highest in the Lower Harbor.

Ichthyoplankton sampling has revealed very few butterfish larvae in the study area. One larval butterfish was collected in plankton net tows conducted in Newark Bay between May 1993 and April 1994 (NMFS 1994). No butterfish larvae were collected in epibenthic sled samples during the 1998-1999 biological monitoring program (USACE 1999). Ichthyoplankton sampling associated with entrainment monitoring at electric generating stations in the study area also failed to collect butterfish eggs or larvae (LMS 1993, 1994).

As with both red hake and bluefish, no early life stage Atlantic butterfish (eggs, larvae, juveniles) were identified in the ichthyoplankton samples collected during the seven month (December 2000 through June 2001) Supplemental Sampling Program (USACE 2002).

Atlantic butterfish were rarely identified in trawl samples collected during the 2001–2002 Aquatic Biological Sampling Program (USACE 2002a). Individuals occurred during May in the shallows and channels of the Upper Bay. Channels in June provided the only occurrence of this species in the Arthur Kill/Newark Bay area. No Atlantic Butterfish were identified in sample collected in the Lower Bay. CPUEs for all trawls were below one.

Post Yolk-sac larvae was the only early life stage of Atlantic butterfish collected during the 2001-2002 program. July was the only month in which this life stage was identified in ichthyoplankton samples. The locations it was found were both channels and shoal/shallows in the Upper and Lower Bays and in channel habitats in the Arthur Kill/Newark Bay area. CPUEs ranged from 1.48 in the Arthur Kill/Newark Bay to 9.81 in the Upper Bay.

Potential Impacts

Butterfish is a pelagic species, not generally associated with bottom habitats. Based on recent biological sampling programs, juvenile butterfish EFH occurs throughout the project area. Juvenile butterfish occur in greatest abundance, however, in the open-water areas of Raritan Bay and the Lower Harbor. Adult butterfish also likely occur in the open water areas of the Lower Harbor and Raritan Bay, but have been collected in very few numbers. Larval butterfish EFH, if present at all, appears to be marginal in the estuary as evidenced by the low occurrence of this species in recent sampling programs.

Due to the pelagic behavior of juvenile butterfish, potential impacts are limited to short-term disturbances in the water column associated with actual deepening activities. These impacts include increased turbidity during dredging and blasting and an interruption in the use of the water column due to the operation of dredging and blasting equipment. Butterfish are expected to avoid in water work areas, finding useable habitat elsewhere in the harbor. Any short-term impacts would be limited to areas of butterfish abundance, primarily the Lower Harbor.

No long-term impacts associated with disturbances to intertidal, littoral, sublittoral or benthic habitats in the channels would occur as these fish are pelagic. As with Bluefish, Atlantic Butterfish habitat may be expanded as a result of the proposed deepening.

Potential short-term indirect impacts could result from effects of the deepening on butterfish forage species. Planktonic organisms and pelagic fish dominate this species food source. Because most butterfish forage species occur in the water column, potential impacts to these species are expected to be minimal. Individuals may be displaced from areas of active in-water disturbance, along with butterfish, resulting in little change in availability as a food source.

Long term indirect impacts are considered negligible because both butterfish and their prey will return to all work areas once the disturbance has ceased.

3.7 Atlantic Mackerel (*Scomber scombrus*)

EFH designation for Atlantic mackerel within the project area is limited to juvenile and adult life stages within the seawater salinity zone (salinity 25ppt or greater) (NMFS 1999). Spatial distribution and relative/seasonal abundance data used in the ELMR program, suggest that both juvenile and adult Atlantic mackerel are common in the Hudson-Raritan estuary during April through June and again in October and November (Stone et al. 1994). However, data reliability for the Hudson-Raritan estuary was classified as that of reasonable inference, indicating that little or no sampling data was available (Stone et al. 1994).

Adults

Adult Atlantic mackerel are pelagic and schooling, often found in open seas along the continental shelf or in open bays (Studholme et al. 1999). EFH includes sea water salinities greater than 25ppt and temperature and depth preferences that vary seasonally (Studholme et al. 1999). Field studies have shown that adults are intolerant to temperatures less than 5 to 6ºC or greater than 15 to 16ºC, while laboratory studies reported that the preferred temperature range is from 7 to 16ºC (Studholme et al. 1999). Laboratory studies have also depicted that the lethal temperature limits are 2 and 28.5ºC (Studholme et al. 1999). Temperature and depth preferences vary seasonally as follows: in the fall between 9 and 12ºC and from 60 to 80 meters; in the winter between 5 and 6ºC and from 20 to 30 meters; at 13ºC and between 60 and 170 meters in spring; and between 10 and 14ºC and from 50 to 70 meters in summer (Studholme et al. 1999). Adult Atlantic mackerel are opportunistic feeders with a variety of dietary components including euphausids, pandalids, crangonid shrimp, chaetognaths, larvaceans, pelagic polychaetes, squids, copepods, amphipods, sand lances, herring, hakes and sculpins (Studholme et al. 1999).

Spawning

Atlantic mackerel typically spawn on the shoreward side of the continental shelf, beginning in mid-April and progressing from the Mid-Atlantic Bight to the Gulf of Maine until June (Studholme et al. 1999). Peak spawning is reported to occur at salinities greater than 30ppt, and at water temperatures between 9 and 14ºC, but spawning can commence at temperatures greater than 7ºC (Studholme et al. 1999).

Eggs

Eggs are pelagic and found within the water column at depths ranging from 10 to 325 meters, and most abundantly at depths between 30 and 70 meters (Studholme et al. 1999). Atlantic mackerel eggs have been collected in water temperatures between 5 and 23ºC, but the preferred temperature range is from 7 to 16ºC (Studholme et al. 1999). Eggs have been collected from sea water where salinities are greater than 30ppt, as well as from estuaries where salinities typically range from 18 to 25ppt; however, mortality has been reported to increase as salinities drop below 25ppt (Studholme et al. 1999). Correlations in timing of peak egg hatching and the highest abundances in zooplankton have been noted (Studholme et al. 1999).

Larvae

Atlantic mackerel larvae primarily reside in offshore waters where salinities are greater than 30ppt, but are also found in estuaries as far south as New Jersey where salinities are less than 25ppt (Studholme et al. 1999). Preferred depths vary with larval age and the thermocline and can range from 10 to 130 meters (Studholme et al. 1999). Water temperatures between 6 and 22ºC support larvae; however larvae have been found most abundant at water temperatures between 8 and 13ºC (Studholme et al. 1999). Atlantic mackerel feeding habits are associated with their size. Larvae less than 6mm typically feed on copepod nauplii and copepodites, while larvae greater than 6mm feed on adult copepods and fish larvae (Studholme et al. 1999).

Juveniles

Juvenile Atlantic mackerel are pelagic and schooling and are found both offshore and within estuaries (Studholme et al. 1999). Juveniles prefer salinities greater than 25ppt, and preferred water temperature and depth vary with season (Studholme et al. 1999). Juveniles tend to use habitats at depths ranging from 20 to 320 meters, and temperatures of 4 to 22ºC (Studholme et al. 1999). In the Hudson-Raritan estuary, juvenile Atlantic mackerel have been collected during July at depths between 4.9 and 9.8 meters, at temperatures from 17.6 to 21.7ºC, at salinities ranging from 26.1 to 28.9ppt and at DO 7.3 to 8.0mg/L (Studholme et al. 1999).

Occurrence in Project Area

No Atlantic mackerel were collected in sampling programs conducted in Newark Bay (NMFS 1994, LMS 1996) and the Hudson-Raritan estuary (NMFS 1994). Only one Atlantic mackerel was collected during the 1998-1999 biological monitoring program (USACE 1999).

There were no early life stage Atlantic Mackerel collected during the seven month (December 2000 through June 2001) Supplemental Sampling Program (USACE 2002). However, the ichthyoplankton samples collected for the 2001-2002 Aquatic Biological Sampling Program (USCAE 2002a) included post yolk-sac larvae Atlantic mackerel throughout the study area in the month of May. CPUEs were greatest in the Lower Bay with values decreasing at stations further into the harbor. Trawling yielded no adult Atlantic Mackerel anywhere in the study area.

Because Atlantic mackerel is an offshore, pelagic species, and not generally associated with bottom habitat or very susceptible to bottom trawl sampling, Atlantic mackerel may be underrepresented. However, fish sampling programs associated with impingement monitoring at electric generating stations in the study area, also failed to collect Atlantic mackerel (LMS 1993, 1994).

Potential Impacts

Based on the extremely rare occurrence of Atlantic mackerel in aquatic sampling programs in the Harbor, Atlantic mackerel EFH does not appear to occur in the study area. Therefore, no direct, indirect or cumulative impacts due to channel deepening are expected to occur.

3.8 Summer flounder (*Paralichthys dentatus*)

Summer flounder EFH within the project area has been designated for larvae, juvenile and adult life stages in the freshwater, brackish, and seawater salinity zones of the project area (NMFS 1999). Summer flounder occurrence is limited to the western Atlantic from Nova Scotia to South Carolina (and possibly Florida), with the majority of the population occurring south of Cape Cod (Vladykov and McKenzie 1935; Wilk et al. 1980; Gilmore et al 1981). Adult and juvenile summer flounder are found in the project area during warmer months, primarily May through October, in shallow water over sand and mud substrate. Larval summer flounder, although generally considered rare in the Hudson-Raritan estuary, may occur in pelagic waters between April and December (Stone et al. 1994).

NMFS has identified summer flounder HAPC as "[a]ll native species of macroalgae, seagrasses, and freshwater and tidal macrophytes in any size bed, as well as loose aggregations, within adult and juvenile summer flounder EFH…" NMFS also indicates that "[i]f native species of SAV are eliminated then exotic species should be protected because of functional value, however, all efforts should be made to restore native species" (NMFS 2003). The authorized project, specifically those areas to be deepened, does not contain this type of habitat.

Adults

Adults of this species occur in shallow, near shore water over sand, hard bottom and mud substrates, and within grasses and around pilings at depths up to 25 meters. Summer flounder adults concentrate in bays and estuaries from late spring through early autumn frequenting deeper waters (to 150 meters) over the Continental Shelf during the winter (NMFS 2003). Preferred habitat characteristics are: temperatures of 9 to 26º in the fall, 4 to 13ºC in the winter, 2 to 20ºC in the spring and 9 to 27ºC in the summer in primarily higher salinity areas; there is a lack of DO data/preferences (Packer et al. 1999). Adult summer flounder are opportunistic feeders with fish (e.g. sand lance and anchovy), squid, shrimp and polychaetes comprising a significant portion of their diet (NMFS 2003).

Spawning

Spawning occurs during their offshore migration to open ocean areas of the continental shelf beginning in early-fall and continuing through winter (Packer and Griesbach 1998) generally outside the project area. In the Mid-Atlantic Bight, adults begin their spawning run in September and continue through the month of December with a peak in October (Packer et al. 1999).

Eggs

Summer flounder eggs area pelagic and buoyant. Eggs of the species are most abundant within 9 miles of the New York and New Jersey shores at depths of 9 to 110 meters (NMFS 2003). This life stage can be found at depths from 10 to 30 meters in the spring, 30 to 70 meters in the fall and to maximum depths of 110 meters in the winter (Packer et al. 1999). Eggs are most abundant in the water temperatures between 12 and 19ºC; but can be found where temperatures range from 9 to 23ºC (Packer et al. 1999). Salinity appears to have little effect on egg development and there is no data documenting DO preference (Packer et al. 1999).

Larvae

The pelagic larvae, which are transported toward coastal areas by prevailing water currents, can be found in waters with salinities ranging from 0.02 to 35ppt and temperatures of 2 to 22ºC (USFWS 1978). Summer flounder larvae are most abundant between 19 to 80km from shore and at depths between 9 to 70 meters (NMFS 2003) at temperatures between 9 and 18ºC (Packer et al. 1999). Transforming larvae and juveniles are most often captured in the higher salinity portions of estuaries (Packer et al. 1999). In the Hudson River Estuary, salinity preference ranged from 20 to 30ppt (AKRF 2002). They are most frequently found in the northern part of the Mid-Atlantic Bight from September to February, and in the southern part from November to May (NMFS 2003).

Juveniles

Development of post-larvae and juveniles occurs mostly in bays and estuarine areas (LMS March 2001) in demersal waters over mud and sand substrates (NMFS 2003). Juveniles use tidal channels, seagrass beds, mudflats and open water bays with salinities ranging from 10 to 30ppt. Following settlement, early juveniles inhabit a variety of high-salinity, subtidal habitats, including subtidal marsh creeks, coves, bays, and inlets in both vegetated and unvegetated habitats (Able and Fahay 1998). Juvenile summer flounder prefer waters with temperatures greater than 11 ºC, salinities ranging from 20 to 30ppt, depths from 0.5 to 5.0 meters, over sand and mud substrates (AKRF 2002) and mean DO levels at 6.4ppm (Packer et al. 1999). The most common forage species of juvenile summer flounder is mysid shrimp (NMFS 2003)

Occurrence in Project Area

Summer flounder eggs and larvae have been collected in the study area during previous biological sampling programs. Both eggs and larvae were collected in epibenthic sled samples at shoal stations in Newark Bay (LMS 1996). Eggs were collected in September and October; larvae were collected in September only. Summer flounder eggs were also found collected in epibenthic sled samples collected in the Arthur Kill channel during this same period (LMS 1996).

Unlike epibenthic sled samples, no summer flounder eggs or larvae were collected in plankton net tows in Newark Bay (NMFS 1994). Summer flounder eggs and larvae were also absent from epibenthic sled ichthyoplankton samples collected during 1998-1999 biological monitoring program (USACE 1999). Summer flounder eggs and larvae (prior to settlement) are pelagic, however, and may not be effectively sampled by epibenthic gear. Summer flounder post-yolk-sac larvae have been collected in ichthyoplankton sampling programs associated with entrainment monitoring at electric generating stations in the study area (LMS 1993, 1994). Larvae were present in ichthyoplankton entrainment samples from November through March.

Summer flounder were present in bottom trawl samples collected at shoal and channel stations in Newark Bay between April and September (NMFS 1994, LMS 1996). Abundance was highest during July. The majority of these fish were greater than 200mm in length. Early juvenile summer flounder (<200mm TL) were noticeably absent from bottom trawls (NMFS 1994, LMS 1996). Summer flounder were generally more abundant at channel stations than at shoal stations (NMFS 1994).

Summer flounder were collected during the 1998-1999 biological monitoring program from April through October, with abundance highest during June (USACE 1999). Summer flounder were generally distributed evenly throughout the project area and were collected at all Harbor Areas. The largest collections were made in South Brooklyn during May and in the Kill Van Kull during July. Adult and juvenile summer flounder migrate offshore in late-summer and early fall, as water temperatures decline.

Post yolk-sac larvae of this species was the only early life stage collected during the seven month (December 2000 through June 2001) Supplemental Sampling Program (USACE 2002). Present in samples collected from December through April, they were found primarily in the samples collected from the channel locations (all months) with individuals identified in shoal/shallow samples in two months and in slope samples in one month. The number of individuals was generally constant over the four-month period they were collected.

Summer flounder were identified in ichthyoplankton samples collected during the 2001-2002 Aquatic Biological Sampling Program (USACE 2002a). Low densities of post yolk-sac larvae were found in January through March. They were confined to channel locations in the Upper Bay (Jan.) and Arthur Kill/Newark Bay (Feb.) and shallows in Upper Bay (Mar.). CPUEs ranged from 0.33 to 1.32.

Adults were identified in samples taken during all months of the 2001-2002 Aquatic Biological Sampling Program (USACE 2002a) except February representing the largest portion of the catch during June. In the Arthur Kill/Newark Bay area, the shallows contained summer flounder from April through June and the channels in March, May and June. Summer flounder was collected from April through June in both the shallows and the channels and in January in the channels only. May was the only month in which individuals were found in the shallows of the Lower Bay but in the channels, they were collected in all months but February. CPUE was highest in the Upper Bay in December and January, in The Arthur Kill/Newark Bay in March and April and in the Upper Bay in May and June. CPUEs ranged between 0.10 (Upper Bay channel stations in January) to 11.25 (Upper Bay shoal/shallow stations in June).

Potential Impacts

Habitat conditions in the project area encompass those that represent EFH for summer flounder. Based on recent sampling programs all three life stages identified by NMFS as having EFH in the Hudson-Raritan Estuary were collected.

Potential short-term impacts to summer flounder EFH include temporary disruption of bottom habitat, increased turbidity and burial of substrate during channel deepening/dredging operations, as well as disturbance to intertidal, littoral and sublittoral habitat. Potential impacts would be limited primarily to demersal life-stage EFH (i.e., older juvenile and adult), and would be localized and confined to the immediate excavation area. No excavation would occur in tidal creeks or shallow subtidal marshes or bays, all of which represent primary habitat for early juvenile summer flounder. Localized impacts to the substrate through burial are expected to return to conditions similar to that prior to dredging (except where sublittoral and littoral habitat will be permanently altered) through redistribution of substrate in the currents and repopulation by adjacent benthic communities. Most of the project area and the greater harbor area would remain available for foraging and growth. Potential sort term impacts would be restricted to warmer months (May through October), when adults and juveniles are most common. Juvenile and adult summer flounder would continue using the shoal and channel habitat in other portions of the harbor limiting the effect of the dredging.

Short-term impacts to pelagic summer flounder larvae would be limited to disturbances within the water column including, bucket-hoisting operations and increased turbidity in the immediate construction area. It is expected that summer flounder larvae will avoid areas undergoing dredging and blasting favoring other similar habitat throughout the harbor.

Potential impacts due to the permanent loss of shallow-water littoral zone areas will be mitigated as described in Appendix D. The acreage of wetland habitat that will be created or restored in the recommended mitigation plan greatly exceeds the requirement to compensate for the littoral zone disturbances. While it is impossible to directly compare the impacts associated with the sublittoral disturbances with the benefits obtained from beneficial use of dredged material and the additional wetland compensation, it is believed that the net beneficial effects resulting from these factors outweigh the disturbances to 42.03 acres of sublittoral habitat.

Beneficial use will be a priority for the management of dredged materials from this project. Given the volume of dredged material likely to be created (approximately 51 million cubic yards from the initial construction alone), the anticipated benefits from the beneficial use of such material are great. The District and NMFS have investigated EFH enhancement opportunities in the New York and New Jersey Harbor for those species with designated EFH occurring in the Harbor. The results of these actions may allow for the implementation of one or more opportunities to enhance EFH throughout New York and New Jersey Harbor while making beneficial use of some dredge material (e.g., rock, sand). Conceptual designs have been developed for several EFH enhancement sites. Details of the conceptual designs are provided in Appendix E.

Indirect impacts are those resulting from disturbance of forage organisms and/or forage habitat related to the channel deepening. Summer flounder feed predominantly on other fishes and to a lesser extent on invertebrates. Temporary loss of water column and river bottom habitats and direct impacts to these forage organisms due to the deepening operations have the potential to impact summer flounder.

Both short- and long-term indirect impacts will be the same for prey species as they are for the summer flounder. The loss of forage species habitat due to burial by settling of resuspended sediments would cause adult winter flounder to search elsewhere for prey. Areas not permanently altered (approximately 40 acres of sublittoral and littoral habitat) will be recolonized within a few months to a year by benthic communities in adjacent areas. Regardless of this impact, adults consume a number of different organisms, including both benthic and pelagic species; therefore, there should be little impact to its food base. Juveniles, which feed primarily on mysid shrimp, will need to follow their prey from the area of disturbance to other acceptable habitats within the harbor.

All potential direct and indirect impacts could be either avoided or minimized through dredge operation limitations (e.g., hoist speeds) and through the mitigation and habitat enhancements. Therefore, no detrimental or unmitigatible impacts to summer flounder EFH are expected to occur.

3.9 Scup (*Stenotomus chrysops*)

EFH designation for the egg, larval, juvenile, and adult life-stage of scup is limited to the seawater salinity zone of the project area (salinity 25ppt or greater) (NMFS 1999).

Adults

EFH for adult scup includes a variety of habitats, including soft, sandy bottoms and on or near submerged structures, rocky ledges, or mussel beds (MAFMC 1996). Smaller size adults inhabit estuaries and bays and larger adults prefer more depth (Steimle et al. 1999). Habitat preferences vary with season. Adult scup use coastal habitats until water temperature falls below 7.5 to 10oC (MAFMC 1998). During warmer seasons, preferred temperatures range from 7 to 25ºC and depths range from 2 to 38 meters. Wintering adults, from January to March, favor temperatures above 7ºC and depth from 38 to 185 meters along the mid- and outer- continental shelf. In the Hudson-Raritan estuary, adults have been found at salinities ranging from 20 to 31ppt and DO levels 4mg/L or greater (Steimle et al. 1999). Adult scup feeding habits vary greatly, and include small crustaceans, polychaetes, mollusks, insect larvae, sand dollars and small fish (Steimle et al. 1999).

Spawning

Spawning occurs during inshore migration in coastal waters from May through August (Steimle et al. 1999). Environmental associations with spawning typically include temperature ranges from above 9 to 24oC at depths less than 30m (Steimle et al. 1999), and have been reported to take place over weedy or sandy areas (Morse 1978). Spawning has been reported to occur from Massachusetts to the New York Bight, including the Raritan Bay; however, recent studies have not found eggs or larvae in the Hudson-Raritan estuary (Steimle et al. 1999).

Eggs

Scup eggs are generally 0.8 to 1.0mm in diameter and found in coastal waters from May through August (Steimle et al. 1999). Eggs are buoyant (pelagic) and found in the water column at temperatures between 11 and 23º (Steimle et al. 1999). The environmental characteristics that support scup eggs are poorly understood (Steimle et al. 1999).

Larvae

Scup larvae are pelagic until they reach approximately 15 to 30mm TL, when they begin transition to demersal juveniles (Steimle et al. 1999). According to Steimle et al., there is no information available regarding habitat use or preferences during the transition between pelagic larvae and demersal juveniles (1999). However, it is documented elsewhere that at the time of transition, demersal larvae are found in shoal waters (MAFMC 1996, Able and Fahay 1998). Larvae reside in of southern New England from May through September, when water temperatures range from 14 to 22oC (MAFMC 1998), with peak larval densities occurring between 15 and 20ºC (Steimle et al. 1999). Feeding habits of scup larvae are unavailable; however rearing experiments indicate that small zooplankton is a dietary component (Steimle et al. 1999).

Juveniles

Like adults, juvenile habitat preferences vary with season. Winter juvenile scup migrate offshore and little information is available regarding their habitat preferences; however, scup distributions suggest that they reside in varying habitats, from flat bottoms to submarine canyons with varying sediment types (Steimle et al. 1999). During warmer seasons, young of year and older juveniles occur in estuaries and coastal waters at depths to approximately 38 meters from May to November (Steimle et al. 1999). Stemle et al (1999) state that the various juvenile habitats include mussel and eelgrass beds, as well as sand and mud. Water characteristics typically favored by juveniles include temperatures ranging from greater than 9 to 27oC. In the Hudson-Raritan estuary, juvenile scup have been reported at temperatures ranging from 9 to 26oC, where salinities range from 18 to 33ppt and DO levels are greater than 4mg/L (Steimle et al. 1999).

Occurrence in Project Area

Although earlier studies report scup larvae in southern New England waters, Able and Fahay (1998) have stated that there has not been a verified collection of scup larvae in these waters since Sisson (1974). Their assertion is supported by recent ichthyoplankton sampling during which no scup larvae were collected (NMFS 1994, LMS 1996). Moreover, no scup larvae were collected during the 1998-99 epibenthic ichthyoplankton sampling conducted in the study area. Although early stages are pelagic, and would not be expected to occur in epibenthic samples, larger demersal larvae should have been collected if present.

Within the project area, juveniles and adults occur in similar demersal habitats, using intertidal and subtidal waters over a variety of substrates. Juveniles were collected during bottom trawls in October 1998 and from May through September in 1999 (USACE 1999). Abundance was greatest at South Brooklyn and Port Jersey sites during July through September. Juveniles were collected at several other stations in August.

During earlier studies (e.g., Croker 1965, Berg and Leviton 1985) scup eggs were not collected in the Hudson-Raritan estuary. Similarly, no eggs were collected in epibenthic ichthyoplankton sampling conducted in the study area during 1998 and 1999 (USACE 1999). Again, eggs are pelagic and would not be expected to occur in epibenthic samples.

Older, possibly adult scup were collected in October 1998, and from July through September 1999 (USACE 1999). As was the case for juveniles, adults were found in greatest numbers at South Brooklyn and Port Jersey stations from July to September. Adults were also collected at several other stations in August.

No early life stages of scup were identified during the seven month (December 2000 through June 2001) Supplemental Sampling Program (USACE 2002). This was also the case for the seven month (January to July 2002) Aquatic Biological Sampling Program (USACE 2002a). Adults, however, were identified in trawls during May and June during this second study. During these two months, individuals were gathered at the shoal/shallow stations in the Upper and Lower Bays and in the channels in the Upper Bay. The shallows in the Arthur Kill/Newark Bay area of this study yielded scup in June as did the channels in the Lower Bay in May. CPUE was relatively low in the Arthur Kill/Newark Bay and Upper Bay areas ranging in value from 0.3 to 4.5. In the Lower Bay, CPUEs were 12.33 (June in the shallows), 20.00 (May in the shallows) and 42.42 (May in the channels).

Potential Impacts

Habitat within the project area, although identified as EFH for all life stages, appears to lack characteristics important for scup eggs and larvae as supported by the literature and lack of these life stages in recent sampling programs. Impacts therefore would be very limited when considering these early life stages.

Potential short term impacts to juvenile and adult scup EFH would be related to the temporary disruption of bottom and, to a lesser extent, water column habitats during channel deepening/dredging activities. These impacts would be localized and confined to the immediate excavation area and include increased turbidity and disruption/burial of substrate by settling sediments. Most of the project area, however, would remain available for foraging and growth and scup would take advantage of the undisturbed habitat elsewhere in the harbor. Potential impacts to EFH would be restricted to warmer months (May through October), when adults and juveniles are most common.

Since scup eggs and larvae are pelagic, impacts should they occur, would be limited to disturbances within the water column (such as bucket hoisting operations) and in the immediate construction area. Disturbance to littoral and sublittoral bottom habitat would be temporary and would be mitigated as described in Section 6. Therefore, no detrimental or unmitigable impacts to scup EFH are expected to occur.

Long term impacts would include continued disruption of EFH over the course of the project and permanent alteration of the existing habitat composition. Effects of the earlier are expected to by minimal as other viable habitat outside of the construction area will be available for scup to use. The later will result in a reconfiguration of available habitat but is not expected to cause the loss of any available habitat and therefore would have a negligible impact on this species EFH.

Indirect impacts are those resulting from the temporary loss of forage organisms and/or forage habitat and the alteration of existing habitat related to the deepening of the channels. Scup typically feeds on organisms associated with the substrate. Benthic communities will be displaced (mobile organisms would relocate) and lost (sessile benthic organisms would be removed with the substrate) as a result of dredging and blasting. Impacts to these resources would cause scup to locate other acceptable habitat in which to feed. Over time (months to a year), the macroinvertebrate community is expected to recolonize any disturbed areas as communities in adjacent habitats expand. The reconfiguration of habitats resulting from the deepening is not expected to result in long term loss of EFH for this species as physical process reclaim those areas previously disturbed.

These potential impacts could be easily avoided and mitigated through dredge operation limitations (e.g., hoist speeds) and BMPs.

3.10 Black sea bass (*Centropristis striata*)

EFH designation for juvenile and adult black sea bass includes the marine and estuarine waters of the project area (NMFS 1999). This species can be found from the Gulf of Maine to as far south as the Florida Keys (Steimle et al. 1999). In the Mid-Atlantic Bight, juvenile and adult black sea bass move inshore and north in the summer and offshore and south in the winter (Steimle et al. 1999). Individuals of this species are strongly associated with structured habitats (e.g., reefs, piling fields). Black sea bass use both estuarine and inner continental shelf habitats as nurseries during the first summer. Annual occurrence in the Hudson-Raritan estuary and the project area is highly variable.

Adults

Adult black sea bass reside offshore between November and March and mostly occur at depths between 60 and 150 meters, but can reach depths of 240 meters (Steimle et al. 1999). During winter months, adult black sea bass prefer temperatures greater than 6ºC and salinities approximately between 30 and 35ppt (Steimle et al. 1999). Adult black sea bass reside throughout the coastal areas of the Middle Atlantic Bight between April and December, and are associated with mussel beds, rocks, artificial reefs and other structures in depths of 2 to 38 meters (Steimle et al. 1999). During the summer, adult black sea bass prefer water temperatures between 13 and 21ºC and salinities greater than 20ppt (Steimle et al. 1999). Adults feed on small fish, squid and benthic invertebrates (NMFS 2003).

Spawning

Spawning occurs in coastal bay but not in estuaries (NMFS 2003) between May and October with a peak in June (Steimle et al. 1999). Spawning habitats consist of sand, rocks and reefs at depths approximately between 20 and 50 meters in temperatures between 18 and 20ºC and salinities greater than 15ppt (Steimle et al. 1999).

Eggs

Eggs are buoyant and occur in coastal areas of the Middle Atlantic Bight between May and October within the upper water column in waters to 200 meters in depth (Steimle et al. 1999). Black sea bass eggs are reported sensitive to extreme temperatures and salinities (Steimle et al. 1999).

Larvae

Black sea bass larvae occur in the upper water column of the Middle Atlantic Bight and near shorelines or mouths of some estuaries between May and November and abundance peaks between June and July (Steimle et al. 1999). Larvae are sensitive to temperature and salinity extremes and are most abundant at water temperatures between 14 and 23ºC (Steimle et al. 1999) salinities ranging from 30 to 35ppt and depths less than 100 meters (NMFS 2003). Black sea bass larvae feed on zooplankton after yolk reserves (Steimle et al. 1999). After becoming demersal, larvae prefer inshore structured habitats (NMFS 2003).

Juveniles

Juvenile black sea bass occur inshore and in estuaries during mid and late summer using channels and salt marsh edges (NMFS 2003). Young of year are found among shellfish, sponge and eelgrass beds at the bottom and are reported to exhibit habitat fidelity (Steimle et al. 1999). Preferred habitat characteristics include water temperatures between 17 and 25ºC, salinities between 18 and 20ppt and depths between 1m and 38m (Steimle et al. 1999). Wintering juveniles occur offshore from December to April preferring depths between 90 and 100 meters along the mid and outer continental shelf (Steimle et al. 1999). Wintering juveniles are associated with nearshore shell patches and prefer water temperatures greater than 5ºC and salinities greater than 18ppt (Steimle et al. 1999). Juveniles feed on small epibenthic invertebrates, such as crustaceans and mollusks (Steimle et al. 1999).

Occurrence in Project Area

Due to their preference for structured habitat, black sea bass are not generally collected in bottom trawl sampling programs. No black sea bass were collected during previous sampling programs in Newark Bay at channel or shoal stations (NMFS 1994, LMS

1996). Bottom trawls conducted in the Hudson Raritan estuary between January and December 1993 collected only 50 individuals. Black sea bass were most abundant in the Hudson-Raritan estuary in fall (NMFS 1998).

As expected, very few black sea bass were collected during the 1998-1999 biological monitoring program (USACE 1999). Black sea bass were present in bottom trawl samples during June, August-October, and December. The majority of these were collected during October, at the Port Jersey and South Brooklyn Marine Terminal areas. Black sea bass were not collected at Red Hook, Kill Van Kull, Newark Bay Arthur Kill, or South Brooklyn approach channel areas.

During the seven month (December 2000 through June 2001) Supplemental Sampling Program (USACE 2002), no early life stages (eggs, larvae, and juveniles) of black sea bass were identified in the ichthyoplankton samples collected.

In the 2001 – 2002 Aquatic Biological Sampling Program (USACE 2002a) trawl samples collected in December and April through June (program ran from December through June) contained black sea bass. The CPUEs were low (0.17 to 3.00) and roughly the same at all stations (all but one below 1.00) from which this species was collected the exception being the December sample from the Lower Bay. Trawls in the Arthur Kill/Newark Bay shoal/shallows yielded individuals from April through June; none were collected from the channel station in this area. The shoal/shallows of the Upper Bay and the channels of the Lower Bay produced black sea bass in the month of April. December, April and May in the channels of the Lower Bay and May and June in the shoals/shallows of the Upper Bay were the months during which black sea bass were identified in trawls. No black sea bass were collected in trawls at the Arthur Kill/Newark Bay channels and no early life stage black sea bass were identified in any of the ichthyoplankton samples taken during the program.

Potential Impacts

Short term direct impacts to black sea bass EFH would include increased turbidity and temporary sediment disturbances resulting from the settling of resuspended solids. Individuals of this species would avoid areas of active in-water construction and may relocate to less turbid areas to find acceptable structured and benthic habitat.

Due to the strong affinity of this species for structured habitats, rough bottoms, and shallow waters, potential impacts to black sea bass EFH within the project area are minimal, since these habitat types do not occur within the immediate vicinity of channels to be deepened. Some impact may occur due to the temporary disturbance of shallow-water habitat. Since these areas are not associated with pile fields or structured habitat, such impacts would likely be minimal.

Indirect impacts to black sea bass EFH would be directly related to temporary loss and/or displacement of benthic forage species. Burial of benthic invertebrates and avoidance of work areas by finfish prey may cause black sea bass in the project area to search for more prey in less disturbed areas. Due to the low densities of this species collected in the project area, all impacts to potential prey would have a limited effect on individuals foraging in the vicinity of the project.

3.11 Cumulative Impacts

Short term cumulative impacts would be related to dredging and blasting associated with this and other deepening and/or maintenance projects that are ongoing concurrently within the greater harbor area. These short term cumulative impacts to EFH would be a combination of the disturbances associated with each project. For example, should the consolidation schedule have channel deepening ongoing simultaneously at two separate locations, impacts to EFH would be the combined effect on EFH related to avoidance of turbidity or temporary disruption of benthic habitat, as it occurs at both locations. However, even large scale dredging efforts run concurrently will impact only a small percent of the total EFH that exists throughout the harbor for any one of the managed species assessed. Therefore, it is expected that effects from channel deepening at multiple locations within the harbor on EFH and on the associated response of each species (managed and forage) would be the same as those covered in the discussion of direct and indirect short term impacts above. The assessed managed fish species are expected to adjust their behavior to avoid these short-term cumulative.

Specifically, in response to short term cumulative impacts, mobile life stages are expected to locate acceptable habitat elsewhere within the harbor impacts. Early life stages that are pelagic and planktonic will be carried through areas of dredging by tidal currents resulting in little effect on them. The life stages that would be most susceptible to the deepening will be winter flounder eggs and larvae which are demersal, adhesive (eggs), and non-dispersive (larvae). The magnitude of short term cumulative impacts from this and other projects would be directly related to work occurring in specific areas that winter flounder had used as spawning grounds the past winter and spring, and then only if the eggs and/or larvae were still present. In recent sampling programs, spawning areas have been identified at different locations from year to year suggesting that this species has multiple areas of acceptable habitat for spawning. This flexibility combined with the use of dredging BMP would minimize these types of impacts on early life stage winter flounder.

Long term cumulative impacts resulting from dredging and blasting will be related to the permanent alteration of habitats within and adjacent to the deepened channels. Permanent changes in depth, width and bathymetry within channels and changes in habitat types will impact the EFH of some managed species.

The alteration of habitat composition including the loss of intertidal, littoral and sublittoral habitat and the potential changes in the composition of sediments will result in a permanent change in habitat configuration in these shallow water areas. Similar habitats exist at other locations within the harbor and can be used by those species whose EFH lies in the shallow areas. The larger (deeper and wider) channels resulting from the project may enhance certain pelagic species habitats by increasing the useable volume of water in the water column.

Unavoidable impacts will be offset through mitigation. Potential impacts due to the permanent loss of intertidal and shallow-water littoral zone areas will be mitigated as described in Appendix D. The acreage of wetland habitat that will be created or restored in the recommended mitigation plan greatly exceeds the requirement to compensate for the littoral zone disturbances. While it is impossible to directly compare the impacts associated with the sublittoral disturbances with the benefits obtained from beneficial use of dredged material and the additional wetland compensation, it is believed that the net beneficial effects resulting from these factors outweigh the disturbances to 42.03 acres of sublittoral habitat. Therefore, no detrimental or unmitigatible impacts to EFH are expected to occur.

Beneficial use will be a priority for the management of dredged materials from this project. Given the volume of dredged material likely to be created (approximately 51 million cubic yards from the initial construction alone), the anticipated benefits from the beneficial use of such material are great. The District and NMFS have investigated EFH enhancement opportunities in the New York and New Jersey Harbor for those species with designated EFH occurring in the Harbor. The results of these actions may allow for the implementation of one or more opportunities to enhance EFH throughout New York and New Jersey Harbor while making beneficial use of some dredge material (e.g., rock, sand). Conceptual designs have been developed for several EFH enhancement sites. Details of the conceptual designs are provided in Appendix E.

Cumulative impacts will also be related to the duration of this project. Dredging and blasting will be conducted over many years with associated impacts to EFH of the ten identified managed species occurring over several/many generations. Impacts related to the duration of the project, as with both direct and indirect impacts, will be limited to areas undergoing deepening and dredging activities. Sequencing of the consolidation activities will result in the impacts moving from one area to another as the project progresses. Although in-water work will be ongoing for many years, the impacted areas will shift from channel to channel, thereby altering the type and/or location of habitat disturbed. This means that previously disturbed areas will be available for use by managed species for the majority of the time the project is underway.

Cumulative impacts are not expected to cause a significant adverse impact to the managed species assessed.

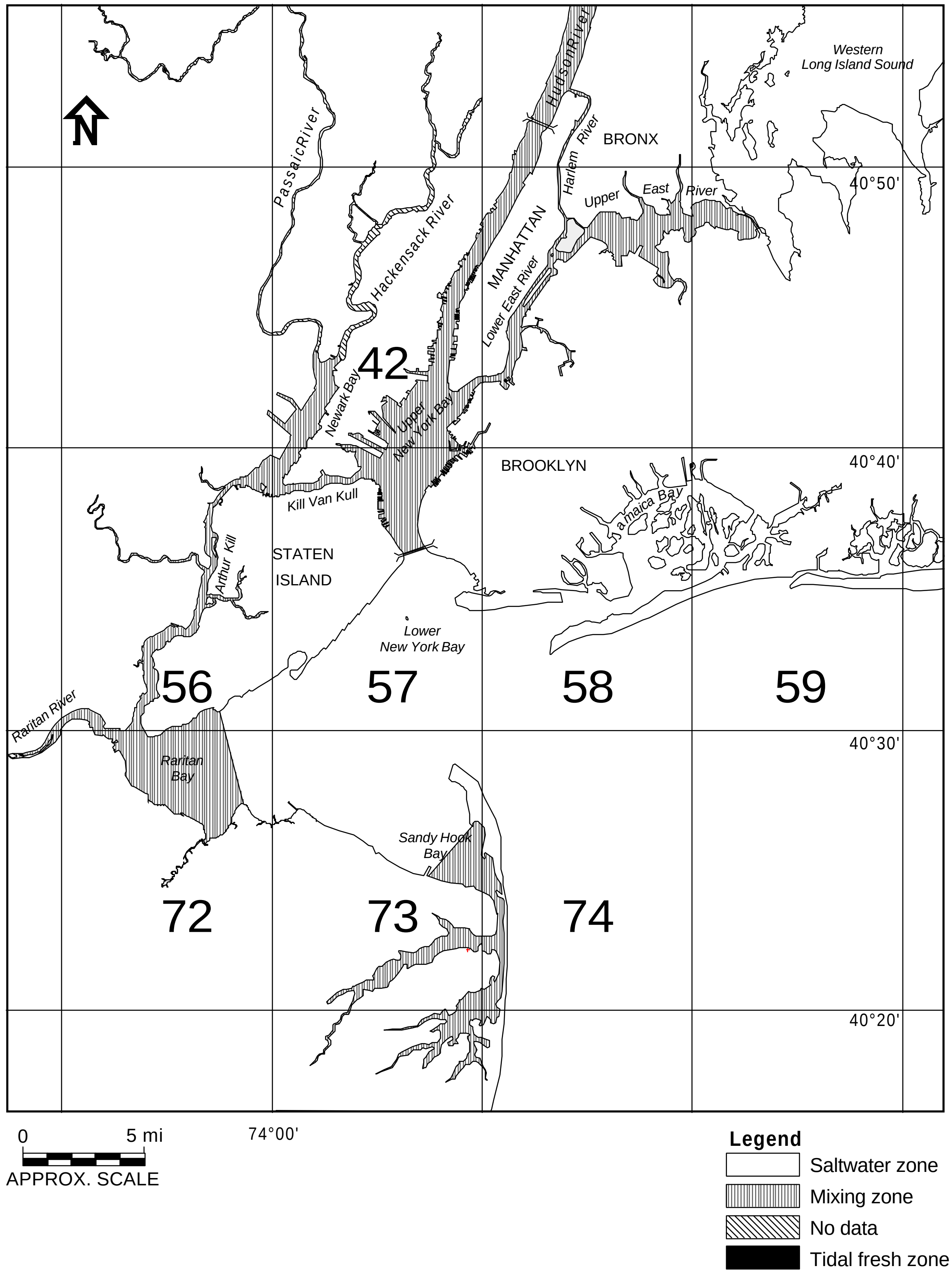

Figure E1-1 Map of summarized Squares of EFH Designation of Selected 10' x 10' latitude and longitude squares for the project area

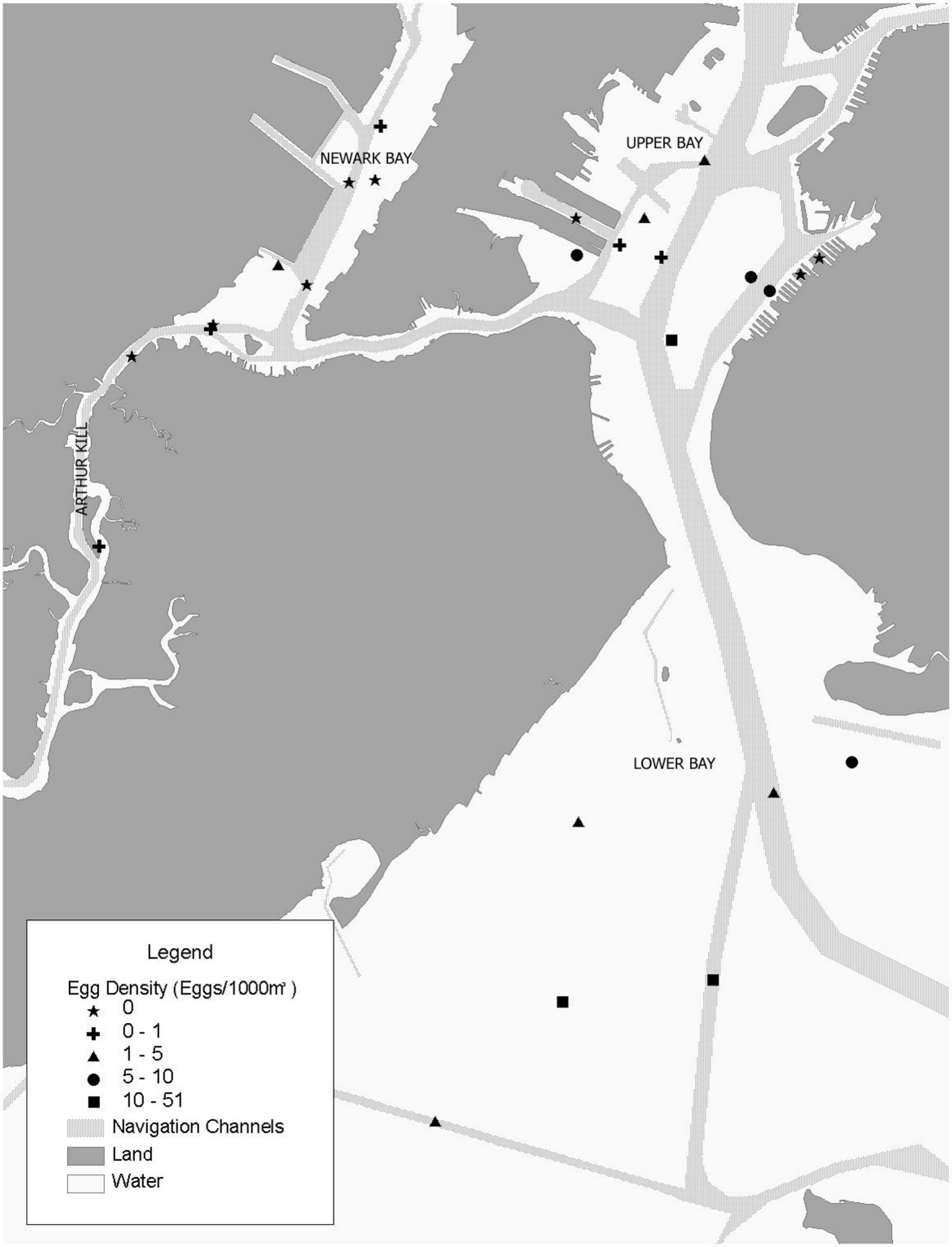

Figure E1-2. Average winter flounder egg densities collected in the Arthur Kill/Newark Bay, Upper Bay and Lower Bay areas of New York and New Jersey Harbor during the Harbor Navigation Project's 2002 and 2003 sampling seasons.

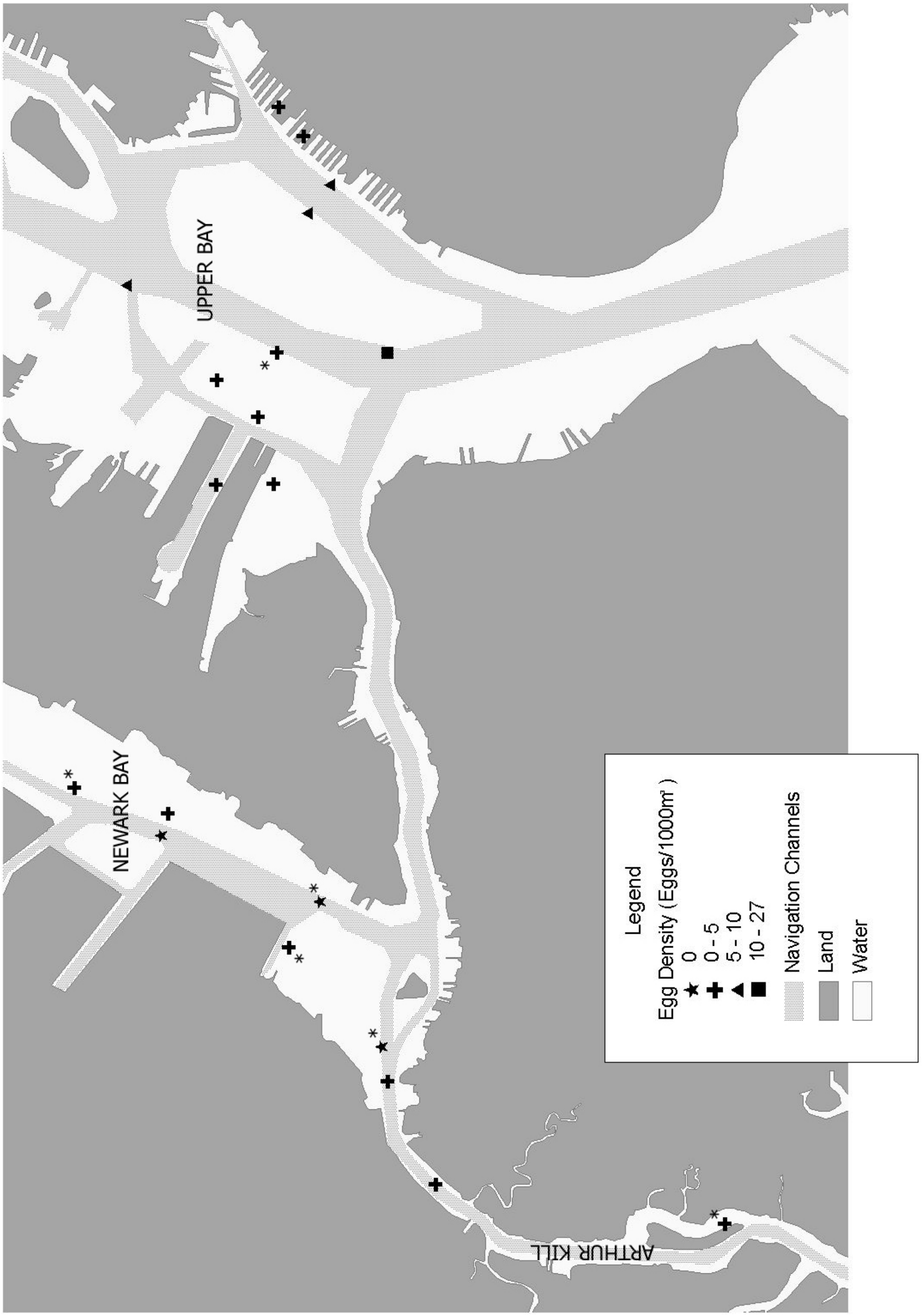

Figure E1-3. Average winter flounder egg densities collected in the Arthur Kill/Newark Bay and Upper Bay areas of New York and New Jersey Harbor during sampling as part of the Harbor Navigation Project's 1999, 2001, 2002, and 2003 sampling seasons. Note the asterisk (*) areas sampled during three years.

Table E1-3

Inventory of Fish Species Collected from Various Sampling Programs Conducted in the Project Area

Family Genus species	Common Name	**A** **1988**	**B** **1991**	**C** **1991-1992**	**D** **1993-1994**	**E** **1994**	**F** **1995-1996**	**G** **1992-1997**	**H** **1998-1999**	**I** **2000-2001**	**J** **2001-2002**
Carcharhinidae	**Requiem Sharks**										
Mustelus canis	Smooth dogfish		X								X
Rajidae	**Skates**										
Raja eglanteria	Clearnose skate							X			X
Raja erinacea	Little skate			X	X			X	X		
Raja ocellata	Winter skate							X			
Acipenseridae	**Sturgeons**										
Acipenser oxyrhyncus	Atlantic sturgeon		X		X						
Anguillidae	**Freshwater Eels**										
Anguilla rostrata	American eel	X	X	X	X	X			X		X
Ophichthidae	**Snake eels**										
Myrophis punctatus	Speckled worm eel			X							
Congridae	**Conger Eels**										
Conger oceanicus	Conger eel			X	X				X	X	X
Clupeidae	**Herrings**										
Alosa aestivalis	Blueback herring		X	X	X		X	X	X		X
Alosa pseudoharengus	Alewife	X	X	X	X	X	X	X	X		X
Alosa sapidissima	American shad	X	X	X	X	X	X		X	X	X
Alosa mediocris	Hickory shad		X	X		X			X		X

Table E1-3

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Brevoortia tyrannus	Atlantic menhaden		X	X	X				X	X	X
Clupea harengus	Atlantic herring		X		X		X	X	X	X	X
Dorosoma epedianum	Gizzard shad		X	X	X		X		X		X
Engraulidae	**Anchovies**										
Anchoa mitchilli	Bay anchovy	X	X	X	X	X	X	X	X	X	X
Anchoa hepsetus	Striped anchovy		X				X		X		
Osmeridae	**Smelts**										
Osmerus mordax	Rainbow smelt				X				X		
Synodontidae	**Lizardfishes**										
Synodus foetens	Inshore lizardfish		X	X					X		
Gadidae	**Cods**										
Merluccius bilinearis	Silver hake		X	X		X		X	X		X
Microgadus tomcod	Atlantic tomcod	X	X	X	X		X		X	X	X
Urophycis chuss	Red hake	X	X	X	X	X		X	X		X
Urophycis regia	Spotted hake	X	X		X		X	X	X		X
Urophycis tenuis	White hake	X	X								
Gadus morhua	Atlantic cod	X									
Enchelyopus cimbrius	Fourbeard rockling			X						X	X

TABLE E1-3 (Cont.)

Inventory of Fish Species Collected from Various Sampling Programs Conducted in the Project Area

Family *Genus species*	Common Name	**A** **1988**	**B** **1991**	**C** **1991-1992**	**D** **1993-1994**	**E** **1994**	**F** **1995-1996**	**G** **1992-1997**	**H** **1998-1999**	**I** **2000-2001**	**J** **2001-2002**
Opsanus tau	Oyster toadfish		X	X					X		X
Belonidae	**Needlefishes**										
Strongylura marina	Atlantic needlefish			X							
Cyprinodontidae	**Killifishes**										
Fundulus heteroclitus	Mummichog	X		X		X					
Fundulus majalis	Striped killifish	X		X	X	X					X
Fundulus diaphanus	Banded killifish			X							
Atherinidae	**Silversides**										
Menidia beryllina	Inland silverside		X								
Menidia peninsulae	Tidewater silverside			X							
Menidia menidia	Atlantic silverside		X		X		X		X	X	X
Gasterosteidae	**Sticklebacks**										
Gasterosteus aculeatus	Threespine stickleback			X	X						
Apeltes quadracus	Fourspine stickleback		X	X							
Syngnathidae	**Pipefishes**										
Hippocampus erectus	Lined seahorse		X	X	X				X		X
Syngnathus fuscus	Northern pipefish	X	X	X		X	X		X	X	X
Triglidae	**Searobins**										
Prionotus carolinus	Northern searobin		X	X				X	X		X

TABLE E1-3 (Cont.)

Inventory of Fish Species Collected from Various Sampling Programs Conducted in the Project Area

Family *Genus species*	Common Name	**A** **1988**	**B** **1991**	**C** **1991-1992**	**D** **1993-1994**	**E** **1994**	**F** **1995-1996**	**G** **1992-1997**	**H** **1998-1999**	**I** **2000-2001**	**J** **2001-2001**
Myoxocephalus octodecemspinosus	Longhorn sculpin		X								X
Myoxocephalus aenaeus	Grubby		X	X		X	X		X	X	X
Percichthyidae	**Temperate Basses**										
Morone americana	White perch			X	X	X	X		X		X
Morone saxatilis	Striped bass		X	X	X	X	X	X	X	X	X
Serranidae	**Sea Basses**										
Centropristis striata	Black sea bass		X	X				X	X		X
Centrarchidae	**Sunfishes**										
Pomoxis nigromaculatus	Black crappie			X							
Lepomis macrochirus	Bluegill		X								
Micropterus salmoides	Largemouth bass			X							
Pomoxis annularis	White crappie			X							
Pomatomidae	**Bluefishes**										
Pomatomus saltatrix	Bluefish	X	X	X		X	X	X	X		X
Carangidae	**Jacks**										
Caranx hippos	Crevalle jack		X		X		X		X		
Trachurus lathami	Rough scad		X								
Selene vomer	Lookdown		X	X					X		
Selene setapinnis	Atlantic moonfish		X	X					X		

Table E1-3 (Cont.)

Inventory of Fish Species Collected from Various Sampling Programs Conducted in the Project Area

Family *Genus species*	Common Name	**A** **1988**	**B** **1991**	**C** **1991-1992**	**D** **1993-1994**	**E** **1994**	**F** **1995-1996**	**G** **1992-1997**	**H** **1998-1999**	**I** **2000-2001**	**J** **2001-2002**
Sparidae	**Porgies**										
Stenotomus chrysops	Scup		X	X	X		X	X	X		X
Sciaenidae	**Drums**										
Cynoscion regalis	Weakfish	X	X	X	X	X	X	X	X	X	X
Leiostomus xanthurus	Spot	X	X	X	X	X	X	X	X		X
Sciaenidae (cont.)	**Drums**										
Menticirrhus saxatilis	Northern kingfish		X	X	X		X		X		
Bairdiella chryosura	Silver perch			X	X						
Micropogon undulatas	Atlantic croaker						X				
Chaetodontidae	**Butterflyfishes**										
Chaetodon ocellatus	Spotfin butterflyfish		X	X							
Mugilidae	**Mullets**										
Mugil cephalus	Striped mullet		X	X							
Labridae	**Wrasses**										
Tautoga onitis	Tautog		X	X	X	X			X		X
Tautogolabrus adspersus	Cunner		X	X	X	X	X		X		X
Pholidae	**Gunnels**										
Pholis gunnellus	Rock gunnel		X	X	X				X	X	X
Uranoscopidae	**Stargazers**										

Table E1-3 (Cont.)

Inventory of Fish Species Collected from Various Sampling Programs Conducted in the Project Area

Family *Genus species*	Common Name	**A** **1988**	**B** **1991**	**C** **1991-1992**	**D** **1993-1994**	**E** **1994**	**F** **1995-1996**	**G** **1992-1997**	**H** **1998-1999**	**I** **2000-2001**	**J** **2001-2002**
Astroscopus guttatus	Northern stargazer		X	X					X		
Blenniidae	**Combtooth Blennies**										
Hypsoblennius hentz	Feather blenny			X					X		X
Ammodytidae	**Sand Lances**										
Ammodytes americanus	American sand lance		X	X		X			X	X	X
Gobiidae	**Gobies**										
Gobiosoma bosc	Naked goby		X	X					X		X
Gobiosoma ginsburgi	Seaboard goby		X	X							X
Scombridae	**Mackerels**										
Scomberomorus maculatus	Spanish mackerel			X							
Scomber japonicus	Chub mackerel				X						
Scomber scombrus	Atlantic mackerel		X						X		X
Stromateidae	**Butterfishes**										
Peprilus triacanthus	Butterfish		X		X		X	X	X		X
Bothidae	**Lefteye Flounder**										
Etropus microstomus	Smallmouth flounder		X	X	X				X		X
Paralichthys dentatus	Summer flounder		X	X	X		X	X	X	X	X
Scopthalmus aquosus	Windowpane		X	X				X	X	X	X
Paralicthys oblongus	Fourspot flounder		X		X				X		X

Table E1-3 (Cont.)

Inventory of Fish Species Collected from Various Sampling Programs Conducted in the Project Area

Family *Genus species*	Common Name	**A** **1988**	**B** **1991**	**C** **1991-1992**	**D** **1993-1994**	**E** **1994**	**F** **1995-1996**	**G** **1992-1997**	**H** **1998-1999**	**I** **2000-2001**	**J** **2001-2002**
*Limanda ferruginea**	Yellowtail flounder*										X
Soleidae	**Soles**										
Trinectes maculatus	Hogchoker		X	X	X					X	X
Symphurus plagiusa	Blackcheek tonguefish			X							
Balistidae	**Leatherjackets**										
Cantherhines pullus	Orangespotted filefish			X							
Monacanthus hispidus	Planehead filefish				X						
Ostraciidae	**Boxfishes**										
Lactophrys quadricornis	Scrawled cowfish			X							
Tetraodontidae	**Puffers**										
Sphoeroides maculatus	Northern puffer		X	X					X		X
Chilomycterus schoepfi	Striped burrfish			X							
Mullidae	**Goatfishes**										
Pseudupeneus maculatus	Spotted goatfish								X		
Lophiidae	**Goosefishes**										
*Lophius americanus**	Goosefish*										X
Stichaeidae	**Pricklebacks**										
*Ulvaria subbifurcata**	Radiated Shanny*										X

TABLE E1-3 (Cont.)
Inventory of Fish Species Collected from Various Sampling Programs Conducted in the Project Area

Source	Study Location	Source Reference
A	Arthur Kill and Old Place Creek	Louis Berger & Associates, Inc. (LBA). 1992. Staten Island Bridges Program Environmental Report. Submittal to the Port Authority of New York/New Jersey.
B	Raritan Bay and Sandy Hook Bay Trawls	Woodhead, P.M.J. 1991. *Inventory and Assessment of Habitat and Fish Resources and Assessment of Information on Toxic Effects in the New York/New Jersey Harbor Estuary.* New York/New Jersey Harbor Estuary Program. Marine Sciences Research Center, State University of New York, Stony Brook, New York.
C	Arthur Kill Generating Station	Lawler, Matusky & Skelly Engineers (LMS). 1993. Arthur Kill Impingement and Entrainment Report, September 1991-September 1992. Report to Consolidated Edison Company of New York, Inc.
D	Newark Bay	National Marine Fisheries Service. 1994. Results of a Biological and Hydrological Characterization of Newark Bay, New Jersey, May 1993-April 1994.
E	Arthur Kill and Old Place Creek	U.S. Coast Guard (USCG). 1995. Draft Environmental Impact Statement/Draft Section 4(f) Statement. Staten Island Bridges Program, Modernization and Capacity Enhancement Project.
F	Newark Bay	Lawler, Matusky & Skelly Engineers LLP (LMS). 1996. Newark Bay Biological Monitoring Program April 1995-March 1996. Report prepared for the Port Authority of NY/NJ.

Table E1-3 (Cont.)

Inventory of fish species collected from various sampling programs conducted in the project area

Source	Study Location	Source Reference
G	Hudson-Raritan Estuary	Wilk, S.J.; Pikanowski, R.A.; McMillan, D.G.; MacHaffie, E.M. 1998. Seasonal Distribution and Abundance of 26 Species of Fish and Megainvertebrates Collected in the Hudson-Raritan Estuary, January 1992-December 1997. *Northeast Fish. Sci. Cent. Ref. Doc.* 98-10; 145 p.
H	New York Harbor, Arthur Kill, Kill van Kull, and Newark Bay	U.S. Army Corps of Engineers (USACE). 1999b. New York New Jersey Harbor Navigation Study – Biological Monitoring Program. USACE New York District.
I	New York Harbor, Arthur Kill, Kill van Kull, and Newark Bay	U.S. Army Corps of Engineers (USACE). 2002a. New York and New Jersey Harbor Navigation Study – Supplemental Sampling Program 2000-2001. USACE New York District.
J	New York Harbor, Arthur Kill, Kill van Kull, and Newark Bay	U.S. Army Corps of Engineers (USACE). 2002b. New York New Jersey Harbor Navigation Study – Aquatic Biological Sampling Program 2001-2002. USACE New York District.

* Species presence only confirmed for 2000-2001 and 2001-2002 sampling programs.

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Environmental Assessment
Appendix E2:
Essential Fish Habitat Enhancement Program

U.S. Army Corps of Engineers
New York District

January 2004

NEW YORK AND NEW JERSEY HARBOR NAVIGATION PROGRAM

ESSENTIAL FISH HABITAT ENHANCEMENT PROGRAM

Draft Report

OCTOBER 2003

U.S. Army Corps of Engineers - New York District
Environmental Analysis Branch
Jacob K. Javits Federal Building
26 Federal Plaza
New York, New York 10278

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1. Introduction

1.1 Background

The technical evaluations for aquatic resources performed to support the New York and New Jersey Harbor Navigation Project identified opportunities, per the Environmental Operating Principles (EC 1105-2-404), for USACE to evaluate enhancement opportunities for Essential Fish Habitat (EFH) in the NY/NJ Harbor. Under the Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act (SFA) of 1996, the EFH are those waters and substrate necessary to fish and shellfish for spawning, breeding, feeding, or growth to maturity. A total of 22 managed species have been designated for EFH in the NY/NJ Harbor and these species are listed in **Table 1**. Based on their life cycle and reported occurrence in the NY/NJ Harbor, a total of 13 EFH-designated species were targeted for this study. This list includes pollock, red hake, winter flounder, windowpane flounder, Atlantic sea herring, bluefish, Atlantic butterfish, Atlantic mackerel, summer flounder, scup, black sea bass, surf clam, and ocean quahog. In addition to these EFH-designated species, habitat restoration/enhancement opportunities for other non-managed but commercially important species like American Lobster (*Homarus americanus*) (a.k.a. Maine or Northern lobster), soft clam (*Mya arenaria*), northern quahog (*Mercenaria mercenaria*) (a.k.a. hard clam), blue mussel (*Mytilus edulis*), and American oyster (*Crassostrea virginica*) were also identified (Rhoads et al., 2001) and will be evaluated in this report. The detailed lifestage history of each species is summarized in **Appendix A**. Additionally, the EFH enhancement opportunities could indirectly and further benefit the above EFH-managed and non-managed (but commercially important) species by enhancing the habitat characteristics of their respective forage species. Those EFH-managed and non-managed (but commercially important) species will be hereon referred as species of concern.

The purpose of this study is to describe and evaluate enhancement opportunities for Essential Fish Habitat (EFH) in the New York/New Jersey Harbor. A total of 7 EFH enhancement sites have been identified from various reconnaissance studies (USACE, 2001; USACE, 2000) and consultation between USACE and NMFS. Those 7 sites are representative of different habitat types typically found in the Harbor such as reef, shoal, shallow water, and tidal creek habitats. As a baseline for evaluation, 3 additional sites (hereon named as "reference site") were selected and considered as representative of existing reef, shoal and tidal creek habitats. In this report, identification and description of the specific physical and biological attributes at each of the selected habitats are presented in order to assess their existing EFH characteristics based on habitat utilization by flora and fauna, and ultimately determine their respective potential opportunities for enhancement.

1.2 Objectives

The objectives of this report consisted of: (1) characterizing the physical and biological characteristics in the potential sites; (2) characterizing the utilization of habitat by fish, shellfish and other macroinvertebrates in selected sites in order to evaluate their potential EFH enhancement opportunities; and (3) developing conceptual plans for EFH enhancement opportunities for each of the habitat types according to the targeted species as listed above.

1.3 Site Description

A total of 10 sites, characterized by reef/shoal/shallow water/tidal creek habitats, were selected within the NY/NJ Harbor including 7 enhancement sites and 3 reference sites. A reference site was identified for each habitat except for the shallow water habitat.

The enhancement sites and respective habitats include Gravesend Bay (reef), Hoffman/Swinburne Islands (reef), Verrazano-Narrows (reef), Raritan Bay Shellfish Beds (shoal), Raritan Bay Rock Berm (shoal), Bowery Bay (shallow water), and Woodbridge Creek (tidal creek). The reference sites and respective habitats included Old Orchard Shoal (shoal), West Bank ATN (reef), and Cheesequake Creek (tidal creek). The site selection was conducted based on the proposed habitat enhancement objectives, the target EFH species, existing bathymetry and depth contours, potential navigational issues, and existing ecological data.

2. Methods and Materials

The survey effort was conducted in two phases based on the types of habitat. The survey of the reef, shoal, and shallow water habitats (8 sites) were conducted during the marine survey onboard the R/V Heather, while the survey of the tidal creek habitats (2 sites) was conducted during the stream survey. **Table 2** summarizes the sampling effort for each site based on the habitat type and target EFH species. Definitions and further technical information on the following methods are provided in **Appendix C**.

2.1 Marine Survey

As depicted in **Table 2**, the surveyed areas at the marine sites were relatively small with an acreage approximately ranging from 80 to 250 acres. The locations of each site are illustrated on **Figure 1**.

2.1.1 Side-Scan Sonar and Bathymetry Survey

Image and bathymetry data of the seafloor in each project area were collected using a side-scan sonar unit (EdgeTech DF-1000DSSS Towfish). The survey was conducted from March 31, 2003 to April 3, 2003 along geo-referenced 50-m wide transect lines and at a towing speed of 2.5-3.1 m/s (5-6 knots).

The side-scan sonar (SSS) is a remote sensing technique that can provide a description of bottom morphology over large areas for habitat characterization purposes, giving also the possibility to indicate substrate type. The SSS imagery provides a picture of the sea-floor by transmitting a series of acoustic pulses that are reflected off the sea-floor surface. Side-scan sonar data is interpreted by the shade or amplitude of the reflection. Fine-grain (e.g. silt and mud) will appear very light or low amplitude, whereas coarse grain areas (e.g. sand) are dark or high amplitude. Hard bottom areas (e.g. bedrock outcroppings) and artificial structures are also characterized by high amplitude returns.

2.1.2 Benthic Grab Survey

Benthic grab surveys were conducted from April 7, 2003 to April 14, 2003 in each project site to identify the biota present and determine sediment composition and quality (i.e. grain size, organic content and Redox Potential Discontinuity-RPD). Six (6) sampling stations were evenly selected and collected within each project site using a 0.1 m2 Smith-McIntyre Grab (SMG).

At each sampling station, the SMG was lowered vertically from the R/V Heather until contact was made with the bottom sediments. The SMG was then raised slowly to minimize sample disturbance. Once the sample was secured onboard, the SMG was examined for acceptability (undisturbed surface sediment, inspection for signs of leakage, penetration depth of at least 5 cm) and redeployed if unacceptable. At each station, two (2) suitable grabs were collected; the first grab was collected for benthic macroinvertebrate analysis, while the second grab was collected for sediment geotechnical analysis and apparent Redox Potential Discontinuity (RPD) depth measurements. Station location (i.e., name, station coordinates), survey time/date, weather/oceanographic conditions, water depth, sediment temperature/color/odor, grab penetration/volume, visual sediment texture, epibenthic fauna/flora were recorded on-site.

2.1.2.1 Sediment Analysis

When possible, three (3) subsamples were randomly collected from the second grab for sediment quality analysis using a 1.5-inch diameter PVC core tube made of Nexan transparent plastic. The apparent Redox Potential Discontinuity (RPD) layer, if any, was visually determined and measured directly from the core tube. Only then, the 3 subsamples were combined into a 1-liter sample bottle and then stored into a cooler (3-4^{o}C) for later shipping and laboratory sediment analysis (grain size and organic content).

The depth measurements of the apparent RPD layer were initially estimated by visually examining the sediment surface. If the surface of the grab sample was black, with few or no infaunal organisms visible, and/or produced an odor of hydrogen sulfide (H_2S), then the surface had no measurable RPD layer and was considered as anoxic (recorded as 0 mm). If the sediment surface was oxidized, the apparent RPD was measured using two techniques. The first RPD method, as indicated above, consisted of taking direct measurements on the 3 core subsamples used for the sediment analysis. The second method consisted on pushing a plastic ruler into the sediments collected in the grab and creating a vertical profile by pulling the ruler toward the field technician. The RDP depths were measured to the nearest millimeter and an average RPD depth was calculated from both methods.

In the laboratory, analysis of the sediment samples was conducted by Advanced Testing (Campbell Hall, NY). Sediment texture was determined through soil gradation and wash sieve analysis according to ATSM D422. Hydrometer Analysis was conducted according to ASTM D422 when 75% of the sample was coarser than 3.75 ? (or 0.075mm). Organic Content measurements were done using the method of loss on ignition (LOI) according to the ASTM D2974.

2.1.2.2 Benthic Macroinvertebrates Analysis

When possible, subsamples were randomly collected from the first grab for benthic macroinvertebrate analysis using a 1.5-inch diameter PVC core tube. Three (3) subsamples were actually combined and gently washed through a sieve of 0.5-mm mesh size in order to separate the benthic organisms from the sediments. The organisms retained within the sieve were placed into a labeled 1-liter sample bottle and preserved within 10% buffered/Rose Bengal solution for laboratory analysis.

Additionally, the remaining sediments within the grab were washed through a larger box sieve (30x30cm and 10cm deep) with a 19-mm mesh size in order to identify any large organisms that may have been underrepresented in the subsamples. Any large collected organisms (i.e., crabs, shellfish …) were accounted for in order to determine their respective population densities per species (i.e., Northern Quahog, Ocean Quahog, Surf Clam…).

In the event of impossible core subsampling due to non-cohesive sediments (i.e., coarse shelly sand), subsamples were not collected and the entire grab sample was washed through a 0.5-mm mesh sieve in order to separate the benthic organisms from the sediments. As described above, the organisms retained within the sieve were placed into a labeled 1-liter sample bottle and preserved within 10% buffered/Rose Bengal solution for laboratory analysis.

In the LMS laboratory, organisms were sorted from the remaining debris, identified by experienced taxonomists, and enumerated. Identifications were made to the lowest practical identification level (LPIL) when not to the specie level. Strict quality control (QC) procedures consisting of a Continuous Sampling Plan (CSP) to assure an Average Outgoing Quality Limit (AOQL) of ≥ 90% was followed during sample sorting, enumeration, lifestage designation, and identification. When the number of organisms in a sample were large (>500) sub-sampling was conducted using a sampling tray with 30, 6 cm x 6-cm grids. Organisms in randomly selected grids were counted until the total number of organisms removed and sorted was >100; or the entire sample was sorted. Selected squares were sorted in their entirety, even after the 100-organism count was reached.

Benthic Community and Assemblage Structure Analysis

In the context of assessing benthic community biodiversity and structure, the species richness, the Shannon-Wiener's Index, and the evenness (or equitability) (**Appendix C**) were calculated for each benthic sample as an indicator of the species utilizing the available habitat. The use of benthic indicator species (that are pollution-tolerant or pollution-sensitive) has also been used to determine the ecological health of each site.

Benthic Habitat Classification

Whenever feasible and based on grab data (sediment and benthic analyses), a similar habitat classification strategy to the one developed in Iocco, et al. (2000) was used to identify the principal benthic habitats in the NY/NJ Harbor. The typical benthic habitat classes of the NY/NJ Harbor are described in **Appendix C**.

2.1.3 Clam Dredge Survey

A clam dredge survey was conducted at each of the three shoal habitat sites (Old Orchard Shoal, Raritan Bay Shellfish Bed, and Raritan Bay Rock Berm) in order to evaluate the shellfish population of large macroinvertebrates. A 48-in steel knife commercial style clam dredge was towed to an adjusted speed of 150 cm/sec (~3 knots) over the bottom for 5 minutes. The clam dredge survey consisted of two sampling events per site. The crabs collected were enumerated while the remaining contents (i.e., live shellfish and shell debris) were noted by ratio.

2.1.4 Water Quality Survey

At each site, dissolved oxygen (DO), temperature and salinity were measured at surface, mid-depth, and bottom waters using calibrated meters. Water quality parameters collected near the bottom were recorded one foot (0.3 m) above the substrate.

2.2 Stream Survey

The physical condition of Cheesequake Creek and Woodbridge Creek were assessed on 23 June 2003 as part of a synoptic stream survey to investigate the enhancement potential of Woodbridge Creek. The physical condition of each stream was evaluated by adapting the National Resource Conservation Service (NRCS, 1998) stream visual assessment protocol (VAS). To complete the visual assessment, two sample reaches, one upstream and one downstream were chosen on Cheesequake creek; and four sample reaches were chosen on Woodbridge Creek. Each sample reach was approximately 12 stream-widths long. The physical condition of each reach was evaluated with regard to 8 criteria specified by the NRCS assessment protocol. Scores for these stream characteristics (generally on a scale of 1-10) were combined into a single score for the reach. The evaluation was based on the following characteristics:

- Channel condition: General channel shape, evidence of downcutting, and anthropogenic alterations.
- Hydrologic alteration: Evidence of water withdrawals or control structures affecting flood regimes.
- Riparian zone: Existence of natural riparian vegetation on both sides of the stream.

- Bank stability: Potential for bank erosion, evidenced by over steepened banks or lack of stabilizing vegetation.
- Water appearance: Clarity of water, presence of algae, oil sheens, or odors.
- Nutrient enrichment: Evidenced by green water color or presence of algal mats/ macrophytes in stream.
- Barriers to fish movement: Presence and height of drop structures, dams, or culverts.
- Instream fish cover: Diversity of in-stream structures for fish habitat

3. Results

As a reconnaissance marine survey, the six stations of each of the marine project sites were selected in order to capture different bathymetric contours and their respective habitat characteristics. Water depth is a critical factor influencing hydrodynamic conditions, sediment composition and texture and thus the benthic community characteristics. Whenever applicable, the following results are then addressed not only to characterize the general physical/biological conditions of each site but also to capture spatial variations in habitat characteristics within each site based on water depth. A reconnaissance stream survey was conducted at the tidal creek sites.

3.1 Hydrodynamics

The Lower Bay complex of the New York harbor consists of the Lower, Raritan, and Sandy Hooks Bays. These waters mix and exchange with the waters of the Upper Bay to the north through the Narrows and the sea to the south through the Sandy Hook-Rockaway transect. The Lower Bay complex is an estuary, having a mean depth less than 4.6 m and a surface of 155 km^2 (or 38.338 acres). The irregular submarine topography of the Bay, composed of numerous shoals, banks, and ship channels, slopes uniformly and gently toward the central axis where the depths are approximately 6.7 m in Raritan Bay and 8.5 m in Lower Bay (Berg and Levinton, 1985). Maximum depths in the Bay average 9 m, excluding the major shipping channels and borrow pits which have depths ranging to 12 m. The system is characterized by a number of peripheral shoals located both on the Staten Island and the New Jersey south shore beaches, a factor which is quite significant with respect to the resultant hydrodynamic patterns exhibited within the Lower Bay Complex (McCormick, 1984).

Mean tidal range within the Lower Bay Complex is from 4.6 to 4.9 ft (5.6 to 5.9 ft for spring tide) and tidal currents vary from about 0.1 to 3.0 fps (Duedall et al, 1979). The mixing of the Hudson and Raritan freshwater and New York Bight seawater, resulting from the runoff-tidal exchanges, produces a large counterclockwise gyre (**Figure 2**). During flood tide higher salinity water enters the Lower Bay between the Ambrose Channel and Rockaway Point and continues in a southwesterly direction along the Staten Island shore. During ebb tide, the lower salinity water from Sandy Hook Bay and Raritan Bay escapes Sandy Hook and water from the Lower Bay and the Hudson River flows out over the Ambrose Channel. Less saline water leaves the Lower Bay near the surface while a tongue of more saline NY Bight water persists at depth in channels and depressions, which creates a non-tidal circulation pattern and little opportunity for significant flushing with each tidal cycle (Berg and Levinton, 1985). The general current pattern changes substantially with changes in runoff from the Raritan and Hudson Rivers and strong winds (Walford, 1971). Tidal currents, described in the NOAA tidal current charts (**Figure 3**), show a strong east-west flow through the bay from the Raritan River and Arthur Kill in the west, to the ocean north of Sandy Hook, NJ on the east. A similar northwest-to-southwest flow occurs through the Lower Bay between the Hudson River and the sea south of Rockaway Point, NY. Studies of water circulation in Raritan Bay indicate an effective separation of Raritan and Hudson River waters. The sluggish flow of water through the Arthur Kill from Newark Bay provides a very minor input of water to Raritan Bay (McCormick, 1984).

The Bowery Bay is a tidal embayment (or cove) located near Rikers Island along the south shore of the Upper East River and approximately 8 miles from the entrance to Long Island Sound. It is bordered by LaGuardia Airport and the New York City's Bowery Bay Water Pollution Control Plant (WPCP). Because of its enclosed geometry and hardened shoreline similar to a dead-end basin, Bowery Bay is characterized by poor water circulation and high detention time. Water circulation in the bay is solely influenced by tidal circulation, the input of above-ground runoff, and two combined sewer overflow (CSO) outfalls (**Figure 32**)

3.2 Water Quality

Major water quality parameters (temperature, salinity, and DO), measured during the marine survey, are summarized in **Table 3**. However, this data only provides a single snapshot of the year. Therefore, long-term data from the New York City Department of Environmental Conservation's Harbor Water Quality Survey was obtained (NYCDEP, 1991-2001) in order to evaluate better the water quality conditions near the EFH enhancement sites. The Harbor Survey consists on numerous water quality stations throughout the harbor that have been consistently monitored since 1990s for different parameters including temperature, salinity, DO, pH, biological oxygen demand (BOD), fecal coliform, secchi depth, and chlorophyll A. **Table 4** summarizes the seasonal averages of those parameters for each water quality stations located near the EFH enhancement sites as depicted in **Figure 1**. Only bottom water quality data is presented since the enhancement opportunities would be bottom-oriented.

The water quality data collected during the marine survey (**Table 3**) indicates that all sites across the Lower Bay demonstrated the same stratification patterns. Bottom waters had consistently colder temperature, higher salinity, and lower DO than surface and mid-waters. The long-term data (**Table 4**) indicates that the water quality conditions are relatively similar throughout the Lower Bay excepted for Station K6, located in the middle of the bay (near Old Orchard Shoal), which showed better DO and fecal coliform levels. Annual temperature, DO, and salinity averages in the Lower Bay (stations K5, K5A, K6, N8, and N8A) ranged respectively between 15.0-16.5 ^{o}C, 7.4-9.0 mg/L, and 24.4-27.4 psu.

Bowery Bay actually showed fairly homogeneous water quality characteristics throughout its water column (**Table 3**) which is typical of sluggish waters of an enclosed embayment with minimum flushing and vertical mixing. The long-term data in the East River (**Table 4**) indicates poorer water quality levels than in the Lower Bay with lower DO and higher fecal coliform levels. Annual temperature, DO, and salinity averages in the Upper East River (Stations E5, E6) ranged respectively between 16.3-16.4 ^{o}C, 6.0 mg/L, and 23.9-24.1 psu. Bowery Bay, due to industrial/urban pollution and a limited water circulation, is expected to have poorer water quality with a highly degraded habitat (Iocco et al., 2000; Cerrato and Bokuniewicz, 1986; Yozzo et al., 2001).

3.3 Reef Habitat

3.3.1 West Bank ATN

3.3.1.1 Physical Conditions

The West Bank (WB) site, a reference site for this study, is located in the middle of the Lower Bay, immediately west of the northern Chapel Hill Channel (**Figure 4**). The surveyed area was located around the West Bank Aid To Navigation (ATN), a man-made rock pile. A cable and pipeline corridor crosses through the site and the nearby Chapel Hill Channel (NOAA Navigation Chart).

The side-scan sonar (SSS) and bathymetry surveys covered approximately 148 acres (**Figure 5**). Water depths ranged from 7-9 m on the shoal and 9-13 m in the deep-water areas. Changes in relief along the edges of the shoal ranged between 1-3 m. The SSS imagery identified that the artificial rock pile that makes up the ATN is the only significant bottom structure at the site. Areas of coarser substrate, possibly gravel and sand, were also observed in the northern section of the site.

Overall the substrate of the West Bank ATN site was composed of coarse silt to fine sand with a mean grain size ranging between 0.044 and 0.140 mm (**Table 5**; **Figure 6**). The sediments characteristics on the shoal (WB4 WB5, WB7, WB8) were coarser (0.059-0.140mm) with a higher sand fraction (72.1-93.4%) than in the deep-water areas (WB9, WB10) with a mean grain size ranging between 0.044-0.058 mm and a sand fraction of 62.3-16.5%. The high gravel content of the station WB8 supported the coarser substrate findings of the SSS imagery. Organic content and RPD depth ranged between 0.8-3.6% and 10-41mm on the shoal, and between 2.5-4.5% and 17-70mm in the deep-water areas.

3.3.1.2 Biological Conditions

A total of 47 taxa were collected in the grabs with 66% of annelids, 9% of arthropods, and 25% of mollusks (**Tables 6-8**, **Figure 7**, **Appendix B**). Overall, the West Bank ATN had the highest community complexity and greatest diversity of all sites with a mean density of 29,264 organisms/m^2, H'=3.84, and E=0.69. The benthic community at the shallow stations (WB4, WB5, WB7, WB8) was mainly composed of annelids while the deep-water stations (WB9, WB10) were dominated by mollusks. A review of pollution-tolerant (8%) and pollution- sensitive taxa (12%) indicated that the benthic community was fairly undisturbed and well established (**Table 8**).

The annelids were mainly composed of *Paraonidae* (LPIL), *Streblospio benedicti*, *Oligochaeta* (LPIL), and *Glycera sp.* with density ranging from 1,097 to 6,586/m^2. The dominant arthropod species was *Ampelisca abdita* with 1,664/m^2 while the mollusks were dominated by *Mulinia lateralis* (dwarf surfclam), *Nucula sp.*, and *Mytilus edulis* (blue mussels) with densities ranging from 1,124 to 2,743/m^2. The station located just south of the ATN (WB5) had a high density of blue mussels indicating the possible existence of a blue mussel bed. Similarly, WB7 and WB10 revealed a high density of *Ampelisca abdita* indicating the possible existence of *Ampelisca* mats.

A number of species were only present at the West Bank ATN site including *Ampithoidae* (LPIL), *Busycon carica*, *Cirratulidae* (LPIL), *Crangon septemspinosa*, *Goniadidae* (LPIL), *Lepidametria commensalis*, *Paraonis sp.*, *Pectinaria sp.*, *Polygordius sp.* and *Tellina agilis*.

3.3.2 Gravesend Bay

3.3.2.1 Physical Conditions

The Gravesend Bay (GB) site, a potential enhancement site for this study, is located in the southern section of the bay near the mouth of the Coney Island Creek (**Figure 8**). The site is outside the federally maintained Gravesend Anchorage area which is located further northwest in the bay closer to the Ambrose Channel (NOAA Navigation Chart).

The side-scan sonar (SSS) and bathymetry surveys covered approximately 147 acres (**Figure 9**). Water depths were relatively uniform (6-7 m) excepted for a small deep hole (7-8 m) in the northeastern section of the surveyed area. The SSS imagery did not identify any significant structure on the bottom.

Overall the substrate of the Gravesend Bay site was composed of coarse silt to very fine sand with a mean grain size ranging between 0.033 and 0.063 mm (**Table 4**, **Figure 10**). The station GB10 in the deep hole was composed of finer sediment (0.033 mm) with a higher silt fraction (48%) than the other stations in shallower areas. Organic content and RPD depths respectively ranged between 2.3-3.1% and 9-16 mm excepted for the station GB10 in the deep hole with a higher organic content (7.8%). A hydrogen sulfide odor was detected throughout most of the stations.

3.3.2.2 Biological Conditions

A total of 28 taxa were collected in the grabs with 69% of annelids, 1% of arthropods, and 30% of mollusks (**Tables 6-8**, **Figure 11**, **Appendix B**). Overall, the Gravesend Bay site relatively high community complexity and diversity with a mean density of 44,979 organisms/m^2, H'=2.70, and E=0.56. The station GB10 did not show a significantly different benthic community than the other stations.

The Gravesend Bay site had one the highest densities of organisms of all other sites. Annelids where largely dominated by *Paraonidae* (LPIL) (21,598/m^2) followed by *Leitoscoloplos fragilis* (3,996/m^2) and *Leitoscoloplos sp.* (2,193/m^2). The dominant mollusks species were *Mulinia lateralis* (6,335/m^2) followed by *Acteocina canaliculata* (4,288/m^2) and Cephalaspidea (1,559/m^2). All stations excepted GB10 had some Mya arenaria (soft clam) with densities varying between 585 and 1,462 individuals/m^2.

3.3.3 Hoffman/Swinburne Islands

3.3.3.1 Physical Conditions

The Hoffman-Swinburne Islands (HSI) site, a potential enhancement site for this study, is located approximately 2.0 km west of the northern Ambrose Channel on the West Bank Shoal (**Figure 12**). The surveyed area was located southwest of the Swinburne Island in order to capture the change of bathymetry contours from the West Bank Shoal to the deep-water areas of the historic West Bank subaqueous borrow pit. A cable and pipeline corridor runs adjacent to the site and the West Bank borrow pit is designated as an anchorage area (NOAA Navigation Chart).

The side-scan sonar (SSS) and bathymetry surveys covered approximately 180 acres (**Figure 13**). Water depths ranged from 4-7 m on the shoal and 7-10m in the deep-water areas of the borrow pit. Along the outer edge of the shoal, a gradual slope was observed before dropping off into deeper waters. The SSS imagery did not identify any significant structure on the bottom. When compared to the deep-water areas, the SSS imagery on shoal was darker indicating a coarser substrate type. On the shoal, an area of even coarser substrate type and irregular bottom, possibly field of small rocks or depressions, was observed in the northwestern section of the site. On the deep-water areas, numerous track marks were observed, probably resulting from some commercial fishing operations or some anchoring activities.

Overall the substrate of the Hoffman-Swinburne Islands site was composed of medium silt to medium sand with a mean grain size ranging between 0.016 and 0.281 mm (**Table 4**, **Figure 14**). Sediment characteristics on the shoal (HSI6, HSI7, HSI8) were significantly coarser (0.219-0.241 mm) than in the deep-water areas (HSI3, HSI4, HSI5) (0.016-0.032 mm). The deep-water sediments were actually composed of a higher silt fraction (45.9-56.8%). Organic content and RPD depths were relatively uniform on the shoal with respective values ranging between 0.4-0.5% and 29-31 mm. In the deep-water area (HSI3, HSI4, HSI5), the organic content was significantly higher than on the shoal (6.7-7.5%) which probably resulted in the shallower RPD depths measured between 9-24 mm. A hydrogen sulfide odor was detected at the deep-water stations. The combination of finer sediment, higher organic content and shallower RPD depths in the deep-water areas is typical of a low-gradient and low-energy environment where sedimentation rates would be higher than on the shoal.

3.3.3.2 Biological Conditions

A total of 26 taxa were collected in the grabs with 76% of annelids, 3% of arthropods, and 21% of mollusks (**Tables 6-8**, **Figure 15**, **Appendix B**). Overall, the Hoffman-Swinburne Islands site indicated a relatively high community complexity and diversity with a mean density of 4,778 organisms/m^2, H'=2.88, and E=0.61. On the shoal (HSI6, HSI7, HSI8), the benthic community was significantly more complex and diverse than in the deep-water areas with a dominance of mollusks and annelids. The station HSI7, closer to the Swinburne Island and with a higher gravel content, showed the most mature benthic community with an almost even species distribution of annelids, arthropods, and mollusks (H'=3.01 and E=0.79). In the deep-water areas of the borrow pit (HSI3, HSI4, HSI5), the benthic community was less complex with fewer species diversity than on the shoal with a dominance of annelids. For example, only one species of mollusk was identified at station HSI3.

On the shoal, the dominant annelids were *oligochaetes* (LPIL), Nephtys sp., *Paranoidae* (LPIL), and *Leitoscoloplos fragilis* (with densities up to 8,187/m^2) while the dominant mollusks were *Mya arenaria* (soft clams) and *Crepidula fornicata* (with densities up to 877/m^2). In the deep-water areas, the dominant annelids were chiefly *Paranoidae* (LPIL).

3.3.4 Verrazano-Narrows

3.3.4.1 Physical Conditions

The Verrazano-Narrows (VN) site, a potential enhancement site for this study, is located west of Swinburne Island and approximately 1 km off the eastern shoreline of Staten Island (**Figure 16**). The surveyed area covered part of the West Bank Shoal and some of the historic Hoffman-Swinburne South subaqueous borrow pit. The general area is designated as an anchorage area (NOAA Navigation Chart). This selected site is actually adjacent to the Hoffman-Swinburne site.

The side-scan sonar (SSS) and bathymetry surveys covered approximately 250 acres (**Figure 17**). Water depths ranged from 5-6 m on the shoal and 6-13 m in the deep-water areas of the borrow pit. Along the outer edge of the shoal, a gradual slope was observed before dropping off into deeper waters. The SSS imagery did not identify any significant structure on the bottom. When compared to the deep-water areas, the SSS imagery on shoal was darker indicating a coarser substrate type. On the shoal, an area of even coarser substrate type and irregular bottom, possibly field of small rocks or depressions, was observed in the southeastern section of the site. On the deep-water areas, numerous track marks were observed, probably resulting from some commercial fishing operations or some anchoring activities.

Overall the substrate of the Verrazano-Narrows site was composed of coarse silt to medium sand with a mean grain size ranging between 0.041 and 0.469 mm (**Table 4**, **Figure 18**). Sediment characteristics on the shoal (VN4, VN5) were significantly coarser (0.466-.0469 mm) than in the deep-water areas (VN1, VN2, VN6, VN9) (0.041-0.072

mm). The deep-water sediments were actually composed of a higher silt fraction (23.4-43.0%). Organic content and RPD depths on the shoal respectively ranged between 0.4-0.7% and 12-31 mm. In the deep-water area, the organic content was significantly higher than on the shoal (4.9-8.2%) with RPD depths measured between 0-51 mm. The combination of finer sediment and higher organic content in the deep-water areas is typical of a low-gradient and low-energy environment where sedimentation rates would be higher than on the shoal.

3.3.4.2 Biological Conditions

A total of 29 taxa were collected in the grabs with 59% of annelids, 3% of arthropods, and 38% of mollusks (**Tables 6-8**, **Figure 19**, **Appendix B**). Overall, the Verrazano-Narrows site indicated a high community complexity and diversity with a mean density of 17,864 organisms/m^2, H'=3.33, and E=0.69. On the shoal (VN4, VN5), the benthic community was significantly more complex and diverse than in the deep-water areas with a dominance of mollusks and annelids. In the deep-water areas of the borrow pit (VN1, VN2, VN6, VN9), the benthic community was less complex eventhough they had a higher species diversities than on the shoal. The deep-water areas were also dominated by annelids and mollusks but they showed lower species densities.

On the shoal, the dominant annelids were *Paraonidae* (LPIL) and *Glycera sp.* while the dominant mollusks were *Crepidula fornicata*, *Mercenaria mercenaria* (N. Quahog), and *Mya arenaria* (soft clams). Actually, the station VN5 had a relatively high density of soft clams (3,216/m^2) and N. Quahog (2,924/m^2) indicating the possible presence of a shellfish bed habitat. In the deep-water areas, the dominant annelids were *oligochaeta* (LPIL), *Capitellidae* (LPIL), *Capitella sp.*, *Paraonidae* (LPIL), *Leitoscopolos fragilis*, and *Streblospio bendecti*, while the dominant mollusks were largely *Mulinia lateralis* with densities ranging from 3,552 up to 17,618/m^2.

3.4 Shoal Habitat

3.4.1 Old Orchard Shoal

3.4.1.1 Physical Conditions

The Old Orchard Shoal (OOS) site, a reference site for this study, is located on the southern section of the Old Orchard Shoal approximately 3.5 km off the Crookes Point on Staten Island (**Figure 20**). The surveyed area was conducted around the Old Orchard Shoal Light, an aid to navigation mounted on a man-made rock pile.

The side-scan sonar (SSS) and bathymetry surveys covered approximately 70 acres (**Figure 21**). Water depths were uniform throughout the surveyed area and ranged between 6-7 m. The SSS imagery identified that the artificial rock pile of the Old Orchard Shoal Light was the only significant bottom structure at the site. The substrate appeared to be relatively coarse throughout the site based on the coloration of the SSS imagery.

Overall the substrate of the Old Orchard Shoal site was composed of fine to medium sand with a mean grain size ranging between 0.204 and 0.269 mm and a large sand content ranging between 93.4-97.1% (**Table 5**; **Figure 22**). Gravel content was slightly higher at the station OOS4 near the rock pile. The shoal was consistently characterized by a low organic content (0.8-1.2%) and a moderate RPD depth (16-35 mm).

3.4.1.2 Biological Conditions

A total of 39 taxa were collected in the grabs with 44% of annelids, 3% of arthropods, and 53% of mollusks (**Tables 6-8**, **Figure 23**, **Appendix B**). Overall, the Old Orchard Shoal site had one of the highest number of identified species of all sites with a high community complexity and greatest diversity (H'=3.55, E=0.67) and a mean density of 6,559 organisms/m^2. The benthic community throughout the shoal was mainly composed of mollusks and annelids excepted for the station OOS6 which indicated a high concentration of arthropods (67%). A review of pollution-tolerant (7%) and pollution-sensitive taxa (10%) indicated that the benthic community was fairly undisturbed and well established (**Table 8**).

Mollusks were mainly composed of *Mulinia lateralis* (1,754/m^2), *Pandora gouldiana* (621/m^2), and *Crepidula fornicata* (518/m^2) while the dominant annelids where *Polychaeta* (LPIL) (781/m^2) and *Glycera sp.* (662/m^2). Few *Mercenaria mercenaria* (N. Quahog) were found at stations OOS1 and OOS3 (292 and 303/m^2 respectively) which are located east of the Old Orchard Shoal Light. In addition, *Mya arenaria* (soft clams) were found in small numbers (40-877/m^2) throughout all stations.

Two clam dredge tows were conducted over an estimated total area of 1,000 m^2 within the Old Orchard Shoal site. For both runs, the dredge was 100% full with a extensive amount of shells fragments (Northern Quahog, Blue Mussel, and American Oyster) and live *Crepidula fornicata* (Atlantic slipper shells) indicating the presence of substantial shell cultch. Additionally, numerous macro-decapods (Phylum: *Arthropoda*), *Libinia emarginata* (spider crabs) and *Panopeus sp.* (common mud crab), were captured.

3.4.2 Raritan Bay Rock Berm

3.4.2.1 Physical Conditions

The Raritan Bay Rock Berm (RBRB) site, a potential enhancement site for this study, is located in the Raritan Bay northeast of Keyport Harbor and approximately 2.3 km off the Conaskonk Point on the New Jersey shore (**Figure 24**). A cable and pipeline corridor runs north of the site (NOAA Navigation Chart).

The side-scan sonar (SSS) and bathymetry surveys covered approximately 190 acres (**Figure 25**). Water depths ranged between 4.0-6.5 m gradually increasing in the northwestern direction moving away fro the New Jersey shore. The SSS imagery did not identify any significant structure on the bottom. The substrate appeared to be relatively uniform and coarse throughout the site based on the coloration of the SSS imagery.

Overall the substrate of the Raritan Bay Rock Berm site was composed of medium to coarse sand with a mean grain size ranging between 0.282 and 0.514 mm and a large sand content ranging between 71.4-97.3% (**Table 5**; **Figure 26**). A hydrogen sulfide odor was detected at the RBRB1, RBRB2, and RBRB4. A higher gravel and silt content was observed within the 5.0 to 6.5 m depth range. Organic content was lower at the shallower stations (RBRB4, RBRB5) (0.4-0.5%) than in the deeper ones (RBRB1, RBRB2, RBRB3, RBRB4) (2.4-5.3%). Similarly, RPD depths were higher at the shallower stations (21-28 mm) than at the deep ones (19 mm). No RPD measurements could be taken at RBRB1, RBRB2, and RBRB4.

3.4.2.2 Biological Conditions

A total of 28 taxa were collected in the grabs with 84% of annelids, 5% of arthropods, and 10% of mollusks (**Tables 6-8**, **Figure 27**, **Appendix B**). Overall, the Raritan Bay Rock Berm site had a moderate community complexity and diversity (H'=2.80, E=0.58) and a mean density of 7,673 organisms/m^2. The benthic community throughout the shoal was mainly composed of mollusks and annelids excepted for the station RBRB4 which indicated a high concentration of arthropods (50%).

Annelids were mainly composed of *Paraonidae* (LPIL) (3,990/m^2), *Capitella sp*. (582/m^2), and *Streblospio benedicti* (487/m^2) while the dominant mollusks were *Crepidula fornicata* (518/m^2), *Llyanassa trivittata* (244/m^2), and *Mya arenaria* (soft clams) (146/m^2). The high concentration of arthropods at Station RBRB4 was chiefly composed of *Ampelisca abdita* (1,000/m^2) indicating the possible presence of *Ampelisca* beds.

Two clam dredge tows were conducted over an estimated total area of 1,000 m^2 within the Raritan Bay Rock Berm site. For both runs, the dredge was only 5-10% full with a few unidentified shells fragments, sponges, and *panoepus sp.* (common mud crabs).

3.4.3 Raritan Bay Shellfish Bed

3.4.3.1 Physical Conditions

The Raritan Bay Shellfish Bed (RBSB) site, a potential enhancement site for this study, is located in the Raritan Bay northwest of Keyport Harbor and approximately 1.0 km off the Seidler Beach on the New Jersey shore. (**Figure 28**). Two major sewer outfalls are located on the shore adjacent to Seidler Beach (NOAA Navigation Chart). Due to a miscalculation of the coordinates, the benthic grab survey failed to be located within the SSS/Bathymetry survey area. However, the overall survey still provided valid results and coherent interpretations because in this part of the bay, the substrate is relatively uniform as indicated by the lack of bottom relief on the NOAA Navigation Chart.

The side-scan sonar (SSS) and bathymetry surveys covered approximately 160 acres (**Figure 29**). The entire site was relatively flat and shallow with water depths ranging between 3.5 and 5.0 m. The SSS imagery did not identify any significant structure on the bottom and the substrate appeared to be relatively uniform and coarse throughout the site based on the imagery coloration. Few bottom scars, probably from clam rakes, were observed.

Overall the substrate of the Raritan Bay Shellfish Bed site was composed of fine to coarse sand with a mean grain size ranging between 0.132 and 0.552 mm (**Table 5**; **Figure 30**). The sand fraction dominated the substrate composition with a 56.8-74.6% range; however the silt (11.0-26.8%) and gravel (6.6-25.6%) fractions were sizeable. The site was characterized by a relatively high organic content (5.2-7.6%) when compared to the other sites in the Lower Bay Complex. The RPD depths varied from 0-29 mm.

3.4.3.2 Biological Conditions

A total of 19 taxa were collected in the grabs with 27% of annelids, 72% of arthropods, and 0% of mollusks (**Tables 6-8**, **Figure 31**, **Appendix B**). Overall, the Raritan Bay Shellfish Bed site had a low community complexity and diversity (H'=1.76, E=0.41) and a mean density of 46,353 organisms/m^2. This high mean density of organisms is solely due to the extremely high concentration of *Ampelisca abdita* (31,833/m^2). The stations RBSB1, RBSB2, RBSB3, and RBSB5 actually indicated the possible presence of dense *Ampelisca* beds. Even though *Ampelisca abdita* are known to be important environmental quality indicators due their limited mobility, a review of pollution-tolerant (19% mainly *Capitella sp.*) and pollution-sensitive taxa (5%) indicated that the benthic community revealed some level of disturbance (**Table 8**). This indication is associated to the large concentration of *Capitella sp.* and the paucity of mollusks which are significant pollution-sensitive species.

The site was fairly depleted of mollusks with only two species identified in small numbers: *Mercenaria mercenaria* (N. Quahog) (55/m^2) and *Crepidula fornicata* (2/m^2). Annelids were mainly composed of *Paraonidae* (LPIL) (5,896/m^2), *Capitella sp.* (3,128/m^2), and *Oligochaeta* (LPIL) (1,462/m^2) while the dominant arthropods were by far *Ampelisca abdita* as noted above.

Two clam dredge tows were conducted over an estimated total area of 1,000 m^2 within the Raritan Bay Shellfish Bed site. For both runs, the dredge was only 10-15% full with a few shells fragments of Northern Quahog and American oyster (*Crassostrrea virginica*) and a few sponges.

3.5 Shallow Water Habitat

3.5.1 Bowery Bay

3.5.1.1 Physical Conditions

The Bowery Bay (BB) site, a potential enhancement site for this study, is an inland bay located along the East River next to the LaGuardia Airport (**Figure 32**). A cable corridor runs north of the site along the bridge connecting Queens and Rikers Island (NOAA Navigation Chart).

The side-scan sonar (SSS) and bathymetry surveys covered approximately 83 acres (**Figure 33**). The site is relatively shallow along the bulkheaded and rip-raped shoreline (0-3 m) with a deeper basin in the middle of the bay (3-7 m). The SSS imagery did not identify any significant structure on the bottom. The substrate appeared to be relatively fine in the backwaters and coarser at mouth of the bay based on the coloration of the SSS imagery. Few unidentified bottom scars were observed.

Overall the substrate of the Bowery Bay site was composed of fine silt to very fine sand with a mean grain size ranging between 0.044 and 0.151 mm and a large silt and clay content (**Table 5**; **Figure 34**). The collected sediments were black and pasty (i.e., goo) with a strong hydrogen sulfide odor. Organic content was high (11.5-13.3%) and no RPD layer (<2 mm). The sediment characteristics of the Bowery Bay were typical of low-energy habitats (i.e. minimal exposure to waves and currents) where the settling of high organic and silt-clay sediment occurs. These sediments indicated a strong accumulation of organic matter and detritus from the water column which in turn provided for the colonization of bacteria mats within most of the sites. The high organic content can also result from inputs of sewage of the two nearby combined sewage overflows (CSOs).

3.5.1.2 Biological Conditions

A total of 12 taxa were collected in the grabs with 99% of annelids, 0% of arthropods, and 1% of mollusks (**Tables 6-8**, **Figure 35**, **Appendix B**). Overall, the Bowery Bay site had a moderate community complexity and diversity (H'=2.50, E=0.70). This moderate community complexity level for the Bowery Bay site is due to the fact that it accounts for all grabs stations and therefore a greater sampling effort where the probability of species sampling is increased considerably. When looking at the diversity level of each station, it ranged between 0.06 and 1.77 which is relatively poor because the benthic community was chiefly composed of annelid species such as *Capitella sp.* (11,549/m^2), *Leitoscoloplos sp.* (8,771/m^2), *Streblospio benedicti* (5,068/m^2), *Oligochaeta* (LPIL) (4,386/m^2), and *Polichaeta* (LPIL) (3,167/m^2). Only three species mollusk were collected in very small numbers (*Mulinia lateralis*, *Cephalaspidea*) at the station BB1 near the mouth of the bay. A review of pollution-tolerant (29%) and pollution-sensitive taxa (0%) strongly indicated that the benthic community was disturbed and polluted (**Table 8**). This indication was associated to the large concentration of the opportunistic *Capitella sp.* A visual inspection of the sediment grabs indicated the presence of white bacteria mats, probably *Beggiatoa sp.*, at some of the stations in the bay's backwaters.

3.6 Tidal Creek Habitat

Cheesequake Creek, a reference site for this study, is fed by 3 major tributaries and Hooks Creek Lake that together drain a watershed of approximately 9 square miles (5.75 acres) into the Raritan Bay (**Figure 36**). Cheesequake Creek is a continuously flowing, low-gradient stream with an average of 12 m wide, 0.4 m deep, and salinity ranging from 5 to 16.5 ppt. Impediments within the Hooks Creek Lake tributary have been reported (Durkas, 1992, 1993) including "a small tide gate that freshwater flows over from the lake at times of high rainfall." Historically, Cheesequake Creek was a confirmed spawning area for blueback herring (NJDEP, 2000; Zich, 1977, 1978). Additionally, Cheesequake creek has been reported to be nursery and adult area for bluefish, summer flounder, weakfish, and winter flounder (USFWS, 1980). Cheesequake Creek is part of the Metropolitan Watershed of New Jersey Watershed Management Area (WMA) 12. The wetland habitat along Cheesequake Creek mainly characterizes as subtidal/intertidal estuarine habitat as well as emergent/scrub-shrub/forested palustrine habitat (**Figure 36**; **Table 9**).

Woodbridge Creek, a potential enhancement site for this study, has a similarly sized drainage area (approximately 5.5 acres) and drains into the Arthur Kill (**Figure 37**). The creek runs roughly 5.2 miles, varying from a narrow stream at its headwater to 30 m in width and 4.5 m in depth where the river becomes tidal roughly 350 feet north of Morrisey Avenue in Avenel (Greiling, 1993). Heards Brook, Wedgewood Brook, Turtle Creek and Spa Spring Creek are the creek's major tributaries totaling 8 miles. The mouth of the river is bulkheaded/rip-raped and has tank farms on both sides as part of the Seawaren Plant, making access to this section difficult. Based on other reports (Kane, et. al., 1990), the creek is very shallow with some tidal flats along near the mouth. Woodbridge Creek is part of the Metropolitan Watershed of New Jersey Watershed Management Area (WMA) 7. The wetland habitat along Woodbridge Creek mainly characterizes as subtidal/intertidal estuarine habitat as well as emergent/scrub-shrub/forested palustrine habitat (**Figure 37**; **Table 9**).

The total VAS score for Cheesequake Creek was 7.4 (out of 10) or "fair". The upstream reach in Cheesequake Creek was scored as "good" and the downstream reach was "poor". The four sites assessed along Woodbridge Creek were each evaluated as "poor" with a combined score of 4.0 (**Figures 38-41**).

The visual assessment of Cheesequake Creek (reference site) resulted in a "good" rating for almost all characteristics evaluated except instream fish cover. Within the banks of the upstream sample reach were hardened with timbers and old piers providing evidence of past disturbance. The riparian zone was mostly vegetated and is protected from future encroachment by being part of Cheesequake State Park. In general this area shows evidence of past channel alteration, but with significant recovery of the riparian vegetation, channel and bank. Riparian zone vegetation, through the soil-binding action of roots, is an important part in protecting stream banks from erosion and the stream itself from sediment loading. Healthy vegetation growth along a stream also intercepts and slows runoff from disturbed areas and impervious surfaces through water uptake and evapotranspiration. Nutrients and pollutants carried by runoff can also be partly bound up by vegetation.

The downstream reach of Cheesequake Creek was impacted by bank erosion more than the upstream reach and had a greater potential for high nutrient loads. Bank erosion in the downstream reach appeared to be exacerbated by boat traffic. The nutrient loads are likely as a result of the upstream treatment plant, the Global Sanitary Landfill on Melvin's Creek, and nutrient inputs from the Raritan Bay.

Visual assessment of Woodbridge Creek resulted in a "poor" rating for all four sample reaches. In the sample reach, severe bank erosion or bank hardening was evident on both banks, suggesting potential upstream hydrological disturbance. Much of the upstream reach had been straightened and lined with rip-rap. Extensive invasive species (e.g. phragmites and Japanese knotweed) have taken over the original native vegetation.

The downstream reach of Woodbridge Creek has extensive land use encroachment on the riparian areas by roads, parking and industrial area. There appeared to have excessive bank erosion for boat traffic and have a strong potential for high nutrient loads from residential and industrial sources.

In several places along the Woodbridge Creek sites, rocks have been placed along the shoreline to stop eroding banks. While this is effective for protection of a specific bank area, it does little to defuse the water's energy and often necessitates further reinforcement downstream. It also provides poor streamside habitat. Native vegetation planted or allowed to remain on stream banks provides good wildlife habitat while diverting and dispersing the erosive energy of the water.

4. Discussion and Conceptual Plans

4.1 Reef and Shoal Habitats

The finfish community of the NY/NJ Harbor is typical of large coastal estuaries and inshore waterways located along the Mid-Atlantic Bight, supporting a variety of estuarine, marine, and anadromous fish species. Situated in the transition zone between northern cold water (boreal) species and warm water (temperate) species, the New York Bight and Hudson-Raritan Estuary act as spawning ground, migratory pathway, and a nursery/foraging area for a variety of fish species. Many of the species that are seasonally abundant in the NY/NJ Harbor are transient or migratory species, moving through the Lower Bay Complex to upstream spawning grounds, while other species rely on the Lower Bay Complex as a nursery and forage area for juveniles and adults. Those latter species would primarily benefit from any enhancement opportunities to the reef and shoal habitats of the Lower Bay Complex. Based on water quality and benthic habitat characteristics observed in this study, many of the species of concern are expected to be found at the different project sites of the Lower Bay Complex. Similarly, many forage species such as Atlantic menhaden (*Brevoortia tyrannus*), mullet (*Mugil sp.*), American sandlance (*Ammodytes americanus*), and bay anchovy (*Anchoa mitchilli*) are expected to be in the Lower Bay Complex and make use of any enhancement opportunities so that the species of concern would indirectly and further benefit from the proposed project. Based on water quality and benthic habitat characteristics and according to impingement and entrainment studies at the Astoria Generating Station on the East River (LMS, 1994), some species of concern such as Atlantic sea herring, Atlantic butterfish, winter flounder, windowpane flounder, and red hake are expected to be found within or near Bowery Bay.

The shellfish community of the NY/NJ Harbor used to be historically abundant in the Lower Bay Complex, and for more than 200 years, clams, mussels and oysters were a critical part of the Harbor's economy and of the diets of locals. Oysters in particular were large and plentiful in the harbor area, so much that until the mid-1800s a major industry in the harbor region was the processing and export of oysters. The Raritan Bay, especially, has a long history of importance as breeding and feeding grounds for shellfish and it supported a major shellfish industry. However, these shellfish populations largely declined over the last century due to a combination of industrial/domestic pollution, over-harvesting, low dissolved oxygen levels, and diseases (McCormick, 1984; HRF, 2002). In the Lower Bay Complex, a population of inshore American lobsters typically frequent areas of sand with overlying boulders (MacKenzie and Moring 1985). Seasonal distribution is related to water temperature. Migrations into the shallow waters of the Lower Bay take place in spring and summer, and correspond with spawning episodes (USEPA, 1997). Most lobsters are caught in shallow inshore waters (5-30 m). Although the commercial fishery in the study area is not as large as those of northern New England states and Long Island Sound, landings were reported as 28,000 metric tons from New York/New Jersey waters over the past ten years (USACE, 2000).

A total of 93 macroinvertebrate taxa were collected during the marine reconnaissance survey in the Lower Bay Complex and Bowery Bay. The majority of these species were composed of annelids (oligochaetes and polychaetes), arthropods (amphipods, decapods, and a few isopods/ostracods), and mollusks (bivalves and gastropods). A few echinoderms and other worms (i.e., nematoda and nermertea) were also found in some of the project sites. Even though most of those species, typically found in the NY/NJ Harbor, are known to vary considerably in occurrence and abundance both seasonally and spatially (Iocco et al. 2000; Gandarillas and Brinkhuis, 1981; Cerrato et al., 1989; Dean, 1975; BVA, 1998), this benthic macroinvertebrates and sediment surveys allowed for the classification of different benthic habitats as listed in the Methods and Materials (Section 3.1.2.2). In turn, this benthic habitat classification will help establishing EFH enhancement opportunities for the different project sites. Often the commonly-occurring benthic taxa played important roles in ecosystem function, such as increasing habitat structural complexity (e.g., shellfish beds, worm and amphipod tube mats), restructuring sediments (deep-burrowing deposit-feeders), facilitating decomposition of organic matter, and providing food resources for different valuable species including the species of concern and EFH-forage base species.

The West Bank ATN and Old Orchard Shoal sites – both selected as reference sites – indicated the highest benthic habitat quality of all the sites. In summary, both reference sites revealed the coarsest substrate type ranging from fine to medium sand and the highest sand fraction of all sites. When comparing the abundance of benthic taxa (**Table 7**), both reference sites indicated the most uniform community distribution among the annelids, arthropods, and mollusks with an approximate 30:30:30-ratio. Similarly, the number of species and benthic community complexity and diversity was the highest at those references sites with the lowest abundance of pollution-tolerant taxa. Overall, the benthic community at the West Bank ATN and Old Orchard Shoal sites was relatively well developed and mature so that they should continue to be used as reference sites for the basis of long-term comparison with the proposed EFH enhancement sites.

4.1.1 Reef Habitat

When creating a reef, a variety of design options should be considered including configuration/orientation, profile, interstitial space, total surface area, footprint (dispersion), durability/stability, materials, and openness. Site characteristics such as bottom composition, water depth, hydrographic and biological conditions also influence the design of the reef structure. In the case of open bodies of water where average wave energy is considerable, water depth could be a major concern as waves travel free of the bottom when water depth is greater than one half of the wave length. Once the waves enter water shallower than one half their wave lengths, they begin to sound or interact with the bottom and any structure on the bottom (i.e., scouring, siltation, erosion). Understanding the habitat requirements of species potentially impacted by artificial reef creation will help to determine what environmental benefits can be derived in a specific area. Examining the habitat characteristics, as listed in **Appendix A**, enables the identification of relative species and their life history stages associated with reef structures. The EFH and non-managed species that would most likely benefit from artificial reefs are those with demersal, philopatric, territorial, and reef-obligate life histories, as listed in **Table 10** (Banslaben et al., 2003; Steimle and Zetlin, 2000).

<u>Table 10</u>: EFH and Non-Managed Species Likely to Benefit from Reef Habitats in NY/NJ Harbor and Middle Atlantic Bight.

American lobster (*Homerus americanus*)	Ocean pout (*Macrozoarces americanus*)
Atlantic cod (*Gadus morhua*)	Red hake (*Urophycis chuss*)
Black sea bass (*Centropristus striata*)	Rock crab (*Cancer irroratus*)
Blue mussel (*Mytilus edulis*)	Scup (*Stenotomus chrysops*)
Bluefish (*Pomatomus saltatrix*)	Striped bass (*Morone saxatilis*)
Cunner (*Tautogolabrus adspersus*)	Summer flounder (*Paralicthys dentatus*)
Gray triggerfish (*Balistes carolinensus*)	Tautog (*Tautoga onitis*)
Pollock (*Pollachius virens*)	American oyster (*Crassostrea virginica*)

For the purposes of this study, two types of artificial reef are presented based on their vertical relief and targeted species: (1) a low-profile artificial reef (<1m high) is designed to target mainly epibenthic species (i.e., American lobster) while (2) a high-profile reef (up to 3m high) would provide habitat for epibenthic species as well as habitat for structure-oriented and pelagic species (i.e., black sea bass, bluefish, red hake, scup).

4.1.1.1 Gravesend Bay

The Gravesend Bay site, due to its configuration and location, is somewhat protected from the hydrodynamic forces of the Lower Bay Complex. According to the SSS imagery, the site is relatively deprived of major structures on the bottom, and the benthic habitat classifies as a sandy bottom habitat. The benthic habitat also supported a high abundance of polychaetes (i.e *Leitoscoloplos sp.*, *Paraonidae* LPIL) that have been reported to succeed in polluted environments with sewage content (Llanso, 2002). Few shell beds of dwarf surfclam (*Mulinia Lateralis*) and soft clam (*Mya arenaria)* were also identified. *Mya arenaria* is typical of euryhaline waters and are reported sensitive to oil pollution but tolerant to organic content changes (NOAA 2003). Additionally, *Mya arenaria* is an important food source for bottom feeders, such as the EFH-managed winter flounder (*Pseudopleuronectes americanus*). The dwarf surfclam *(Mulinia lateralis*) survives in a wide range of salinities and are also pollution-sensitive taxa (Llanso, 2002). The occurrence of these polychaetes and bivalve species indicates that the benthic habitat in Gravesend Bay provides adequate substrate for suitable clam beds and that the habitat is improving from a previously degraded state.

The habitat of Gravesend Bay could be improved with the addition of bottom structure (i.e., high-profile artificial reef) to increase the availability of vertical and interstitial habitat in the area. This habitat would mainly provide forage and refuge opportunities for resident and migratory EFH-managed species. This high-profile artificial reef would consist of creating numerous rock piles or a field of reefs in order to increase the "edge effect" and surface area while preventing any major changes to the hydrodynamic conditions of the area. This "reef field" would indeed maintain the limited local hydrodynamic forces without increasing sedimentation rates that could be detrimental to the newly constructed reef. As depicted in **Figure 42**, each rock pile would have a diameter of 5-10 meters with a 3-meter vertical profile and should consist predominantly of boulders (300-1500 mm in diameter) as well as of cobbles (64-300 mm in diameter). The "reef field" should be located on the shallow water area (6-7 m) of the site (away from the deep hole) and each rock pile should be distant from each other by approximately 25-50 meters. On an acre-basis, it is estimated that the field of reef would require up to 880 CY of boulders and 360 CY of cobbles.

4.1.1.2 Hoffman-Swinburne Islands

The Hoffman-Swinburne Islands site, located adjacent to the Ambrose Channel, is an open water area that is exposed to the hydrodynamic forces of the Lower Bay Complex. The survey indicated two distinct benthic habitats based on water depth (e.g., shoal area and deep-water area of the West Bank borrow pit). The shoal area characterizes as a sandy bottom benthic habitat with coarse substrate and has a complex and diverse benthic community, while the deep-water area characterizes as silty bottom benthic habitat with a finer substrate and lower species diversity. The shoal area was mainly populated with annelids and mollusks (*Oligochaetes* LPIL, *Paraonidae* LPIL, and *Mulinia laterialis*) while the deep-water area was relatively depleted of benthic species, probably due to some intensive bottom disturbance (i.e., bottom-trawl scars on the SSS imagery). According to the SSS imagery, the site is deprived of significant structure on the bottom; however the shoal revealed an irregular bottom surface, possibly a field of small rocks or depressions.

The Hoffmann-Swinburne Islands site has suitable environmental characteristics for all lobster lifestages based on substrate and water quality conditions (salinity, temperature, DO), and the shoal area would especially provide the most suitable site for lobster habitat enhancement not only because the area is known to support lobsters and have substrates that may physically support an overburden of rocks but also because the prevailing hydrodynamic forces would prevent the silting in of the artificial reef. Additionally, the benthic community of the Hoffman-Swinburne Islands site would provide food resources for lobsters, because their preferred prey, rock crab and mollusks (m*ulinia lateralis, mya arenaria, cancer irroratus, pagarus sp., mytilus edulis*), have been identified in the area.

The range of commercial lobster fisheries in the Lower Bay has been documented to extend south of the Verrazano Narrows Bridge to Sandy Hook Bay, and in an East-West direction from a small portion of Raritan Bay Channel to the Atlantic Bight (NJDEP, 1988). A 1992-97 survey in the Lower Bay indicated that lobster are typically found in higher numbers along immediate areas of the navigation channels (Raritan Bay, Chapel Hill, and Ambrose channels) as well as on the shoals of West Bank, Romer, and East Bank (Steimle et al., 2000; Wilk et al., 1998). The Hoffman-Swinburne Islands area actually showed one of the highest lobster concentrations during this 1992-97 sampling effort. These nearby lobster populations (Wilk et al., 1998; Steimle et al., 2000; NJDEP, 1988) could then facilitate adolescent and adult recruitment (walk-in) to a proposed artificial lobster reef. Similarly, these lobster populations have the potential to facilitate larval recruitment at the Hoffman-Swinburne Islands site as the planktonic Stage IV larvae, carried by prevailing currents, would settle onto suitable substrate and ultimately promote the recruitment of juvenile lobsters in the artificial reef. Additionally, it is expected that the artificial reef would provide habitat for a number of species other than just the targeted lobster community.

Pending further investigation and sampling effort, an artificial reef made of suitably sized and stable rocks would be placed in an area southwest of the Swinburne Island off the edge of the West Bank Shoal. The rock material excavated from the Kill Van Kull deepening could be used for this intent as it would provide a sufficient volume and rock sizes for such proposed reef. The expectation is that the habitat would become populated first by adult lobsters that settle on the material or walk in from nearby natural areas and eventually by juvenile and larval lobsters that would sense environmental cues for suitable development. Upon completion of the construction, a post-placement monitoring would be conducted to confirm the desired shape and vertical relief characteristics of the artificial reef. Physical modifications would be made if deemed necessary.

The proposed artificial reef would be composed of two different zones based on the habitat characteristics associated of the different lobster lifestages (Whale and Steneck, 1991, 1992; Whale 1992; Spanier, 1994; Cobb et al., 1998; Factor, 1995; Castro et al., 2001; Paille and Gendron, 2001). As depicted in **Figure 43**, these two zones would provide suitable habitat for respectively early benthic phase (EBP) lobsters, and mature lobsters.

Early Benthic Phase (EBP) Lobster Habitat

The first type of habitat would consist of a field of mostly pebbles/cobbles (20-300mm in diameter with a magnitude of 70%) with a few scattered small boulders (300-600 mm in diameter with a magnitude of 30%) in order to create a shelter-providing habitat for the early benthic phase (EBP) lobsters. The preponderance of material should be in the smaller size range since these EBP lobsters are highly dependent on shelter-providing habitat in order to minimize predation risks. EBP lobsters include settling post-larvae and juvenile lobsters (shelter-restricted/emergent) with a carapace length (CL) ranging from 5 to 40mm.

Mature Lobster Habitat

The second type of habitat would consist of a field of few scattered cobbles (64-300 mm in diameter with a magnitude of 40%) and mostly small boulders (300-1000 mm in diameter with a magnitude of 60%) in order to provide shelter-providing habitat for adolescent/vagile lobsters as well as adult lobsters. This type of lobsters typically ranges from 40 mm and above in CL (up to 200 mm).

Due to the territorial behavior of adult lobsters, it is anticipated that the habitat for mature lobsters should cover a larger area than for the EBP lobsters. A 3/5 to 2/5 habitat ratio per acre is then proposed for the mature and EBP lobsters respectively. Besides, it is expected that the reef will be first colonized by migrating adult lobsters, which in turn would provide scent cues to benthic settling post-larvae. The two distinctive habitats should be interspersed within the proposed area in order to create complex and diverse habitat where lobster recruitment and migrating opportunities would be increased. In addition, these intermingled habitats should allow for uncovered substrate in order to allow benthic invertebrates recruitment and re-colonization of the constructed reef while providing benthic food resources to all the lobster life stages. Therefore it is proposed that the mature and the EBP lobster habitat lobster habitat should respectively have a 50%- and a 75%-coverage (or dispersal factor) over the substrate. On an acre-basis, it is estimated that the lobster reef would require 1,326 CY of small boulders and 530 CY of pebbles/cobbles.

4.1.1.3 Verrazano-Narrows

The Verrazano Narrows site, located adjacent to the Hoffman-Swinburne Islands site, is also an open water area that is exposed to the hydrodynamic forces of the Lower Bay Complex. The site encompasses shallow water area of the West Bank Shoal as well as deep-water areas of the Hoffman-Swinburne South borrow pit. The benthic community is distinctively different based on water depth. The shoal characterizes as a sandy bottom benthic habitat with coarse substrate and has a complex and diverse benthic community; while the deep-water area characterizes as silty bottom with finer substrate and low species diversity. While the shoal areas were mainly populated with annelids and mollusks (*Oligochaetes* LPIL, *Paraonidae* LPIL, and *Mulinia laterialis*), the deep-water area also indicated a high concentration of the mollusks especially the dwarf surfclam (*Mulinaria Lateralis*) that are pollution-sensitive taxa. According to the SSS imagery, the site is deprived of significant structure on the bottom; however the shoal revealed an irregular bottom surface, possibly a field of small rocks or depressions.

The habitat of Verrazano Narrows site could be improved with the addition of bottom structure (i.e., high-profile artificial reef) to increase the availability/complexity of vertical and interstitial habitat in the area. This habitat would mainly provide forage and refuge opportunities for resident and migratory EFH-managed fish species but also the adult lobster and blue mussel populations. As the deep-water area is essentially featureless and provide sufficient water depth (6-13 m), the proposed high-profile reef (3-meter high) could be placed there without creating any navigational hazard. As depicted in **Figure 44**, the artificial reef would have the shape of a serpentine-like belt, 50-100 meters long and 5-10 meters wide, and would consist predominantly of boulders (300-1500 mm in diameter) and cobbles (64-300 mm in diameter). It is estimated that a single artificial reef would require up to 2,740 CY of boulders and 1,180 CY of cobbles.

The artificial reef could also be located on the shoal area (5-6 m deep) of the site but maintaining navigational safety would require marking clearly this reef with limited clearance. One should note that this artificial reef could also be located within the deep-waters of the West Bank borrow-pit, south of the Hoffman-Swinburne Islands site, where the hydrodynamic forces could be more suitable.

4.1.2 Shoal Habitat

The shoals of the Raritan Bay historically supported a major shellfish industry in the NY/NJ Harbor. Over-harvesting, degraded water qualities and diseases resulted in the significant decline of the shellfish fishery and the removal of shellfish beds from many areas in the estuary. Nowadays, with the major improvements in sewage treatment and water quality in the NY/NJ Harbor that have occurred over the past 30 years (NYCDEP, 2001), some areas in the Raritan Bay are once again available for shellfish harvesting which in turn increases the likelihood of successful opportunities for habitat enhancement that could benefit such commercially important species including soft clam (*Mya arenaria*), northern quahog (*Mercenaria mercenaria*) (a.k.a. hard clam), blue mussel (*Mytilus edulis*), and American oyster (*Crassostrea virginica*). Enhancement opportunities for the Ocean Quahog (*Artica islandica*) and surf clam (*Spisula solidissima*) are very limited in the Raritan Bay since these species require more saline waters and is unlikely to occur in the area.

Blue mussels and oysters require suitable hard substrate such as various-sized rocks (boulders, cobbles, pebbles) or shells for their planktonic larvae to settle upon and spend the rest of their life immobile and attached to the surface of the hard substrate. The planktonic larvae of soft clams and northern quahogs also require a firm bottom consisting of sand and shell fragments to provide optimal settling substrates. However, upon the growth of the attached larvae into juveniles, the juvenile soft clam and northern quahog burrow into the sediments and take up active, adult-like lifestyles. The northern quahog had often been reported within oyster beds as the habitat provides predator protection for juvenile clams. Therefore, the habitat enhancement opportunities at the Raritan Bay Rock Berm and the Raritan Bay Shellfish Bed sites, even though slightly different in design, would most likely have direct benefits to all those species as well as other fish species of concern. For example, the role of oyster reefs as essential fish habitat falls into two categories: (1) reefs as habitat for oysters and (2) reefs as habitat for resident and transient species (Coen et al., 1999; Coen and Luckenbach, 2000; Harding and Mann, 2001). It is believed that fully functional oyster reef habitats will provide ecosystem services and EFH benefits that have the potential to increase regional fish production beyond increases provided by artificial reef habitats for at least three reasons:

1. In high-sedimentation environments typical of many estuaries inhabited by American Oysters, growth of the entire reef, via growth of individual oysters and annual recruitment, provides a mechanism for maintaining the reef in the face of sedimentation. It is doubtful that any other species within the oyster reef assemblage, including mussels, is capable of providing sufficient structural integrity and vertical relief to overcome natural sediment deposition rates and near-bottom hypoxia.
2. Living oyster reefs provide a diversity of micro-habitats – both for support of oyster survival and for nesting and shelter sites for resident and transient finfish – that are not necessarily provided by artificial reef structures lacking high densities of oysters.
3. In some mid- and south-Atlantic coastlines with tidal ranges in excess of 1-2 meters, oyster reefs provide extensive intertidal habitat that cannot be mimicked with traditional artificial fishing reefs.

In addition to providing habitat for a variety of fish and invertebrates, oyster reefs and shellfish beds also serve as an important ecological function by improving water quality through filtering algae and sediments from coastal waters.

4.1.2.1 Raritan Bay Rock Berm

The Raritan Bay Rock Berm site is semi-sheltered and moderately exposed to the hydrodynamic forces of the Lower Bay Complex where the tidal currents are somewhat weak but with good tidal circulation along the shoal. According to the SSS imagery, the site is deprived of significant structure on the bottom and the substrate appeared uniform. The site characterizes as sandy bottom benthic habitat with medium to coarse sand mainly populated by polychaetes (*Paraonidae* LPIL) and few mollusks (*Crepidula fornicata*, *Llyanassa trivittata*).

With its adequate water depth (4.0 to 6.5 m) and nearby oyster beds (Figley, 1988), the Raritan Bay Rock Berm site offer a suitable enhancement opportunity for oyster habitat. Besides, the site would be a good candidate because the Raritan Bay is known to have historical oyster abundance where the physical conditions (i.e., relatively sheltered waters with good tidal circulation and water exchange, low bottom profile) are appropriate. This enhancement would consist of constructing an adequate sediment substrate and relief for the development of an oyster reef. Oyster reefs have already been implemented in the NY/NJ Harbor by a joint effort of National Marine Fisheries Services (NMFS) and the NY/NJ Baykeeper Program of the American Littoral Society at Liberty Island (1999), Keyport Harbor (2001), and recently in the Navesink River (2003). The most important factor in successfully constructing these reefs appears to be the material on which the oysters are placed. Oyster veliger larvae prefer to settle out the water column onto oyster shell, of cultch (Turner et al., 1994). To enhance settlement, the majority of oyster reefs are constructed primarily using a combination of by-product or fossilized oyster shells and other shellfish species with small interstitial spaces providing an optimal environmental for larvae survival. However, the supply of such shells is often limited, making this approach difficult, so that alternate suitable material can be used for the construction of oyster reefs including fly or coal ash, sludge bricks, construction concrete rubble, or dredged rocks. Even porcelain consisting primarily of new but defective sinks and toilets has been used as they are similar to oyster shell and made up of calcium carbonate (Back River Project - VDEQ, 2003). With the NY/NJ Harbor deepening project, there is an opportunity to use the dredged bedrock from Kill Van Kull to create such oyster reef. Banlsaben et al. (2003) determined that dredged sandstone and shale rocks may be preferable for oyster reefs because of their availabilities to naturally break into very small fragments with minimum mechanical effort when compared to serpentinite, schist or diabase.

Therefore, using a combination of dredged rocks and shell material could be feasible option as the oyster reef would still provide chemical cues to the settling oyster larvae while significantly limiting the amount of shell material required for construction. According to similar oyster reef projects in the Chesapeake Bay (Earhart et al., 1988; Clarke et al., 1999), oyster reefs were created by depositing dredged material in areas historically known to support oyster populations, and by capping the dredged material mounds with a layer of oyster cultch. The cultch layer thickness of less than 10 inches may be adequate (Yozzo et al., 1999) and an estimated 100,000 bushels of shell material would be required on an acre-basis in order to construct a 3-dimensional oyster reef (VDEQ, 2003). As depicted in **Figure 45**, the core of the mound would have a height of 1 to 2 meters and would consist of dredge material (>60% sand) that would be capped by a combination of pebble/cobble-sized rocks (<250 mm in diameter) and shell fragments of 10 inches thick minimum (or 25 cm). This practice would save shells and prevent from tapping into this limited resource for future projects. The configuration of the oyster eeef would consist of a berm 25-50 meters long and 5-10 wide. It is estimated that the proposed oyster reef would require up to 980 CY for the reef core, while the cultch would require up to 96 CY of cobbles/pebbles and up to 64 CY of shell fragments. The cultch should consist of at least 40% of shell fragments. Shell material, preferably oyster shells, could be obtained from local or out-of-state shellfish fisheries or restaurants.

A 3-dimensional oyster reef with vertical relief is proposed as it was determined to promote healthy oyster population as well as habitat advantages for other species associated with the reef (Lenihan and Peterson, 1998). The highly stratified water column of the NY/NJ Harbor during the summer months could result in hypoxic bottom waters that are fatal to oysters. However, oyster reefs with enough vertical relief to be raised above this benthic boundary layer experience considerably less mortality (Yozzo et al., 2001). Additionally, reef height also affects local hydrodynamics, creating down-current, low-flow zones that are attractive to larvae and enhance the survival and growth of juvenile oysters (Lenihan et al., 1996). As a result, the elevated cultch would mimic the vertical relief and interstitial space provided by natural dense oyster clusters (or hummocks) to ensure that viable oyster populations can persist and that natural reef communities can exist.

Establishing oyster population on artificial reefs requires natural recruitment from other oyster beds, seeding the reef with cultured oysters, or a combination of both. Natural recruitment would likely occur in the Raritan Bay (Figley, 1988; Banslaben et al., 2003) but it may not be in sufficient magnitude to establish oyster populations. Therefore, it is recommended to "jump start" the oyster reef by artificial larvae seeding or juvenile planting in order to increase the success of the enhancement opportunity. Mature broodstock oysters can be purchased from culturists or transplanted from other oyster beds and placed on the reef to enhance production, however coordination with local organization might reduce the project costs. For example, the Oyster Gardening Program of the NY/NJ Baykeeper could be a co-sponsor of the project by providing large number of immature oysters that can be used to seed the reef. Ultimately, these newly settled oysters upon reaching maturity would enhance production and larvae settlement.

4.1.2.2 Raritan Bay Shellfish Bed

The Raritan Bay Shellfish Bed site is semi-sheltered and moderately exposed to the hydrodynamic forces of the Lower Bay Complex where the tidal currents are somewhat weak but with good tidal circulation along the shoal. According to the SSS imagery, the site is deprived of significant structure on the bottom and the substrate appeared uniform. The SSS imagery also revealed some clam rake scars indicating some shellfish harvesting in the area. The site's benthic habitat characterizes as mats of tube-dwelling amphipods (*Ampelisca abdita*) with fine to coarse sand. The benthic community also consisted of polychaetes (*Paraonidae* LPIL, *Capitella sp.*), oligochaetes, and only few northern quahogs (*Mercenaria mercenaria*). Amphipods are generally absent from areas of high pollution, leading to their recognition as an environmental indicator or pollution-sensitive taxa (NOAA, 2003). Though there is no commercial fishery for amphipods, *Ampelisca abdita* is an important food source for many invertebrate species as well as for many juvenile and adult bottom-feeding fish including the EFH-managed species of winter flounder (*Pleuronectes americanus*) and scup (*Stenotomus chrysops*). One should note the unusually high concentration of *Capitella sp*. (3,128/m^2) that indicated some level of disturbance (i.e., pollution) at the site. However, this slight level of disturbance might be related to the ruptured sewage pipe of the Middlesex County Utilities Authority that diverted an estimated 570 million gallons of raw sewage directly into the Raritan Bay in early March 2003 (NJDEP Bulletin News).

The Raritan Bay Shellfish Bed site is shallower (3.5-5.0 m) than the Raritan Bay Rock Berm site, and would be less viable for a 3-dimensional oyster reef with a 1 to 2-meter vertical relief because of navigational reasons. In addition, the sandy bottom of the Raritan Bay Shellfish Bed site contained a higher gravel content that would be more feasible to a shellfish bed enhancement opportunity. As the planktonic larval clams (both softshell and N. quahog) generally need a firm or hard substrate consisting of sand and shell fragments to settle and initiate juvenile development before burying into the sediments, it is then proposed to replicate this condition by adding a layer of medium silt to coarse sand mixed with pebble-sized dredged rocks (<150 mm in diameter). Rocks, preferably sandstone and shale rocks, excavated from the Kill Van Kull could be used. If available, an additional layer of clam shells could also be scattered along the bottom in order to better replicate the conditions of a natural shellfish bed. Similarly to the oyster habitat enhancement, coordination with local organizations could be conducted for acquiring and planting sets of juvenile shellfish at the site in order to “jump-start” the recolonization. These techniques have been successfully implemented in the Long Island Sound and Barnegat Bay, NJ. Natural recruitment could also occur from the existing nearby clam populations (Figley et al., 1988). As depicted in **Figure 46**, the proposed layer would be no more than 20 inches thick (or 50 cm) and consist of 70% clean sand and 30% pebbles. Ultimately, clam shell fragments would be scattered around the site. On acre-basis, it is estimated that the shellfish bed would require 1,850 CY of clean medium silt to coarse sand, 800 CY of pebble-size rocks, and 1,000 CY of shell fragments.

4.2 Shallow Water Habitat

4.2.1 Bowery Bay

Benthic habitat of Bowery Bay consisted silty-bottom communities dominated by opportunistic or pollution-tolerant species. The strong concentrations of *Capitella sp.* and *Leitoscoloplos sp.* and the presence of bacteria mats in conjunction with strong hydrogen sulfide odor, no RPD layer, and high organic content indicated that the sediments were highly anoxic due to pollution. It is believed that the sluggish waters along with the deposition of the fine fraction sewage detritus from the nearby CSOs contributed to the disturbed conditions and a benthic colonization ranging from azoic to dominance by low diversity opportunistic polychaetes (i.e., Stage I infaunal succession). A 1994-95 benthic survey of the bay also observed the presence of sub-surface methane pockets (Iocco et al., 2000) which indicated high organic contamination because methane gas usually accumulates within the bottom sediments when sulfate has already been used up. Areas with low sediment oxygen conditions, or high sediment oxygen demand (SOD), can occur when the bottom sediment experiences severe organic loading. For example, deposition of the fine fraction sewage detritus can form a blanket at the sediment-water interface, and dense populations of sulfate-reducing bacteria can populate this blanket. Organic material on the sediment surface is covered by a white bacterial mat usually found in areas of detrimentally high organic loading. Such a surface has a high SOD and a thin or non-existent RPD within the sediment column. Macro faunal colonization can range from azoic to dominance by low diversity opportunistic polychaetes (i.e., Stage I infaunal succession).

Limited recruitment from open-water habitat may prevent enhancement opportunities at the Bowery Bay; however it is believed filling the dead-end basin with dredged material to create shallow water habitat could significantly improved the tidal circulation of Bowery Bay and therefore its water and sediment quality. As depicted in **Figure 47**, the enhancement opportunity (Option 1) would consist of placing a submerged dike at the mouth of the bay and back-filling the bay with clean sediments in order to create a shallow water and unvegetated habitat. Of course, this enhancement opportunity could have some navigation impacts for boats or barges that need to access waterfront facilities of the NY/NJ Port Authority. Therefore, the shallow water and unvegetated habitat on both edges of the bay could be the focus of this enhancement

(Option 2) in order to maintain a navigation channel in the center of Bowery Bay. Such designs would require the use of dredged rocks to create a subtidal containment berm (or dike) for a sloping terrace filled with dredge sediment along the shoreline of the bay. Both designs would be similar to creating an "in-bay terrace" as described by Yozzo et al. (2001). These unvegetated shallow water habitats could provide significant spawning areas (i.e., for winter flounder, windowpane flounder, summer flounder), while the rock berm would also provide added benefit of complex structure for refuge/foraging habitat by structure-depending fishes (i.e., black sea bass) and invertebrates. For Option 2, the two "in-bay terraces" would be approximately 150 meters wide and constructed on both the western and eastern shores in order to maintain a navigation channel (approximately 100 meters wide) and turning basing at the end of Bowery Bay. In any event, the water depth of the shallow water habitat should be maintained at a minimum of 1 meter deep below mean tide level (MTL) as the local spring tidal range varies from 5.0 up to 8.0 feet (1.5 to 2.4 m) (NOAA, 2003). For Option 1, an estimated 637,220 CY of clean medium silt to coarse sand material and 3,140 CY of boulder/cobble-size rocks would be required to construct the submerged dike and back-fill the in-bay terrace. For Option 2, an estimated 413,000 CY of medium silt to coarse sand material and 7,800 CY of boulder/cobble-size rocks would be required to construct the submerged dikes and back-fill the two in-bay terraces. A filter fabric would be used for the submerged dike construction in order to prevent sediments from seeping through the dike. Because the two existing CSOs are subject to highly variable flow rates, flow equalization via detention basin or other engineering structures should be implemented concurrently in order to reduce scouring effects on the shallow water habitat.

4.3 Tidal Creek Habitat

Anadromous species that migrate from marine waters to spawn in the freshwater reaches or tributaries of the Hudson-Raritan Estuary includes several common species of herrings (Clupeidae) such as blueback herring (*Alosa aestivalis*). Alewife (*Alosa pseudoharengus*), Atlantic sea herring (*Clupea harengus*), and American shad (*Alosa sapidissima*), as well as the relatively less common hickory shad (*Alosa mediocris*) and gizzard shad (*Dorosoma cepedianum*) (USFWS, 1997). Other anadromous species include the Atlantic tomcod (Microgadus tomcod), Atlantic sturgeon (*Acipenser brevirostrum*), rainbow melt (*Osmerus mordax*) and striped bass (*Morone saxatilis*). Enhancement opportunities therefore exist in the NY/NJ Harbor in order to improve the habitat quality of tidal creeks for anadromous and EFH-forage fishes.

A comparison of the visual assessment scores for Woodbridge Creek versus the reference site (Cheesequake) indicated that Woodbridge Creek ranked significantly lower in almost every category both upstream and downstream (**Figure 39**). The one exception was that instream fish cover for the downstream site was lower in the reference stream. The general pattern indicated that restoration efforts would have significant potential of improving the stream. Some of the strategies identified in the survey are listed below. The "Enhancement" strategies are stream improvements that can be implemented with relative ease and in a short period of time (**Table 11**). The "Restoration" strategies are longer range improvements that would require a greater allocation of time and resources

(**Table 12**). The categories with the largest difference between enhancement site and reference site would yield the largest improvement (**Figure 39-c**). These categories are riparian zone, water quality (appearance and nutrients), channel conditions, and hydrologic alteration.

The categories closest linked to improving fish habitat include instream fish cover, and riparian zone improvement linked to a water quality improvement. Improving these three would provide additional quality rearing habitat needed for increased fish production.

5. Summary and Recommendations

5.1 Reef/Shoal/Shallow Water Habitats

Even though, the herein-identified enhancement opportunities are solely conceptual, the reconnaissance survey at each site allowed for the determination of several opportunities to enhance and increase the complexity of essential fish habitat throughout the NY/NJ Harbor while making beneficial use of some dredge material of the future harbor deepening. Overall, these enhancement opportunities should be first implemented at a small-scale and experimental level (approximately one acre) with post-monitoring before conducting such design on a larger scale. However, any enhancement opportunities would require further investigation in order to confirm the environmental and engineering feasibility of the project. At all enhancement sites, more field monitoring should be conducted in order to acquire further information on the benthic community, the substrate geotechnical characteristics, the local hydrodynamics forces, as well as water quality. For example, previous studies in stratified estuaries indicated that placement of materials for subtidal reef habitat requires prior knowledge of local hydrographic conditions (i.e., prevailing current velocities, wave energy levels, sedimentation rates, temperature and density stratification, and oxygen levels). Typically, a one-year long monitoring would be recommended in order to depict seasonal variations but it could be shortened for diverse scheduling or economical reasons.

A recurring point of discussion among scientists and managers is the effect of artificial reefs or shellfish beds on fisheries production. Natural populations may be reduced due to overfishing or other environmental effects, and recruits can be limited by forage and habitat availability. An enhanced habitat site may concentrate those limited populations and make them more vulnerable to fishing pressure. If habitat is already a limiting factor for production, the enhanced habitat will promote production of new biomass by increasing the growth and survival of juveniles but it should be designated and enforced as a sanctuary (no fishing allowed) in order to prevent fishing pressure. Once the reef will be created and mapped, SSS surveys can be periodically conducted to determine the profile of the structure and comparing the SSS images over time can provide information about its structural stability.

The placement of dredged material is most simply achieved using a slip-bottom barge, a process known as bottom dumping. Using any size of rock material will allow a reef structure to achieve relief, with flexible options for reef configuration and profile. The mounds of rock material achieved by bottom dumping could be conical mounds, or elongated ridges of material. Large pieces of rock will allow for increased interstitial space, total surface area, and openness, while maintaining options for configuration and profile. However, due to navigational draft requirements, bottom dropping might be virtually impossible to accomplish in a control manner at some of the selected sites. Therefore, the use of flat deck barges might be more suitable where the material can be bulldozed, hauled, craned or washed over the side of the barge in a controlled fashion.

One of the major key to success for enhanced EFH is the colonization of the habitat by target species. Too often, enhanced habitats result in the debate of attraction versus production. Therefore, artificial stock enhancement, through coordination with local/state environmental organization, is highly recommended in order to "jump start" this colonization in addition to natural recruitment. For example at the Barnstable Harbor Shellfish Restoration and Enhancement Program in Massachusetts, the use of "clam tents" at selected areas was implemented in order to promote recruitment for artificial seeding/ planting onto enhanced habitat. Clam tents are netted structures that are placed over native intertidal sand flats to promote the recruitment of softshell clams (WHOI Sea Grant, 1998). A similar program could actually be conducted in a tidal creek of the NY/NJ Harbor or even at the selected Woodbridge Creek site if feasible. Anyhow, post-construction monitoring should then include the evaluation of recruitment.

5.2 Tidal Creek Habitat

This synoptic survey was a reconnaissance level assessment only. Access was limited to road access and the purpose of the survey was the selection of enhancement sites. Additional sample sites should be evaluated, basic water chemistry data collected, and some bottom grab sample collected for substrate characterization and assessment of the benthic community. Additional data will help clearly define areas of concern and target resources for remedial action to where they will be most effective.

1. Expand the Visual Assessment to include a larger number of reaches on both the reference site and the enhancement site.

   The reconnaissance survey was a quick snapshot of each stream and confined to vehicular access. A more extensive survey would allow a more balanced and thorough evaluation of stream impairments and restoration potential.

2. Identify specific watershed and stream sources of impairments.

   Sources of bank erosion, stormwater discharges, and major nutrient sources should be identified within the watershed.

3. Collect additional stream data on bed, banks and water quality.

   Information on soils (bank), stream substrate, and benthic organisms should be collected at the same reaches being evaluated. Additional measurements of stream characteristics such as stream width, stream depth with provide valuable information in developing specific restoration plans.

4. Identify effective stream restoration alternatives and possible best management practices.

   Design "before and after" monitoring programs to evaluate the effectiveness of improvements.

5. Monitor streams before and after enhancement to measure improvement.

   These synoptic surveys provide a great deal of information within a relatively short and focused effort. Data collected on a regular basis can be used for trend analysis to define changes in stream quality over time.

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Table 1: Summary of the Designated EFH-Managed Species and Lifestages Located in the New York / New Jersey Harbor.

Species	Lifestages				
	Eggs	Larvae	Juveniles	Adults	Spawning Adults
Pollock (*Pollachius Virens*)			X	X	
Red hake (*Urophycis tenuis*)		M,S	M,S	M,S	
Winter flounder (*Pleuronectes americanus*)	M,S	M,S	M,S	M,S	M,S
Windowpane flounder (*Scopthalmus aquosus*)	M,S	M,S	M,S	M,S	M,S
Atlantic sea herring (*Clupea harengus*)		M,S	M,S	M,S	
Bluefish (*Pomatomus saltatrix*)			M,S	M,S	
Long finned squid (*Loligo pealei*)	n/a	n/a			
Short finned squid (*Illex illecebrosus*)	n/a	n/a			
Atlantic butterfish (*Peprilus triacanthus*)		M	M,S	M,S	
Atlantic mackerel (*Scomber scombrus*)			S	S	
Summer flounder (*Paralicthys dentatus*)		F,M,S	M,S	M,S	
Scup (*Stenotomus chrysops*)	S	S	S	S	
Black sea bass (*Centropristus striata*)	n/a		M,S	M,S	
Surf clam (*Spisula solidissima*)	n/a	n/a			
Ocean quahog (*Artica islandica*)	n/a	n/a			
Spiny dogfish (*Squalus acanthias*)	n/a	n/a			
King mackerel (*Scomberomorus cavalla*)	X	X	X	X	
Spanish mackerel (*Scomberomorus maculatus*)	X	X	X	X	
Cobia (*Rachycentron canadum*)	X	X	X	X	
Sand tiger shark (*Odontaspis taurus*)		X			
Dusky shark (*Charcharinus obscurus*)		X			
Sandbar shark (*Charcharinus plumbeus*)		X		X	

Source: National Marine Fisheries Service (2003), "Summary of Essential Fish Habitat (EFH) Designation" for the Hudson River / Raritan /Sandy Hook Bays, NY-NJ Harbor. *The designation list is posted on the NOAA's website at* http://www.nero.noaa.gov/ro/doc/webintro.html.

Legend:

- S = Includes the seawater salinity zone (salinity 25.0‰), M = Includes mixing water / brackish salinity zone (0.5‰ < salinity < 25.0‰), F = Includes tidal freshwater salinity zone (0.0‰ < salinity < 0.5‰), and X = Designated EFH but no salinity zone specified
- "n/a" indicates that the species either have no data available on the designated lifestages, or those lifestages are not present in the species' reproductive cycle. These species are:
  - redfish, which have no eggs (larvae born already hatched);
  - long finned squid, short finned squid, surf clam, and ocean quahog which are referred to as pre-recruits and recruits (this corresponds with juveniles and adults in the tables);
  - spiny dogfish, which have no eggs or larvae (juveniles born live);
- black sea bass, for which there is insufficient data for the life stages listed, and no EFH designation has been made as of yet (some estuary data is available for all the life stages of these species, and some of the estuary squares will reflect this)

Table 2: Sampling Effort at each Site Based on Habitat Type and Target Species.

Site Name	Surveyed Area (acres)	Habitat Type	Target Species	Side-Scan Sonar Survey	Bathymetry Survey	Benthic Survey	Sediment Survey	Water Quality Survey	Clam Dredge Survey	Desktop/GIS Survey	Vegetation Survey
West Bank ATN **	150	Reef	Black Sea Bass / Scup / Lobster	X	X	X	X	X			
Gravesend Bay	150		Black Sea Bass / Scup	X	X	X	X	X			
Hoffman/Swinburne Islands	180		Black Sea Bass / Scup / Lobster	X	X	X	X	X			
Verrazano Narrows	250		Black Sea Bass / Scup	X	X	X	X	X			
Old Orchard Shoal **	70	Shoal	Surf Clam / Northern Quahog / Soft Clam / Blue Mussel / American Oyster	X	X	X	X	X	X		
Raritan Bay Shellfish Bed	190		Surf Clam / Northern Quahog / Soft Clam / Blue Mussel / American Oyster	X	X	X	X	X	X		
Raritan Bay Rock Berm	160		Surf Clam / Northern Quahog / Soft Clam / Blue Mussel / American Oyster	X	X	X	X	X	X		
Bowery Bay	80	Shallow Water	EFH Forage Base	X	X	X	X	X			
Cheesequake Creek **	n/a	Tidal Creek	EFH Forage Base							X	X
Woodbridge Creek	n/a		EFH Forage Base							X	X

Note:

** - Selected as baseline for evaluation or "Reference Site".

n/a - not applicable.

Table 3: Major Water Quality Parameters at the Project Sites.

Site	Station	Water Stratum	Depth (m)	Temperature (^oC)	Salinity (psu)	DO (mg/l)
West Bank ATN	WB7	Surface	1	6.2	18.1	10.4
		Mid	9	6.2	18.1	10.2
		Bottom	18	6.7	18.1	10.2
	WB9	Surface	1	5.0	16.2	11.8
		Mid	14	5.0	19.0	10.8
		Bottom	29	4.9	26.7	9.6
Gravesend Bay	GB5	Surface	1	5.9	16.4	11.2
		Mid	9	5.2	19.4	10.8
		Bottom	18	5.3	21.2	10.5
	GB7	Surface	1	5.7	16.9	11.1
		Mid	9	5.2	20.0	10.6
		Bottom	17	5.4	24.4	10.1
Hoffman-Swinburne Islands	HSI5	Surface	1	4.9	16.1	11.2
		Mid	17	4.8	24.1	10.1
		Bottom	34	4.8	27.3	9.8
	HSI8	Surface	1	5.0	16.0	11.4
		Mid	6	4.9	16.0	11.4
		Bottom	12	5.0	21.0	10.2
Verrazano-Narrows	VN2	Surface	1	5.3	16.3	13.8
		Mid	12	5.2	16.4	13.4
		Bottom	23	5.0	24.2	9.2
	VN6	Surface	1	5.0	14.9	11.5
		Mid	9	5.0	15.4	11.7
		Bottom	18	4.9	20.7	10.3
	VN9	Surface	1	5.3	16.3	13.9
		Mid	11	5.3	16.3	13.9
		Bottom	21	4.8	24.1	9.6
Old Orchard Shoal	OOS1	Surface	1	6.9	16.9	11.7
		Mid	8	6.4	18.6	9.6
		Bottom	16	6.7	21.4	8.7
	OOS6	Surface	1	8.4	17.2	12.5
		Mid	10	6.0	20.7	8.8
		Bottom	19	6.6	21.3	8.6
Raritan Bay Rock Berm	RBRB1	Surface	1	7.9	17.4	12.1
		Mid	7	6.4	17.4	9.6
		Bottom	14	6.6	19.6	9.1
	RBRB4	Surface	1	8.1	12.8	12.5
		Mid	7	7.1	14.6	12.5
		Bottom	14	6.4	18.6	9.8
Raritan Bay Shellfish Bed	RBSB1	Surface	1	8.5	11.8	11.8
		Mid	4	7.2	15.7	10.8
		Bottom	8	7.1	16.4	10.2
	RBSB6	Surface	1	8.7	13.5	12.8
		Mid	6	7.2	16.0	11.6
		Bottom	12	7.4	16.4	10.8
Bowery Bay	BB1	Surface	1	4.9	18.8	10.8
		Mid	4	4.9	18.9	10.6
		Bottom	7	4.9	19.6	10.5
	BB9	Surface	1	5.2	19.8	10.4
		Mid	5	5.1	19.4	10.4
		Bottom	9	5.0	18.4	10.9

Note: Measurements were conducted between April 7, 2003 to April 14, 2003

Table 4: Seasonal and Annual Bottom Water Quality Characteristics from 1991-2001 in the NY/NJ Harbor.

Waterbody	DEP Station	Depth Range (ft)	Season	Temperature (ºC)	CTD DO (mg/L)	BOD (mg/L)	Salinity (psu)	pH	Chl A (ug/L)	Fecal coliform (MPN/100mL)	Secchi (ft)
Lower Bay	K6	12-15	Spring	12.6	12.3	2.9	23.5	8.0	34.9	13.8	4.6
			Summer	21.8	6.6	2.8	26.3	7.8	33.3	9.2	4.6
			Fall	15.3	8.0	1.8	25.5	7.7	13.0	2.6	6.8
			Winter	4.3	11.7	2.4	23.5	7.9	23.4	--	4.7
			Annual	15.7	9.0	2.6	25.0	7.9	29.5	9.5	5.0
	N8	55-63	Spring	11.3	10.5	1.8	26.9	7.8	10.2	52.2	4.6
			Summer	20.5	5.3	1.4	27.8	7.6	12.3	33.0	5.8
			Fall	15.8	6.4	1.1	27.7	7.7	3.5	19.4	6.3
			Winter	4.9	10.4	1.9	27.0	7.9	4.8	19.0	3.9
			Annual	15.0	7.6	1.5	27.4	7.7	9.5	35.2	5.3
	N8A	20-25	Spring	11.9	9.0	1.8	25.2	7.8	18.5	17.8	4.5
			Summer	21.2	6.3	1.4	26.7	7.6	19.7	34.1	5.6
			Fall	17.4	7.4	1.2	26.7	7.6	8.4	13.5	6.2
			Winter	4.2	11.9	2.7	25.0	7.8	13.4	--	4.5
			Annual	16.0	8.0	1.9	26.1	7.7	17.4	29.0	5.2
Raritan Bay	K5	27-34	Spring	13.0	10.2	2.8	23.3	7.8	30.1	32.9	3.7
			Summer	22.9	4.9	1.8	25.2	7.5	22.2	50.4	4.3
			Fall	15.5	6.9	1.3	25.1	7.5	7.4	42.0	5.9
			Winter	4.2	11.4	2.8	23.5	7.9	22.3	17.0	3.8
			Annual	16.5	7.4	2.2	24.5	7.6	22.1	46.6	4.4
	K5A	16-21	Spring	13.5	10.8	2.7	22.7	7.8	33.3	13.8	3.7
			Summer	22.6	5.2	1.7	25.5	7.5	26.9	29.7	4.3
			Fall	15.1	6.8	1.4	25.5	7.6	9.6	35.6	5.2
			Winter	4.2	11.1	2.7	23.2	7.9	28.5	--	3.7
			Annual	16.2	7.7	2.0	24.4	7.7	26.0	27.4	4.2
Upper East River	E5	44-52	Spring	12.5	8.8	2.8	22.7	7.7	15.5	160.1	4.3
			Summer	21.6	3.8	1.5	24.4	7.3	7.8	203.7	5.2
			Fall	15.5	6.1	1.3	24.5	7.4	3.1	347.4	5.3
			Winter	3.8	11.3	2.4	23.5	7.8	14.7	--	3.9
			Annual	16.4	6.0	1.8	23.9	7.5	9.6	204.4	4.9
	E6	14-16	Spring	12.4	8.5	2.7	22.9	7.7	20.3	347.0	4.3
			Summer	21.5	3.7	1.6	24.5	7.3	13.6	362.1	4.9
			Fall	15.5	6.8	1.4	24.7	7.4	3.7	492.2	5.2
			Winter	3.8	11.4	2.3	23.7	7.9	16.7	--	4.1
			Annual	16.3	6.0	1.9	24.1	7.5	13.9	368.4	4.7

Source: NYCDEP, Harbor Water Quality Survey 1991-2001

Table 5: Sediment Characteristics at the Project Sites

Site	Station	Coordinates				Water Depth (ft)	Grab and Sediment Characteristics						Organic Content % by wt	Particle Size Analysis							
		Latitude (N)		Longitude (W)			Temp (°C)	Texture	Color	Odor	Grab Vol (%)	RPD (mm)		Fraction Content (%)				Geometric Mean Grain Size		Standard Deviation (?)	Description **
		Deg	Min	Deg	Min									Gravel (>2.0mm)	Sand (2.0 - 0.05mm)	Silt (0.05 - 0.002mm)	Clay (<0.002mm)	mm	?		
West Bank ATN	WB4	40	32.4244	74	02.6500	21.0	5.7	Sand	Brown	None	70	13	2.3	0.6	72.1	20.0	7.3	0.059	4.08	-2.35	Very Fine Sand
	WB5	40	32.2198	74	02.5318	21.0	5.7	Sand	Brown	None	55	41	0.8	3.6	93.4	3.0*	0.0*	0.14	2.84	-0.93	Fine Sand
	WB7	40	32.3288	74	02.8320	19.0	5.8	Fine Gravel	Brown	Sulfur	90	10	3.6	6.7	55.2	29.9	8.2	0.079	3.66	-3.16	Very Fine Sand
	WB8	40	32.5679	74	02.9600	20.0	5.0	Mud/Shells	Black/Brown	None	40	n/a	2.0	6.2	84.8	8.5*	0.5*	0.123	3.02	-1.2	Very Fine Sand
	WB9	40	32.7700	74	02.9572	30.0	5.0	Mud	Black/Gray	None	105	70	4.5	0.9	62.3	27.8	9.0	0.044	4.51	-2.57	Coarse Silt
	WB10	40	32.6708	74	03.0900	33.0	4.8	Mud	Black	None	100	17	2.5	0.9	76.5	17.9	4.7	0.058	4.11	-2.33	Coarse Silt
Gravesend Bay	GB4	40	35.3961	74	00.3891	17.0	5.2	Mud	Black/Brown	Sulfur	80	14	3.0	3.9	69.7	19.6	6.8	0.053	4.24	-2.85	Coarse Silt
	GB5	40	35.5538	74	00.5650	19.0	5.2	Mud	Black/Brown	None	70	16	2.3	1.5	73.1	18.6	6.8	0.058	4.11	-2.44	Coarse Silt
	GB6	40	35.2763	74	00.1762	16.0	5.2	Mud	Black/Brown	Sulfur	90	15	2.6	0.6	73.6	18.1	7.7	0.059	4.08	-2.48	Coarse Silt
	GB7	40	35.1889	74	00.4953	18.0	5.4	Mud	Black/Brown	Sulfur	90	9	2.4	3.1	69.5	21.0	6.4	0.063	3.99	-2.57	Very Fine Sand
	GB8	40	35.3709	74	00.1444	17.0	5.1	Mud	Black/Brown	Sulfur	85	16	3.1	0.8	73.3	19.5	6.4	0.062	4.01	-2.5	Coarse Silt
	GB10	40	35.3748	74	00.2691	18.0	5.2	Mud	Black/Brown	Sulfur	120	10	7.8	0.2	42.5	48.0	9.3	0.033	4.92	-2.78	Coarse Silt
Hoffman-Swinburne Islands	HSI3	40	33.5011	74	03.4946	30.0	5.0	Mud	Black	Sulfur	110	24	7.6	0.9	28.0	56.8	14.3	0.016	5.97	-3.34	Medium Silt
	HSI4	40	33.6593	74	03.3031	30.0	4.9	Mud	Black	Sulfur	120	9	7.5	0.6	42.0	44.7	12.7	0.028	5.16	-3.2	Medium Silt
	HSI5	40	33.4828	74	03.1363	35.0	5.1	Mud	Black	Sulfur	110	20	6.7	1.2	42.9	45.9	10.0	0.032	4.97	-2.76	Coarse Silt
	HSI6	40	33.8081	74	03.4662	15.0	5.1	Sand/Shells	Tan/Brown	None	50	31	0.5	1.8	95.2	3.0*	0.0*	0.219	2.19	-0.93	Fine Sand
	HIS7	40	34.0337	74	03.2414	10.0	5.0	Sand	Brown	None	50	n/a	0.4	12.2	86.8	1.0*	0.0*	0.241	2.05	-1.83	Fine Sand
	HSI8	40	33.8231	74	03.0469	13.0	4.9	Sand	Brown	None	50	29	0.5	0.4	98.6	1.0*	0.0*	0.286	1.81	-0.61	Medium Sand
Verrazano-Narrows	VN1	40	34.0367	74	03.6909	25.0	5.1	Mud	Black/Brown	None	75	50	6.5	5.5	53.2	32.0	9.3	0.07	3.84	-3.5	Very Fine Sand
	VN2	40	34.3034	74	03.7793	24.0	5.1	Mud	Black/Brown	None	110	51	6.3	1.0	54.0	35.1	9.9	0.041	4.61	-2.68	Coarse Silt
	VN4	40	33.8962	74	03.9056	16.0	5.1	Sand	Tan/Brown	None	50	31	0.4	11.8	86.2	2.0*	0.0*	0.469	1.09	-1.53	Medium Sand
	VN5	40	34.2212	74	04.1088	16.0	4.9	Mud/Sand	Brown	None	70	12	0.7	3.3	92.7	3.5*	0.5*	0.466	1.10	-1.17	Medium Sand
	VN6	40	33.6698	74	04.2620	19.0	5.1	Mud	Black/Brown	None	110	0	4.9	2.0	67.4	23.4	7.2	0.072	3.80	-3.11	Very Fine Sand
	VN9	40	34.1250	74	04.0648	22.0	5.1	Mud	Black/Brown	Sulfur	110	15	8.2	4.5	44.2	43.0	8.3	0.054	4.21	-2.81	Coarse Silt
Old Orchard Shoal	OOS1	40	30.8937	74	05.6976	17.0	6.4	Sand	Brown	None	70	32	0.9	1.9	97.1	1.0*	0.0*	0.204	2.29	-0.89	Fine Sand
	OOS2	40	30.7367	74	05.6413	17.0	6.2	Sand	Brown	None	70	35	1.0	2.1	97.1	0.8*	0.0*	0.269	1.89	-0.71	Medium Sand
	OOS3	40	30.6670	74	05.7802	18.0	6.2	Sand	Brown	None	65	32	0.8	1.3	96.7	2.0*	0.0*	0.204	2.29	-0.94	Fine Sand
	OOS4	40	30.7641	74	05.9609	18.0	6.6	Sand	Brown	None	68	19	1.2	5.6	93.4	1.0*	0.0*	0.249	2.01	-1.32	Fine Sand
	OOS5	40	30.6893	74	06.1940	19.0	6.3	Sand	Brown	None	50	16	1.0	1.3	96.4	2.3*	0.0*	0.208	2.27	-0.98	Fine Sand
	OOS6	40	30.8778	74	06.5536	20.0	6.2	Sand	Brown	None	50	33	1.0	1.7	96.5	1.8*	0.0*	0.251	1.99	-1.12	Medium Sand
Raritan Bay Rock Berm	RBRB1	40	28.8030	74	09.6438	15.0	6.1	Silt/Shells	Brown	Sulfur	60	n/a	3.7	14.2	75.8	9.0*	1.0*	0.386	1.37	-2.08	Medium Sand
	RBRB2	40	28.6539	74	09.5679	14.0	6.2	Silt/Shells	Brown	Sulfur	50	n/a	2.4	18.6	73.6	7.8*	0.0*	0.514	0.96	-2.36	Coarse Sand
	RBRB3	40	28.6231	74	09.9282	12.0	6.2	Mud/Shells	Brown	None	60	19	5.3	6.4	71.4	20.2*	2.0*	0.310*	1.69	-1.87	Medium Sand
	RBRB4	40	28.7947	74	10.0379	14.0	6.0	Silt/Mud	Black/Brown	Sulfur	60	n/a	3.6	7.7	76.8	14.5*	1.0*	0.419*	1.25	-1.69	Medium Sand
	RBRB5	40	28.5804	74	10.1864	8.0	6.0	Sand	Brown	None	70	28	0.4	0.1	97.3	2.6*	0.0*	0.282	1.83	-0.39	Medium Sand
	RBRB6	40	28.7817	74	10.2934	10.0	6.0	Sand	Brown	None	40	21	0.5	4.0	95.0	1.0*	0.0*	0.3	1.74	-0.56	Medium Sand
Raritan Bay Shellfish Bed	RBSB1	40	27.7881	74	12.3312	9.0	6.3	Silt	Brown	None	95	9	5.2	6.6	74.6	17.5*	1.3*	0.552*	0.86	-2.22	Coarse Sand
	RBSB2	40	27.9436	74	12.3539	10.0	6.4	Silt	Brown	None	90	0	6.3	12.4	67.6	18.0*	2.0*	0.283*	1.82	-2.8	Medium Sand
	RBSB3	40	27.9765	74	12.5368	11.0	6.4	Silt	Brown	None	95	29	7.6	12.0	56.8	26.8	4.4	0.132	2.92	-3.54	Fine Sand
	RBSB4	40	27.7770	74	12.5705	11.0	6.4	Silt	Brown	None	75	0	4.5	14.6	73.4	11.0*	1.0*	0.399	1.33	-2.16	Medium Sand
	RBSB5	40	27.7890	74	12.7673	12.0	6.4	Silt	Brown	None	100	10	6.8	25.6	59.4	14.0*	1.0*	0.518*	0.95	-2.8	Coarse Sand
	RBSB6	40	27.9344	74	12.7801	13.0	n/a	Silt	Black	None	70	0	6.1	22.6	60.4	16.0*	1.0*	0.457*	1.13	-2.78	Medium Sand
Bowery Bay	BB1	40	46.7673	73	53.2481	8.0	5.4	Mud	Black	Sulfur	120	0	12.7	2.3	24.2	67.2	6.3	0.024	5.38	-2.3	Medium Silt
	BB2	40	46.6912	73	53.3407	10.0	5.5	Mud	Black	Sulfur	130	2	12.8	0.0	1.4	83.2	15.4	0.008	6.97	-1.57	Fine Silt
	BB4	40	46.6269	73	53.1528	10.0	5.5	Mud	Black	Sulfur	120	0	11.5	14.6	47.5	34.3	3.6	0.151	2.73	-3.34	Fine Sand
	BB5	40	46.6228	73	53.2482	13.0	5.4	Mud	Black	Sulfur	120	0	12.0	12.8	40.2	43.2	3.8	0.089	3.49	-3.51	Very Fine Sand
	BB9	40	46.4839	73	53.2144	10.0	5.5	Mud	Black	Sulfur	130	0	12.3	7.8	43.5	42.0	6.7	0.087	3.52	-3.38	Very Fine Sand
	BB10	40	46.4605	73	53.3381	14.0	5.5	Mud	Black	Sulfur	100	0	13.3	7.7	42.5	29.2	20.6	0.044	4.51	-4.2	Coarse Silt

*Estimated; particle size data extrapolated for sizes finer than 0.075mm

** According to the Wentworth Classification

Table 6: Average Benthos Density (No./m^2) at each Project Site.

Phylum	Class	Order	Family	GenusSpecies	West Bank ATN	Gravesend Bay	Hoffman-Swinburne Islands	Verrazano-Narrows	Old Orchard Shoal	Raritan Bay Rock Berm	Raritan Bay Shellfish Bed	Bowery Bay
Annelida	Oligochaeta	---	---	---	3,610	682	1,462	1,902	298	439	1,462	4,386
	Polychaeta	---	---	---	487	49	0	13	781	0	0	3,167
		Archiannelida	Polygordiidae	Polygordius sp.	49	0	0	0	0	0	0	0
		Ariciida	Orbiniidae	---	0	0	63	0	0	0	0	0
				Haploscoloplos robustus	0	49	0	0	0	0	0	0
				Leitoscoloplos Fragilis	390	3,996	292	828	0	252	292	487
				Leitoscoloplos robustus	0	97	0	0	0	0	0	97
				Leitoscoloplos sp.	0	2,193	0	0	0	0	0	8,771
		Capitellida	Capitellidae	---	0	0	0	536	0	0	0	0
				Capitella sp.	251	195	13	780	97	582	3,128	11,549
			Maldanidae	Asychis elongata	5	2	0	0	0	0	0	0
		Cirratulida	---	---	2	0	0	0	0	0	0	0
			Cirratulidae	---	7	0	0	0	0	0	0	0
		Eunicida	Arabellidae	Arabella iricolor	0	0	0	0	2	0	0	0
			Onuphidae	Diopatra cuprea	0	0	2	49	0	0	0	0
		Phyllodocida	Glyceridae	Glycera sp.	1,097	933	17	439	662	84	393	2
			Goniadidae	---	195	0	0	0	0	0	0	0
			Nephtyidae	Nephtys sp.	684	487	532	0	439	390	13	0
			Nereidae	Nereid succinea	0	0	0	49	0	3	49	4
				Nereis sp.	50	0	7	49	18	8	97	0
				Nereis virens	0	0	0	0	2	0	0	0
			Phyllodocidae	---	0	49	0	0	0	0	0	0
				Eteone sp.	54	52	0	97	151	195	879	536
				Eumida Sanguinea	0	49	0	5	0	0	0	0
				Phyllodoce sp.	0	296	0	0	0	2	0	0
			Polynoidae	Harmothoe sp.	0	0	0	0	0	0	97	0
				Lepidametria commensalis	5	0	0	0	0	0	0	0
			Syllidae	---	146	0	0	49	2	0	0	0
		Spionida	Chaetopteriadae	---	49	49	0	2	2	0	0	0
			Paraonidae	---	6,586	21,598	1,227	4,776	150	3,990	5,896	0
				Paraonis sp.	585	0	0	0	0	0	0	0
			Sabellariidae	Sabellaria vulgaris	0	2	0	49	0	0	0	0
			Spionidae	Polydora ligni	195	0	0	0	0	0	0	828
				Streblospio benedicti	4,584	0	2	587	273	487	49	5,068
		Terebellida	---	---	0	0	0	49	0	0	0	0
			Pectinariidae	Pectinaria gouldii	2	152	0	253	4	7	99	0
				Pectinaria sp.	146	0	0	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda	---	---	0	49	0	0	0	2	0	0
			Ampeliscidae	Ampelisca abdita	1,664	244	49	440	2	167	31,833	0
				Ampelisca sp.	0	0	0	0	0	0	487	0
				Ampelisca Vadorum	7	0	0	0	0	0	0	0
				Byblis Serrata	0	0	0	0	0	49	0	0
			Ampithoidae	---	2	0	0	0	0	0	0	0
			Aoridae	Unciola irrorata	0	0	0	0	4	0	0	0
				Unciola sp.	52	0	0	49	60	0	0	0
			Caprellidae	Caprella penantis	2	0	0	0	3	0	0	0
			Corophiidae	---	0	0	0	0	8	0	0	0
				Corophium sp.	0	0	0	49	0	2	0	0
			Gammaridae	---	292	0	13	0	0	97	739	0
				Gammarus sp.	50	0	0	0	0	0	49	0
			Ischyroceridae	Jassa falcata	0	0	0	0	8	0	0	0
			Melitidae	---	0	0	0	0	2	0	0	0
				Melita netida	0	0	2	0	0	0	0	0
			Photidae	---	0	0	0	0	0	3	0	0
			Phoxocephalidae	---	60	0	0	49	50	0	0	0
				Paraphoxus sp	0	0	57	0	0	0	0	0
			Stenothoidae	---	0	0	0	0	2	0	0	0
		Decapoda	Cancridae	Cancer irroratus	2	0	2	0	2	0	0	0
			Crangonidae	Crangon septemspinosa	5	0	0	0	0	0	0	0
			Magidae	Libinia emarginata	0	0	8	0	0	0	0	0
			Paguridae	Pagurus sp.	3	0	2	0	5	50	0	0
			Portunidae	Ovalipes ocellatus	2	0	0	0	0	2	0	0
			Xanthidae	Panopeus herbstii	5	0	3	0	22	15	2	0
				Rhithropanopeus harrisii	0	0	0	0	5	0	0	0
		Isopoda	Anthuridae	Cyathura polita	341	0	0	0	2	0	0	0
		Ostracoda	---	---	0	0	0	0	0	0	195	0
Mollusca	Bivalvia	Eudesmodontida	Pandoridae	Pandora Gouldiana	54	97	0	2	621	0	0	0
		Myoida	Myidae	Mya arenaria	244	780	191	585	309	146	0	0
		Mytioida	Mytilidae	Mytilus edulis	1,124	2	88	2	2	0	0	0
		Nuculoida	Nuculanidae	Nucula sp.	1,413	146	0	0	0	0	0	0
		Ostreoida	Anomiidae	Anomia sp.	2	0	0	0	2	0	0	0
		Veneroida	Astartidae	Astarte sp.	247	148	0	5	3	0	0	0
			Mactridae	Mulinia lateralis	2,743	6,335	546	4,460	1,754	2	0	97
				Spisula Solidissima	2	0	2	0	0	0	0	0
			Solenidae	Ensis directus	0	0	0	0	2	0	0	0
			Tellinidae	Tellina agilis	244	0	0	0	0	0	0	0
			Veneridae	Mercenaria mercenaria	52	7	3	536	106	42	55	0
	Gastropoda	---	---	---	0	49	0	0	0	0	0	0
		Archaeogastropoda	Naticidae	Neverita Duplicata	49	0	2	2	0	0	0	0
		Cephalaspidea	---	---	0	1,559	0	0	0	0	0	97
			Acteonidae	Rictaxis puntcostriatus	0	244	0	0	0	0	0	0
			Scaphandridae	Acteocina canaliculata	877	4,288	0	195	0	49	0	0
		Mesogastropoda	Calyptraeidae	Crepidula fornicata	57	0	130	884	518	315	2	0
				Crepidula plana	0	0	7	0	167	0	0	0
			Rissoidae	---	0	49	0	0	0	0	0	0
		Neogastropoda	Melongenidae	Busycon carica	49	0	0	0	0	0	0	0
			Muricidae	Eupleura caudata	0	0	0	0	2	0	0	0
				Urosalpinx cinereus	0	0	0	0	5	0	0	0
			Nassariidae	Ilyanassa obsoleta	0	0	0	0	0	0	0	7
				Ilyanassa trivittata	52	0	57	49	12	244	0	0
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius parma	0	49	0	0	0	0	0	0
Nematoda	---	---	---	---	390	2	0	49	0	3	536	0
Nemertea	---	---	---	---	0	0	0	0	2	49	0	0

Table 7: Benthic Abundance (Number of Taxa and Individuals) at the Project Sites

Site	Sampling Station	Number of Taxa								Number of Individuals							
		Annelida		Arthropoda		Mollusca		Misc.		Annelida		Arthropoda		Mollusca		Misc.	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
West Bank ATN	WB4	9	69%	2	15%	2	15%	0	0%	21,052	97%	303	1%	303	1%	0	0%
	WB5	6	43%	4	29%	4	29%	0	0%	13,871	62%	920	4%	7,696	34%	0	0%
	WB7	8	47%	5	29%	3	18%	1	6%	36,840	75%	8,782	18%	909	2%	2,339	5%
	WB8	7	37%	8	42%	4	21%	0	0%	1,160	67%	200	12%	370	21%	0	0%
	WB9	7	50%	1	7%	6	43%	0	0%	4,407	18%	292	1%	20,196	81%	0	0%
	WB10	6	38%	2	13%	8	50%	0	0%	37,739	67%	4,429	8%	13,774	25%	0	0%
	Overall	18	38%	13	28%	15	32%	1	2%	19,178	66%	2,488	9%	7,208	25%	390	1%
Gravesend Bay	GB4	8	57%	1	7%	5	36%	0	0%	45,947	79%	292	0%	12,291	21%	0	0%
	GB5	8	53%	0	0%	6	40%	1	7%	11,813	54%	0	0%	9,952	46%	11	0%
	GB6	6	46%	1	8%	6	46%	0	0%	69,879	83%	292	0%	14,045	17%	0	0%
	GB7	10	67%	1	7%	4	27%	0	0%	13,763	71%	877	5%	4,689	24%	0	0%
	GB8	6	46%	1	8%	6	46%	0	0%	18,149	49%	292	1%	18,442	50%	0	0%
	GB10	5	63%	0	0%	2	25%	1	13%	26,022	53%	0	0%	22,806	46%	292	1%
	Overall	15	54%	1	4%	10	36%	2	7%	30,929	69%	292	1%	13,704	30%	51	0%
Hoffman-Swinburne Islands	HSI3	0	0%	0	0%	1	100%	0	0%	0	0%	0	0%	292	100%	0	0%
	HSI4	3	50%	1	17%	2	33%	0	0%	5,555	63%	292	3%	2,935	33%	0	0%
	HSI5	3	100%	0	0%	0	0%	0	0%	1,765	100%	0	0%	0	0%	0	0%
	HSI6	5	38%	3	23%	5	38%	0	0%	230	23%	30	3%	750	74%	0	0%
	HSI7	5	36%	4	29%	5	36%	0	0%	700	32%	480	22%	1,000	46%	0	0%
	HSI8	4	50%	1	13%	3	38%	0	0%	13,450	92%	11	0%	1,180	8%	0	0%
	Overall	9	35%	8	31%	9	35%	0	0%	3,617	76%	136	3%	1,026	21%	0	0%
Verrazano-Narrows	VN1	6	67%	1	11%	2	22%	0	0%	9,670	97%	11	0%	303	3%	0	0%
	VN2	4	57%	0	0%	3	43%	0	0%	3,562	50%	0	0%	3,573	50%	0	0%
	VN4	4	44%	1	11%	3	33%	1	11%	25,252	96%	292	1%	346	1%	292	1%
	VN5	6	50%	3	25%	3	25%	0	0%	4,093	25%	1,170	7%	11,403	68%	0	0%
	VN6	5	50%	1	10%	4	40%	0	0%	15,204	69%	585	3%	6,194	28%	0	0%
	VN9	4	57%	1	14%	2	29%	0	0%	5,274	21%	1,462	6%	18,495	73%	0	0%
	Overall	14	48%	4	14%	10	34%	1	3%	10,509	59%	587	3%	6,719	38%	49	0%
Old Orchard Shoal	OOS1	10	48%	2	10%	8	38%	1	5%	5,142	70%	43	1%	2,165	29%	11	0%
	OOS2	2	40%	0	0%	3	60%	0	0%	5,566	69%	0	0%	2,487	31%	0	0%
	OOS3	1	9%	3	27%	7	64%	0	0%	1,754	12%	32	0%	12,591	88%	0	0%
	OOS4	5	45%	2	18%	4	36%	0	0%	4,407	59%	303	4%	2,763	37%	0	0%
	OOS5	4	24%	5	29%	8	47%	0	0%	220	18%	100	8%	920	74%	0	0%
	OOS6	3	21%	8	57%	3	21%	0	0%	190	22%	570	67%	90	11%	0	0%
	Overall	12	31%	13	33%	13	33%	1	3%	2,880	44%	175	3%	3,503	53%	2	0%
Raritan Bay Rock Berm	RBRB1	4	44%	2	22%	3	33%	0	0%	520	28%	50	3%	1,300	70%	0	0%
	RBRB2	5	50%	2	20%	3	30%	0	0%	570	33%	70	4%	1,100	63%	0	0%
	RBRB3	5	63%	2	25%	1	13%	0	0%	30,115	97%	877	3%	11	0%	0	0%
	RBRB4	4	40%	3	30%	2	20%	1	10%	990	48%	1,020	50%	30	1%	20	1%
	RBRB5	4	50%	1	13%	2	25%	1	13%	4,386	83%	11	0%	585	11%	292	6%
	RBRB6	3	50%	1	17%	2	33%	0	0%	2,047	50%	292	7%	1,754	43%	0	0%
	Overall	12	43%	8	29%	6	21%	2	7%	6,438	84%	387	5%	797	10%	52	1%
Raritan Bay Shellfish Bed	RBSB1	6	67%	2	22%	0	0%	1	11%	11,111	39%	16,958	59%	0	0%	585	2%
	RBSB2	6	67%	2	22%	1	11%	0	0%	24,560	51%	23,391	48%	292	1%	0	0%
	RBSB3	6	67%	2	22%	0	0%	1	11%	22,806	16%	116,368	83%	0	0%	1,170	1%
	RBSB4	5	50%	3	30%	2	20%	0	0%	1,050	85%	130	11%	50	4%	0	0%
	RBSB5	8	80%	1	10%	0	0%	1	10%	7,310	14%	42,395	83%	0	0%	1,462	3%
	RBSB6	5	83%	1	17%	0	0%	0	0%	7,894	93%	585	7%	0	0%	0	0%
	Overall	12	63%	4	21%	2	11%	1	5%	12,455	27%	33,305	72%	57	0%	536	1%
Bowery Bay	BB1	2	50%	0	0%	2	50%	0	0%	2,350	67%	0	0%	1,170	33%	0	0%
	BB2	6	100%	0	0%	0	0%	0	0%	23,098	100%	0	0%	0	0%	0	0%
	BB4	4	100%	0	0%	0	0%	0	0%	63,739	100%	0	0%	0	0%	0	0%
	BB5	6	86%	0	0%	1	14%	0	0%	70,183	100%	0	0%	32	0%	0	0%
	BB9	5	83%	0	0%	1	17%	0	0%	48,536	100%	0	0%	11	0%	0	0%
	BB10	1	100%	0	0%	0	0%	0	0%	1,473	100%	0	0%	0	0%	0	0%
	Overall	9	75%	0	0%	3	25%	0	0%	34,896	99%	0	0%	202	1%	0	0%

Table 8: Benthic Assemblage at the Project Sites

Site	Sampling Station	Species Richness (No. of taxa)	Mean Density (No. of individuals/m^2)	Diversity H'	Evenness E	Abundance of Pollution-Tolerant Taxa (%)	Abundance of Pollution-Sensitive Taxa (%)
West Bank ATN	WB4	13	21,658	2.98	0.80	14%	14%
	WB5	14	22,487	2.82	0.74	14%	14%
	WB7	17	48,871	2.67	0.65	24%	6%
	WB8	19	1,730	2.41	0.57	5%	5%
	WB9	14	24,895	2.59	0.68	14%	14%
	WB10	16	55,942	2.21	0.55	13%	19%
	Overall	47	29,264	3.84	0.69	8%	12%
Gravesend Bay	GB4	14	58,530	2.12	0.56	13%	13%
	GB5	15	21,776	2.84	0.73	7%	13%
	GB6	13	84,217	1.81	0.49	7%	21%
	GB7	15	19,329	2.67	0.68	12%	18%
	GB8	13	36,883	2.88	0.78	14%	21%
	GB10	8	49,120	2.32	0.77	20%	10%
	Overall	28	44,976	2.70	0.56	9%	9%
Hoffman-Swinburne Islands	HSI3	1	292	0.00	1.00	0%	0%
	HSI4	6	8,782	1.72	0.67	33%	0%
	HSI5	3	1,765	0.70	0.44	0%	0%
	HSI6	13	1,010	2.36	0.64	8%	23%
	HSI7	14	2,180	3.01	0.79	7%	7%
	HSI8	8	14,641	1.91	0.64	25%	25%
	Overall	26	4,778	2.88	0.61	15%	15%
Verrazano-Narrows	VN1	9	9,984	2.19	0.69	33%	11%
	VN2	7	7,135	1.57	0.56	14%	0%
	VN4	9	26,183	0.74	0.23	10%	10%
	VN5	12	16,666	2.91	0.81	0%	23%
	VN6	10	21,982	2.47	0.74	20%	10%
	VN9	7	25,231	1.48	0.53	43%	14%
	Overall	29	17,864	3.33	0.69	12%	12%
Old Orchard Shoal	OOS1	21	7,361	3.19	0.73	9%	9%
	OOS2	5	8,053	1.77	0.76	17%	17%
	OOS3	11	14,378	1.70	0.49	0%	27%
	OOS4	11	7,474	2.50	0.72	18%	18%
	OOS5	17	1,240	2.51	0.61	6%	18%
	OOS6	14	850	2.89	0.76	7%	7%
	Overall	39	6,559	3.55	0.67	7%	10%
Raritan Bay Rock Berm	RBRB1	9	1,870	1.57	0.49	20%	10%
	RBRB2	10	1,740	2.51	0.76	10%	20%
	RBRB3	8	31,003	1.35	0.45	38%	25%
	RBRB4	10	2,060	1.85	0.56	10%	20%
	RBRB5	8	5,274	2.39	0.80	38%	13%
	RBRB6	6	4,093	2.26	0.88	17%	17%
	Overall	28	7,673	2.80	0.58	14%	14%
Raritan Bay Shellfish Bed	RBSB1	9	28,654	2.26	0.71	33%	0%
	RBSB2	9	48,243	1.90	0.60	22%	11%
	RBSB3	9	140,344	1.09	0.34	22%	0%
	RBSB4	10	1,230	1.47	0.44	10%	10%
	RBSB5	10	51,167	1.43	0.43	36%	0%
	RBSB6	6	8,479	1.95	0.76	50%	0%
	Overall	19	46,353	1.76	0.41	19%	5%
Bowery Bay	BB1	4	3,519	1.28	0.64	25%	0%
	BB2	6	23,098	1.77	0.69	50%	0%
	BB4	4	63,739	0.90	0.45	50%	0%
	BB5	7	70,215	1.51	0.54	38%	0%
	BB9	6	48,546	1.70	0.66	67%	0%
	BB10	1	1,473	0.06	1.00	0%	0%
	Overall	12	35,098	2.50	0.70	29%	0%

<u>Table 9:</u> National Wetlands Inventory Mapping Code Description for Cheesequake and Woodbridge Creeks

Tidal Creek	Code	Wetland Habitat Description & Classification
Cheesequake Creek (Reference Site)	E1OW	[E] Estuarine, [1] Subtidal, [OW] Open Water/Unknown Bottom (obs)
	E2BB	[E] Estuarine, [2] Intertidal, [BB] Beach/Bar (obs)
	E2EM	[E] Estuarine, [2] Intertidal, [EM] Emergent
	E2FL	[E] Estuarine, [2] Intertidal, [FL] Flat (obs)
	E2SS1/EM	[E] Estuarine, [2] Intertidal, [SS] Scrub-Shrub, [1] Broad-Leaved Deciduous / , [EM] Emergent
	PEM	[P] Palustrine, [EM] Emergent
	PFL	[P] Palustrine, [FL] Flat (obs)
	PFO/SS1	[P] Palustrine, [FO] Forested / , [SS] Scrub-Shrub, [1] Broad-Leaved Deciduous
	PFO1	[P] Palustrine, [FO] Forested, [1] Broad-Leaved Deciduous
	PFO4	[P] Palustrine, [FO] Forested, [4] Needle-Leaved Evergreen
	POW	[P] Palustrine, [OW] Open Water/Unknown Bottom (obs)
	PSS1	[P] Palustrine, [SS] Scrub-Shrub, [1] Broad-Leaved Deciduous
	PSS1/EM	[P] Palustrine, [SS] Scrub-Shrub, [1] Broad-Leaved Deciduous / , [EM] Emergent
	U	[U] Upland
Woodbridge Creek (Enhancement Site)	E1OW	[E] Estuarine, [1] Subtidal, [OW] Open Water/Unknown Bottom (obs)
	E2EM	[E] Estuarine, [2] Intertidal, [EM] Emergent
	E2FL	[E] Estuarine, [2] Intertidal, [FL] Flat (obs)
	E2SS1/EM	[E] Estuarine, [2] Intertidal, [SS] Scrub-Shrub, [1] Broad-Leaved Deciduous / , [EM] Emergent
	PEM	[P] Palustrine, [EM] Emergent
	PFO1	[P] Palustrine, [FO] Forested, [1] Broad-Leaved Deciduous
	POW	[P] Palustrine, [OW] Open Water/Unknown Bottom (obs)
	PSS1/EM	[P] Palustrine, [SS] Scrub-Shrub, [1] Broad-Leaved Deciduous / , [EM] Emergent
	U	[U] Upland
Source: National Wetland Inventory (NWI). US Fish and Wildlife Services (USFWS). http://www.nwi.fws.gov/atx/atx.html		

<u>Table 11</u>: Tidal Creek Enhancement Strategies.

Method	Stream Characteristic	Restoration Potential	Habitat Benefits	Water Quality Benefits
Modify stream substrate	Channel Characteristics	Good (4)	Good.	Small
Replace hardened shore with natural shore.	Channel Characteristics	Good (4)	Good	fair
Improve shoreline edge through regrading and bioengineering	Hydrologic Alteration	Good (4)	Good. Can improve flooding of stream bank and riparian zone	Fair
Remove invasive species within riparian zone and replace with native species	Riparian zone	High (5+)	Fair	Negligible
Create riparian wetlands adjacent to stream channel	Riparian zone	High (5+)	Good	Good
Enhance upstream wildlife preserve (headwaters of Woodbridge Creek)	Riparian zone	High (5+)	Good	Good
Stabilize banks through vegetation and revetments	Bank stability	Fair (3)	Fair to good aquatic habitat benefits.	Fair
Remove debris and remnant structures	Water quality, (water appearance)	Good (4)	Fair	Fair (improves appearance)
Add structure to provide cover	Instream fish cover	Low (0.5)	Good aquatic habitat	Good

Table 12: Tidal Creek Restoration Strategies.

Method	Stream Characteristic	Restoration Potential	Habitat Benefits	Water Quality Benefits
Replace channel meanders	Channel Conditions	Good (4)	Good.	Good
Increase riparian zone and floodplain through acquisitions and easements	Riparian zone	Good (5+)	Excellent	Good
Create wetland biofilters to treat stormwater from culverts	Water quality	Good (4)	Fair to good aquatic habitat benefits.	Good
Improve water quality using best management practices within the watershed.	Water quality, (water appearance)	Good (4)	Poor	Good
Add instream fish cover	Instream fish cover	Low (0.5)	Good aquatic habitat	Good

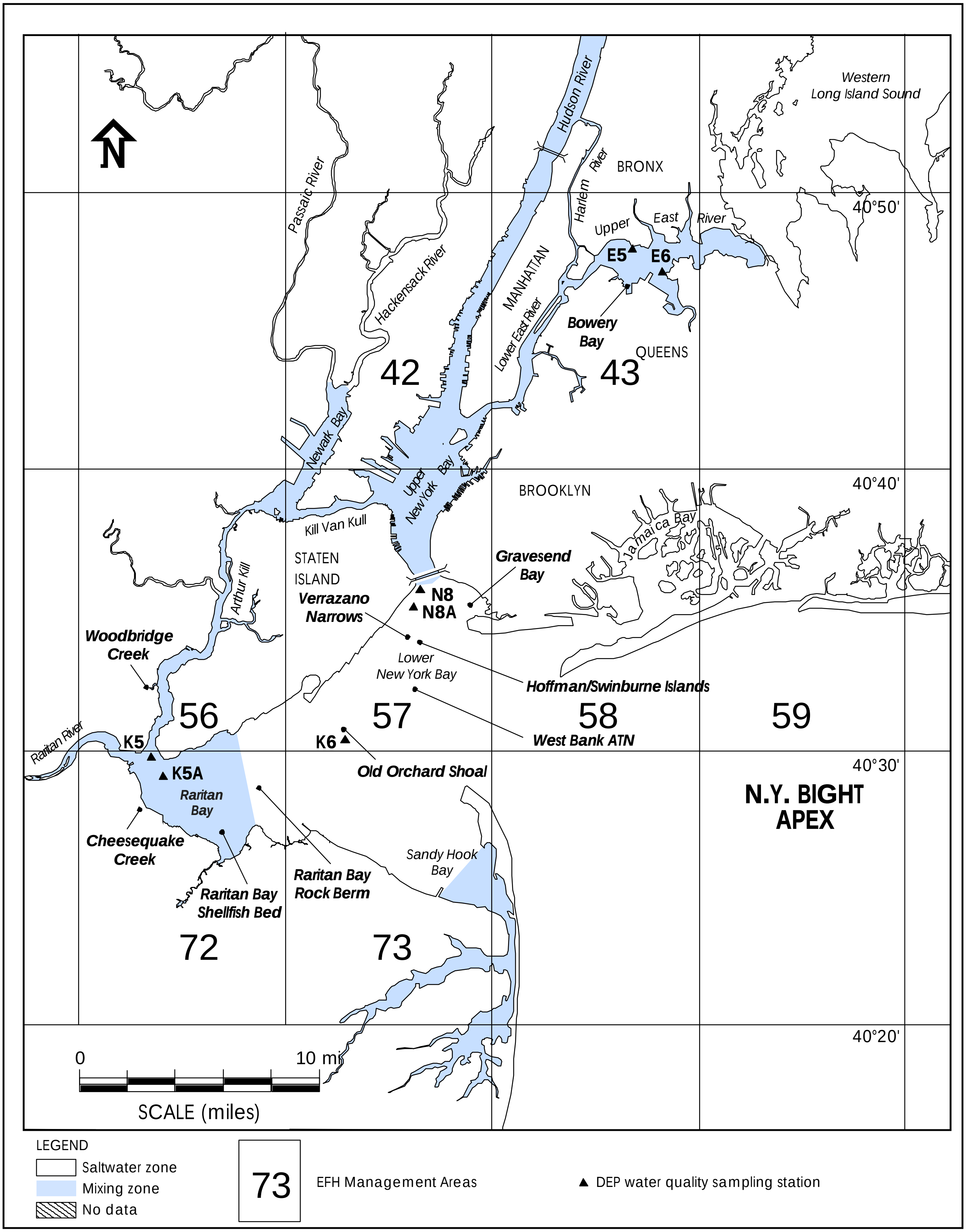


Figure 1. General Site Locations

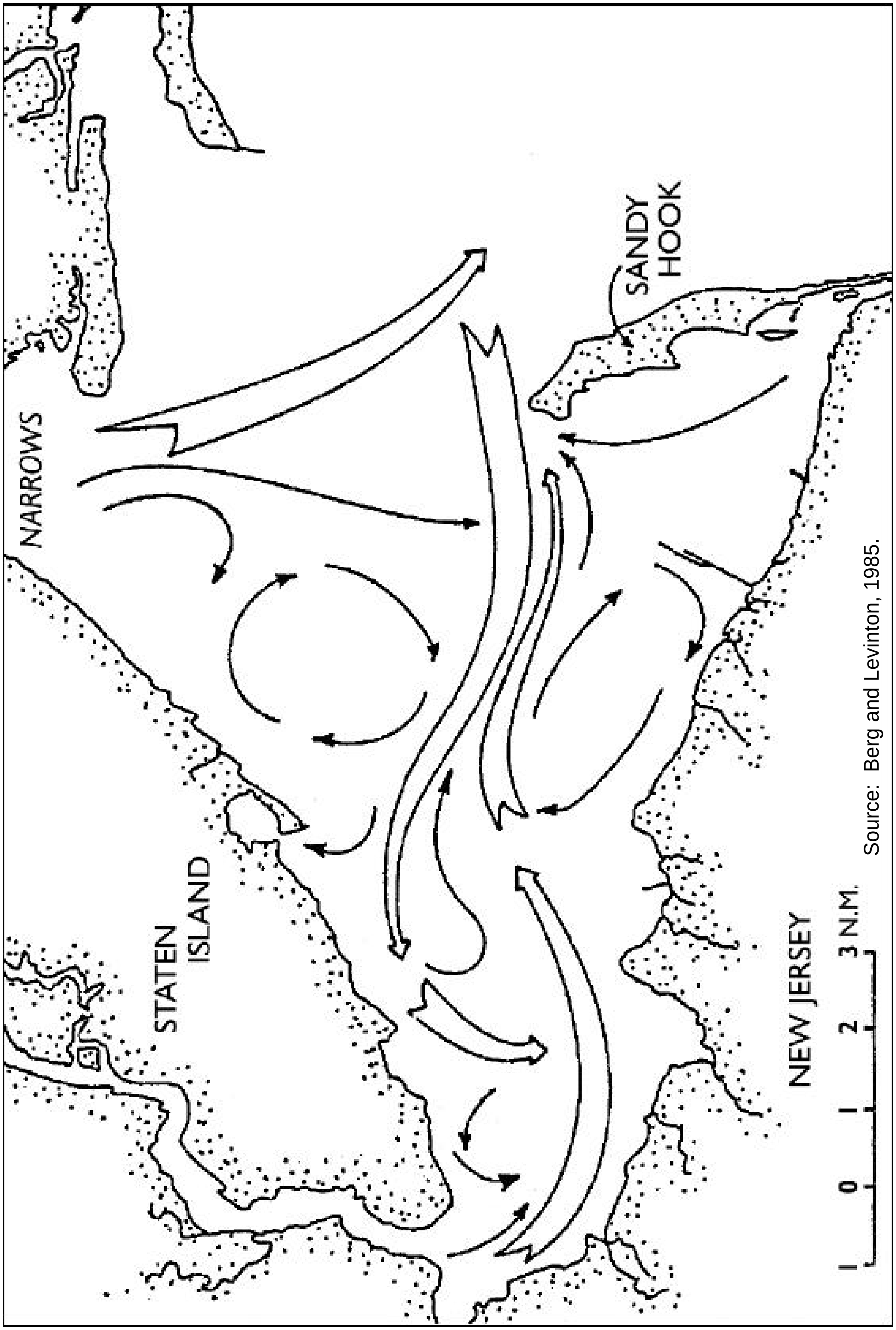
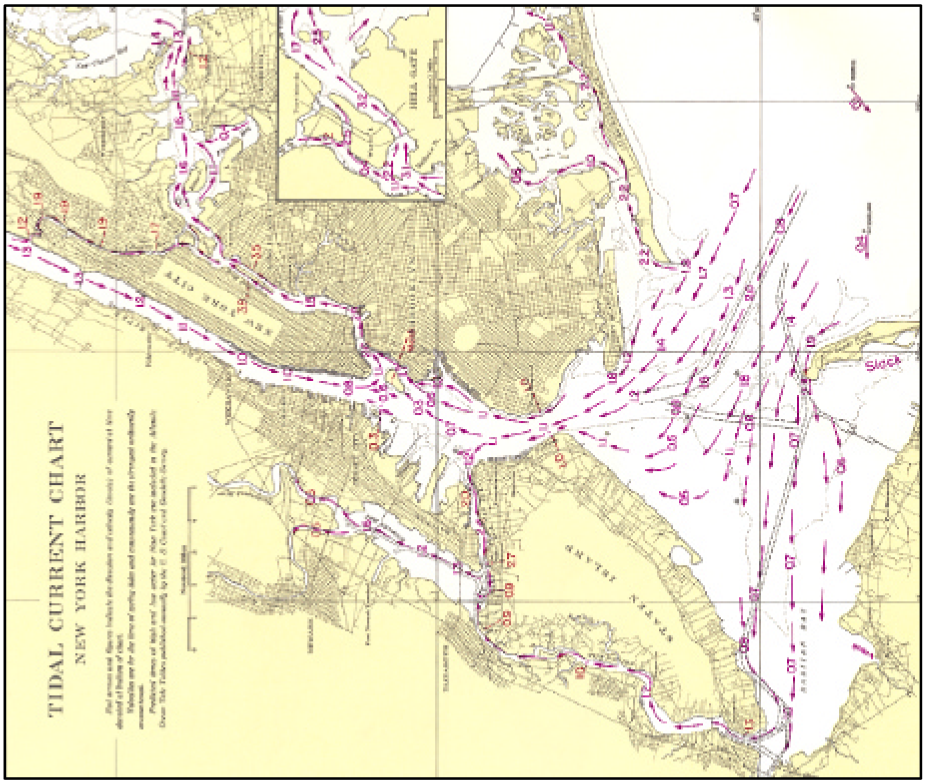
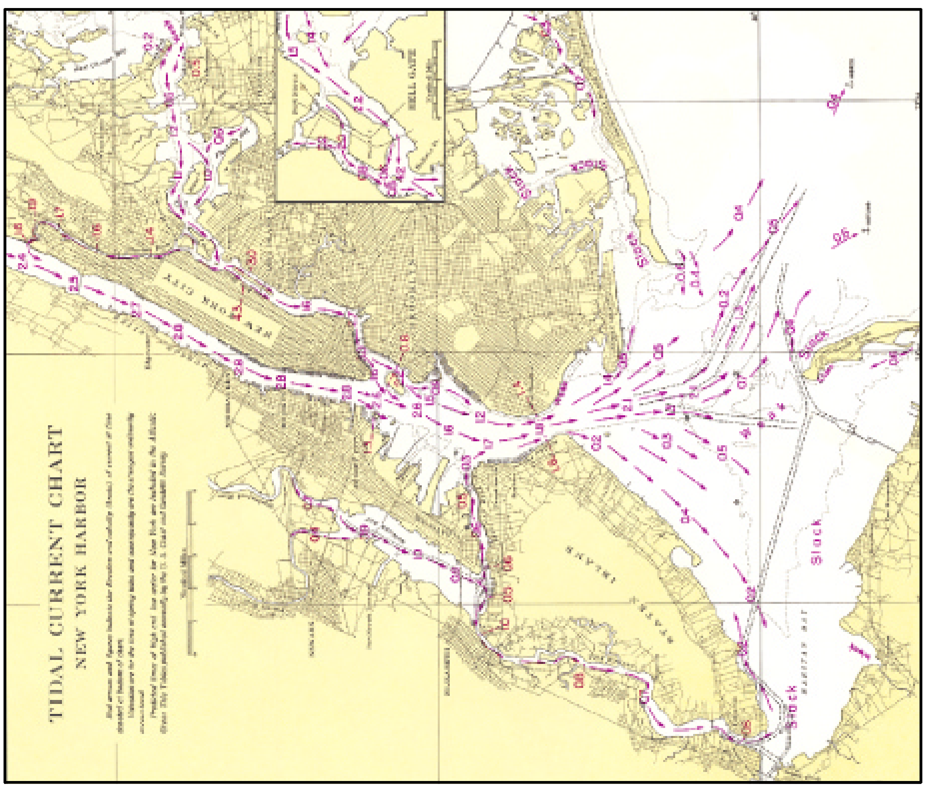


Figure 2. Net current flow in the Lower Bay Complex (Source: Berg and Levinton, 1985).

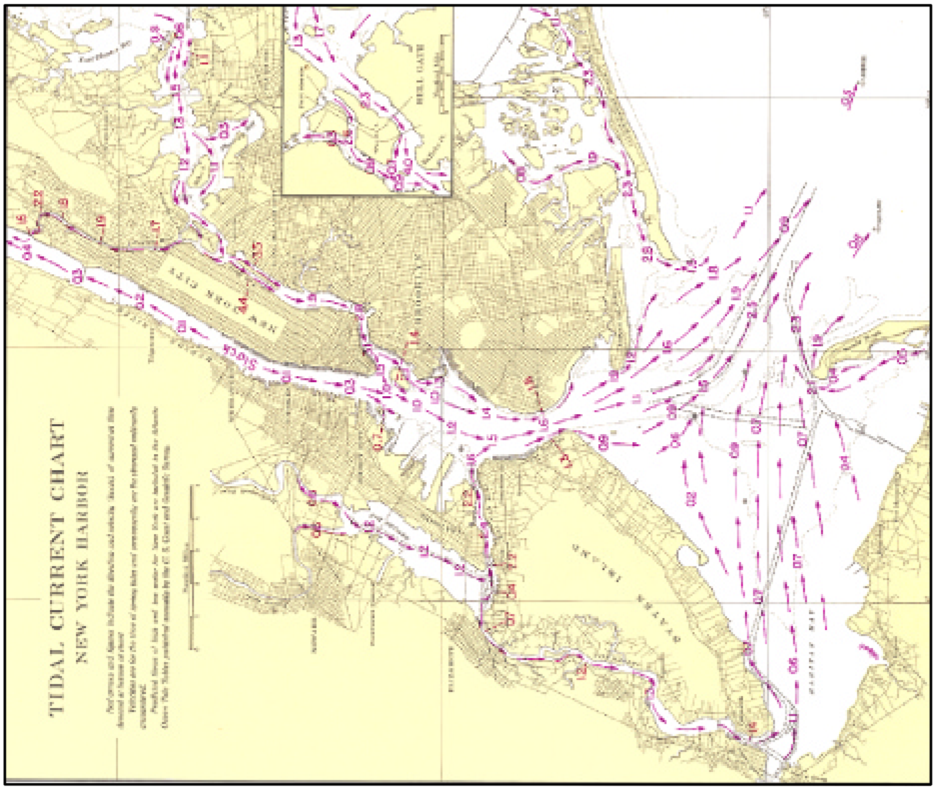


Tidal Currents 3 hrs After Low Water

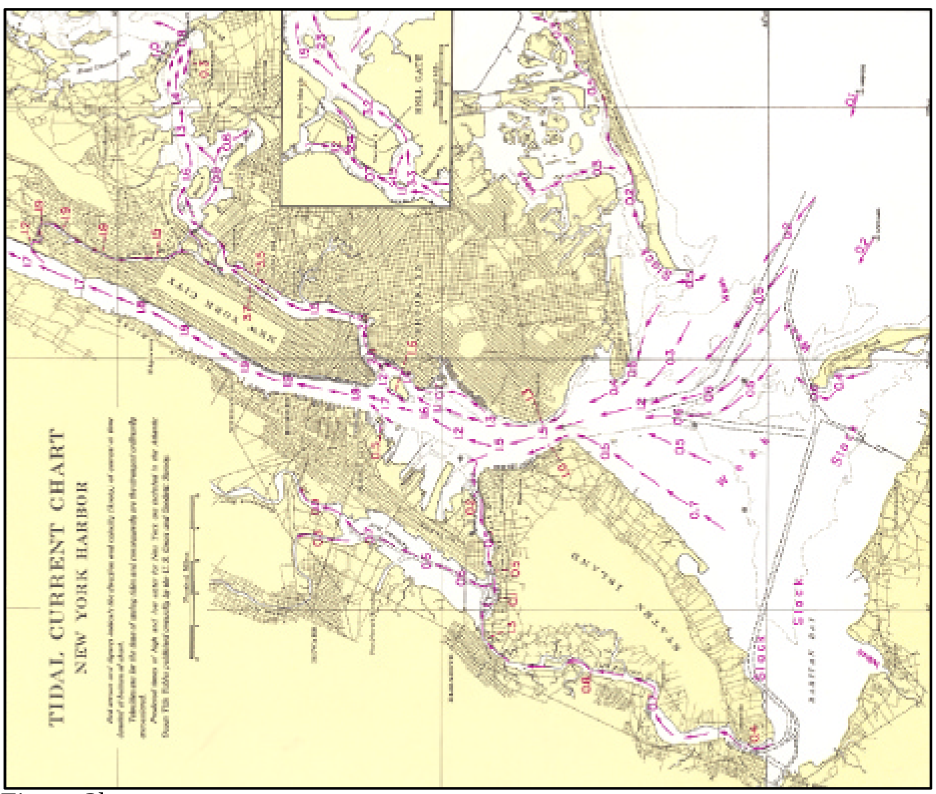


Tidal Currents Low Water

Figure 3a
NOAA Tidal Current Chart in the NY/NJ Harbor (Source: U.S. Dept. of Commerce, 1956)



Tidal Currents 3 hrs After High Water



Tidal Currents High Water

Figure 3b
NOAA Tidal Current Chart in the NY/NJ Harbor (Source: U.S. Dept. of Commerce, 1956)

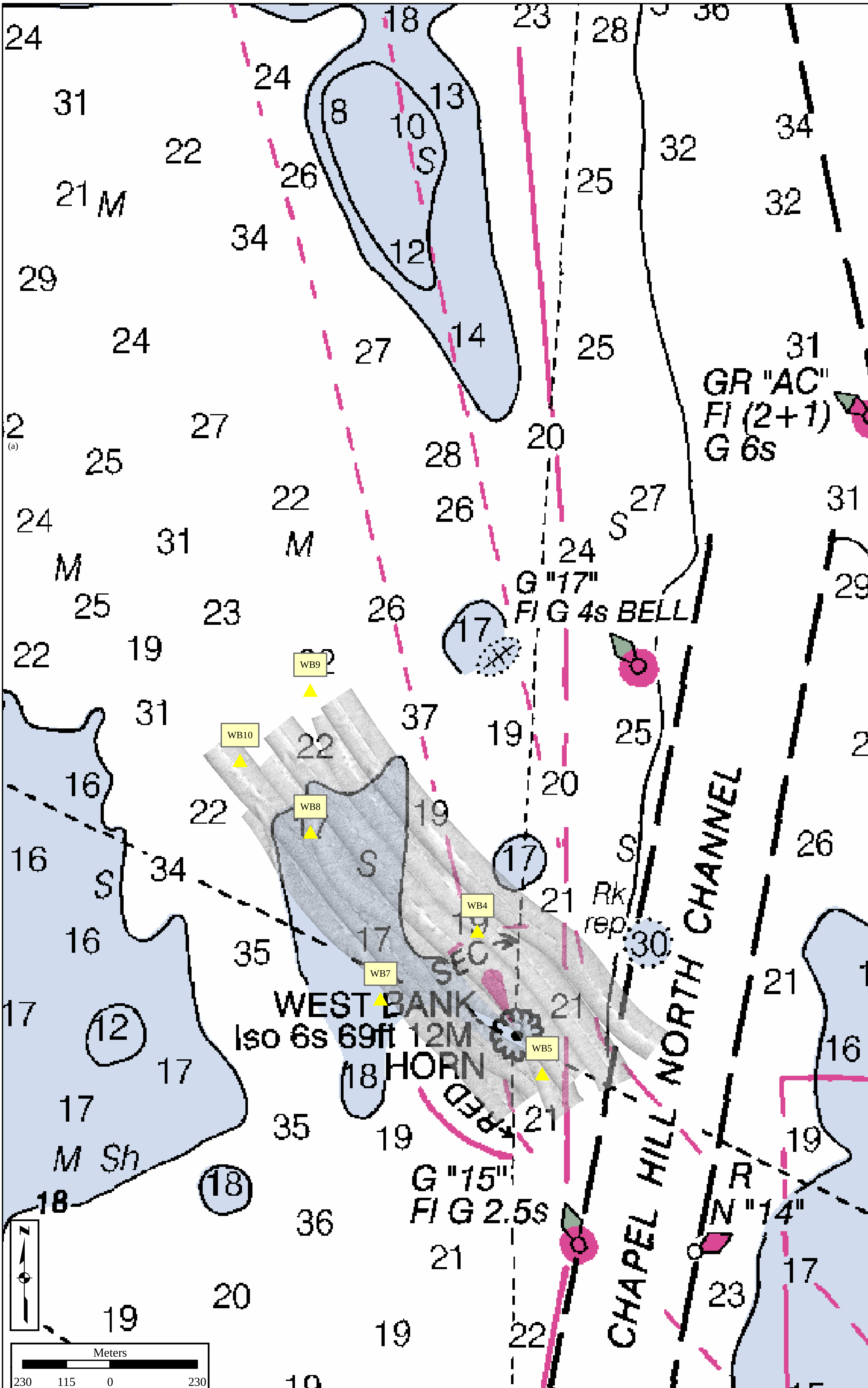


Figure 4. General Area of West Bank ATN Site.
Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.

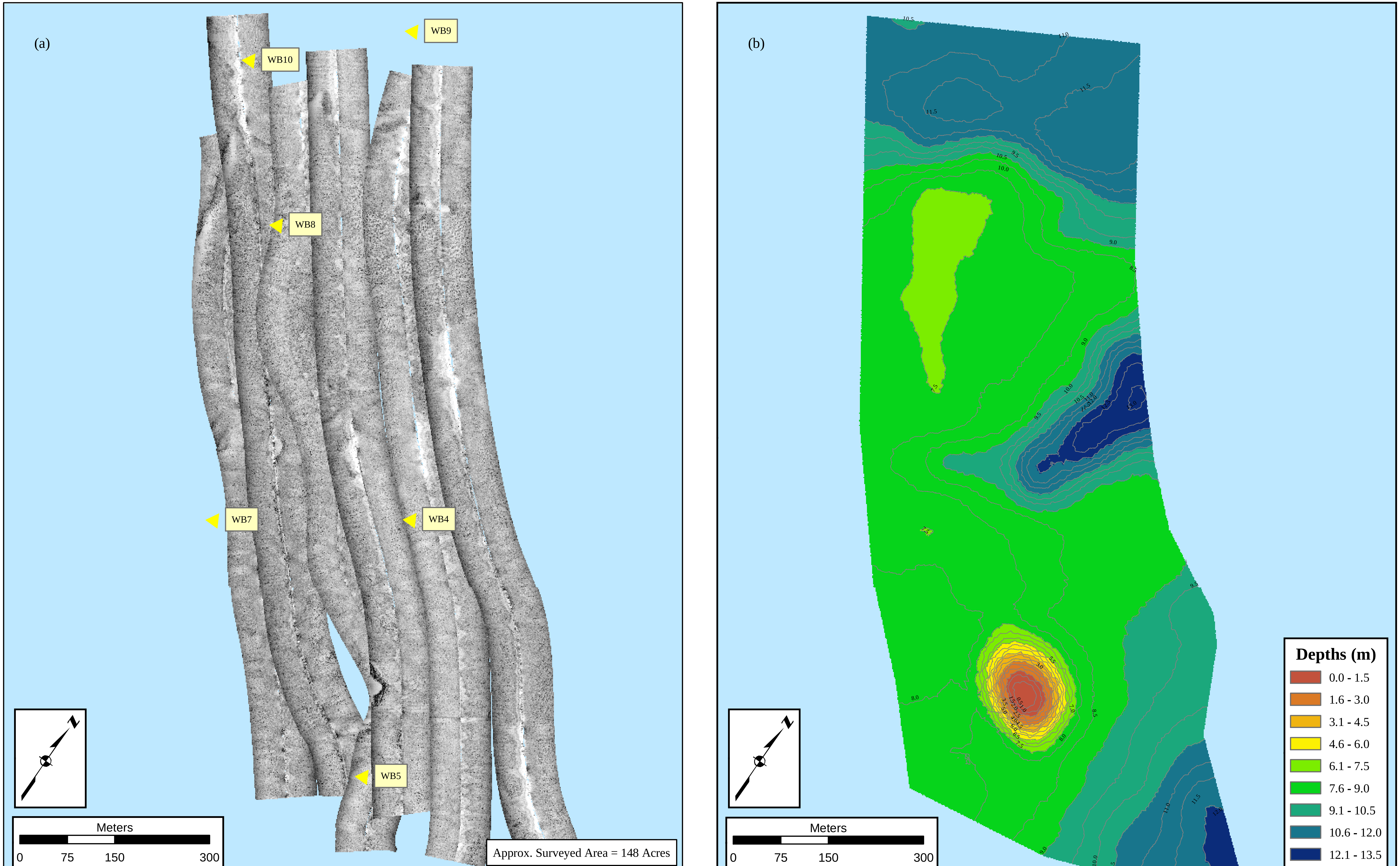


Figure 5. Side-Scan Sonar and Bathymetry data at the West Bank ATN SIte. Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.
Projection: UTM Zone 18N, NAD 1983, Meters.

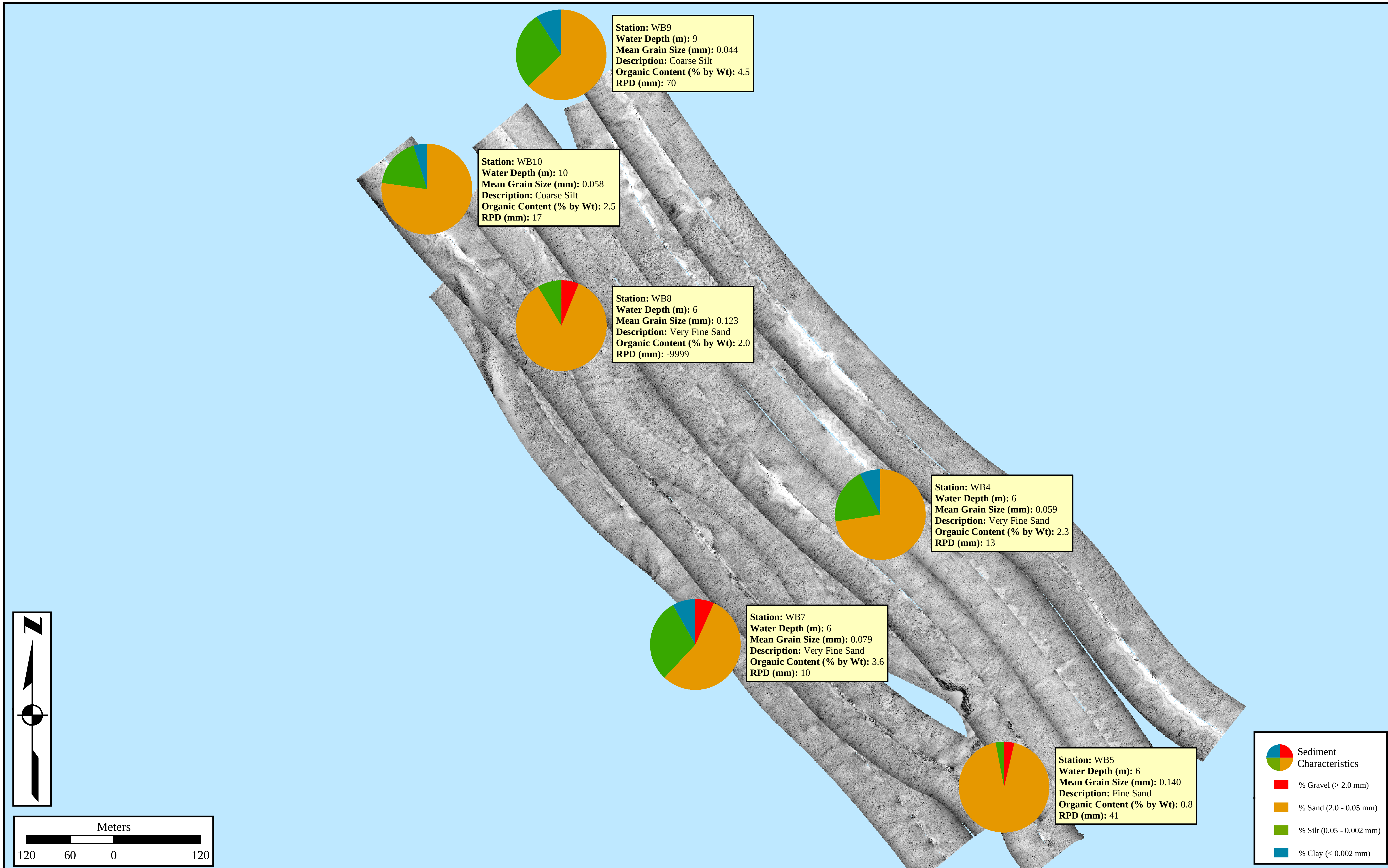


Figure 6. Sediment Characteristics at the West Bank ATN Site.

**Value of -9999 implies "No Possible Measurement"*

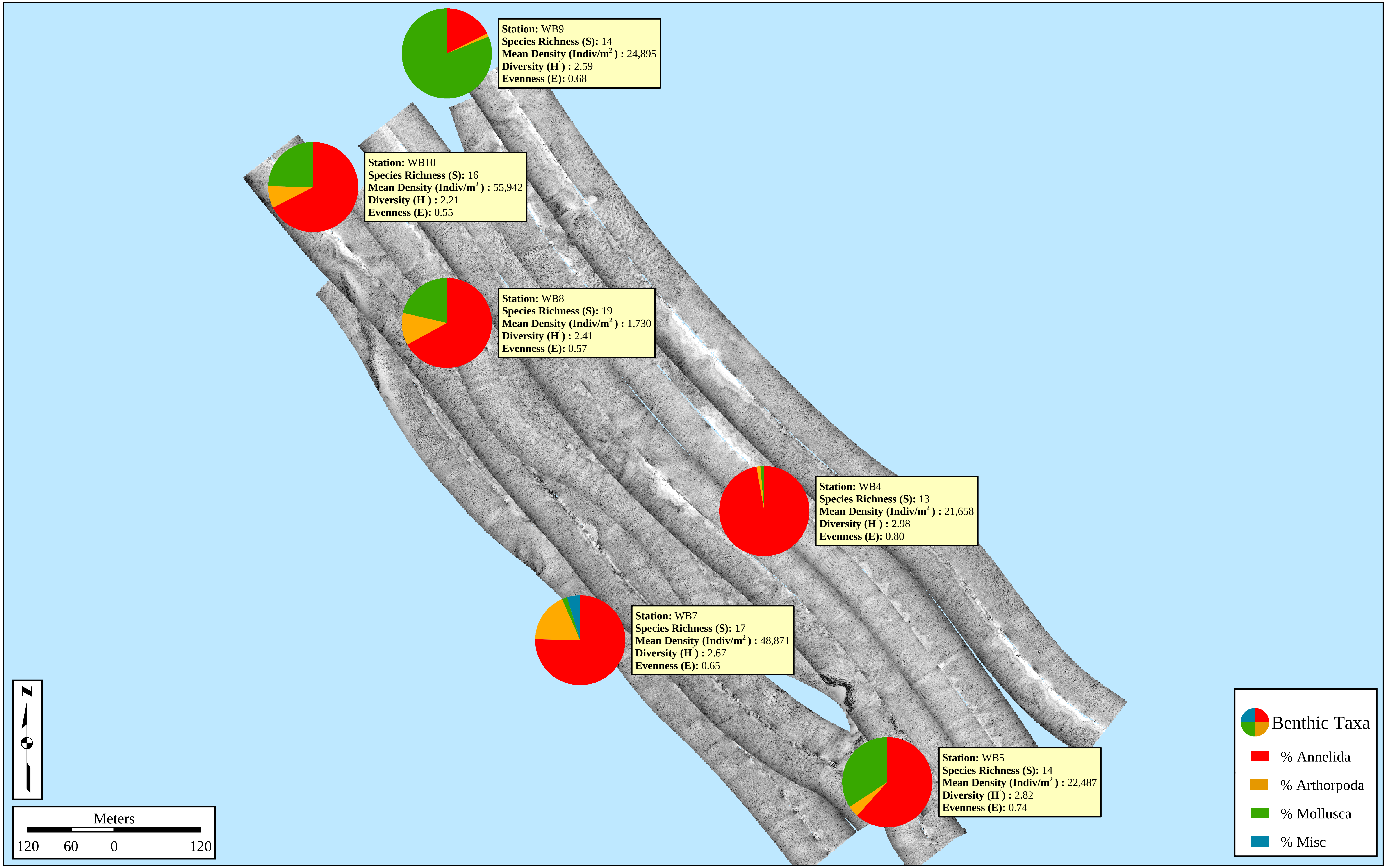


Figure 7. Benthic Characteristics at the West Bank ATN Site.

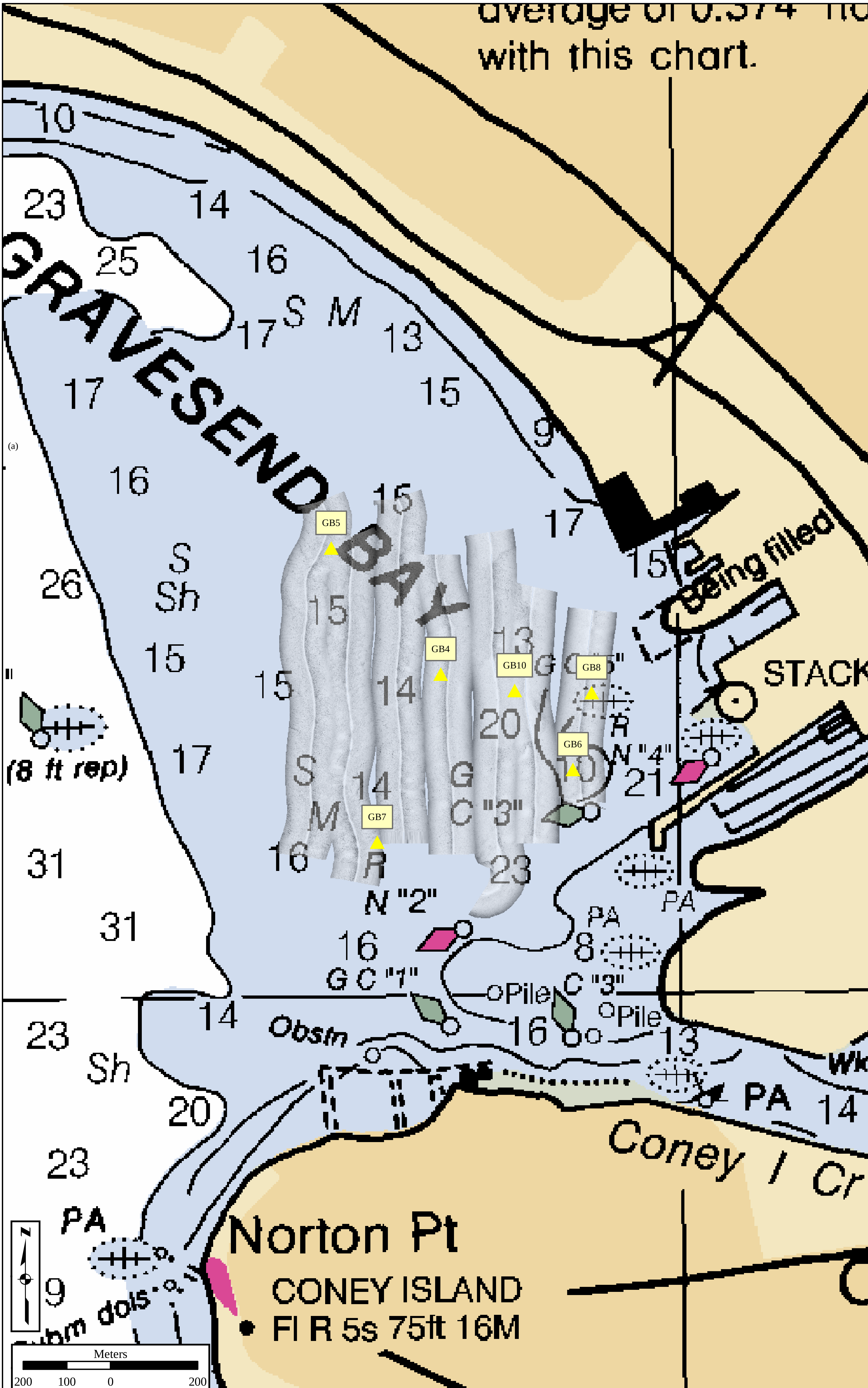


Figure 8. General Area of the Gravesend Bay.
Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.

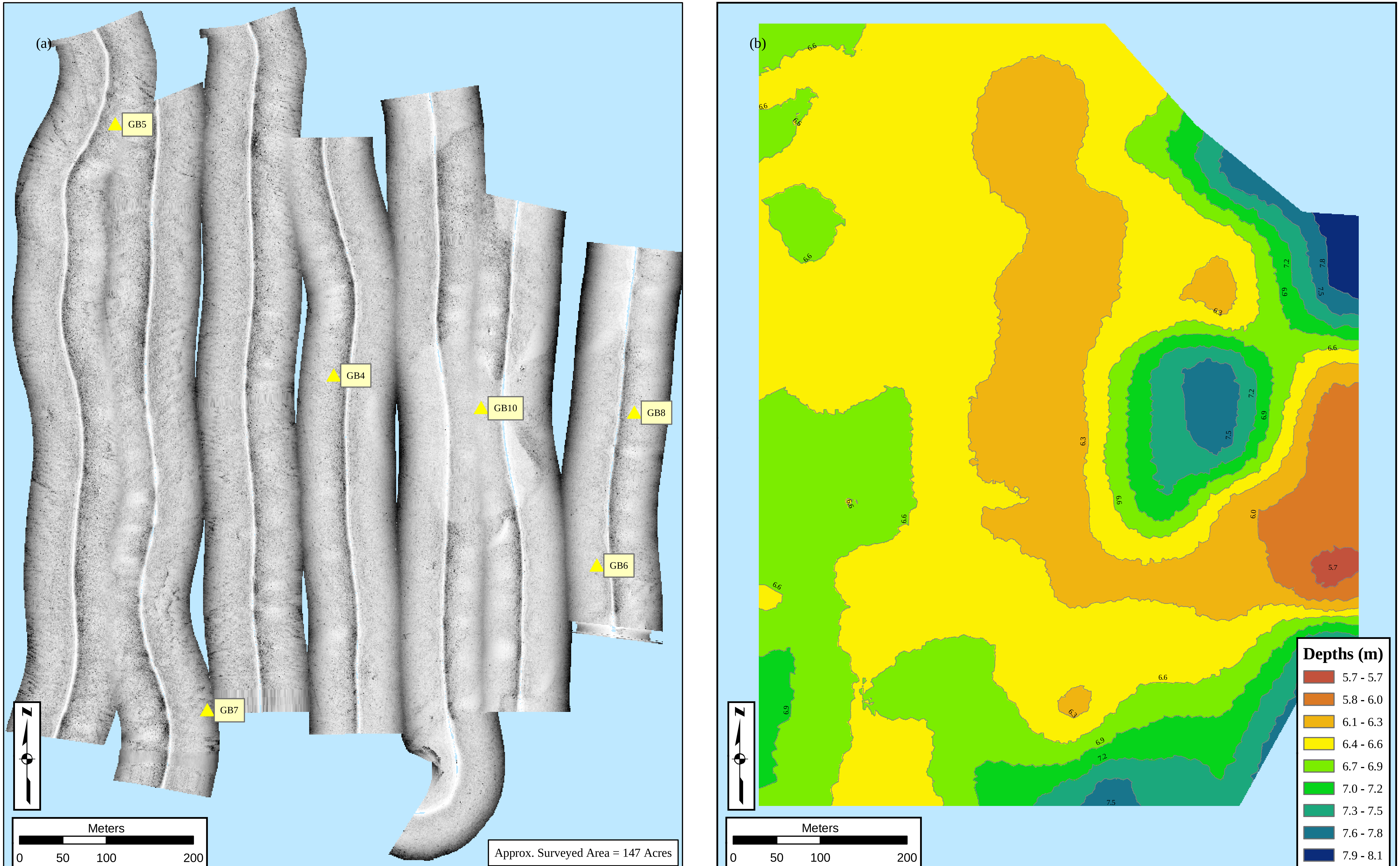


Figure 9. Side-Scan Sonar and Bathymetry data at the Gravesend Bay Site. Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.
Projection: UTM Zone 18N, NAD 1983, Meters.

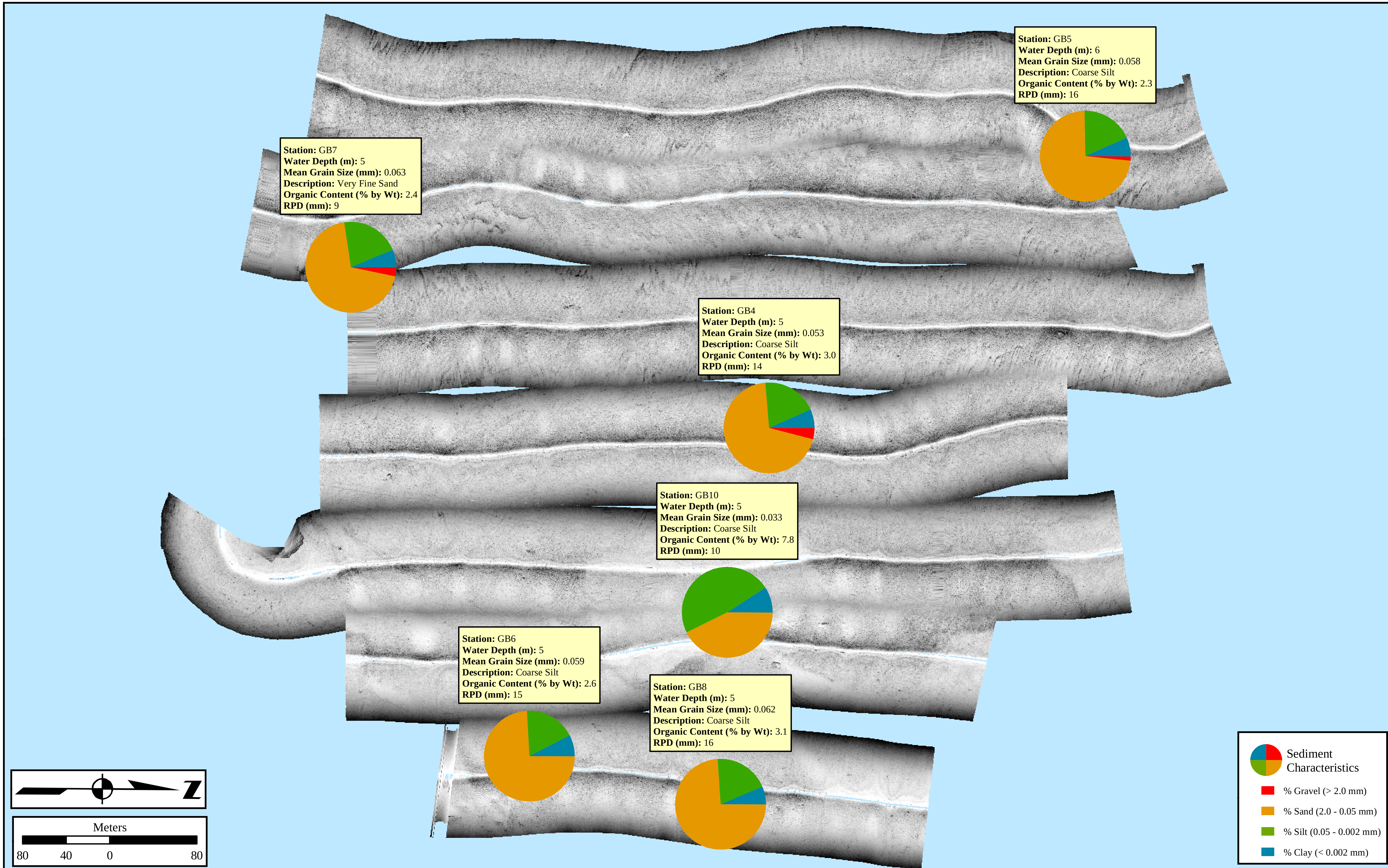


Figure 10. Sediment Characteristics at the Gravesend Bay Site.

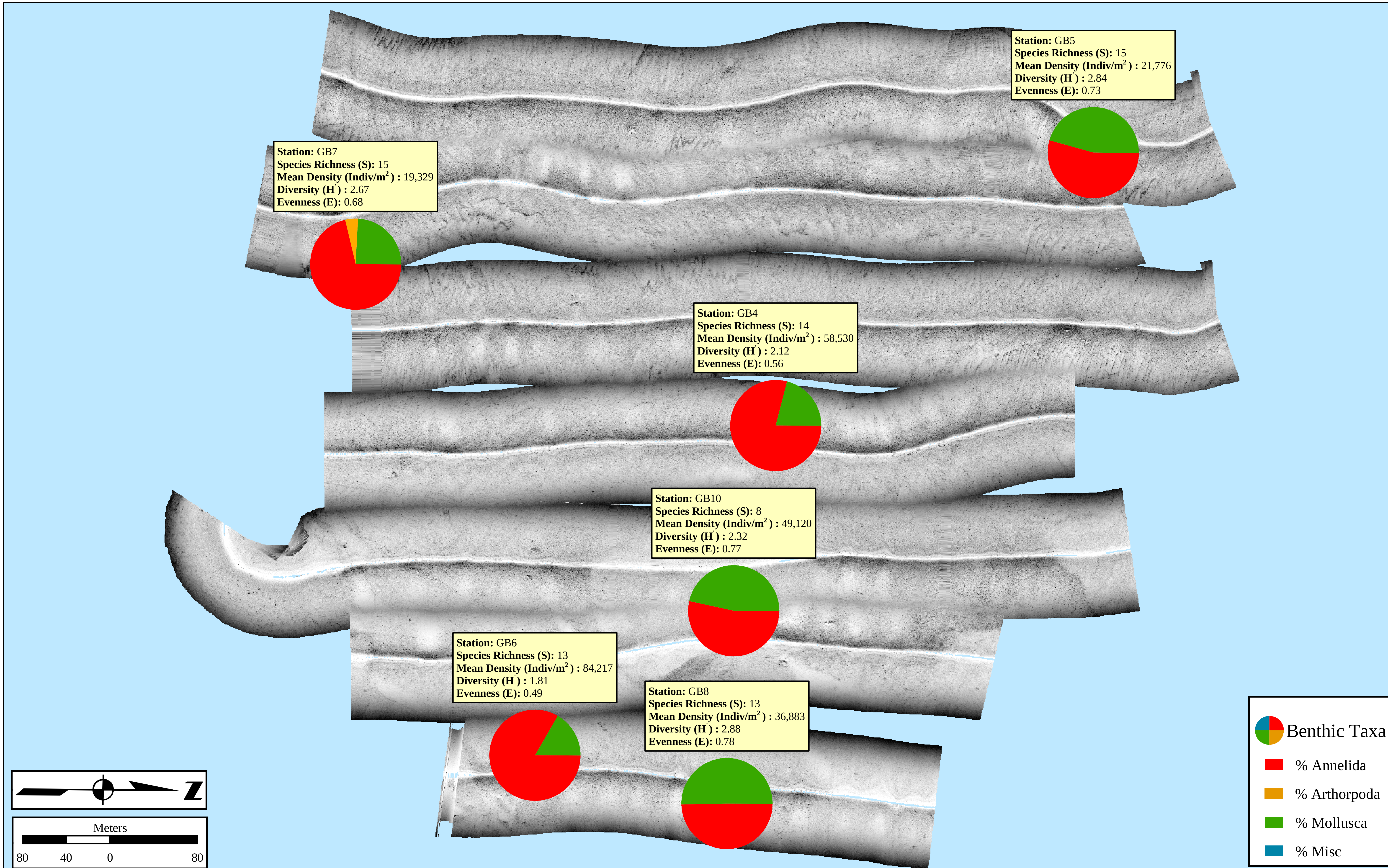


Figure 11. Benthic Characteristics at the Gravesend Bay Site.

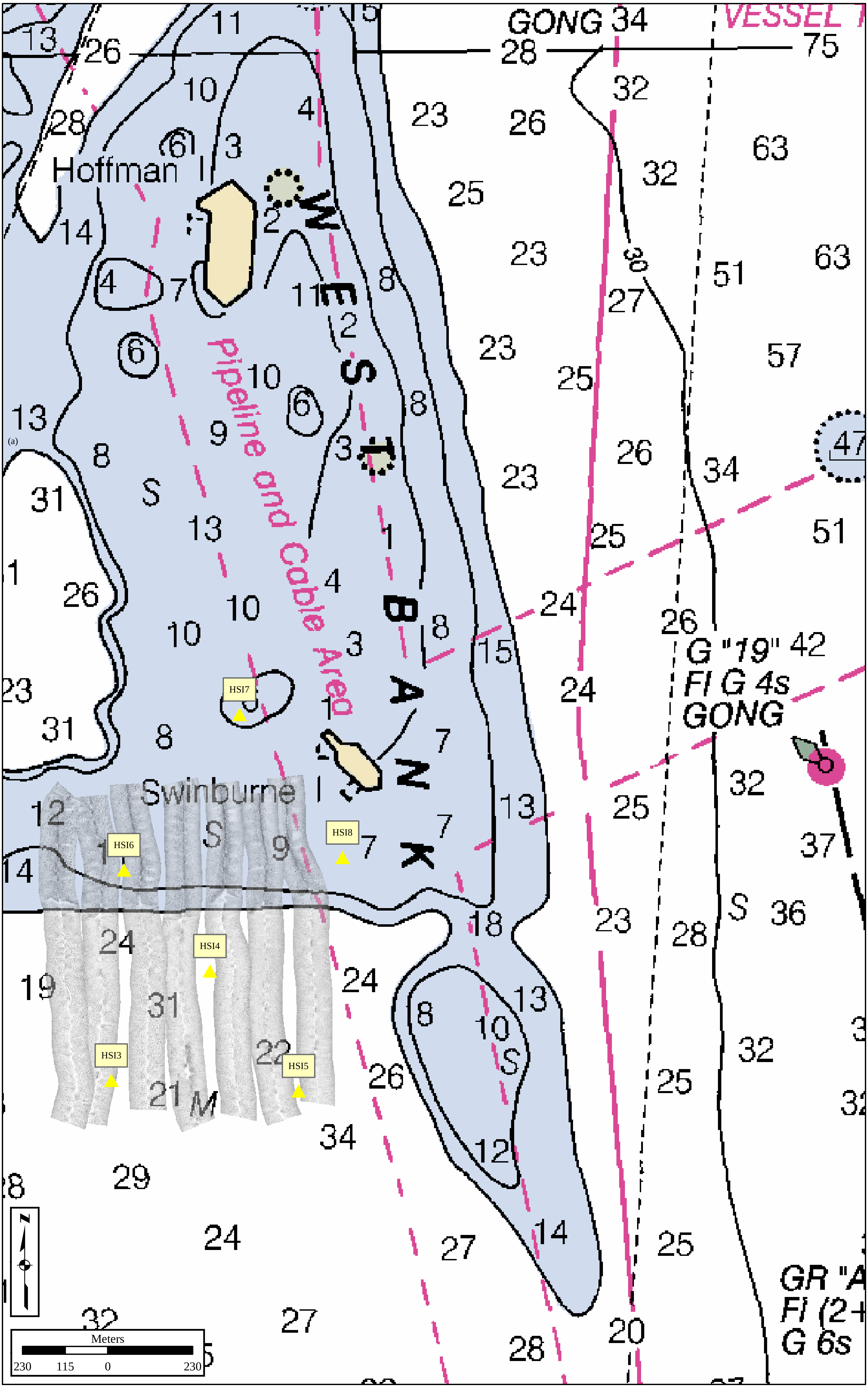


Figure 12. General Area of the Hoffman-Swinburne Islands Site.
Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.

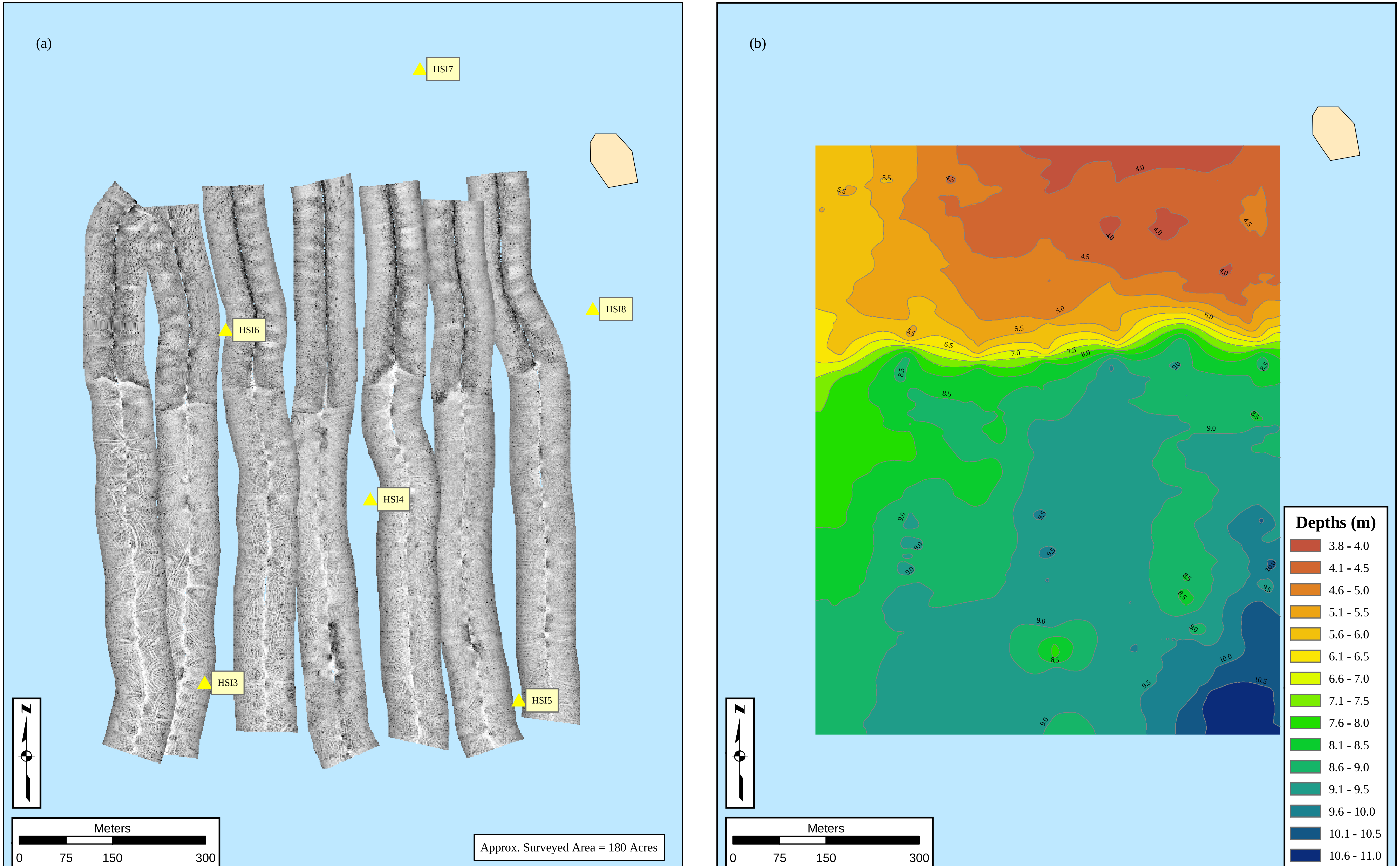


Figure 13. Side-Scan Sonar and Bathymetry data at the Hoffman-Swinburne Islands Site. Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.
Projection: UTM Zone 18N, NAD 1983, Meters.

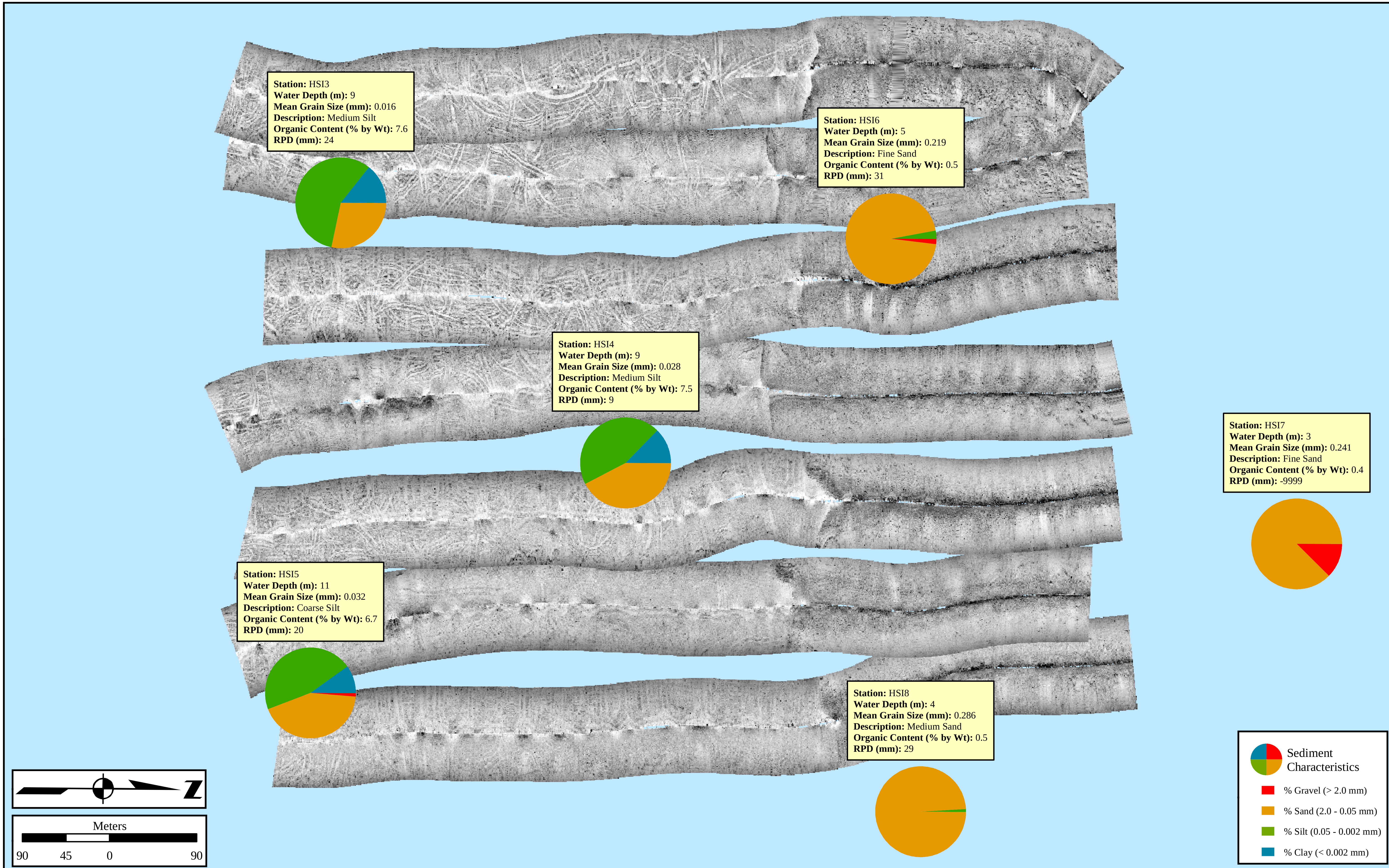


Figure 14. Sediment Characteristics at the Hoffman-Swinburne Islands Site.

Value of -9999 implies "No Possible Measurement"

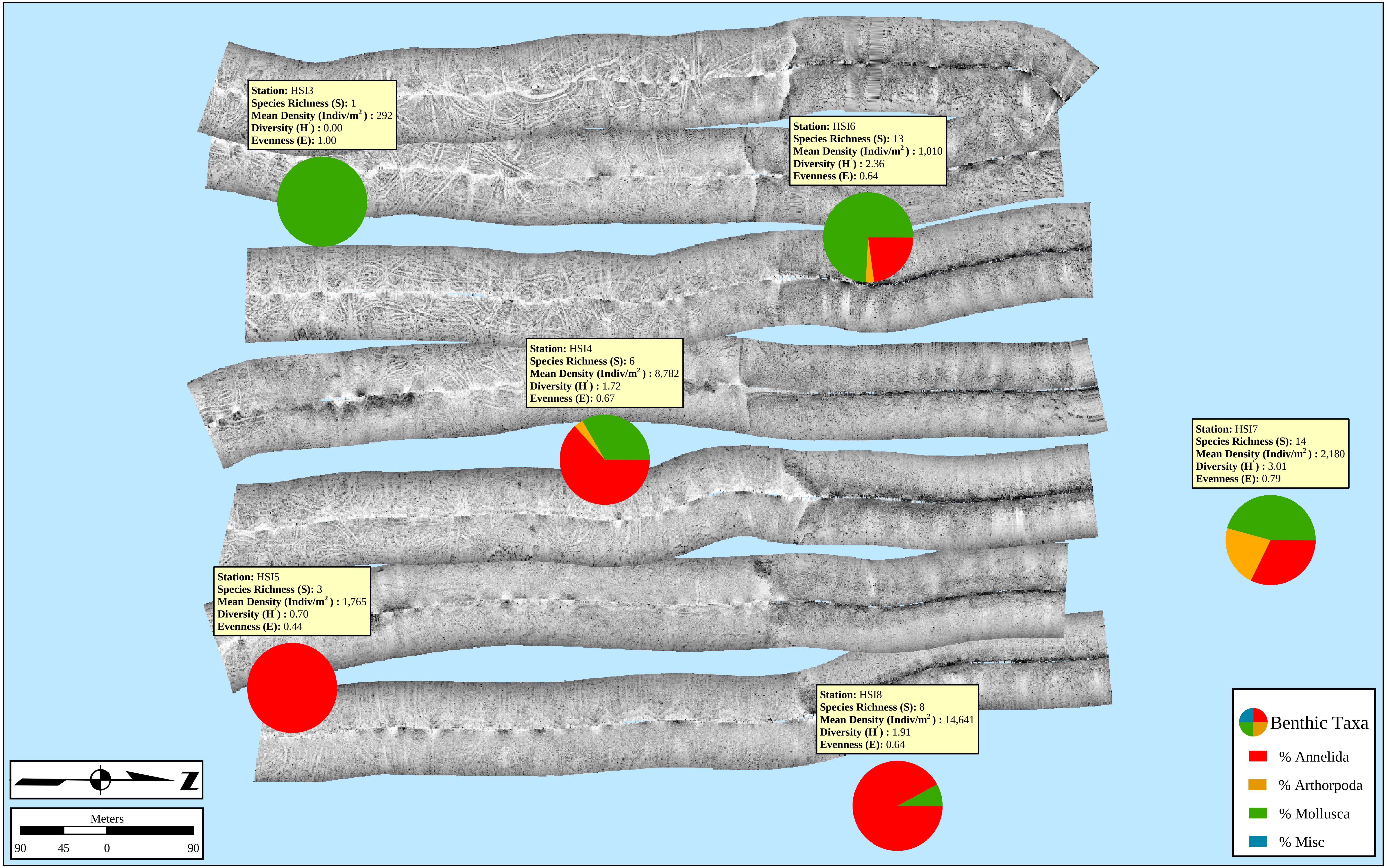


Figure 15. Benthic Characteristics at the Hoffman-Swinburne Islands Site.

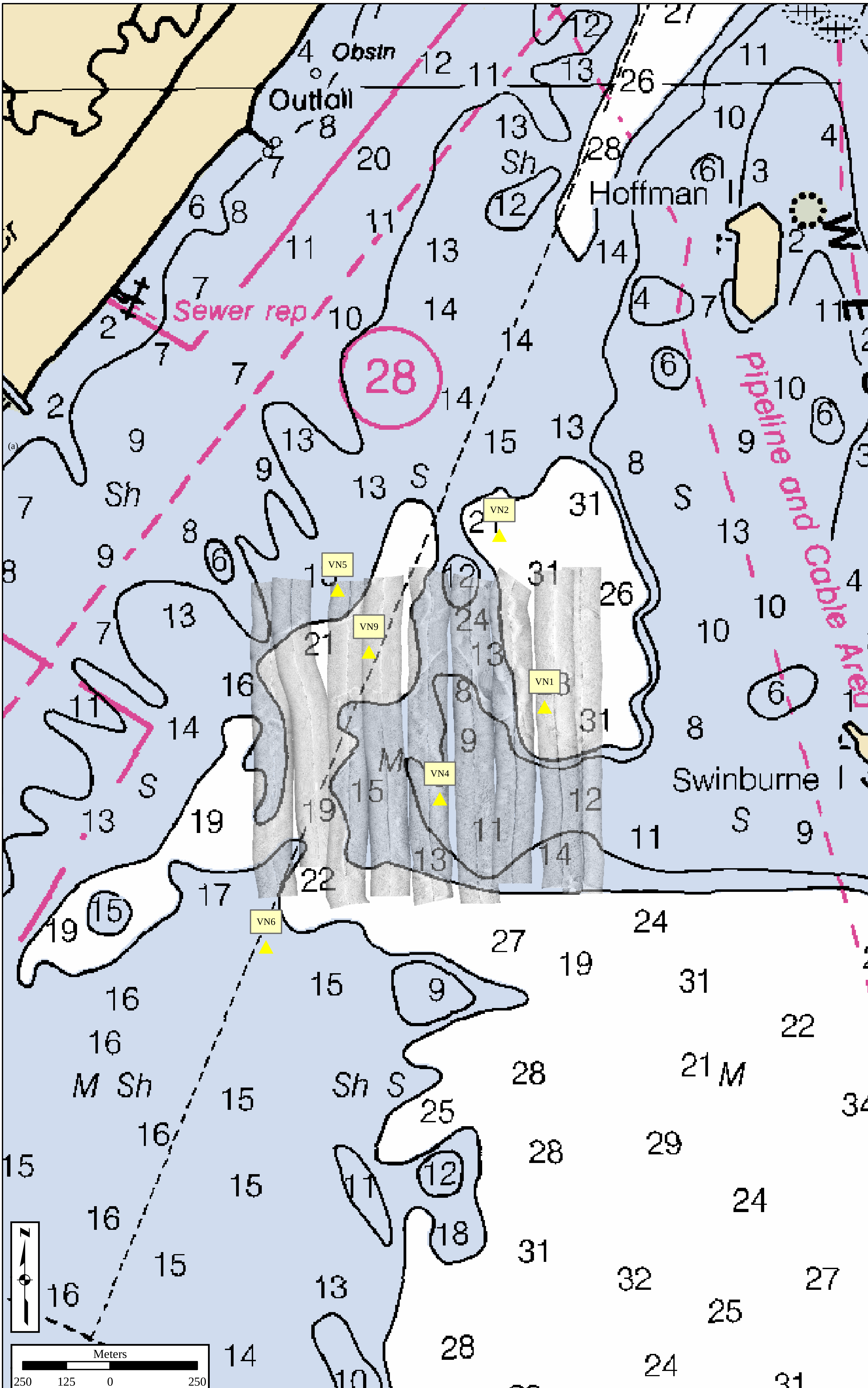


Figure 16. General Area of the Verrazano-Narrows Islands Site.
Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.

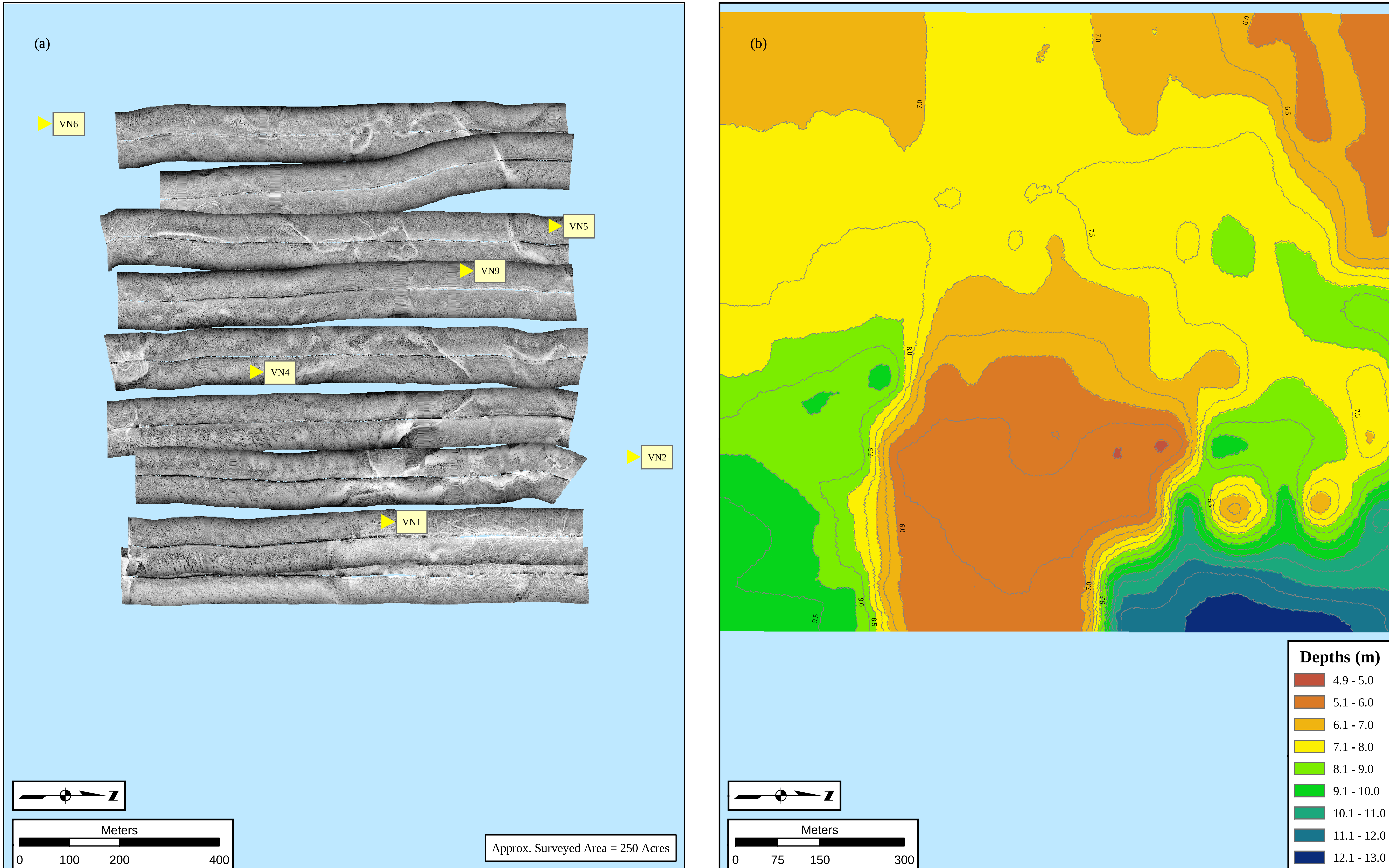


Figure 17. Side-Scan Sonar and Bathymetry data at the Verrazano-Narrows Site. Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.
Projection: UTM Zone 18N, NAD 1983, Meters.

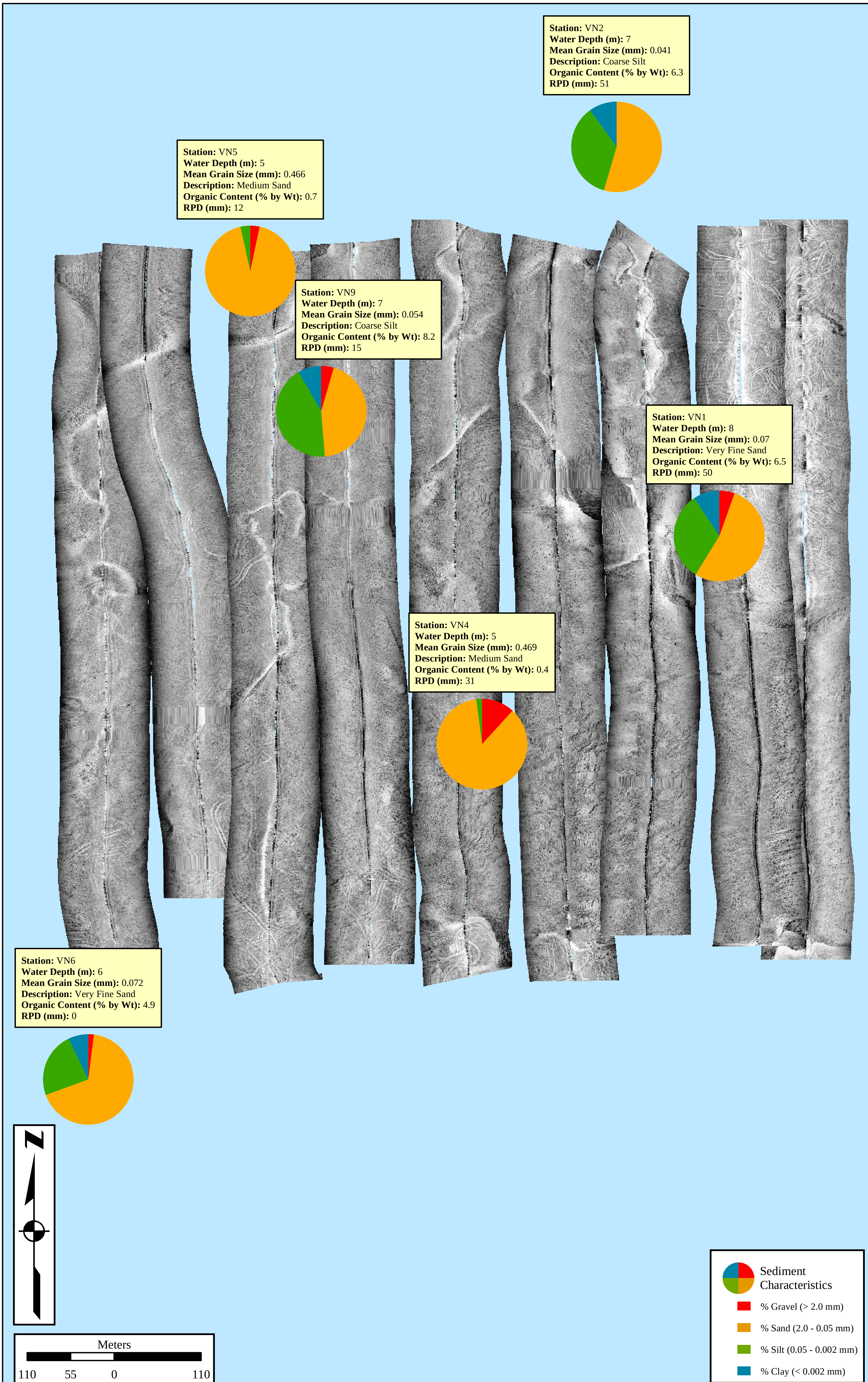


Figure 18. Sediment Characteristics at the Verrazano-Narrows Site.

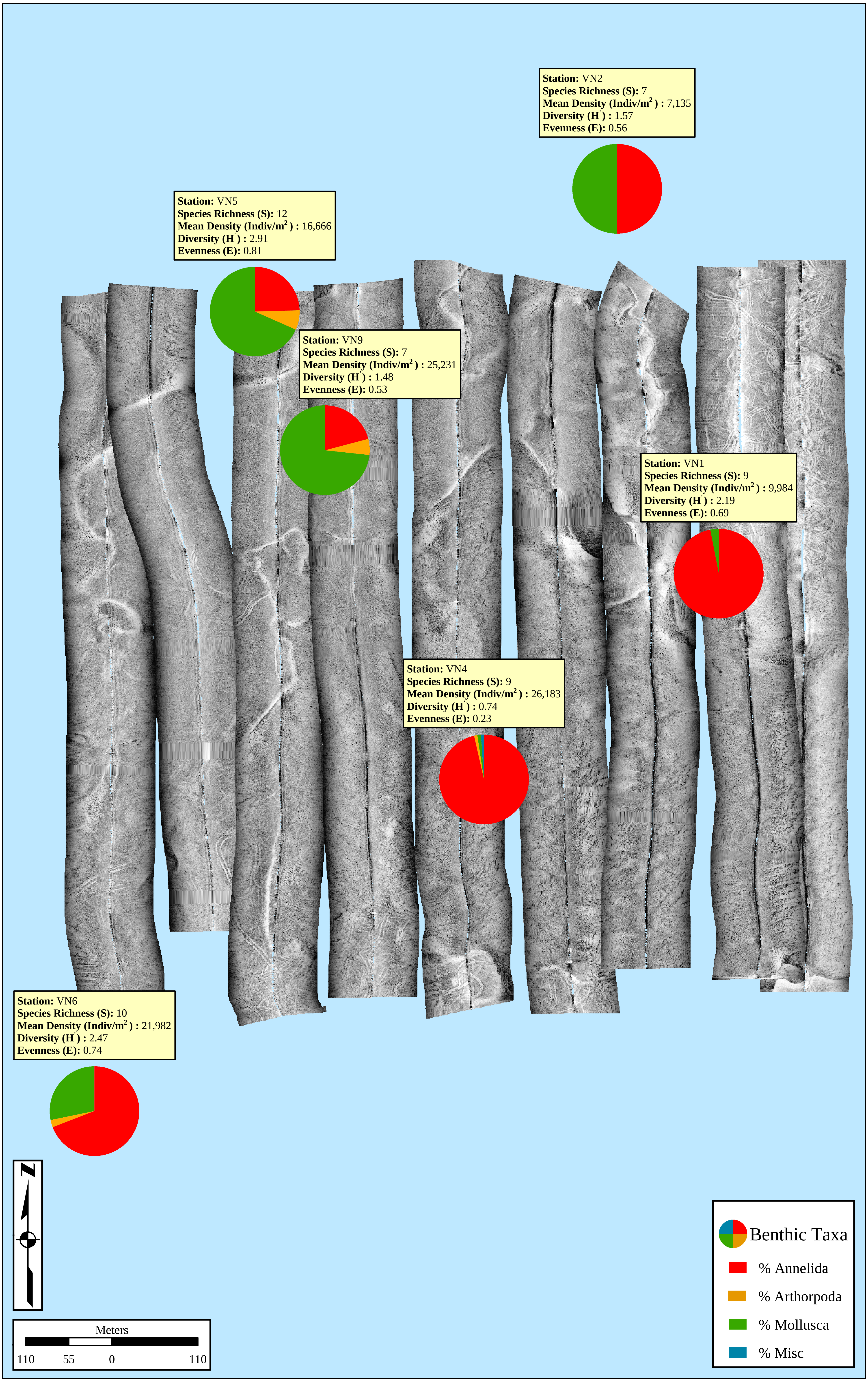


Figure 19. Benthic Characteristics at the Verrazano-Narrows Site.

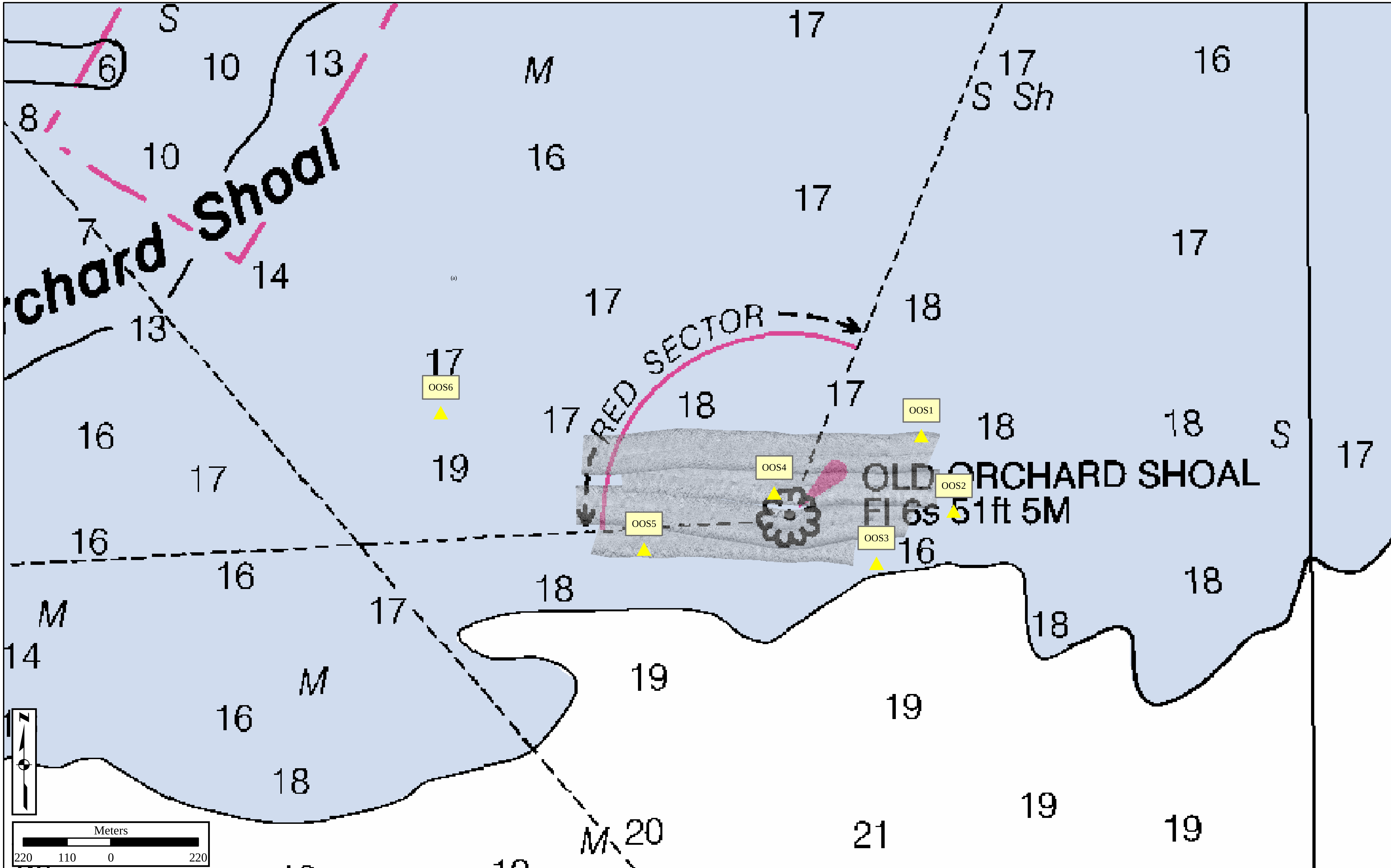


Figure 20. General Area of the Old Orchard Shoal site.
Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.

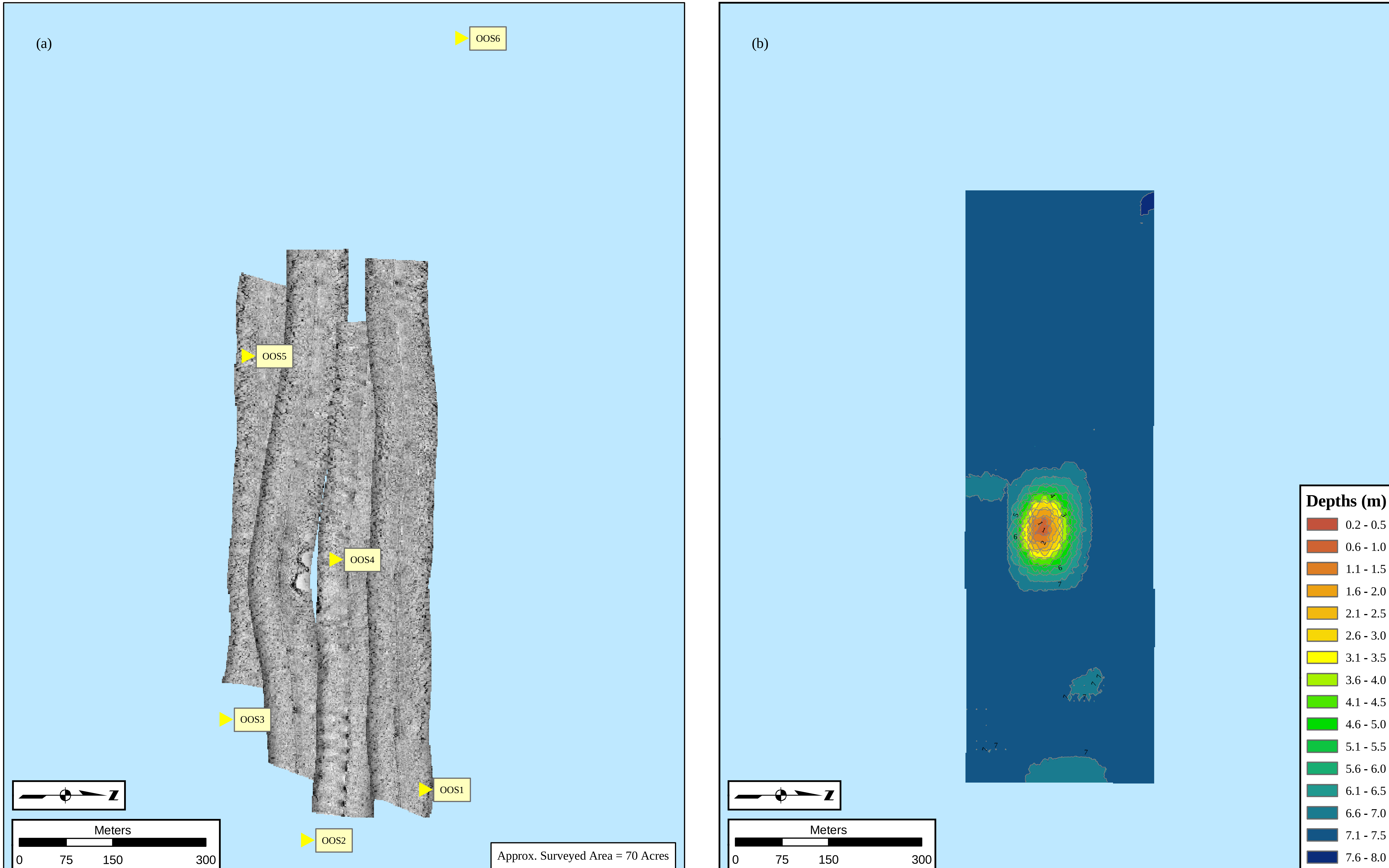


Figure 21. Side Scan Sonar and Bathymetry data at the Old Orchard Shoal site. Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.
Projection: UTM Zone 18N, NAD 1983, Meters.

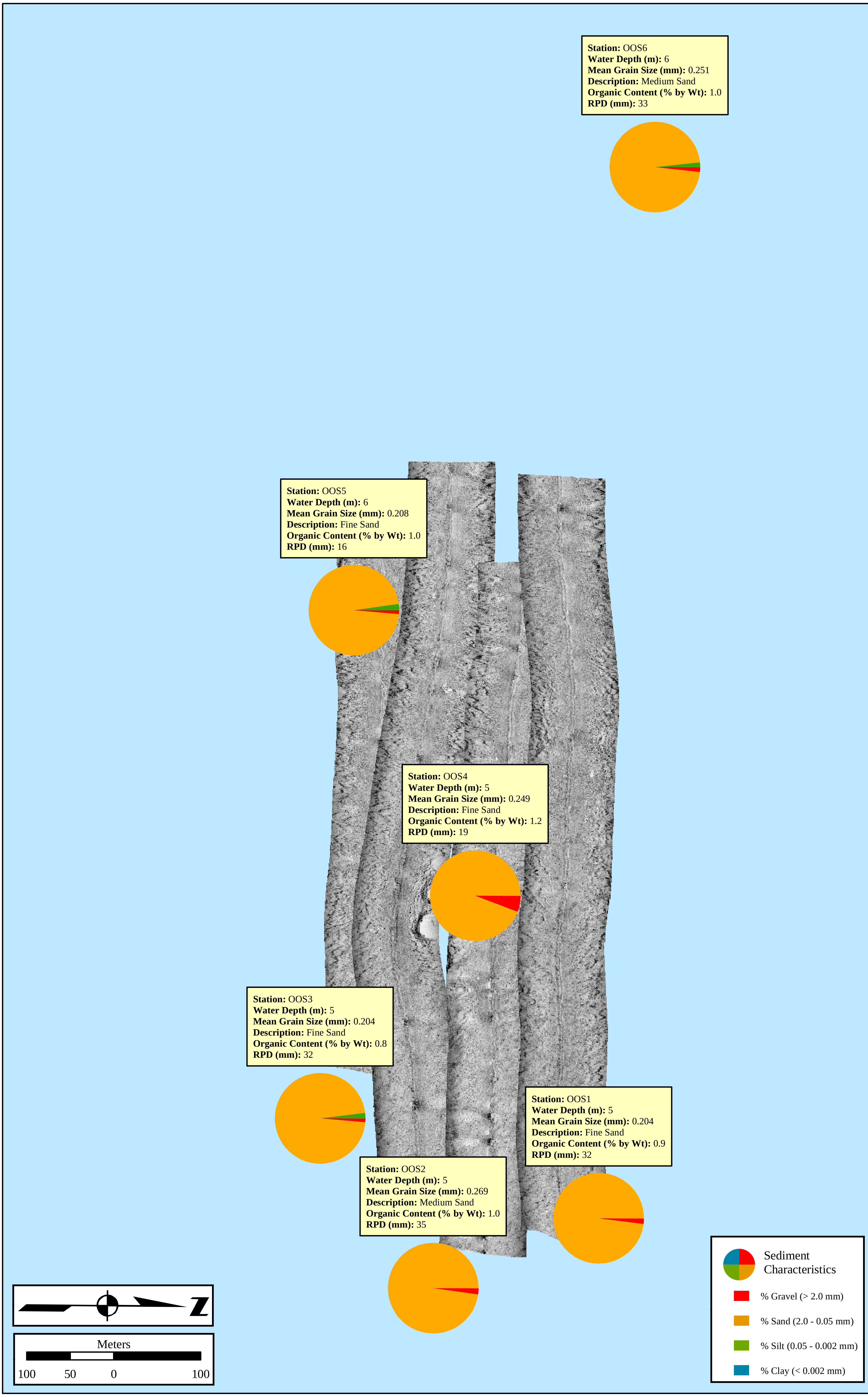


Figure 22. Sediment Characteristics at the Old Orchard Shoal Site.

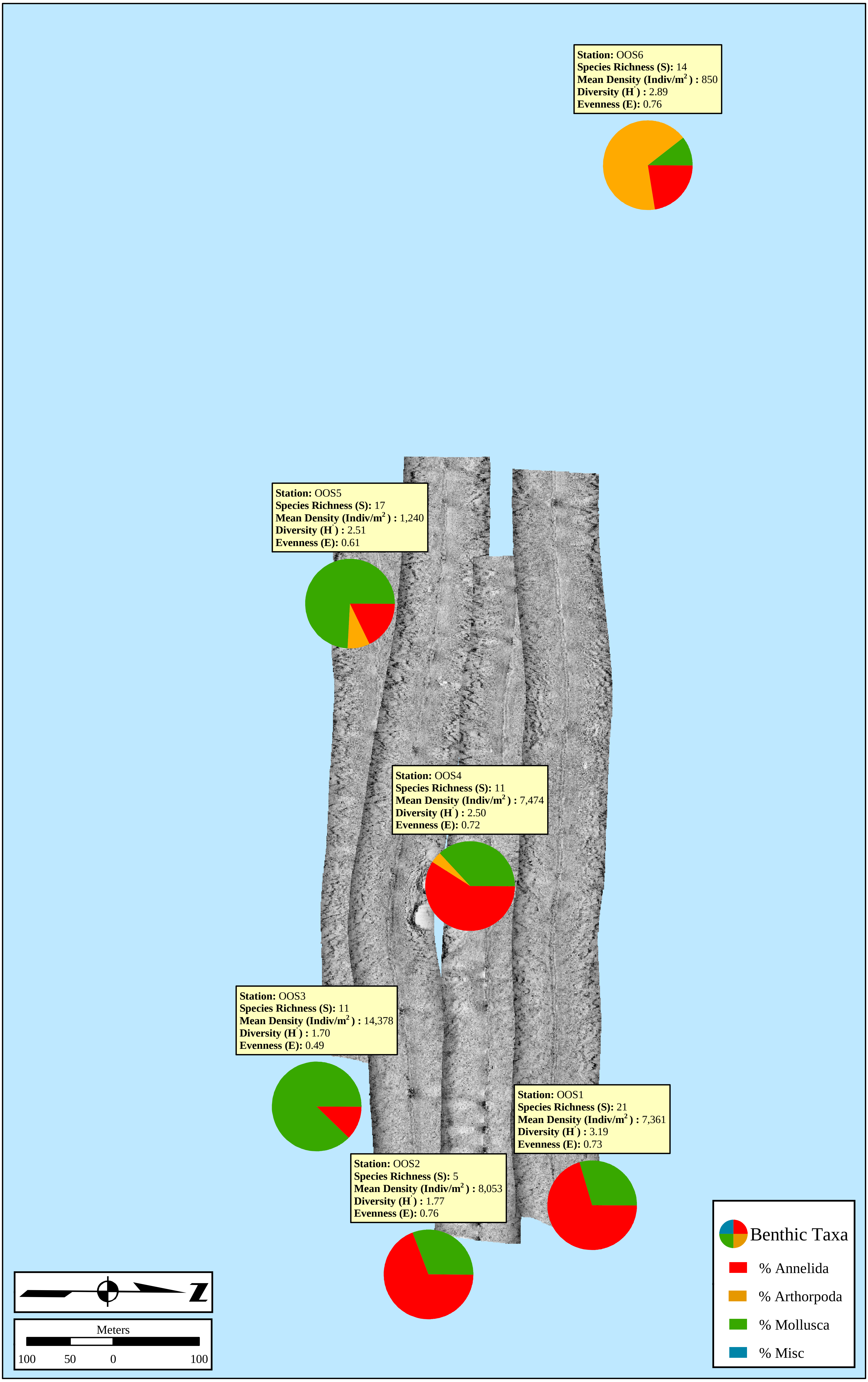


Figure 23. Benthic Characteristics at the Old Orchard Shoal Site.

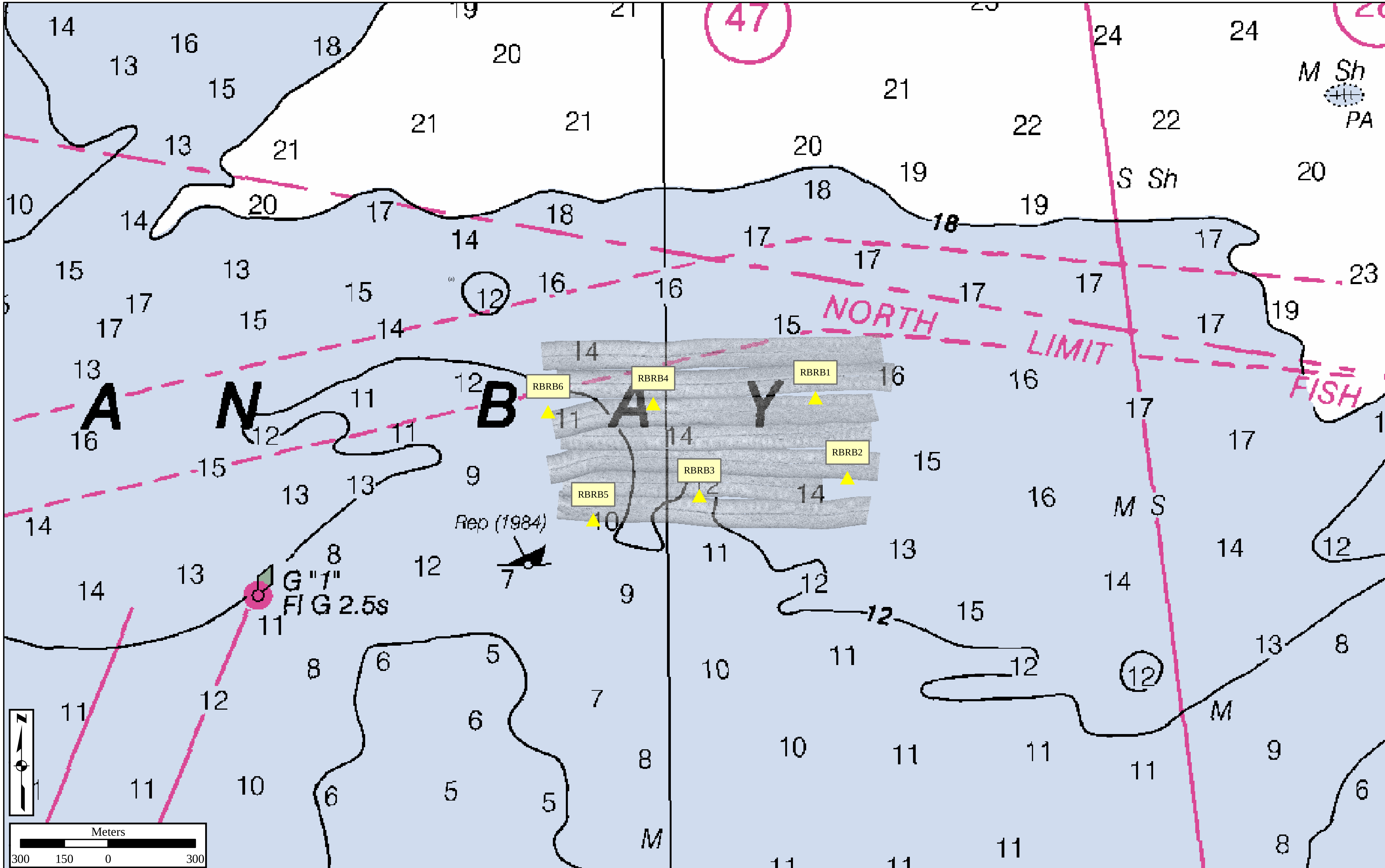


Figure 24. General Area of the Raritan Bay Rock Berm Site.
Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.

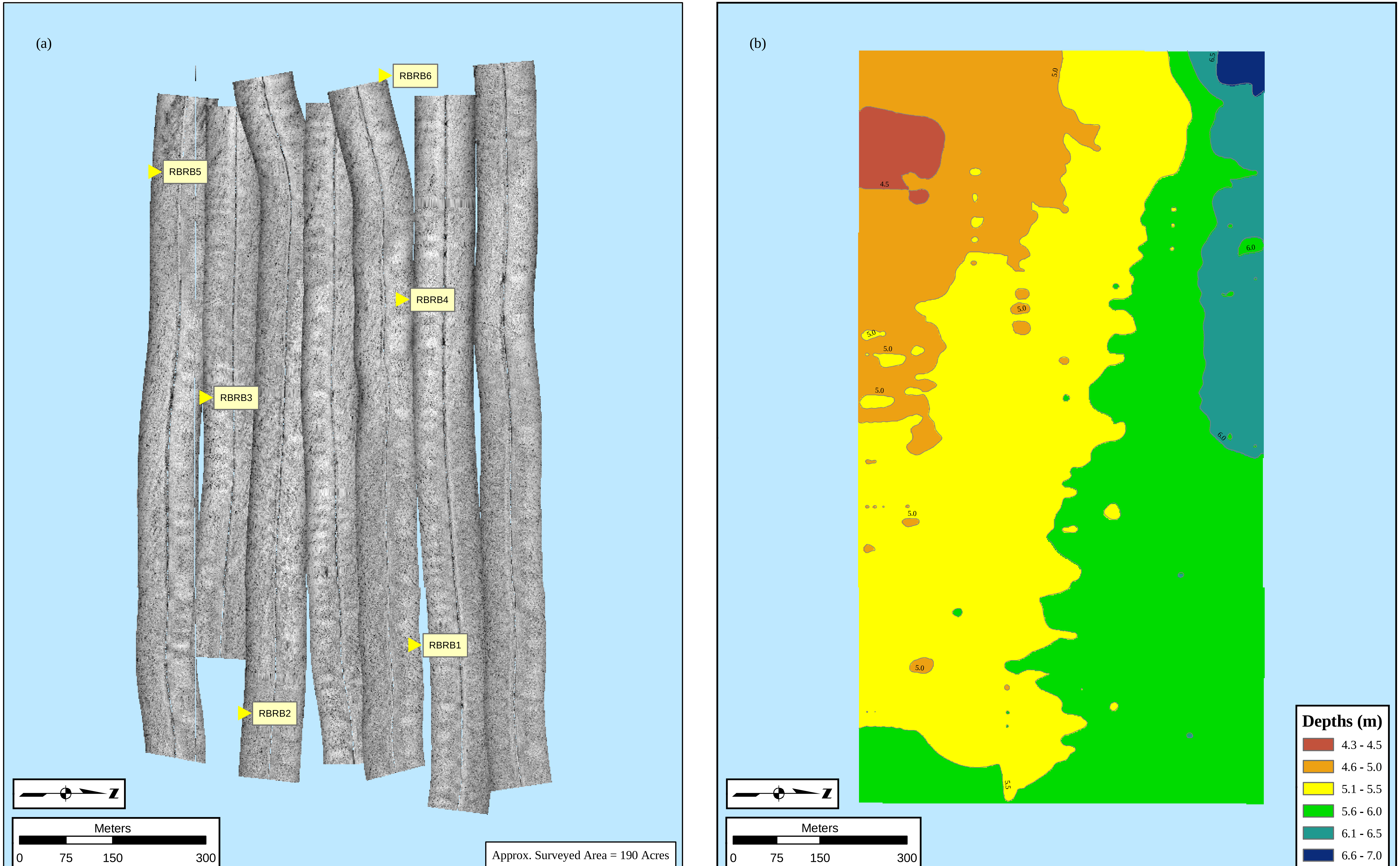


Figure 25. Side Scan Sonar and Bathymetry Data at the Raritan Bay Rock Berm Site. Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.
Projection: UTM Zone 18N, NAD 1983, Meters.

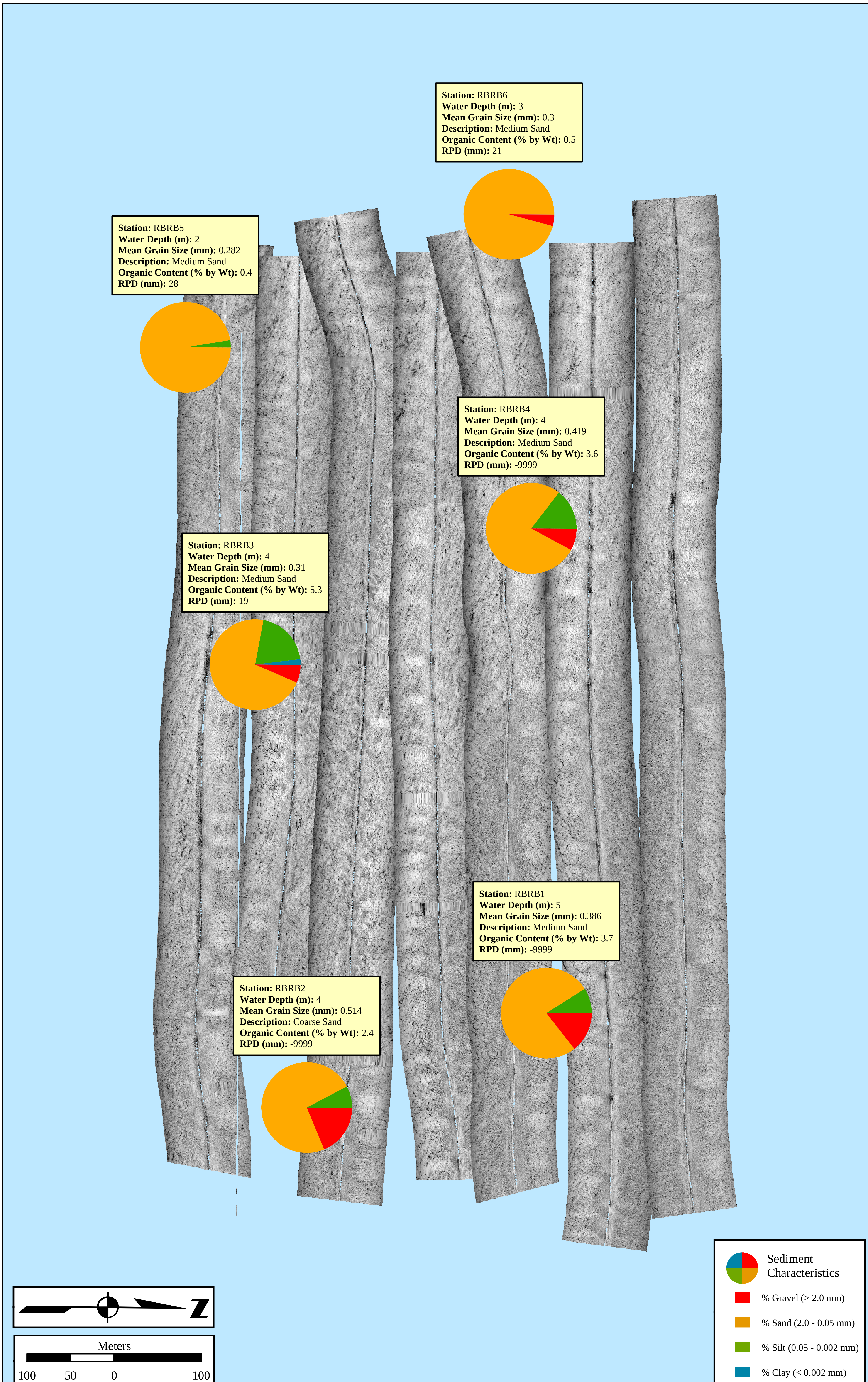


Figure 26. Sediment Characteristics at the Raritan Bay Rock Berm Site.

Value of -9999 implies "No Possible Measurement"

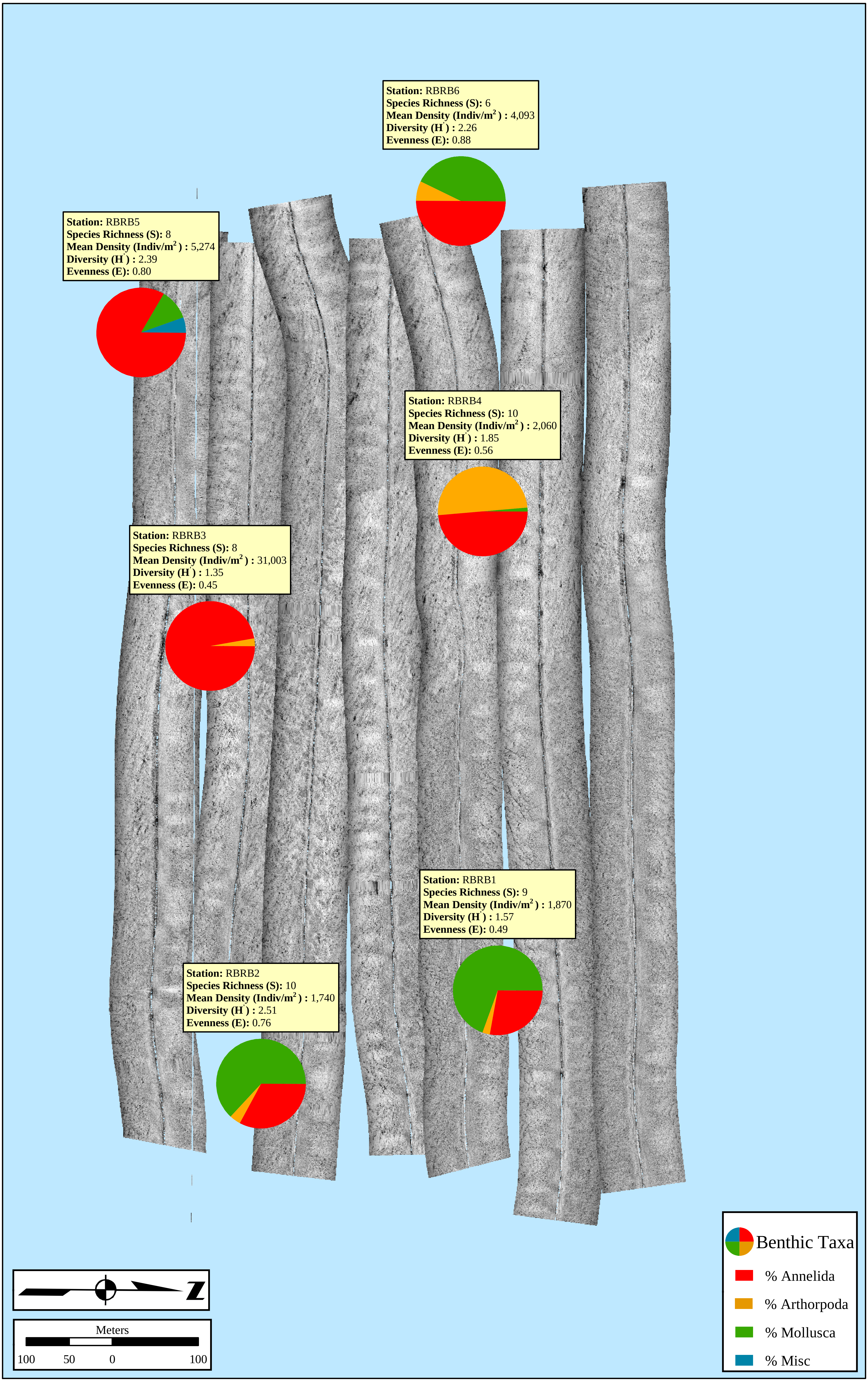


Figure 27. Benthic Characteristics at the Raritan Bay Rock Berm Site.

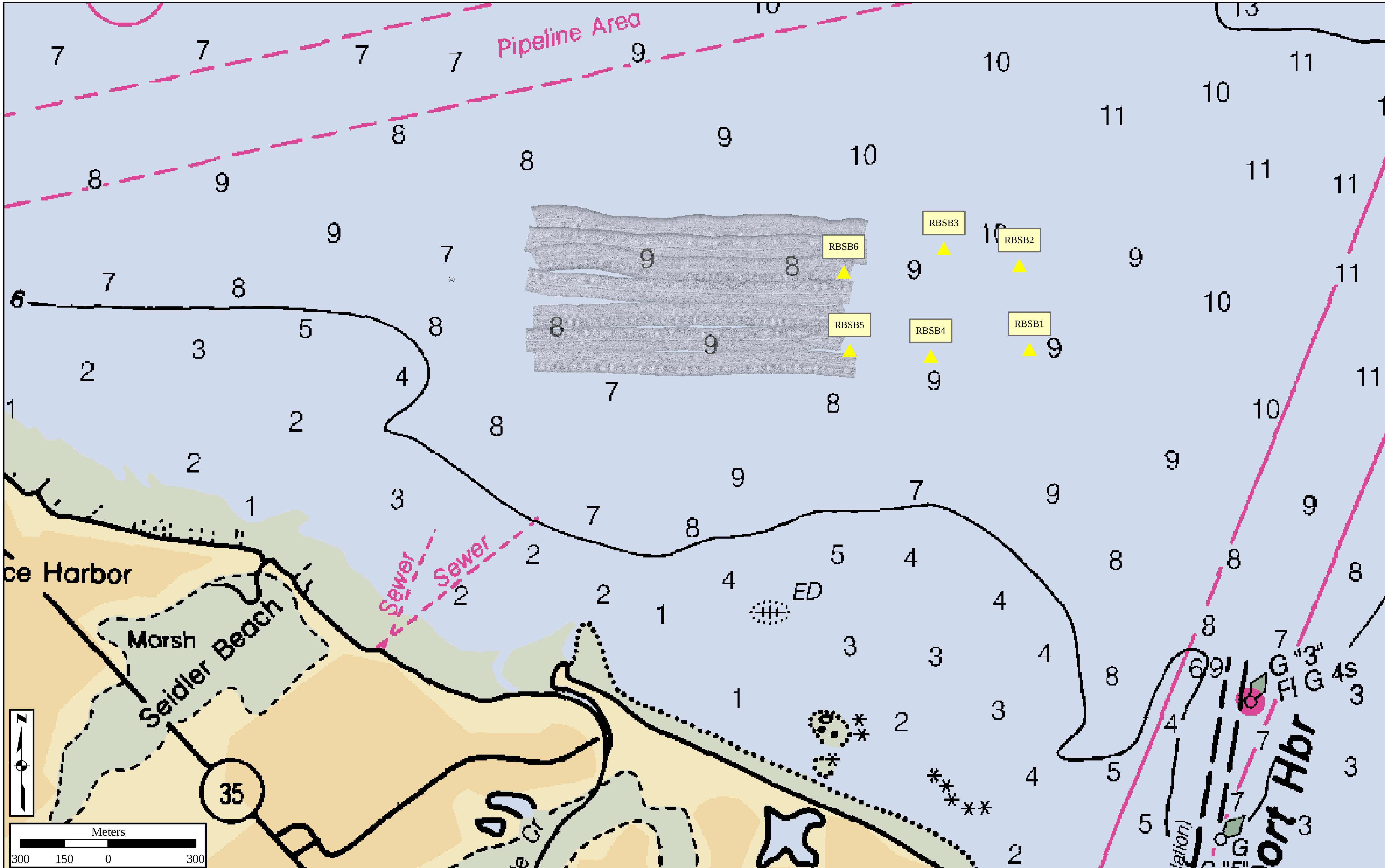


Figure 28. General Area of the Raritan Bay Shellfish Bed Site.
Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.

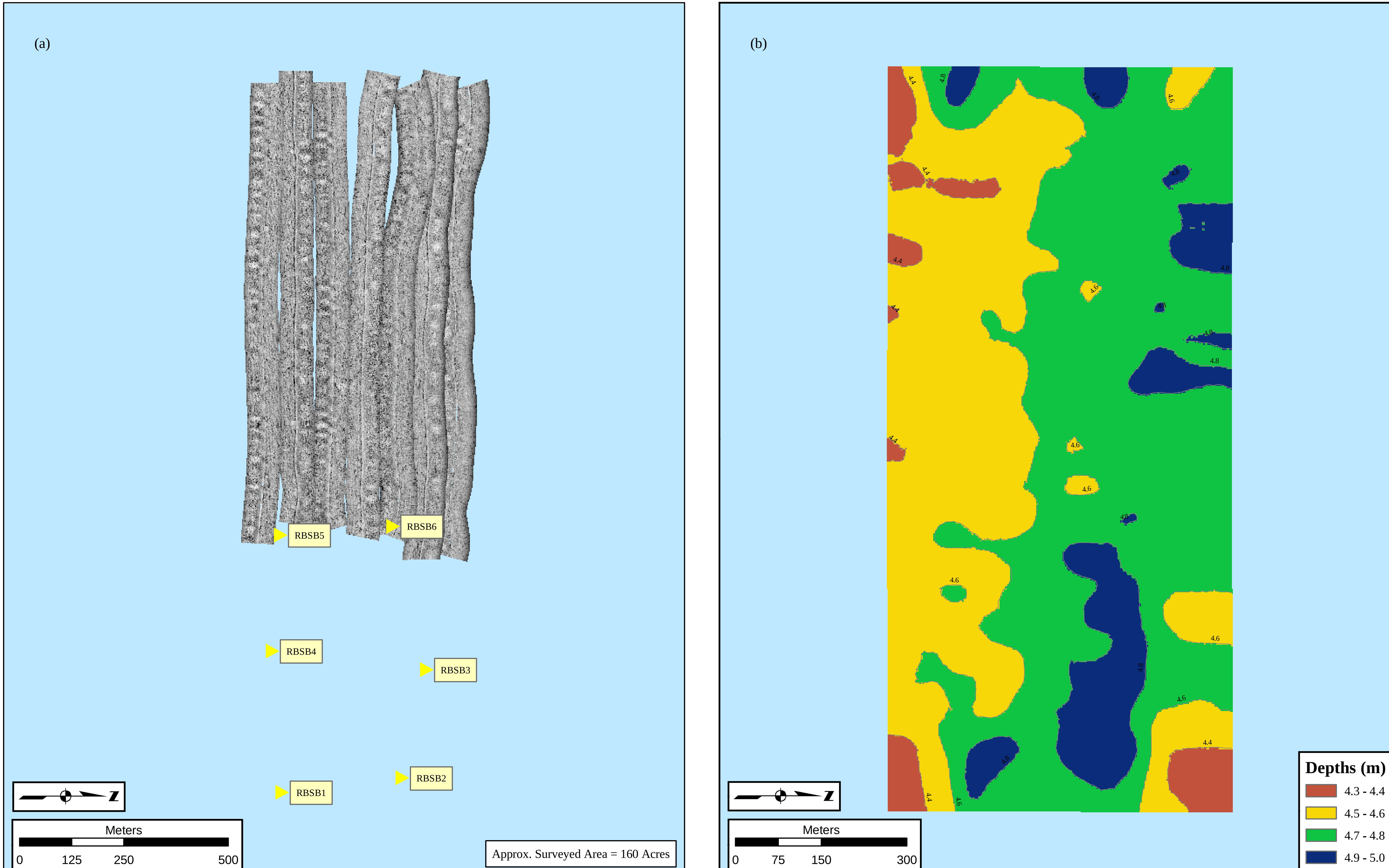


Figure 29. Side-Scan Sonar and Bathymetry Data at the Raritan Bay Shellfish Bed Site. Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.
Projection: UTM Zone 18N, NAD 1983, Meters.

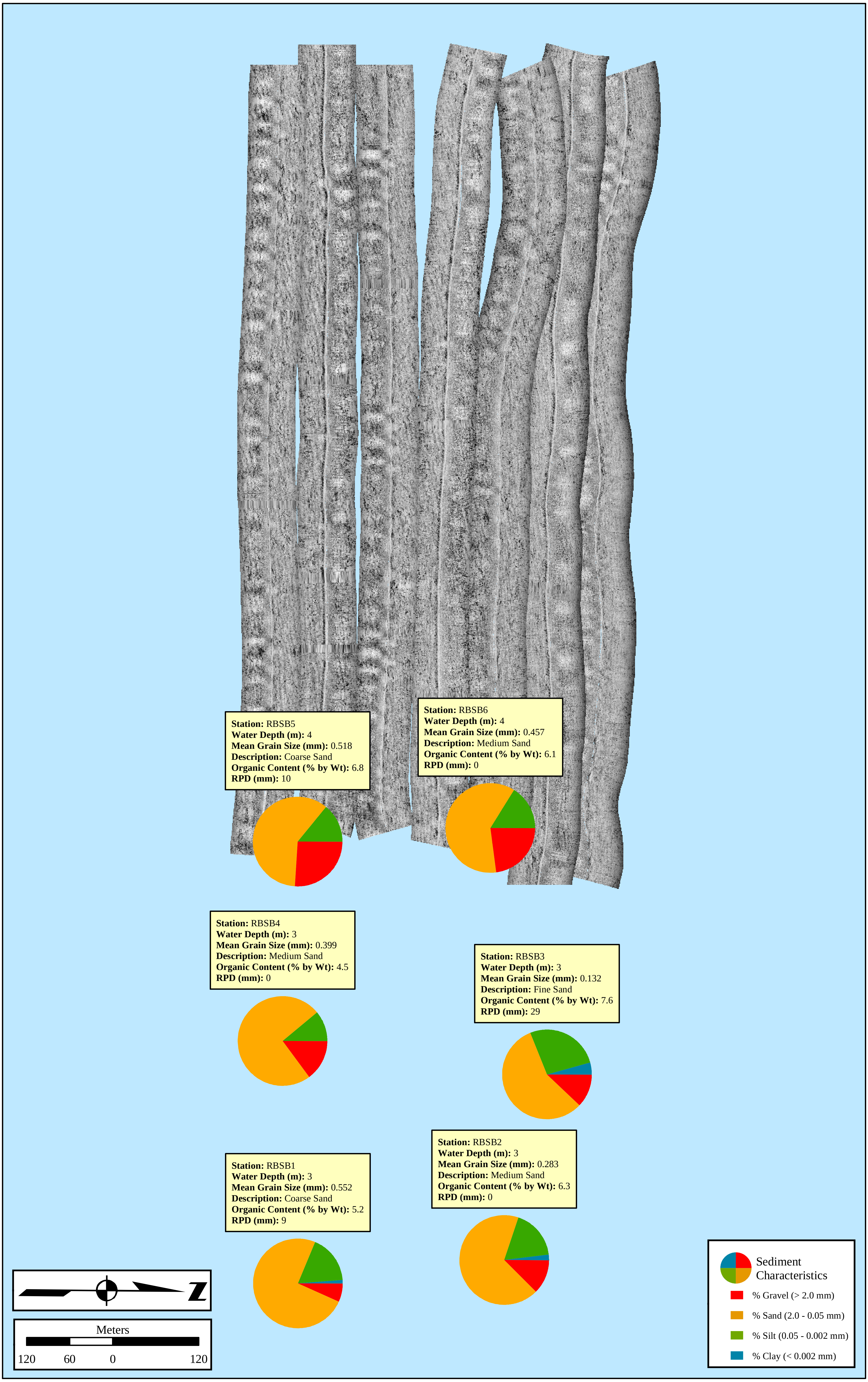


Figure 30. Sediment Characteristics at the Raritan Bay Shellfish Bed Site.

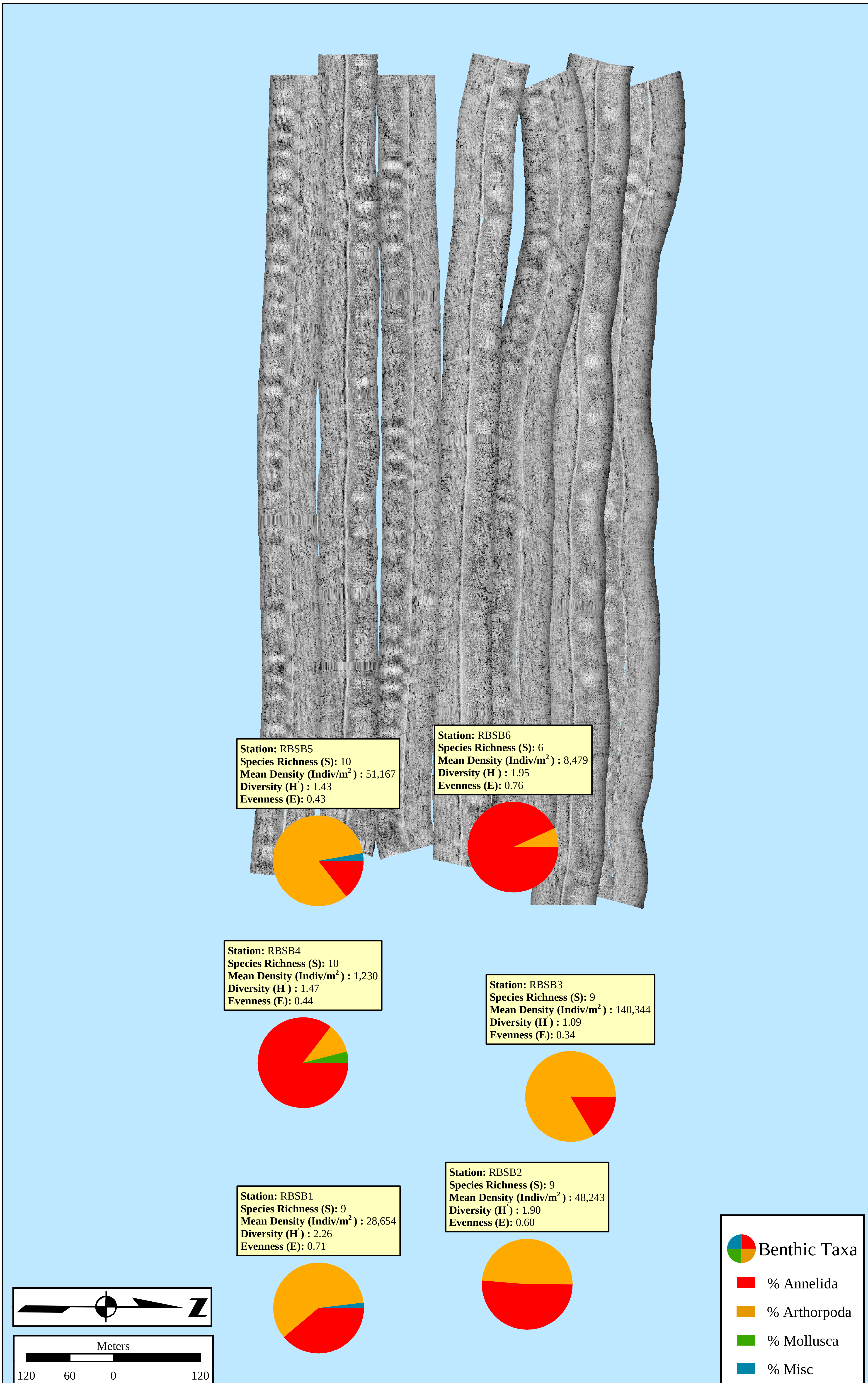


Figure 31. Benthic Characteristics at the Raritan Bay Shellfish Bed Site.

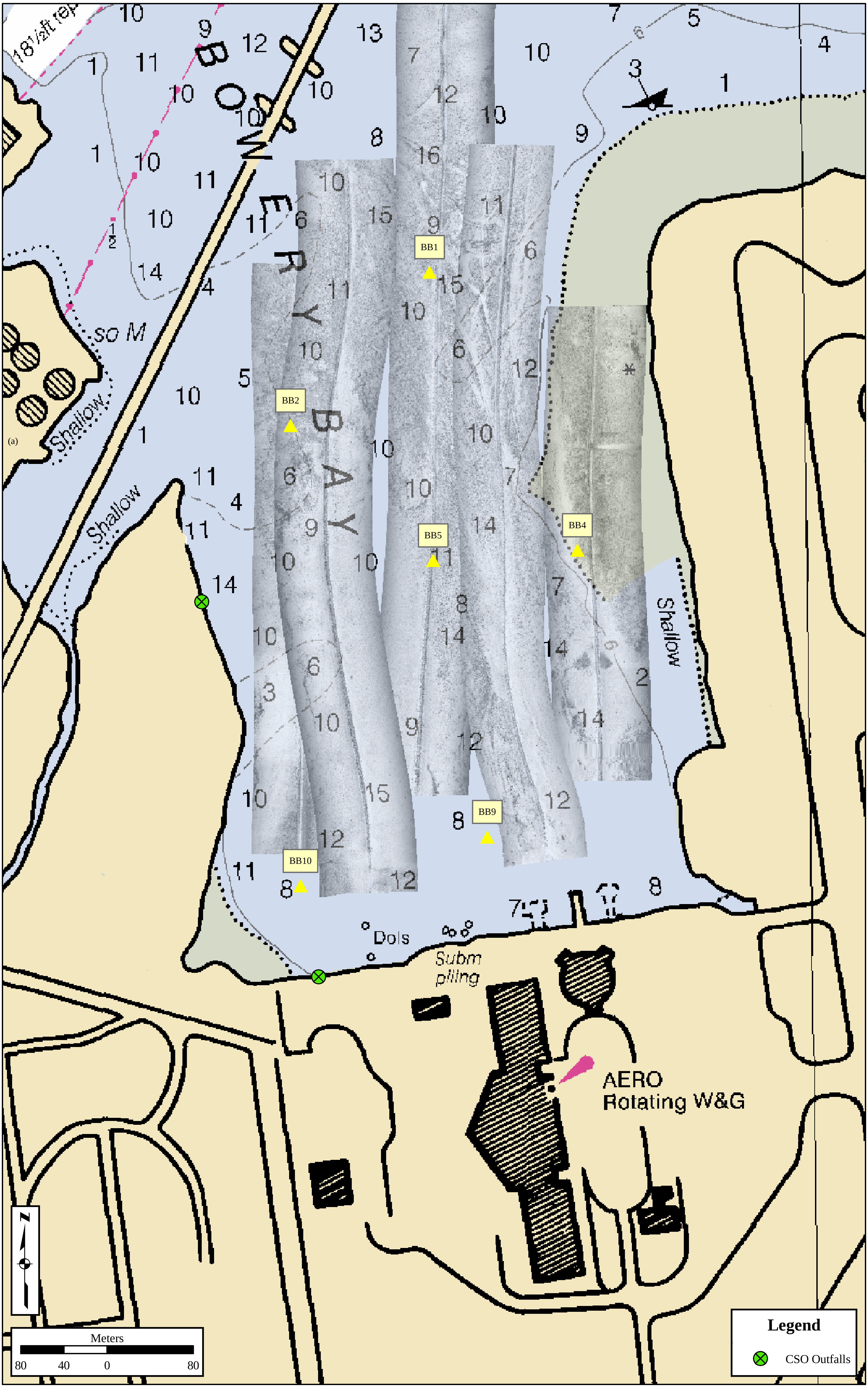


Figure 32. General Area of the Bowery Bay Site.
Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.

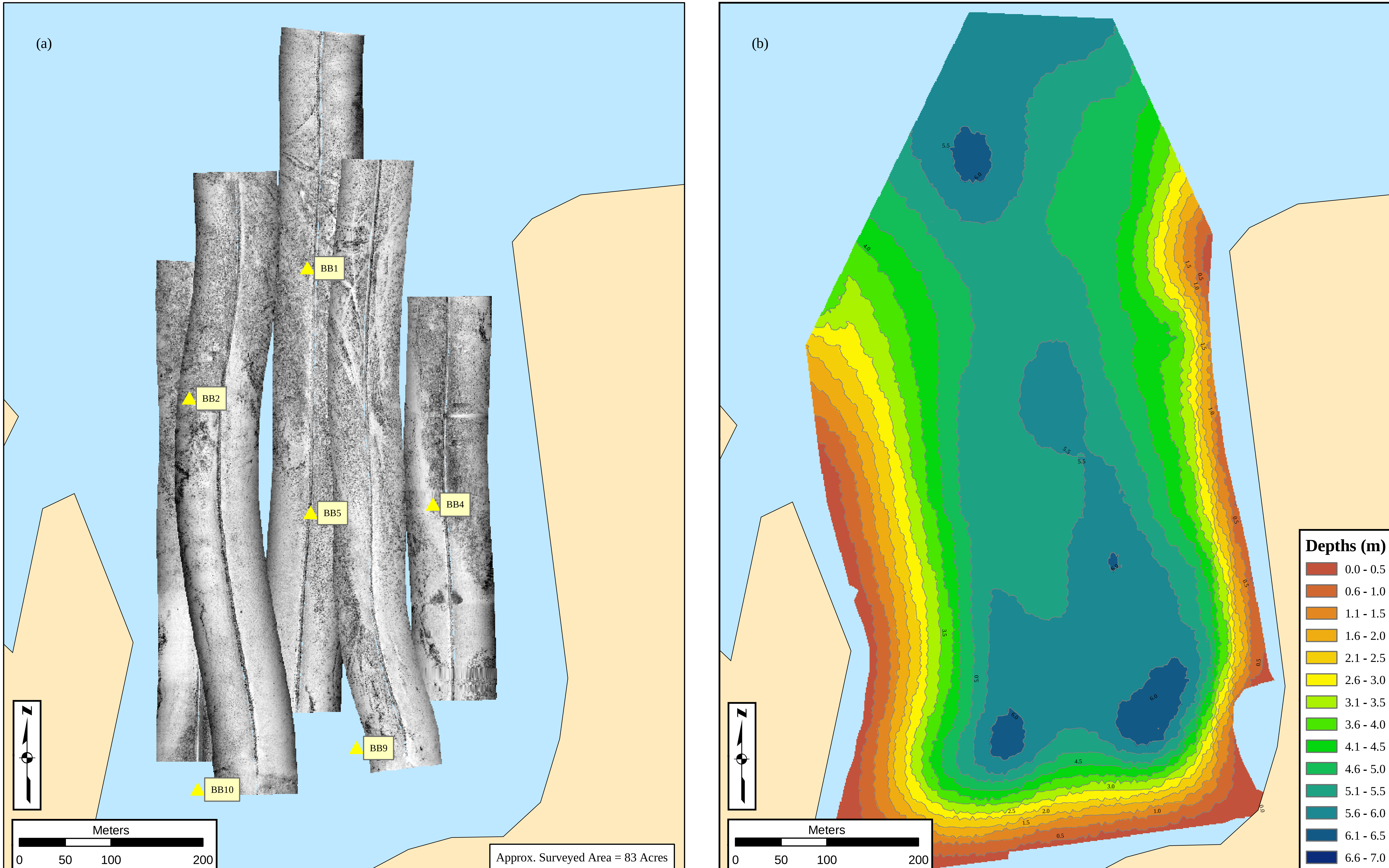


Figure 33. Side-Scan Sonar and Bathymetry Data at the Bowery Bay Site. Sediment and benthic invertebrate sampling locations are indicated by the yellow triangles.
Projection: UTM Zone 18N, NAD 1983, Meters.

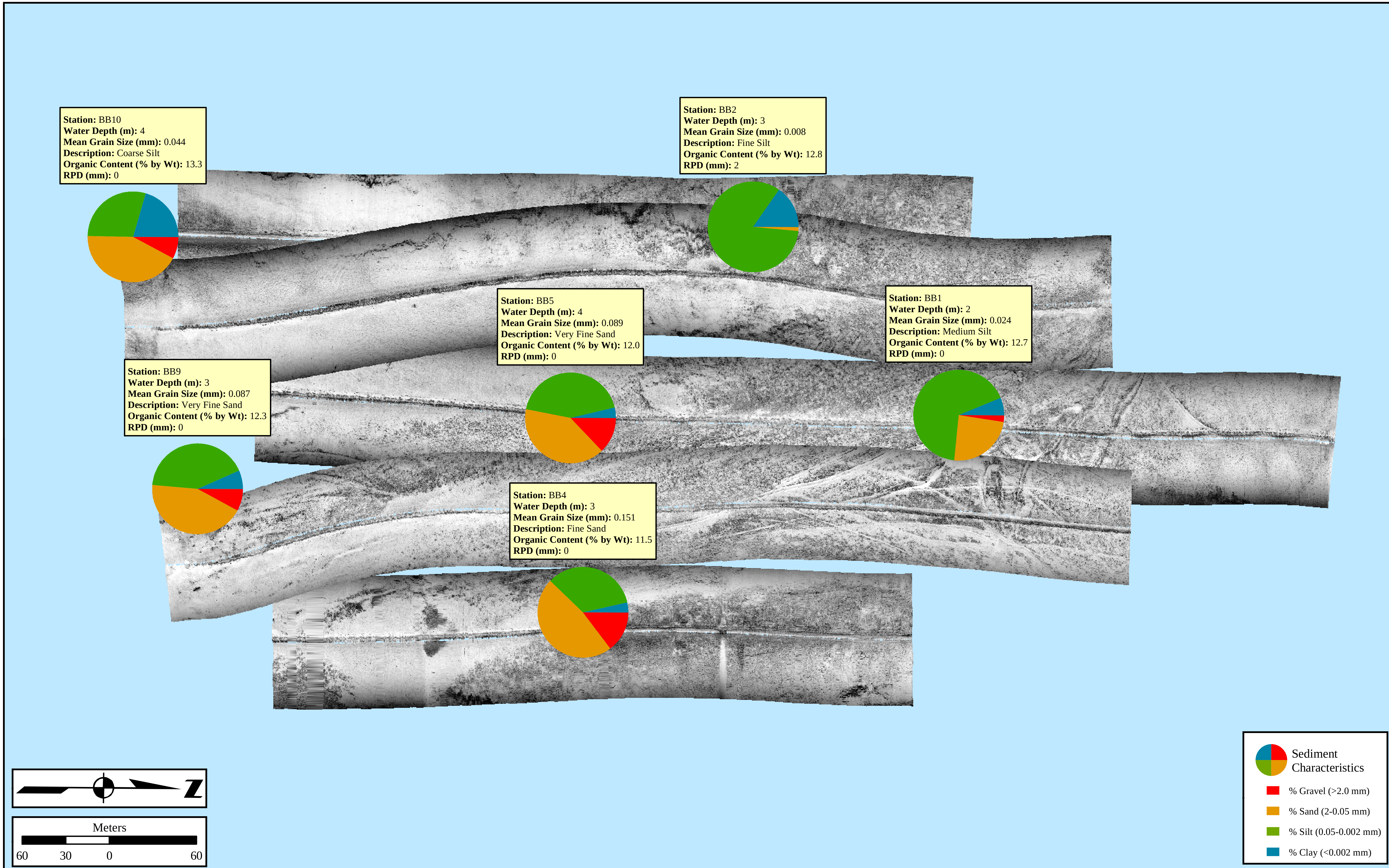


Figure 34. Sediment Characteristics at the Bowery Bay Site.

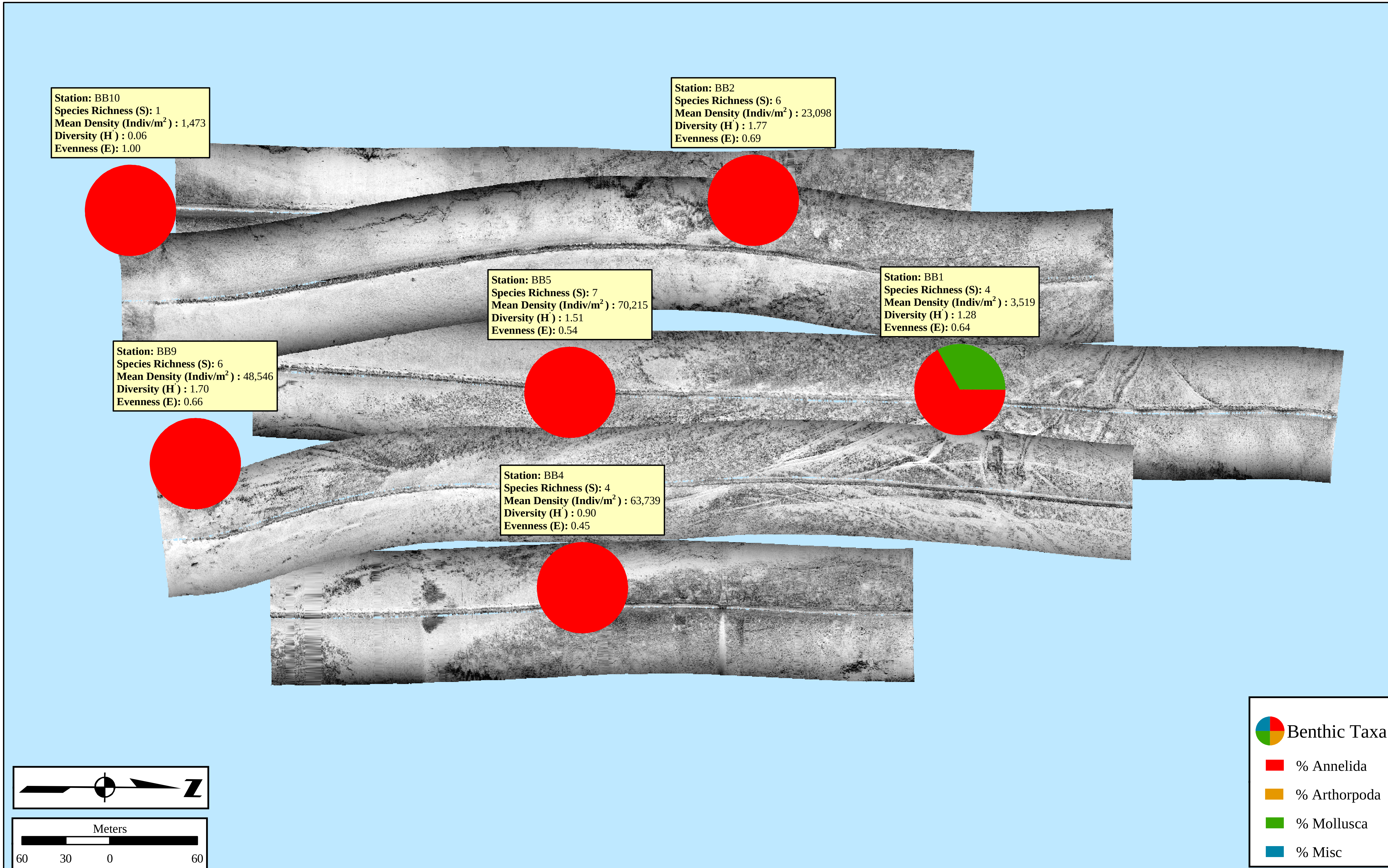
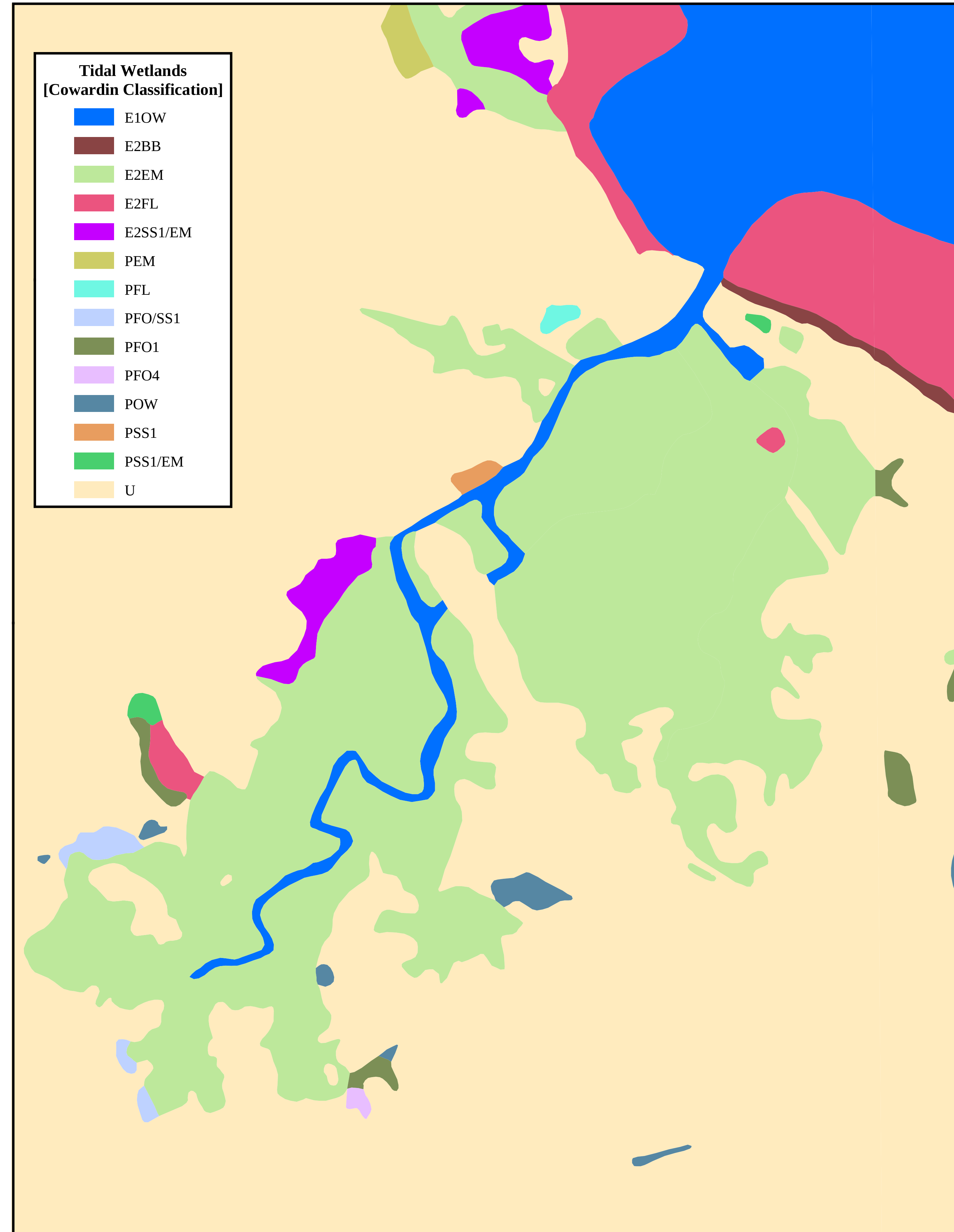
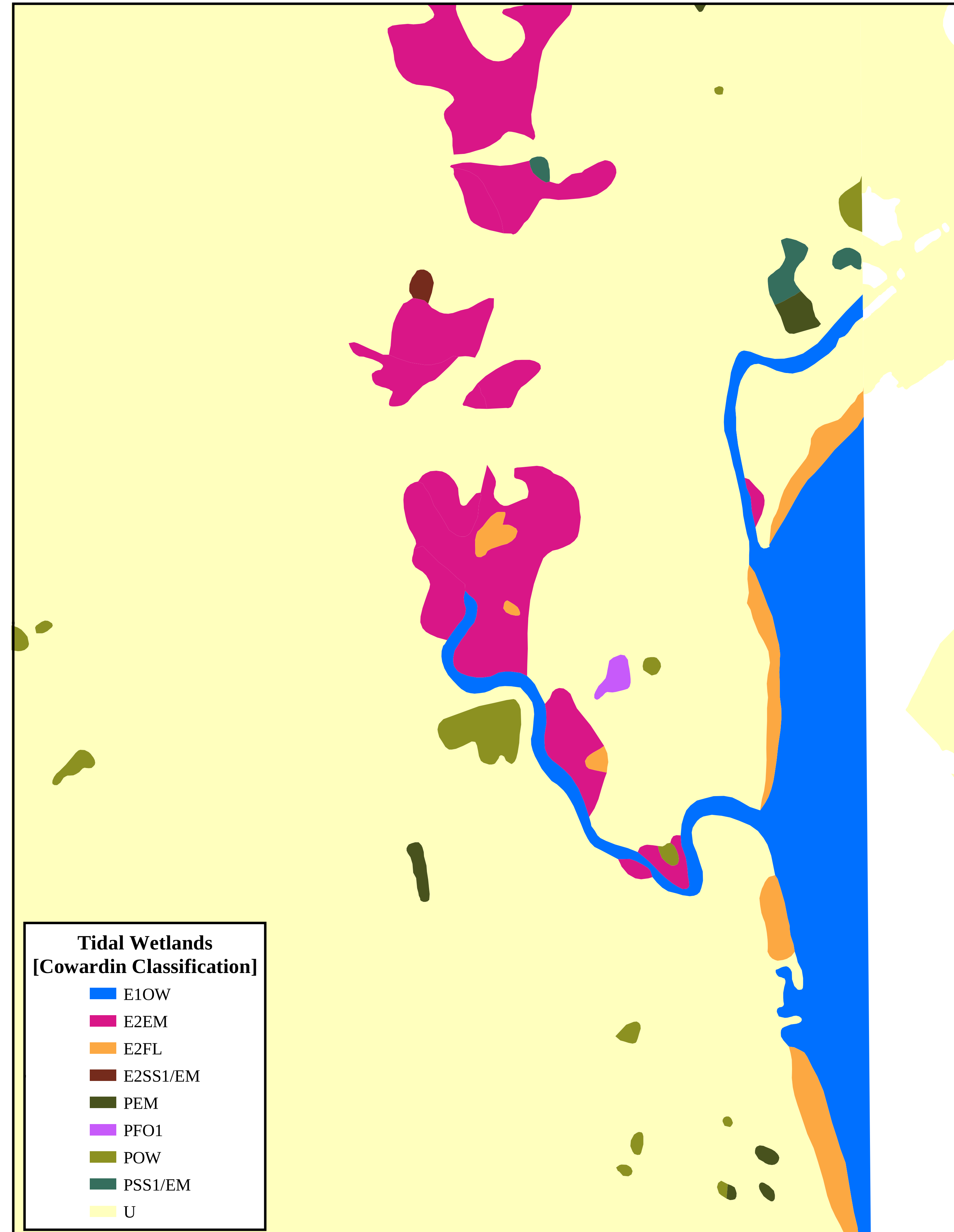


Figure 35. Benthic Characteristics at the Bowery Bay Site.



General Area of Cheesequake Creek Site and Designated Tidal Wetlands (Source: NWI)

Figure 36



Feet
0 450 900 1,800

General Area of Woodbridge Creek SIte and Designated Tidal Wetlands (Source: NWI)

Figure 37

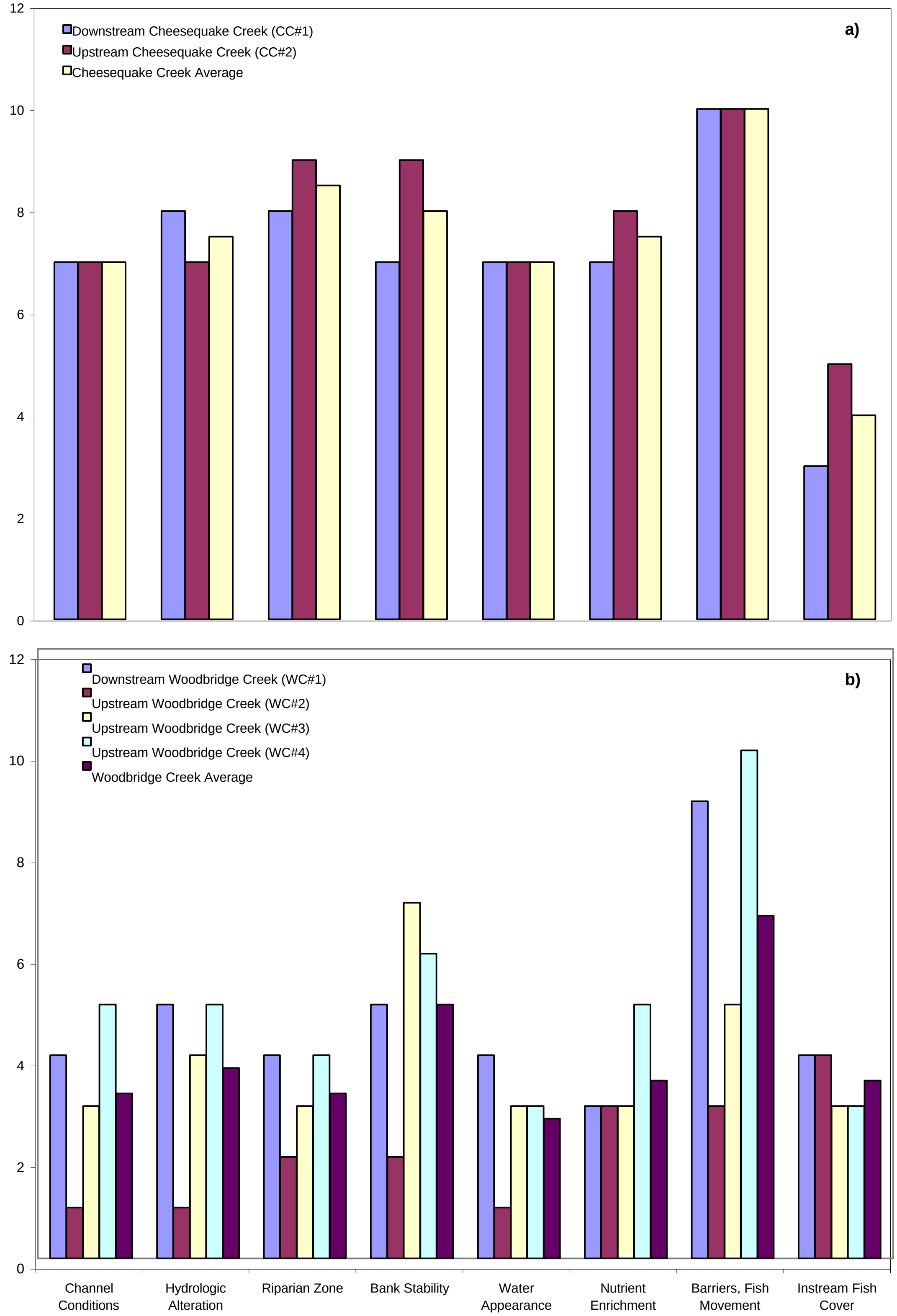
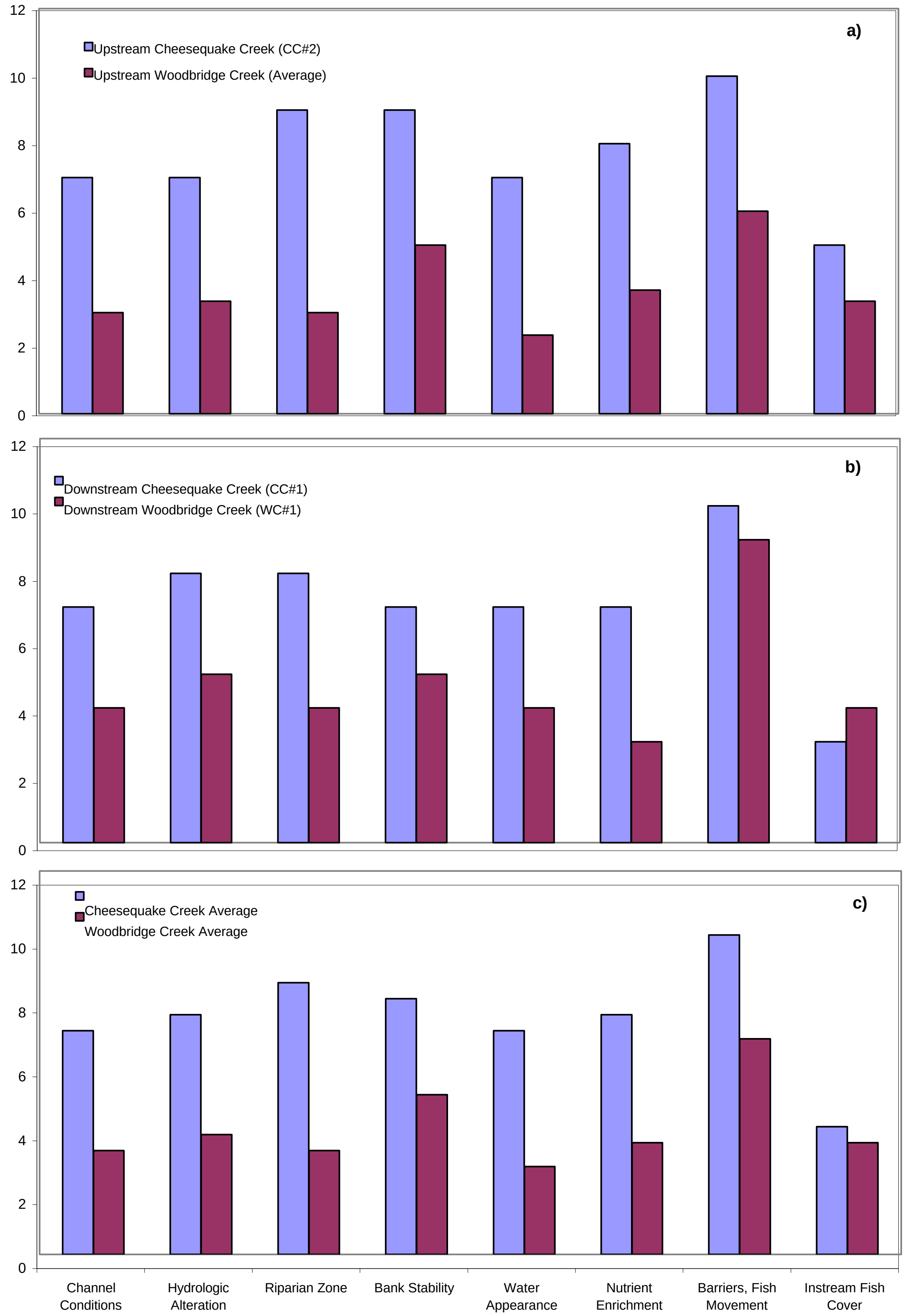
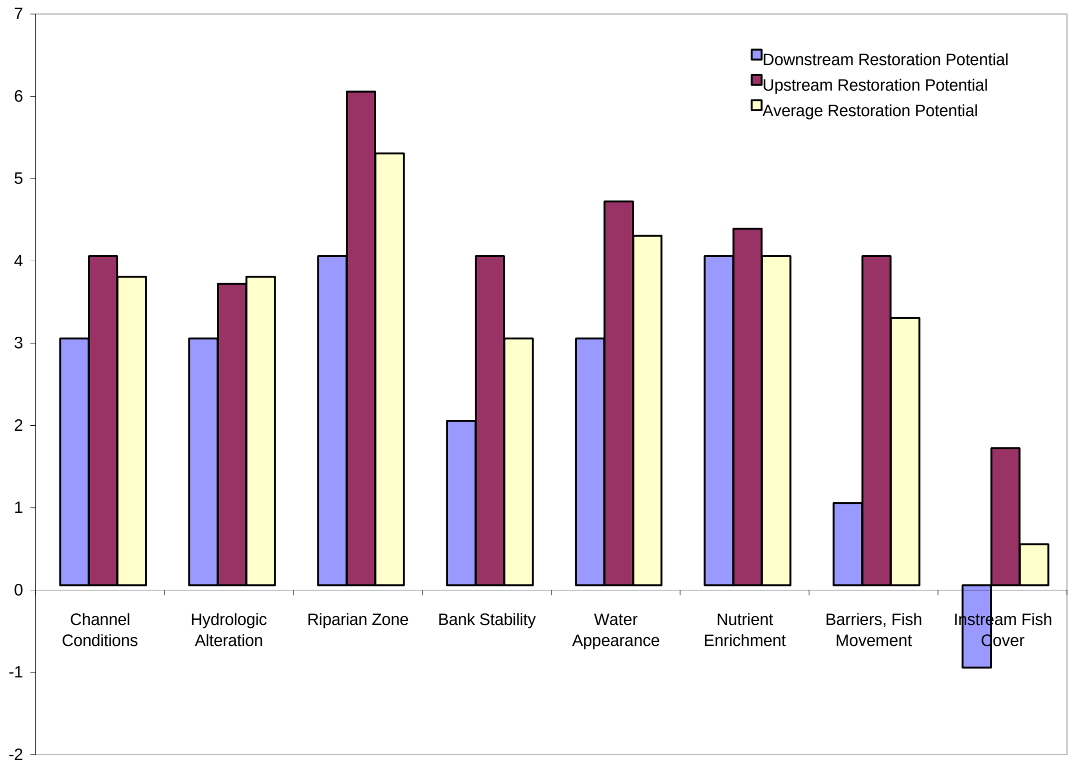


Figure 38: Detailed stream characteristics of upstream and downstream reaches of **a)** Cheesequake Creek reference site and **b)** Woodbridge Creek enhancement site.



<u>Figure 39:</u> General stream characteristics of **a)** Cheesequake Creek reference site vs. **b)** Woodbridge Creek enhancement site and **c)** comparison of average visual assessment score.



<u>Figure 40:</u> Estimated average upstream, downstream and average restoration potential calculated by the difference in Cheesequake Creek reference site visual assessment scores and Woodbridge Creek visual assessment scores

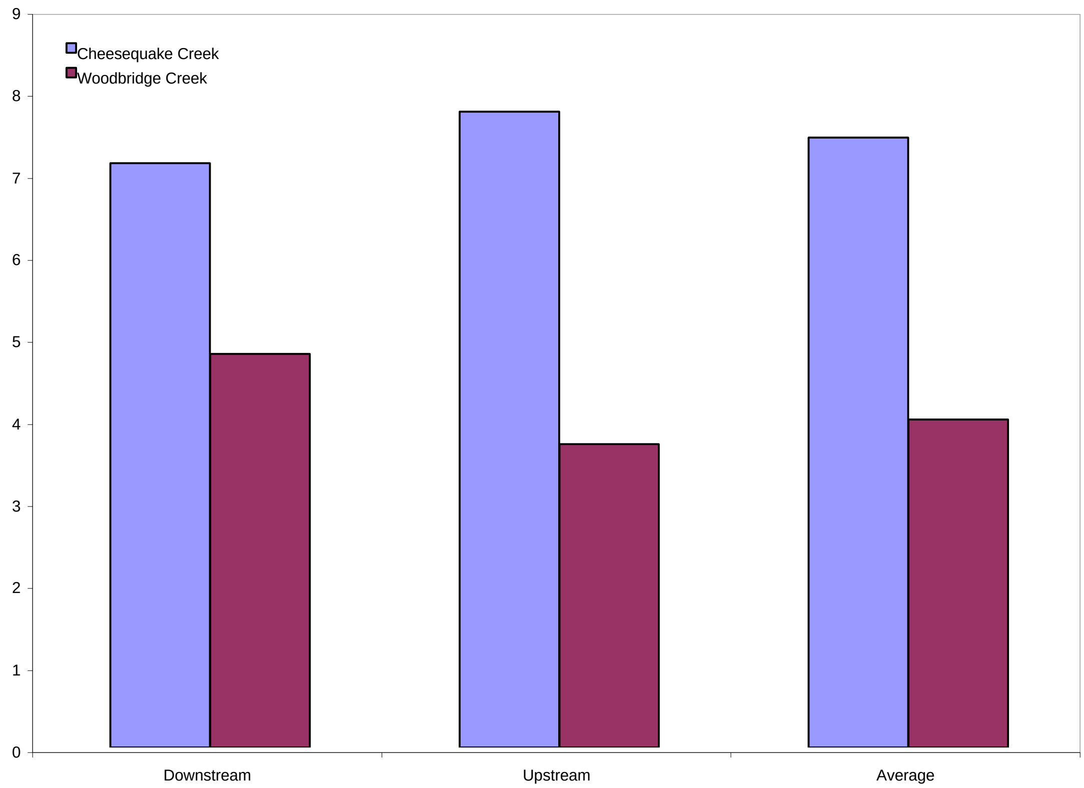
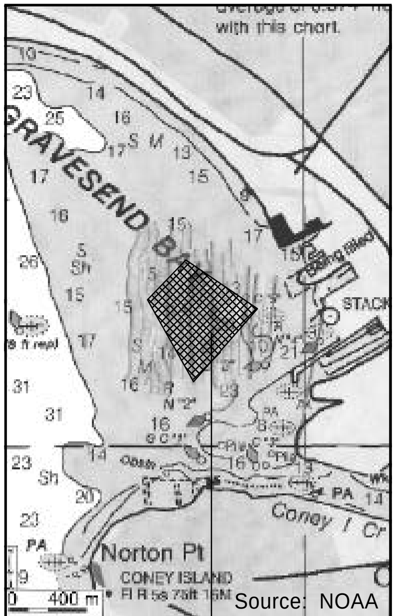


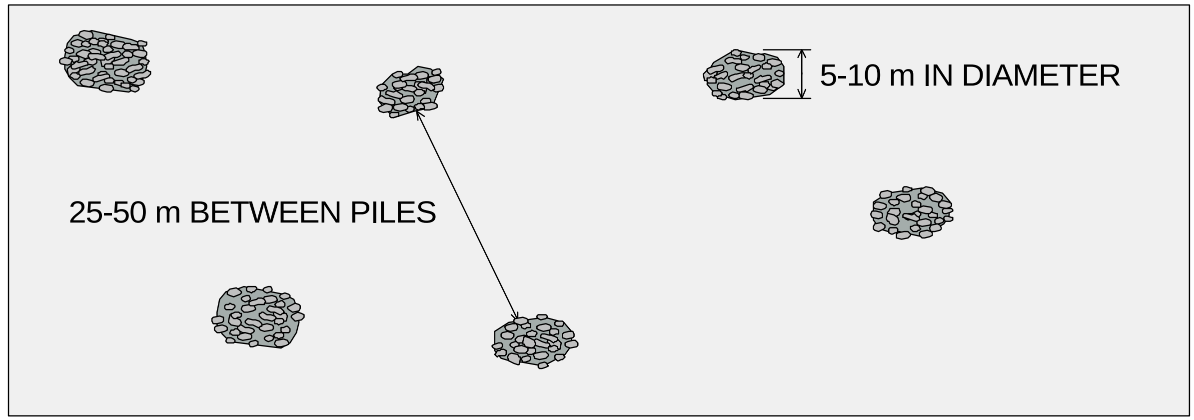
Figure 41: Overall visual assessment score of Cheesequake Creek reference site vs. Woodbridge Creek enhancement site



POTENTIAL ENHANCEMENT AREA

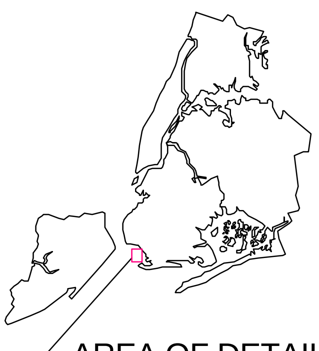
Rock Type	Boulder (300-1500mm)	Cobble (64-300mm)
Rock Volume Fraction	70%	30%
Rock Volume per Rock Pile (5-10m diameter and 3m high)	60 to 220 CY	20 to 90 CY
Rock Volume per Acre (~4 rock piles per acre)	240 to 880 CY	80 to 360 CY

AERIAL VIEW



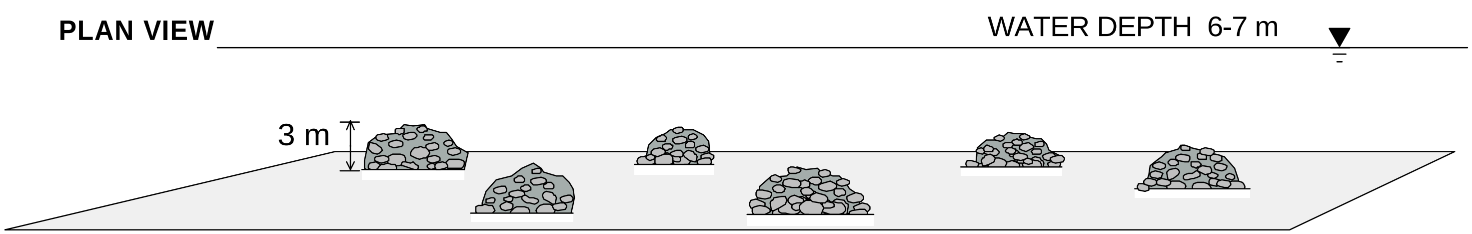
CONCEPTUAL DRAWING NOT TO SCALE

HIGH-PROFILE REEF HABITAT
(or rock pile) MADE OF BOULDERS
AND COBBLES



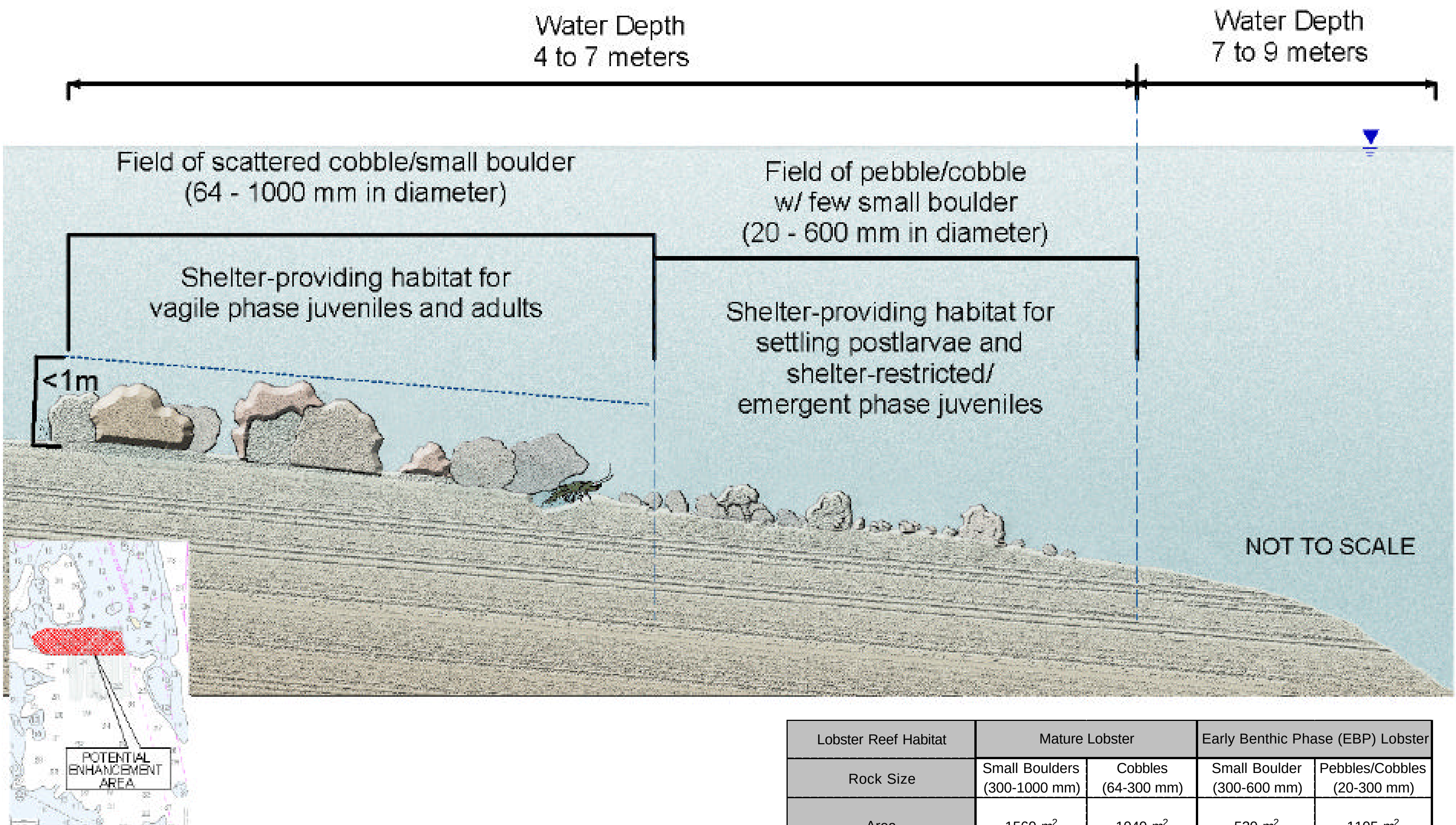
AREA OF DETAIL

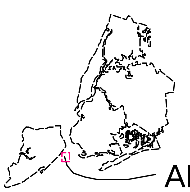
PLAN VIEW



Conceptual Design for High-Profile Reef Habitat Enhancement at Gravesend Bay

Figure 42



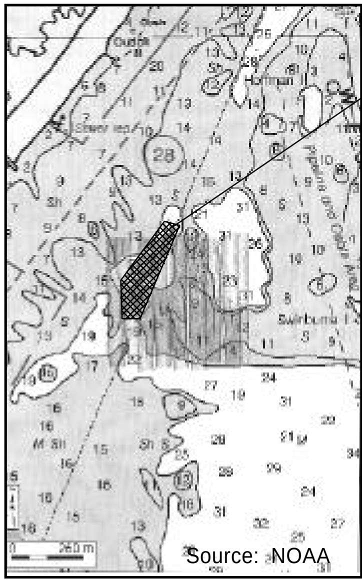


Lobster Reef Habitat	Mature Lobster		Early Benthic Phase (EBP) Lobster	
Rock Size	Small Boulders (300-1000 mm)	Cobbles (64-300 mm)	Small Boulder (300-600 mm)	Pebbles/Cobbles (20-300 mm)
Area	1560 m^2	1040 m^2	520 m^2	1105 m^2
Maximum Height	1 m	0.3 m	0.6 m	0.3 m
Rock Dispersal Factor	50%		75%	
Rock Volume per Acre (considering dispersal factor)	1,020 CY	204 CY	306 CY	326 CY

Conceptual Design for Lobster Reef Habitat Enhancement at Hoffman-Swinburne Islands

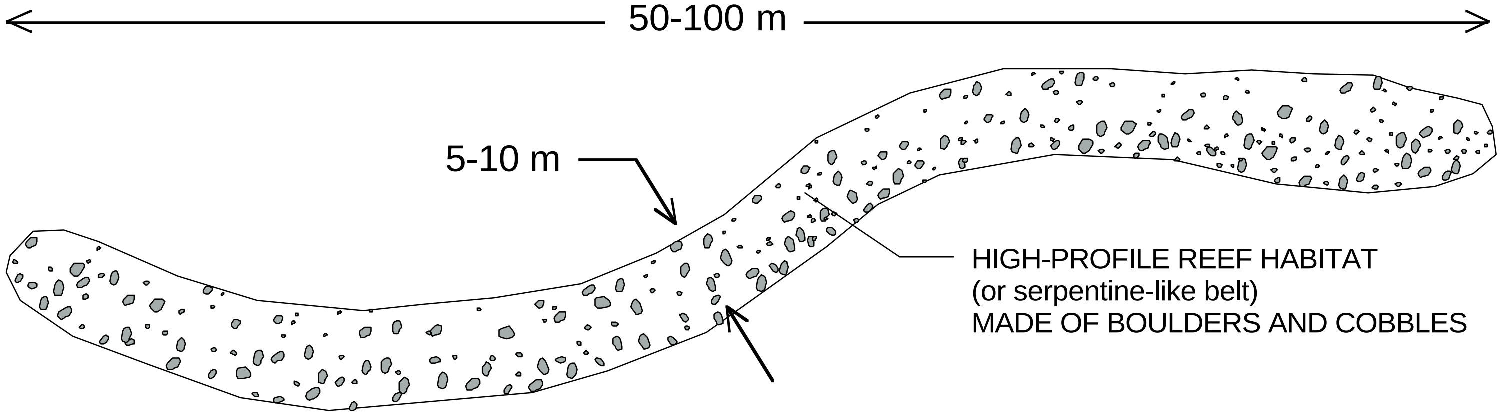
Figure 43

POTENTIAL ENHANCEMENT AREA



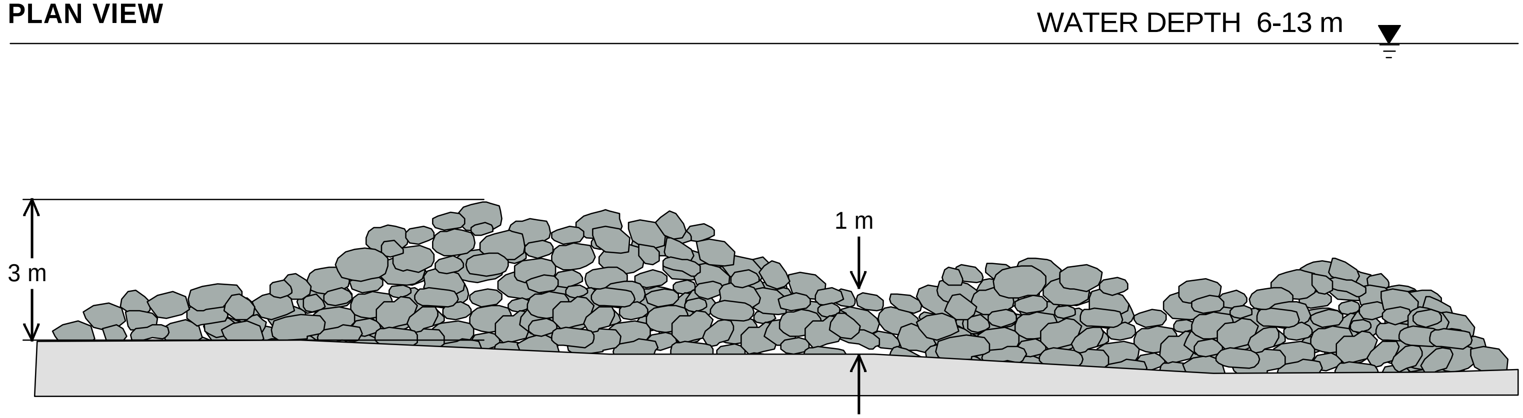
Rock Type	Boulder (300-1500mm)	Cobble (64-300mm)
Rock Volume Fraction	70%	30%
Rock Volume per Belt (50-100m long, 5-10m wide, and 3m high)	690 to 2,740 CY	290 to 1,180 CY

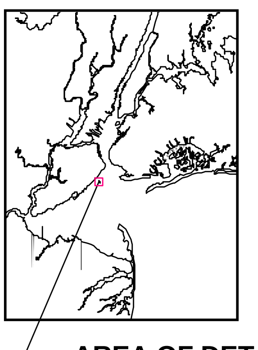
AERIAL VIEW



CONCEPTUAL DRAWING
NOT TO SCALE

PLAN VIEW

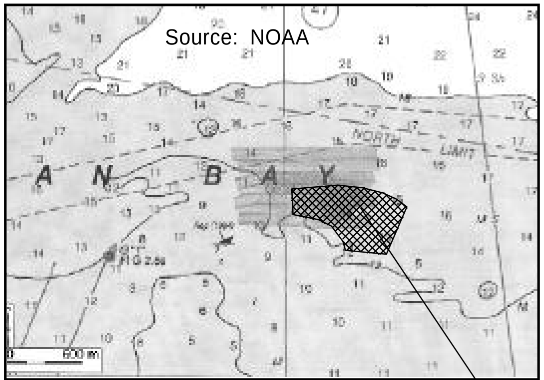




AREA OF DETAIL

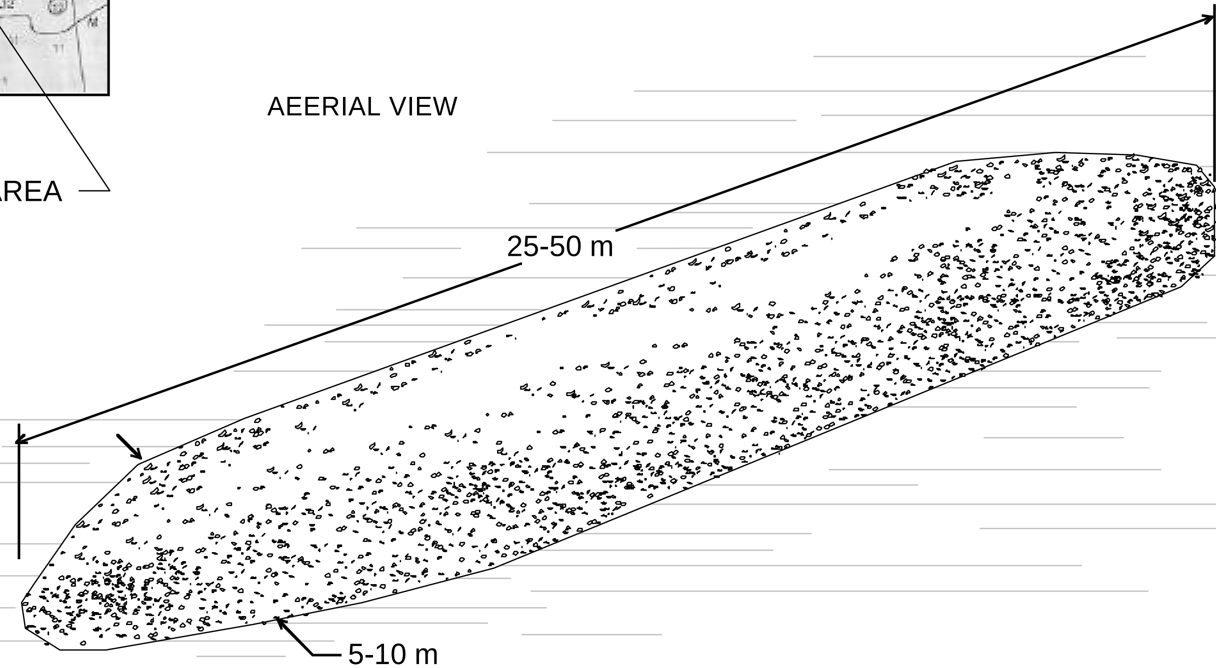
Conceptual Design for High-Profile Reef Habitat Enhancement at Verrazano-Narrows

Figure 44

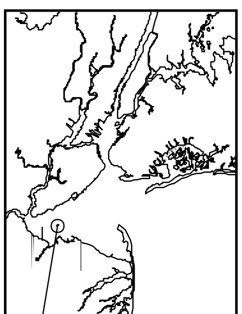


Oyster Reef Habitat	Core Layer	Cultch Layer	
Sediment Type	>60% Sand	cobbles/pebbles (<250 mm)	Shell Fragments (preferably oyster shells)
Sediment Volume Fraction	100%	60%	40%
Reef Layer Volume (25-50m long, 5-10m wide, and 1-2m high)	250 to 980 CY	40 to 160 CY	
Sediment Volume		24 to 96 CY	16 to 64 CY

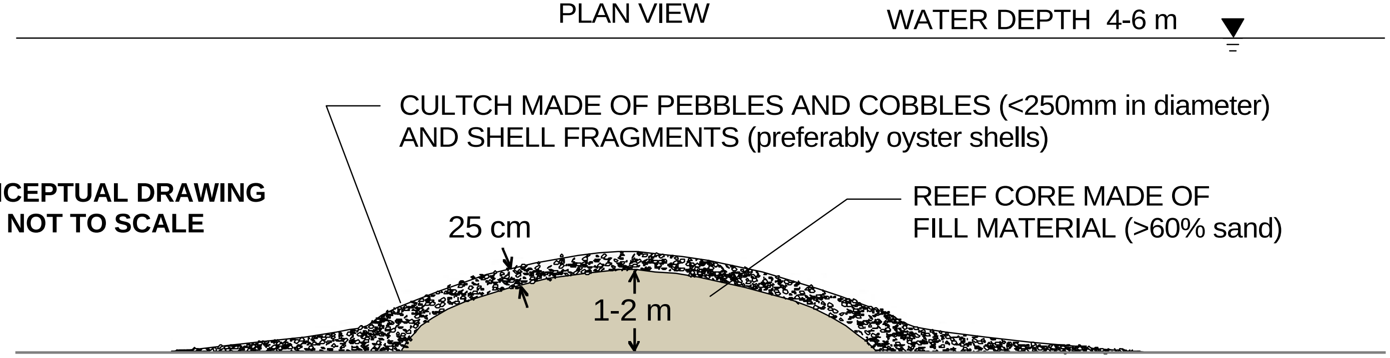
AEERIAL VIEW



PLAN VIEW

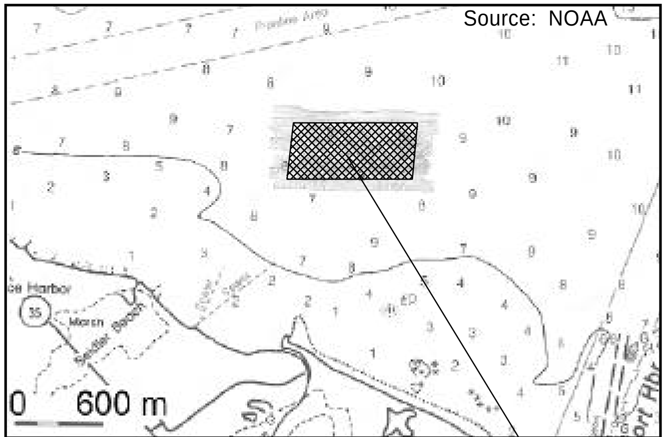


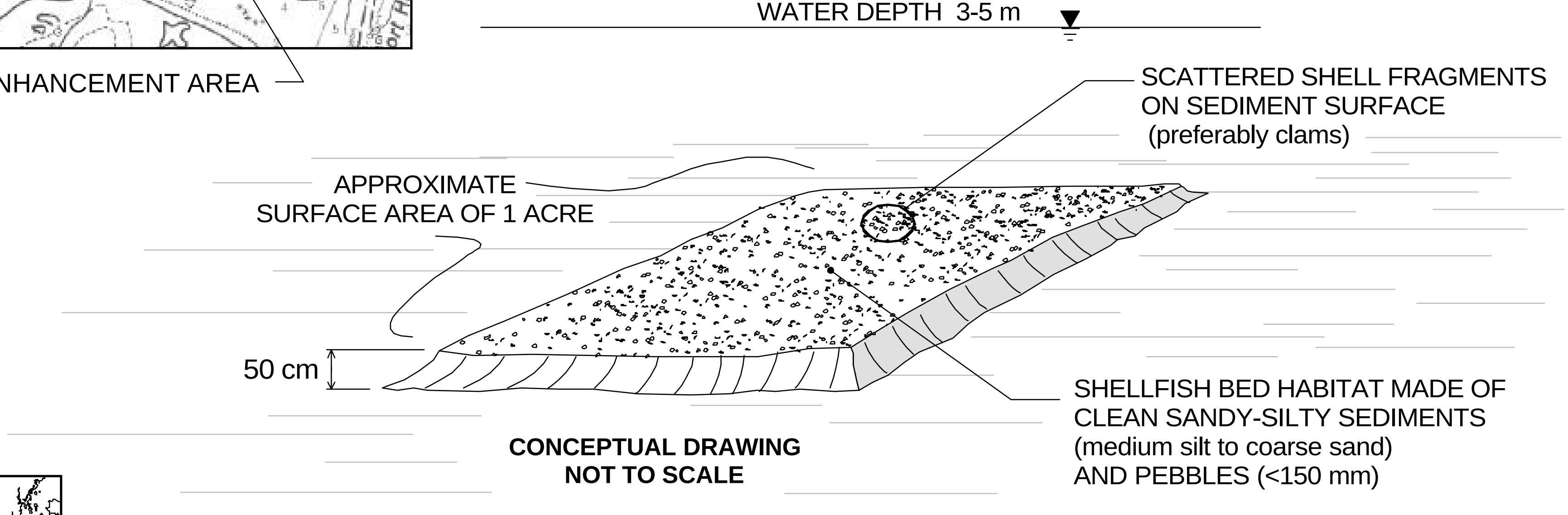
CONCEPTUAL DRAWING NOT TO SCALE

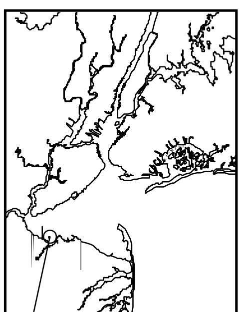


Conceptual Design for Oyster Reef Habitat Enhancement at Raritan Bay Rock Berm

Figure 45



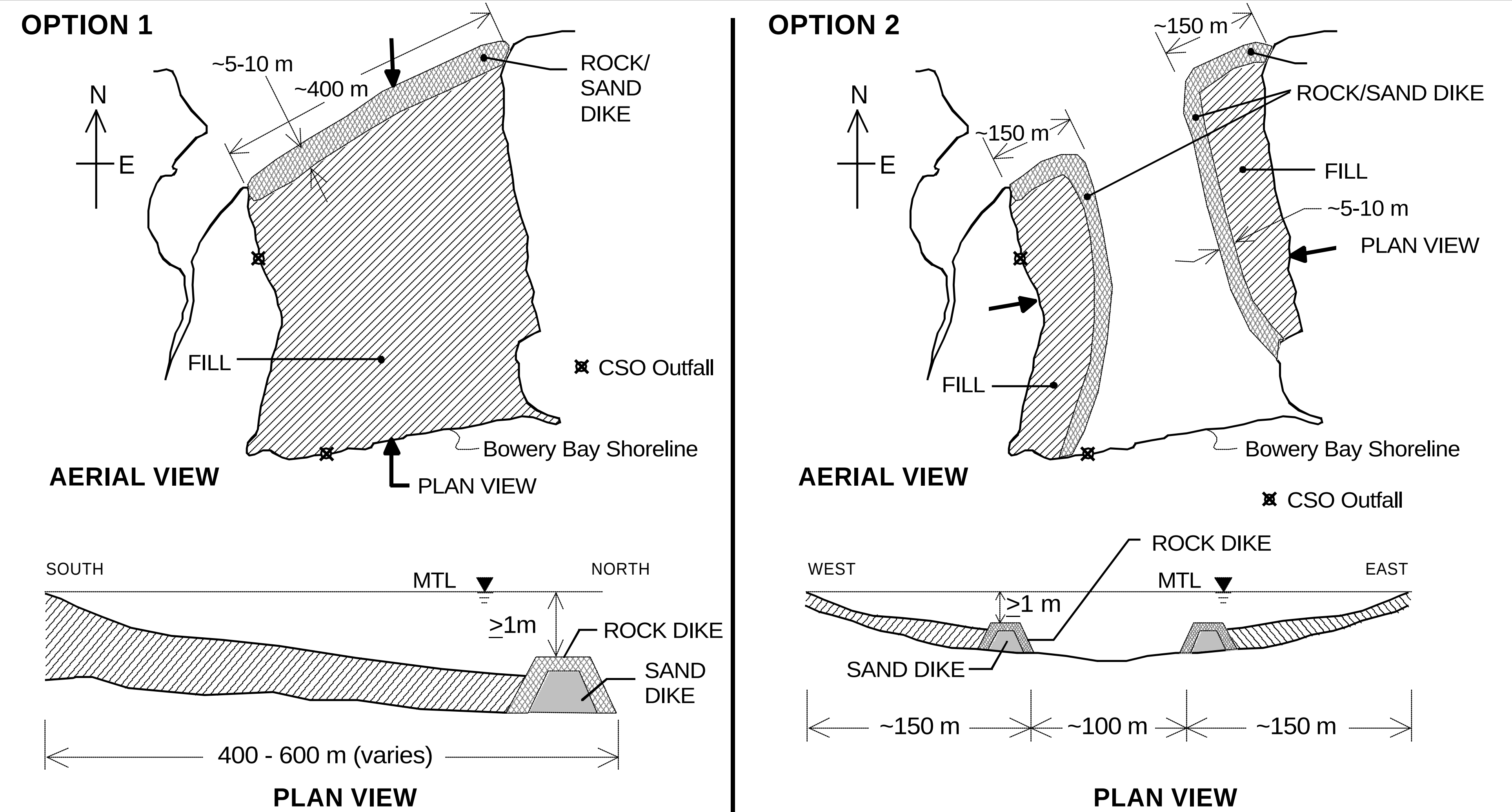


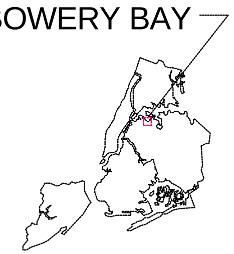


Shellfish Bed Habitat	Sediment Layer		Surface Layer
Sediment Type	Medium Silt to Coarse Sand (0.0156 to 1.0 mm)	Pebble-size Rocks (< 150 mm)	Scattered Shell Fragments (preferably clam shells)
Sediment Volume Fraction	70%	30%	n/a
Volume per Acre (50 cm deep layer)	1,850 CY	800 CY	1000 CY

Conceptual Design for Shellfish Bed Habitat Enhancement at Raritan Bay Shellfish Bed

Figure 46





	Option 1 One "in-bay terrace"			Option 2 Two "in-bay terraces"		
Element	Fill	Dike		Fill	Dike	
Sediment Type	Sand (medium silt to coarse sand)	Sand (medium silt to coarse sand)	Boulder/Cobble-Size Rock (64-1500 mm)	Sand (medium silt to coarse sand)	Sand (medium silt to coarse sand)	Boulder/Cobble-Size Rock (64-1500 mm)
Volume	627,800 CY	9,420 CY	3,140 CY	392,400 CY	20,600 CY	7,800 CY

CONCEPTUAL DRAWING NOT TO SCALE

Conceptual Design for Shallow Water Habitat at Bowery Bay

Figure 47

APPENDIX A

SPECIES LIFESTAGE HISTORY

EFH-MANAGED SPECIES

Pollock (Pollachius virens)

Eggs

Pollock eggs are pelagic and found within the water column at salinities between 32.0 psu and 32.8 psu, and at depths ranging from 30 m to 270 m (Cargnelli et al. 1999). Pollock eggs have been collected at water temperatures less than 17°C, but occur most abundantly at temperatures ranging from 5°C to 11°C (Cargnelli et al. 1999).

Larvae

Pollock larvae are pelagic and reside near the water's surface, typically from shore out 200 m, but are most abundantly collected between 50 m and 90 m (Cargnelli et al. 1999). Larval temperature preferences are generally less than 17°C, but are reported to vary by season (Cargnelli et al. 1999). The primary dietary constituent of larval pollock are copepods (Cargelli et al. 1999).

Juveniles

Pollock juveniles less than two years of age inhabit inshore subtidal and intertidal zones where salinity is about 31.5 psu (Cargnelli et al. 1999). Bottom substrate preferences are reported variable and include mud, sand, rock and vegetative substrates (Cargnelli et al. 1999). Juveniles have been collected from depths ranging from 5 m to 125 m, and at temperatures between 1°C and 18°C. Juvenile prey includes crustaceans, such as Euphausiids (*Meganyctiphanes norvegica*), fish (Atlantic herring) and mollusks (Cargnelli et al. 1999).

Adults

Adult pollock, a schooling species, primarily reside throughout the water column where preferred depths range form 15 m to 365 m (Cargnelli et al. 1999). Preferred temperatures are reported between 0°C and 14°C, and salinities between 31 psu and 34 psu (Cargnelli et al. 1999). Adult pollock diet is similar to juveniles and includes crustaceans, fish and mollusks (Cargnelli et al. 1999).

Spawning

Spawning typically occurs over rocky substrate when temperatures reach 8°C, and peak at temperatures range from 4.5°C to 6°C (Cargnelli et al. 1999). Preferred salinities are reported between 32 psu and 32.8 psu (Cargnelli et al. 1999).

Red hake (Urophycis chuss)

Eggs

Red hake eggs are pelagic and are approximately 0.6 to 1.0mm in diameter (Steimle et al. 1999a). Eggs tend to be restricted to the deeper marine (seawater zone) area (Able and Fahay 1998). Eggs are found in temperatures below 10oC and salinities of 25ppt or less, are most often observed from May to November (NEFMC 1998), and are most abundant during June and July (Steimle et al. 1999). Red hake eggs are not typically separated from eggs of Urophycis or Phycis species as they occur together; therefore, habitat characteristics in which red hake eggs are found may be generally uncertain (Steimle et al. 1999a).

Larvae

Red hake larvae are pelagic and have been collected from the mid- to outer-continental shelf of the Middle Atlantic Bight at temperatures between 8 and 23oC and in water depths of 200m or less (Steimle et al. 1999a). Larvae prefer salinities ranging up from 0.5ppt (NEFMC 1998). Larvae are often found from May through December, and peak abundance is during September and October (Steimle et al. 1999a). Dietary components of red hake larvae include copepods and microcrustaceans (Steimle et al. 1999a).

Juveniles

Red hake juveniles are pelagic until they reach approximately 25mm TL or greater at which time they become demersal seeking shelter along the continental shelf bottom within depressions in the sediment or among live sea scallop beds (Steimle et al. 1999a). Juveniles also may associate with other forms of shelter including debris and artificial reefs (Steimle et al. 1999a). In the Hudson-Raritan estuary, red hake juveniles have been collected at temperatures between 2oC and 22oC, at depths between 5m and greater than 50m when salinities range from 22ppt to 28ppt, and feeding on small epibenthic crustaceans (Steimle et al. 1999a).

Adults

EFH for adult red hake includes bottom habitats of sand, muddy sand, and mud substrate. Adult red hake can be found in the water column; however, they are typically found in depressions within soft sediments or shell beds (Steimle et al. 1999a). General water conditions that make up EFH for adults of this species include depths of 5m to less than 300m (preferred depths are 30 to 130m), salinity between 20 and 33ppt, temperatures of 2 and 20ºC, and dissolved oxygen (DO) concentrations in the Hudson-Raritan estuary of less than 6mg/L (Steimle et al. 1999a). Adult red hake are seasonally common in the Hudson-Raritan estuary between November and May (Stone et al. 1994). The diet of red hake consists of crustaceans, squid and demersal and pelagic fish (Steimle et al. 1999a).

Spawning

Spawning occurs on the continental shelf, at temperatures between 5 and 10^{o}C and is most abundant in May and June in the New York Bight (Steimle et al. 1999a).

Winter flounder (Pseudopleuronectes americanus)

Eggs

Winter flounder eggs are demersal and adhesive. They range from 0.6 to 1.0mm in diameter, with an average diameter of 0.6mm (Topp 1968, Klein-MacPhee 1978, Buckley 1989). The optimal salinity for egg development and survival is 15 to 30ppt

(Buckley 1989), with 100% mortality at low salinities (5 to 10ppt), and high mortality and a high percentage of deformed larvae reported at water salinities of 35 to 40ppt (Klein-MacPhee 1978). Eggs are typically found in water with temperatures less than 10°C and depths less than 5 meters over sand, muddy sand, mud and gravel substrates (NMFS 2003).

Larvae

Larvae are nonbuoyant and have a strong benthic orientation, often resting on the bottom between swimming efforts (Pearcy 1962). Since the early life stages of this species are nondispersive, the spawning grounds and the nursery grounds are essentially the same (Pearcy 1962). Howell et al. (1992) indicate that the nursery habitat for larvae and juveniles includes littoral and sublittoral saltwater coves, coastal salt ponds, estuaries, and protected embayments. Winter flounder larvae prefer water with temperatures less than 15°C, depths less than 6 meters, and a salinity range of 4 to 40ppt (NMFS 2003).

Juveniles

Young-of-year (YOY) and yearlings are tolerant of higher water temperatures and remain in the estuary during the summer (Rose et al. 1996 ESNP). YOY are generally found in areas where the water temperatures are below 28°C, with depths below 10 meters and salinities ranging between 5 and 33ppt. (NMFS 2003).

Following metamorphosis from larvae to juveniles, winter flounder are benthic and seldom lose contact with the substrate (Buckley 1989). The majority of juvenile winter flounder spend most of their first two years in or near shallow, natal waters and on the edge of channels, preferring sand or sand/silt substrate (Topp 1968). Their preferred habitat is found in waters ranging in temperature from 0 to 25°C, in salinity from 4 to 30ppt and in depths up to 18m (37m in colder weather) (USFWS 1978). Early juveniles (6 to 9cm) have been shown to be photopositive, which, because of generally low light penetration in coastal waters, limits their movements to shallow cove areas, while late juveniles (12 to 18cm) reside in deeper water areas and are photophobic (Howell et al. 1992). Briggs and O'Connor (1971) evaluated shore-zone fish populations in Great South Bay, Long Island, NY and found significantly more juvenile winter flounder over natural bottoms (mixture of sand, clay, mud, and detritus and covered with dense growth of eelgrass [*Zostera marina*]) compared to open sand-filled bottoms.

Juvenile winter flounder feed on a variety of small organisms with amphipods and polychaetes being the primary food sources (Pearcy 1962 ESNP). NMFS documents that major prey of juveniles are amphipods, copepods, polychaetes and bivalves (NMFS 2003).

Adults

During summer months, adult winter flounder reside in nearshore coastal waters, with the distance offshore dependent upon water temperature, i.e., the warmer the water temperature the further offshore adults move. Adults of this species frequent water with temperatures below 25°C, salinities ranging from 15 to 33ppt and depths anywhere from 1 to 100 meters (NMFS 2003b). They begin an inshore migration moving into shallow bays and estuaries in the early fall in preparation for spring spawning. By July, mature adults have left the inshore waters for offshore areas with lower water temperatures. Major preys of winter flounder were found to be bivalves, amphipods and polychaete worms (NMFS 2003b). Bowman et al. (2000) documented that adults of this species feed primarily on polychaetes, anthozoans, and amphipods.

Spawning

Spawning in the mid-Atlantic Bight (and the study area) occurs between February and April in estuaries and bays (Howe et al. 1976). Preferred water characteristics include water temperatures below 15°C, salinities between 10 and 32ppt (Pereira et al. 1998) over sand, mud and gravel substrates in depths less than 6 meters (NMFS 2003).

Windowpane flounder (*Scophthalmus aquosus*)

Eggs

Eggs, ranging from 0.9 to 1.4mm in diameter, are typically found in planktonic habitats, less than 70 meters deep and at temperatures between 6 and 14ºC in the spring, 10 and 16ºC in the summer and 14 and 20ºC in autumn (Chang et al. 1999). Eggs are collected in the Middle Atlantic Bight from February to November, with peak densities occurring in May and October (Chang et al. 1999).

Larvae

Larvae, which are pelagic, settle to the bottom at approximately 10 mm to 20 mm Total Length (TL), and are found throughout the polyhaline portion of estuaries in the spring (Morse and Able 1995), but primarily on the shelf in the autumn (Chang et al. 1999). Larvae occur in the Middle Atlantic Bight from February through July and September through November in planktonic habitats less than 70 meters deep (Chang et al. 1999). Larvae prefer temperatures between 3°C and 14ºC in spring, 10ºC and 17ºC in summer, and 14 and 20ºC in autumn. Windowpane flounder larvae feed on copepods and zooplankton (Chang et al. 1999).

Juveniles

Bottom trawls in the Hudson-Raritan estuary showed that juveniles were fairly evenly distributed throughout the estuary, but they were most abundant in the deeper channels in winter and summer (Wilk et al. 1998). Windowpane flounder was the third most abundant species collected in bottom trawls in the Hudson-Raritan estuary (Wilk et al. 1998). Juveniles were most abundant at bottom temperatures of 5 to 23°C, at depths of 7 to 17 meters, at salinities of 23 to 30ppt, and at DO levels of 7 to 11 mg/l (Wilk et al. 1998). Bottom trawls in Newark Bay showed a similar depth distribution, with very few juvenile windowpane flounder collected at shoal stations (NMFS 1994, LMS 1996).

Adults

Adults are found on sandy sediment of the Hudson-Raritan Bay, where preferred temperatures are between 0°C and 24ºC and salinity ranges from 15 to 33ppt (Chang et al. 1999). In the Hudson-Raritan estuary, adults are more abundant during the summer in deeper channels, and at depths less than 25 meters for all seasons (Chang et al. 1999).

Dietary constituents include small crustaceans, such as mysid and decapod shrimp, and tomcod and hake larvae (Chang et al. 1999).

Spawning

Spawning occurs from February through November in coastal, inner continental shelf waters peaking in the mid-Atlantic Bight during May (Able and Fahay 1998). Preferred temperatures for spawning range from 6 to 21ºC (Chang *et al.* 1999). Some spawning may also occur in the high-salinity portions of estuaries in the mid-Atlantic Bight, including Sandy Hook Bay (Croker 1965). Windowpane flounder spawn in the evening or at night on or near the bottom (Bigelow and Schroeder 1953, Ferraro 1980).

Atlantic sea herring (Clupea harengus)

Eggs

Atlantic herring eggs are demersal and often occur in multiple horizontal layers forming egg beds adhered to substrates such as gravel (Reid et al. 1999). In the Georges Bank, egg beds are found at temperatures between 12 and 15ºC, at depths between 40 and 80 meters, and at 32ppt salinity (Reid et al. 1999).

Larvae

Atlantic herring larvae are pelagic and occur in the Gulf of Maine at temperatures between 9 and 16ºC, and salinities around 32ppt (Reid *et al.* 1999). In the Georges Bank, larvae reside at depths greater than 50 meters (Reid *et al.* 1999). Atlantic herring larvae in the Georges Bank make vertical migrations, possibly linked to daylight, tidal currents or shifts in prey abundance (Reid *et al.* 1999). Larval Atlantic herring collected in the study area are most likely from offshore spawning in the northern portion of the Middle Atlantic Bight. Atlantic herring larvae are opportunistic feeders with zooplankton and copepods (Reid et al. 1999) dominating their diet.

Juveniles

Atlantic herring juveniles reside in coastal waters within large schools (Reid *et al.* 1999). Under laboratory conditions, preferred water temperature is between 8 and 12ºC and preferred salinities range from 26 to 32ppt; salinity preference being temperature dependant. In the Hudson-Raritan estuary, Atlantic herring juvenile were most abundant at 4 to 6ºC and at 15 and 18ºC with occurrence not depicted by depth or salinity (Reid *et al.* 1999). Juveniles have been reported abundant throughout the lower Hudson-Raritan estuary during the winter and spring (Reid *et al.* 1999). Juvenile Atlantic herring dominant prey species include copepods, decapod larvae, cirriped larvae and cladocerans (Reid *et al.* 1999).

Adults

EFH for adult Atlantic herring include gravel sea floors where salinities are greater than 28ppt and water temperatures are below 21ºC, while movements become slower at temperatures less than 4ºC (Reid et al. 1999). In the Hudson-Raritan estuary, Atlantic herring catches have been reported most abundant at water temperatures between 3 and 6ºC, depths between 4.5 and 13.5m, salinities greater than 24ppt and at 11mg/L DO

(Reid et al. 1999). Adults have been reported to be most common in the Hudson-Raritan estuary during winter and are occasionally collected during spring and fall (Reid et al. 1999). Adult Atlantic herring predominately feed on euphausiids, chaetognath and copepods, and pteropods, amphipods and mysids have also been reported as dietary constituents (Reid et al. 1999).

Spawning

Spawning typically occurs on stone or gravel material in high energy environments (e.g., strong bottom currents) at temperatures between 7 and 15ºC and salinities ranging from 31.9 to 33.0ppt (Reid *et al.* 1999). The Hudson-Raritan estuary is not considered one of the three historic herring spawning stocks (Reid *et al.* 1999). Able and Fahay (1998) hypothesized that the resurgence of spawning by Atlantic herring over Georges Bank and Nantucket Shoals has also increased reproductive activity in the northern part of the Middle Atlantic Bight, but sampling data in support of this hypothesis are lacking.

Bluefish (Pomatomus saltatrix)

EFH is designated for juvenile and adult bluefish within the project area, including both the estuarine and marine salinity zones (NMFS 1999). This is a pelagic, highly migratory species found in the continental shelf waters in temperate and semi-tropical oceans around the world (Moore 1989). They travel in schools of like-sized individuals and migrate seasonally to be in water of preferred warmer temperatures (Fahay et al., 1999). Bluefish are generally found in estuaries during the juvenile phase and in larger bays and open oceans as adults. This species is most common in the Hudson-Raritan Estuary between May and October (juveniles) and April and October (adults).

While juvenile bluefish have been reported in most estuaries of the Middle Atlantic Bight, eggs and larvae have been recorded in just a few estuaries (Able and Fahay 1998); and are therefore rarely collected in estuarine ichthyoplankton samples. Eggs and larvae are found offshore in the open ocean; while eggs are never found inshore, larvae have been documented in bays (Herman 1963).

Eggs

Bluefish eggs occur on the continental shelf (Fahay *et al.* 1999). Preferred water temperatures are above 18ºC and preferred salinities are greater than 31ppt (NMFS 2003, Fahay *et al.* 1999). No bluefish egg EFH is designated at any inshore location (NMFS 2003).

Larvae

Bluefish larvae reside over the continental shelf (Fahay *et al.* 1999) in waters with temperatures greater than 18ºC, salinities above 30ppt and depth more than 15 meters (Fahay *et al.* 1999). Larvae are considered to be rare in the Hudson-Raritan Esturay (Stone et al 1994). EFH is not designated for bluefish larvae at any location inshore (NMFS 2003).

Juveniles

Stone et al. (1994) considered juvenile bluefish as seasonally abundant in the estuarine and marine areas of the Hudson-Raritan estuary. Juveniles use estuaries during the first summer of their life and move out during the early fall to migrate south. Most of the bluefish population in the New York Bight probably originates from spring-spawned eggs (Chiarella and Conover 1993). Juvenile bluefish produced in the spring travel north with the Gulf Stream (Hare and Cowen 1993) and migrate across the continental shelf to the mid-Atlantic bays and estuaries (which act as productive nursery areas) in early to mid-June (McBride and Conover 1991). Preferred temperatures range from 15 to 20ºC and salinities between 36 and 31ppt (Fahay *et al.* 1999). Bluefish juvenile EFH characteristics include mud, silt, clay and mostly sandy sediments, as well as *Ulva* and *Zostera* beds (Fahay *et al.* 1999). During daytime, juveniles are found near shorelines and in tidal creeks, whereas during night they are found in bays or channels (Fahay *et al.* 1999). Juveniles can not survive in water temperatures below 10 or above 34ºC (Fahay *et al.* 1999). Bluefish juveniles are typically found in estuarine water temperatures greater than 20ºC, but not greater than 30 or less than 15ºC (Fahay *et al.* 1999). Juveniles prefer salinities between 23 and 36ppt, but are reported to be tolerant of salinities as low as 3ppt (NMFS 2003). Hudson River bluefish juvenile were documented feeding on bay anchovy, white perch, American shad, river herring, and striped bass (Texas Instruments 1976).

Adults

Adults of this species tend to occur in large bays and estuaries, as well as across the continental shelf (Fahay *et al.* 1999). Adult bluefish tend to prefer ocean salinities and warm water, and have been reported to tolerate temperatures ranging from 11.8 to 30.4ºC (Fahay *et al.* 1999). Stone et al. (1994) considered adult bluefish common (i.e., frequently encountered but not in large numbers). In the Hudson-Raritan estuary, adult bluefish have been collected at water temperatures greater than 12ºC (most abundant between 21 and 23ºC) and at DO between 5 and 8mg/L (Fahay *et al.* 1999). Collection depths in the Hudson-Raritan estuary ranged from 5 to 17 meters and most abundant at 6m and salinities ranged from 21 to 30ppt while bluefish were most abundant from 25 to 27ppt (Fahay *et al.* 1999). The primary food items consumed by New York Bight bluefish were: anchovy, menhaden, round herring, silversides, sand lance, mackerel, butterfish, shrimps, squids, crabs, mysids, and annelid worms (Wilk 1982). According to Wilk (1977) there does not seem to be a preference for particular prey species, however size does appear to be important, with larger sizes being preferred.

Spawning

Spawning takes place offshore over continental shelf waters during a protracted spawning period (March through July) (Fahay *et al.* 1999).

Atlantic butterfish (Peprilus tricanthus)

Eggs

Butterfish eggs are pelagic and range in size from approximately 0.68 to 0.82mm in diameter (Cross et al. 1999). Often found in surface waters of the continental shelf and estuaries and bays at depths less than 200 meters, eggs have been collected at depths ranging from 10 to 1250 meters (Cross et al. 1999). Butterfish eggs are reported to be most abundant in water with temperatures between 11 and 17ºC but have been collected in temperatures ranging from 6 to 26ºC (Cross et al. 1999). Favorable salinities for butterfish eggs can range from 25 to 33ppt (Cross et al. 1999).

Larvae

Butterfish larvae are pelagic and have been collected from surface waters at the continental shelf and estuaries and bays in the Middle Atlantic Bight (Cross et al. 1999). Larvae have been collected at salinities ranging from 6.4 to 37.4ppt, water temperatures between 7 and 26ºC (most abundantly found at temperatures between 9 and 19ºC) and varying depths ranging from 10 to 1750 meters (Cross et al. 1999).

Juveniles

Butterfish juveniles reside on the continental shelf, inshore bays and estuaries and are common in inshore areas (Cross 1999). Smaller juveniles have been found under floating objects, while larger juveniles have been collected over sandy to muddy substrates (Cross *et al.* 1999). Larger juveniles may congregate near the bottom during the day and move upward at night. Preferred water temperature ranges from 4.4 to 29.7ºC and preferred salinities range from 3.0 to 37.4ppt (Cross *et al.* 1999). In the Hudson-Raritan estuary, juvenile butterfish have been collected at depths between 3 and 23 meters, water temperatures from 8 to 26ºC, salinities from 19 to 32ppt and DO from 3 to 10mg/L (Cross *et al.* 1999). Juvenile butterfish diet is similar to adult feeding habits where diet is dominated by planktonic prey (Cross *et al.* 1999).

Adults

EFH for adult butterfish includes bottom habitats of sandy, sandy-silt and muddy substrates on the continental shelf, coastal bays and estuaries, surf zone and mixed salinity zones (Cross et al. 1999). General water conditions that make up EFH for adult butterfish include water temperatures between 4.4 and 26.0ºC, salinities between 3.8 and 33ppt and DO between 6 and 9mg/L (Cross et al. 1999). In the Hudson-Raritan estuary, adult butterfish have been collected at depths between 3 and 23 meters, water temperatures from 8 to 26ºC, salinities from 19 to 32ppt and DO from 3 to 10mg/L (Cross et al. 1999). Planktonic prey, including thaliaceans, squids, copepods, amphipods, decapods and small fish (Cross et al. 1999), dominates adult butterfish diet.

Spawning

Spawning occurs primarily over continental shelf waters in the middle Atlantic Bight between May and October, although some eggs and larvae have been collected in coastal and estuarine waters (Able and Fahay 1998). Appropriate conditions for spawning include temperatures above 15ºC at depths between 3 and 145 meters (Cross et al. 1999). Butterfish may spawn throughout their annual migration north and inshore as temperatures increase (Cross et al. 1999).

Atlantic mackerel (*Scomber scombrus*)

Eggs

Eggs are pelagic and found within the water column at depths ranging from 10 to 325 meters, and most abundantly at depths between 30 and 70 meters (Studholme et al. 1999). Atlantic mackerel eggs have been collected in water temperatures between 5 and 23ºC, but the preferred temperature range is from 7 to 16ºC (Studholme et al. 1999). Eggs have been collected from sea water where salinities are greater than 30ppt, as well as from estuaries where salinities typically range from 18 to 25ppt; however, mortality has been reported to increase as salinities drop below 25ppt (Studholme et al. 1999). Correlations in timing of peak egg hatching and the highest abundances in zooplankton have been noted (Studholme et al. 1999).

Larvae

Atlantic mackerel larvae primarily reside in offshore waters where salinities are greater than 30ppt, but are also found in estuaries as far south as New Jersey where salinities are less than 25ppt (Studholme et al. 1999). Preferred depths vary with larval age and the thermocline and can range from 10 to 130 meters (Studholme et al. 1999). Water temperatures between 6 and 22ºC support larvae; however larvae have been found most abundant at water temperatures between 8 and 13ºC (Studholme et al. 1999). Atlantic mackerel feeding habits are associated with their size. Larvae less than 6mm typically feed on copepod nauplii and copepodites, while larvae greater than 6mm feed on adult copepods and fish larvae (Studholme et al. 1999).

Juveniles

Juvenile Atlantic mackerel are pelagic and schooling and are found both offshore and within estuaries (Studholme et al. 1999). Juveniles prefer salinities greater than 25ppt, and preferred water temperature and depth vary with season (Studholme et al. 1999). Juveniles tend to use habitats at depths ranging from 20 to 320 meters, and temperatures of 4 to 22ºC (Studholme et al. 1999). In the Hudson-Raritan estuary, juvenile Atlantic mackerel have been collected during July at depths between 4.9 and 9.8 meters, at temperatures from 17.6 to 21.7ºC, at salinities ranging from 26.1 to 28.9ppt and at DO 7.3 to 8.0mg/L (Studholme et al. 1999). Prey species include small crustaceans, such as copepods, euphausiids, amphipods, mysid shrimp and decapod larvae, pelagic mollusks, chaetognaths, nematodes, ammodytes and other larval fish (Cite from table)

Adults

Adult Atlantic mackerel are pelagic and schooling, often found in open seas along the continental shelf or in open bays (Studholme et al. 1999). EFH includes sea water salinities greater than 25ppt and temperature and depth preferences that vary seasonally (Studholme et al. 1999). Field studies have shown that adults are intolerant to temperatures less than 5 to 6ºC or greater than 15 to 16ºC, while laboratory studies reported that the preferred temperature range is from 7 to 16ºC (Studholme et al. 1999). Laboratory studies have also depicted that the lethal temperature limits are 2 and 28.5ºC (Studholme et al. 1999). Temperature and depth preferences vary seasonally as follows: in the fall between 9 and 12ºC and from 60 to 80 meters; in the winter between 5 and 6ºC and from 20 to 30 meters; at 13ºC and between 60 and 170 meters in spring; and between 10 and 14ºC and from 50 to 70 meters in summer (Studholme et al. 1999). Adult Atlantic mackerel are opportunistic feeders with a variety of dietary components including euphausids, pandalids, crangonid shrimp, chaetognaths, larvaceans, pelagic polychaetes, squids, copepods, amphipods, sand lances, herring, hakes and sculpins (Studholme et al. 1999).

Spawning

Atlantic mackerel typically spawn on the shoreward side of the continental shelf, beginning in mid-April and progressing from the Mid-Atlantic Bight to the Gulf of Maine until June (Studholme et al. 1999). Peak spawning is reported to occur at salinities greater than 30ppt, and at water temperatures between 9 and 14ºC, but spawning can commence at temperatures greater than 7ºC (Studholme et al. 1999).

Summer Flounder (Paralichthys dentatus)

Eggs

Summer flounder eggs area pelagic and buoyant. Eggs of the species are most abundant within 9 miles of the New York and New Jersey shores at depths of 9 to 110 meters (NMFS 2003). This life stage can be found at depths from 10 to 30 meters in the spring, 30 to 70 meters in the fall, and to maximum depths of 110 meters in the winter (Packer et al. 1999). Eggs are most abundant in the water temperatures between 12 and 19ºC; but can be found where temperatures range from 9 to 23ºC (Packer et al. 1999). Salinity appears to have little effect on egg development and there is no data documenting DO preference (Packer et al. 1999).

Larvae

The pelagic larvae, which are transported toward coastal areas by prevailing water currents, can be found in waters with salinities ranging from 0.02 to 35ppt and temperatures of 2 to 22ºC (USFWS 1978). Summer flounder larvae are most abundant between 19 to 80 km from shore and at depths between 9 to 70 meters (NMFS 2003) at temperatures between 9°C and 18°C (Packer et al. 1999). Transforming larvae and juveniles are most often captured in the higher salinity portions of estuaries (Packer et al. 1999). In the Hudson River Estuary, salinity preference ranged from 20 to 30 ppt (AKRF 2002). They are most frequently found in the northern part of the Mid-Atlantic Bight from September to February, and in the southern part from November to May (NMFS 2003).

Juveniles

Development of post-larvae and juveniles occurs mostly in bays and estuarine areas (LMS March 2001) in demersal waters over mud and sand substrastes (NMFS 2003). Juveniles use tidal channels, seagrass beds, mudflats and open water bays with salinities ranging from 10 to 30ppt. Following settlement, early juveniles inhabit a variety of high-salinity, subtidal habitats, including subtidal marsh creeks, coves, bays, and inlets in both vegetated and unvegetated habitats (Able and Fahay 1998). Juvenile summer flounder prefer waters with temperatures greater than 11 ºC, salinities ranging from 20 to 30ppt, depths from 0.5 to 5.0 meters, over sand and mud subsrtates (AKRF 2002) and mean DO levels at 6.4ppm (Packer et al. 1999). The most common forage species of juvenile summer flounder is mysid shrimp (NMFS 2003).

Adults

Adults of this species occur in shallow, near shore water over sand, hard bottom and mud substrates, and within grasses and around pilings at depths up to 25 meters. Summer flounder adults concentrate in bays and estuaries from late spring through early autumn frequenting deeper waters (to 150 meters) over the Continental Shelf during the winter (NMFS 2003). Preferred habitat characteristics are: temperatures of 9 to 26º in the fall, 4 to 13ºC in the winter, 2 to 20ºC in the spring and 9 to 27ºC in the summer in primarily higher salinity areas; there is a lack of DO data/preferences (Packer et al. 1999). Adult summer flounder are opportunistic feeders with fish (e.g. sand lance and anchovy), squid, shrimp and polychaetes making up a significant portion of their diet (NMFS 2003).

Spawning

Spawning occurs during their offshore migration to open ocean areas of the continental shelf beginning in early-fall and continuing through winter (Packer and Griesbach 1998) generally outside the project area. In the Mid-Atlantic Bight, adults begin their spawning run in September and continue through the month of December with a peak in October (Packer et al. 1999).

Scup (Stenotomus chrysops)

Eggs

Scup eggs are generally 0.8 to 1.0mm in diameter and found in coastal waters from May through August (Steimle et al. 1999). Eggs are buoyant (pelagic) and found in the water column at temperatures between 11 and 23º (Steimle et al. 1999). The environmental characteristics that support scup eggs are poorly understood (Steimle et al. 1999).

Larvae

Scup larvae are pelagic until they reach approximately 15 to 30mm TL, when they begin transition to demersal juveniles (Steimle et al. 1999). According to Steimle et al., there is no information available regarding habitat use or preferences during the transition between pelagic larvae and demersal juveniles (1999). However, it is documented elsewhere that at the time of transition, demersal larvae are found in shoal waters (MAFMC 1996, Able and Fahay 1998). Larvae reside in of southern New England from May through September, when water temperatures range from 14 to 22^{o}C (MAFMC 1998), with peak larval densities occurring between 15 and 20ºC (Steimle et al. 1999). Feeding habits of scup larvae are unavailable; however rearing experiments indicate that small zooplankton is a dietary component (Steimle et al. 1999).

Juveniles

Like adults, juvenile habitat preferences vary with season. Winter juvenile scup migrate offshore and little information is available regarding their habitat preferences; however, scup distributions suggest that they reside in varying habitats, from flat bottoms to submarine canyons with varying sediment types (Steimle et al. 1999). During warmer seasons, young of year and older juveniles occur in estuaries and coastal waters at depths to approximately 38 meters from May to November (Steimle et al. 1999). Stemle et al. (1999) state that the various juvenile habitats include mussel and eelgrass beds, as well as sand and mud. Water characteristics typically favored by juveniles include temperatures ranging from greater than 9 to 27oC. In the Hudson-Raritan estuary, juvenile scup have been reported at temperatures ranging from 9 to 26oC, where salinities range from 18 to 33ppt and DO levels are greater than 4mg/L (Steimle et al. 1999).

Adults

EFH for adult scup includes a variety of habitats, including soft, sandy bottoms and on or near submerged structures, rocky ledges, or mussel beds (MAFMC 1996). Smaller size adults inhabit estuaries and bays and larger adults prefer more depth (Steimle et al. 1999). Habitat preferences vary with season. Adult scup use coastal habitats until water temperature falls below 7.5 to 10oC (MAFMC 1998). During warmer seasons, preferred temperatures range from 7 to 25ºC and depths range from 2 to 38 meters. Wintering adults, from January to March, favor temperatures above 7ºC and depth from 38 to 185 meters along the mid- and outer- continental shelf. In the Hudson-Raritan estuary, adults have been found at salinities ranging from 20 to 31ppt and DO levels 4mg/L or greater (Steimle et al. 1999). Adult scup feeding habits vary greatly, and include small crustaceans, polychaetes, mollusks, insect larvae, sand dollars and small fish (Steimle et al. 1999).

Spawning

Spawning occurs during inshore migration in coastal waters from May through August (Steimle et al. 1999). Environmental associations with spawning typically include temperature ranges from above 9°C to 24oC at depths less than 30 m (Steimle et al. 1999), and have been reported to take place over weedy or sandy areas (Morse 1978). Spawning has been reported to occur from Massachusetts to the New York Bight, including the Raritan Bay; however, recent studies have not found eggs or larvae in the Hudson-Raritan estuary (Steimle et al. 1999).

Black Sea Bass (Centropristis striata)

EFH designation for juvenile and adult black sea bass includes the marine and estuarine waters of the project area (NMFS 1999). This species can be found from the Gulf of Maine to as far south as the Florida Keys (Steimle et al. 1999). In the Mid-Atlantic Bight, juvenile and adult black sea bass move inshore and north in the summer and offshore and south in the winter (Steimle et al. 1999). Individuals of this species are strongly associated with structured habitats (e.g., reefs, piling fields). Black sea bass use both estuarine and inner continental shelf habitats as nurseries during the first summer. Annual occurrence in the Hudson-Raritan estuary and the project area is highly variable.

Eggs

Eggs are buoyant and occur in coastal areas of the Middle Atlantic Bight between May and October within the upper water column in waters to 200 meters in depth (Steimle et al. 1999). Black sea bass eggs are reported sensitive to extreme temperatures and salinities (Steimle et al. 1999).

Larvae

Black sea bass larvae occur in the upper water column of the Middle Atlantic Bight and near shorelines or mouths of some estuaries between May and November and abundance peaks between June and July (Steimle et al. 1999). Larvae are sensitive to temperature and salinity extremes and are most abundant at water temperatures between 14 and 23ºC (Steimle et al. 1999) salinities ranging from 30 to 35ppt and depths less than 100 meters (NMFS 2003). Black sea bass larvae feed on zooplankton after yolk reserves (Steimle et al. 1999). After becoming demersal, larvae prefer inshore structured habitats (NMFS 2003).

Juveniles

Juvenile black sea bass occur inshore and in estuaries during mid and late summer using channels and salt marsh edges (NMFS 2003). Young of year are found among shellfish, sponge and eelgrass beds at the bottom and are reported to exhibit habitat fidelity (Steimle et al. 1999). Preferred habitat characteristics include water temperatures between 17 and 25ºC, salinities between 18 and 20ppt and depths between 1m and 38m (Steimle et al. 1999). Wintering juveniles occur offshore from December to April preferring depths between 90 and 100 meters along the mid and outer continental shelf (Steimle *et al.* 1999). Wintering juveniles are associated with nearshore shell patches and prefer water temperatures greater than 5ºC and salinities greater than 18ppt (Steimle et al. 1999). Juveniles feed on small epibenthic invertebrates, such as crustaceans and mollusks (Steimle et al. 1999).

Adults

Adult black sea bass reside offshore between November and March and mostly occur at depths between 60 and 150 meters, but can reach depths of 240 meters (Steimle et al. 1999). During winter months, adult black sea bass prefer temperatures greater than 6ºC and salinities approximately between 30 and 35ppt (Steimle et al. 1999). Adult black sea bass reside throughout the coastal areas of the Middle Atlantic Bight between April and December, and are associated with mussel beds, rocks, artificial reefs and other structures in depths of 2 to 38 meters (Steimle et al. 1999). During the summer, adult black sea bass prefer water temperatures between 13 and 21ºC and salinities greater than 20ppt (Steimle et al. 1999). Adults feed on small fish, squid and benthic invertebrates (NMFS 2003).

Spawning

Spawning occurs in coastal bays but not in estuaries (NMFS 2003) between May and October with a peak in June (Steimle et al. 1999). Spawning habitats consist of sand, rocks and reefs at depths approximately between 20 and 50 meters in temperatures between 18 and 20ºC and salinities greater than 15ppt (Steimle et al. 1999).

Atlantic surfclam (*Spisula solidissima*)

Eggs

Atlantic surfclam eggs, approximately 56 µm in diameter, typically occur within the water column above clam beds during summer and early fall where optimal temperatures range from 6°C to 24°C and salinities between 20 psu and 35 psu (Cargnelli et al. 1999).

Larvae

Atlantic surfclam larval concentrations are reported to occur during spring and fall (Cargnelli et al. 1999). Preferred temperatures range from 14°C to 30°C and salinities greater than 16 psu (Cargnelli et al. 1999).

Juveniles

Juvenile Atlantic surfclams are benthic, occurring at depths ranging from 8 m to 66 m, and are found in sand ranging in grain size from silty-fine to medium, preferring the later (Cargnelli et al. 1999). Atlantic surfclam prefer temperatures between 2°C and 30°C, and only salinities greater than 28 psu (Cargnelli et al. 1999). Atlantic surfclam juveniles primarily feed on phytoplankton (Cargnelli et al. 1999).

Adults

Adult Atlantic surfclams utilize the same habitats as juveniles. Adults are benthic and occur at depths ranging from 8 m to 66 m (Cargnelli et al. 1999). Sandy sediments are optimal for Atlantic surfclam burrowing (Cargnelli et al. 1999). Adults prefer temperatures between 2°C and 30°C and salinities greater than 28 psu (Cargnelli et al. 1999). Like juveniles, adults are siphon feeders that primarily prey on phytoplankton (Cargnelli et al. 1999).

Spawning

Spawning occurs during summer and early fall when temperatures range from 19.5°C to 30°C above shellfish beds (Cargnelli et al. 1999).

Ocean quahog (Arctica islandica)

Eggs

Eggs are planktonic and occur within oceanic salinities (Cargnelli et al. 1999). Therefore Ocean quahog eggs are unlikely to be found near any of the sampling areas.

Larvae

Ocean quahog larvae reside at oceanic salinities (average 32.4 psu) and at temperatures ranging from 14°C to 18°C (Cargnelli et al. 1999). Ocean quahog larvae are unlikely to occur near any of the sampling areas.

Juveniles

Ocean quahog juveniles reside in sandy sediments approximately 45 m to 75 m deep at oceanic salinities between 32 psu and 34 psu (Cargnelli et al. 1999). Shell growth increases at temperatures between 1°C and 12°C (Cargnelli et al. 1999). Juvenile ocean quahogs are unlikely to occur near any of the sampling areas.

Adults

Adult ocean quahogs occur in beds within sandy sediments and are most frequently found in oceanic salinities at depths ranging from 25 m to 61 m (Cargnelli et al. 1999). Optimal temperatures for adults range from 6°C to 16°C (Cargnelli et al. 1999). Adult ocean quahogs are unlikely to occur near the sampling areas.

Spawning

Spawning is protracted, typically lasting from spring to fall. The environmental stimuli of spawning are unclear. Jones (1981) notes that the initiation of spawning may be coincident with the highest bottom temperature, and probably in conjunction with other stimuli, such as increases in pH, food availability, and increases in dissolved oxygen (Mann, 1982).

NON-MANAGED SPECIES

American lobster (*Homarus americanus*)

The American lobster, Homarus americanus, (a.k.a. Maine lobster or Northern lobster) inhabit oceanic and coastal waters of the Northwest Atlantic from Labrador (Canada) south to Cape Hatteras (United States) and supports one of the most valuable commercial fisheries in the northeast United States ($301 million in 2000, NMFS landing data). They occur in coastal surf to continental slope waters of 700m. However, this range can be divided into two groups: inshore and offshore populations with some overlapping (Grosslein and Azarovitz 1982).

Lobsters are solitary, territorial crustaceans that live in a variety of different habitats preferring areas that have a rocky or soft mud bottom to one that is sandy. Lobsters are a long-lived animal that grows slowly by molting or shedding its shell. Lobsters reproduce when a recently molted soft-shelled female mates with a hard-shelled male in the summer or fall. The female generally extrudes and fertilizes the eggs about a year after mating, and then carries the eggs on her abdomen until they hatch the following spring or early summer. Hatched larvae go through a planktonic stage for about a month, and then permanently settle to the bottom. They can molt up to 10 times during their first growing season. The rate of growth and number of molts is dependent on the food supply, water temperature, sex, and geographic area. After the first year lobsters generally molt once or twice each year until they mature anywhere from 4 to 9 years after hatching. Inshore lobsters (like those in Long Island Sound) are thought to only move in localized areas during their lifetime, while offshore lobsters often migrate long distances from the edge of the continental shelf to inshore waters in late spring and summer and back again in the fall. The life cycle of the American lobster can be divided into (1) mating, spawning, and hatching, (2) larvae and post-larvae, and (3) juveniles and adults.

Mating, spawning, and hatching

Mating lobsters pair for about 2 weeks when the premolt female leaves its solitary shelter to share the one of a dominant and territorial male. Mating is a complex ritual that is intimately tied to social interactions with the dominant male and to the desirability of his shelter (Atema and Voigt 1995,Lawton and Lavalli 1995). While cohabiting, the female molts and mating usually follows within 30 minutes when the male then inserts his gonopods into the female seminal receptacle and deposits his spermatophore. The vulnerable postmolt female remains in the shelter area until her outer shell has sufficiently hardened and the couple separates (Cowan and Atema 1990, Atema and Voigt 1995).

Spawning is independent of insemination as it is the passage of the eggs from the ovary to the exterior of the female and the release of the spermatophores for external egg fertilization (Talbot and Helluy 1995). Females which molt and mate in the summer usually spawn in the fall. However, if they molt and mate in the fall, then they may not spawn until the following summer (Waddy and Aiken 1995). Spawning usually occurs earlier in warmer waters and depending on environmental conditions egg production can range from a few hundred to more than 100,000 eggs. The fertilized eggs, ranging from

1.5 to 1.7 mm in diameter, remained attached to the mother and to other eggs by means of stalks formed from the egg coat, which are extremely durable.

Hatching and larval release occur following a 9- to 12-month period of embryonic development (Ennis 1995). In order to decrease this egg development time, ovigerous females have been known to migrate into warmer waters. Hatching generally takes place from late May through much of September when temperature ranges from 15°C to 20°C with peak hatching occurring during June and July (MacKenzie and Moring, 1985). The hatching season tends to begin earlier and continue somewhat longer in the southern part of the lobster's range where temperature is warmer. Hatching is highly dependent on water temperature; the warmer the water the faster the hatching rate. Experiments determined at 20°C all eggs in the brood hatched within 2-3 days and eggs that were held at 15°C took 10-14 days to hatch. During hatching, up to 2000 larvae may be released at any one time and the time required to hatch and release a full clutch of eggs can vary from 15-31 days (Ennis 1995).

Larvae and post-larvae

Planktonic larval life begins as the female lobster raises her abdomen and vigorously fans the pleopods to which the prelarvae are attached. Once released, the prelarvae shed the cuticle binding their legs to enter into the first larval stage of the planktonic phase. This planktonic phase includes three larval stages (Stages I, II, and III) followed by a postlarval stage (Stage IV), during which the critical transition from pelagic to benthic lifestyle occurs (Ennis 1995). Larvae prefer temperatures greater than 15°C at salinities up to 30 psu and they occur throughout the water column at a depth of 0-30m. Diet includes plankton, copepods, diatoms, crab, fish, and insect eggs and larvae.

Larval lobsters are not particularly capable swimmers so their gross movements are largely controlled by the direction of wind and water currents, which happen to be onshore during periods of larval release. The distribution and dispersal of American lobster is therefore effected by their planktonic larval phase. Metamorphosis from the larval to a postlarval stage (Stage IV) occurs at the fourth molt. These postlarvae are strong swimmers and they make excursions to the bottom sampling the substrate to find a suitable settlement site. This stage may last for many weeks, as the postlarvae move up and down the water column. Settlement can be delayed quite considerably when unsuitable substrate is provided and molting to the first juvenile stage may also be delayed (Botero and Atema 1982).

Substrate preferences of the settling postlarvae include eelgrass beds, mud flats and salt marsh reefs, cobbles, and gravel or rock on sandy bottoms where they remain hidden for the first year of their lives. The postlarvae show a strong preference for substrate with preformed crevices and macroalgal cover (Ennis 1995), and the densest settlements are found on hard rocky bottoms with a lot of suitable substrates and adequate hiding places. After the postlarvae have found suitable settlement habitat, they will molt into juveniles (a.k.a., early benthic phase–EBP). From this moment onward, the lobster will remain a benthic creature.

This larval and postlarval development is normally completed in 25-35 days (3-4 weeks), but the duration is temperature dependent. Survival rate is low, as out of 10,000 eggs released only 1% will survive beyond the first four weeks of life. Numerous predators (i.e., seabirds, fishes, and other benthic creatures) indeed intensively prey upon the larval and postlarval stages.

Juveniles and adults

As juveniles, the lobsters spend the first year sheltered and feed on small preys by fanning their pleopods to create a current through their shelter. According to Lawton and Lavalli (1995), the juvenile life history stage can be subdivided into three phases as the juveniles grow and progressively forage away from their shelter. Those phases are the (1) shelter-restricted juvenile phase, (2) emergent juvenile phase, and the (3) vagile juvenile. Laboratory experiments have demonstrated that postlarval and juvenile lobsters can burrow in many types of substrate, but until recently, it was unknown which substrates offered the best protection against predators. Using a combination of both laboratory and field techniques, researchers found that cobble substrates, made up of rocks of varying sizes (common in many rocky seashore areas), protected the newly-settled and juvenile lobsters against most predators. Peat from salt marshes, eelgrass, and mud substrates all offered some degree of protection, but not as great as that of cobble.

Adulthood, when lobsters are more than 50 mm CL and sexually mature, is finally reached after 5 to 8 years, depending largely on the water temperature. Adult lobster life changes significantly for the array of physiological, ecological, and behavioral events that are related to courtship, mating and reproduction. Except during courtship or severe environmental stress most adult lobsters live alone in close fitting-shelters where they spend most of their time (Atema and Voigt 1995).

Juveniles and adults lobsters are benthic preferring depths ranging from 100-450m offshore and less than 50m inshore. Juveniles typically prefer temperature ranging 5.0-20.0°C with salinity greater than 26ppt. Adult lobsters can tolerate water temperatures ranging from -1°C to 28°C. Summer temperature preference is 12.5°C and winter preference is 9.7°C. Adverse effects have been documented for adult lobster at salinities below 18.4ppt and DO below 1.7. Juvenile and adult diet consists of mollusks, (mussels, clams, scallops, and some gastropods), crabs, sea urchins, brittle stars, hydroids. Steimle *et al (*1990) determined that the dominate species found in the adult lobster stomach was Atlantic rock crabs (*Cancer irroratus*).

Softshell clam (*Mya arenaria*)

Soft clams are commonly found in polyhaline and mesohaline zones (Ristich et al. 1977), from the littoral zone to 9 meters (Gosner 1971) distributed from the subarctic to Cape Hatteras. Known commonly as a "steamer clam," the softshell clam is the third most important commercially harvested clam in the U.S., with 7.9 million pounds harvested in 1984 (MacKenzie 1992). Historically, the soft clam was a staple food for the Indians of the New York/New Jersey Harbor area. Since settlers arrived in the area, the softshell clam has been harvested from Keyport to Atlantic Highlands, and currently clam populations can support moderate harvesting, mostly in rivers adjacent to New York/New Jersey Harbor (MacKenzie 1990). According to National Marine Fisheries Service data (1999), harvesting reached a peak in 1969 and has been slowly declining since that time.

Commercial harvest of adult clams results in disturbance of juveniles, exposing them to predation before they can rebury (Chesapeake Bay Program 1987). Loss of eelgrass habitat in the 1930s has been suggested as a possible indirect cause of softshell clam population declines in the 1940s (MacKenzie 1990). Protection from wave energy provided by the eelgrass beds was lost, and as a result, mudflats used by harvesters were almost completely washed away by the 1980s.

Preferred substrate is a sandy bottom with less than 50 percent silt, but they have been observed in sandy, sand-mud, or sandy-clay substrates (Abraham and Dillon 1986). The softshell clam resides in clam beds where densities have been observed at 18 to 24 clams per square meter, though they can reach higher quantities in polyhaline to upper mesohaline areas such as the mouth of an estuary (Ristich et al. 1977). The most significant factor affecting the distribution of soft clams is salinity (Abraham and Dillon 1986). The clams tend to be euryhaline, with some living in primarily marine environments (35 psu) and others in estuarine habitats (10 to 25 psu). In laboratory experiments conducted in 1974 to 1976, inhibition of feeding was observed in response to rapid decreases in salinity, but no significant mortality was observed (Abraham and Dillon 1986).The highest densities are found at 3 to 4 meters, temperatures less than 28 ^{o}C, and salinities greater than 4 to 5 psu (Abraham and Dillon 1986). According to Steimle and Caracciolo-Ward (1989) and Dean (1975), softshell clam populations show cyclic occurrences with periods of high and low densities.

Softshell clams feed on small detrital particles, phytoplankton, small zooplankton, and bacteria (Chesapeake Bay Program 1987). The larger incurrent siphon draws food into the clam, and wastes are released through the excurrent siphon. Most of the predation on soft clams occurs during the larval and juvenile stages. Larvae are an important food source for larger planktonic organisms, including larval fish, jellyfish, and comb jellies; juveniles are preyed on by oyster drills, crabs, starfish, horseshoe crabs, whelks, and moon snails (Abraham and Dillon 1986). Additionally, softshell clams are an important food source for many adult and juvenile bottom-dwelling fish, such as spot (*Leiostomus xanthurus*) and winter flounder (*Pleuronectes americanus*).

Softshell clams spawn twice each year, generally in May and October, when water temperatures range 10 to 20 degrees Celsius. Softshell clams have high fecundity and very low survivorship (estimated at 0.1 percent of total egg production; Abraham and Dillon 1986). After fertilization, eggs develop into planktonic larvae that pass through various developmental stages, marked by growth and the formation of calcareous shell valves. After 2 to 6 weeks, the larvae settle onto hard substrates and attach via secreted byssus. The attached juveniles continue to grow and foot development occurs. At 7 millimeters, juveniles burrow into the sediments and take up active, adult-like lifestyles. In approximately two years, the juveniles reach the commercial size of 5 centimeters, and sexual maturity is reached at approximately 5 years. Life span is estimated between 10 and 12 years, but some shells have been estimated at greater than 28 years (Abraham and Dillon 1986).

Soft clams are relatively tolerant to changes in sediment organic content (Diaz and Boesch 1982), and they have been observed with the pollution-tolerant polychaete, *Streblospio benedicti* (Reish 1979). Numerous beds have been closed as a result of sewage contamination and accompanying high coliform bacteria counts. Softshell clams are seriously affected by oil pollution, more so than other shellfish, and may suffer from inhibited growth, development of gonadal tumors, or increased mortality (Abraham and Dillon 1986). Additionally, softshell clams are known to take up silver and other metals from industrial wastes in very high concentrations. Once beds are destroyed, repopulation can take many years for sufficient larval recruitment and growth (Abraham and Dillon 1986).

Northern quahog (*Mercenaria mercenaria*) (a.k.a. hard clam)

Northern quahogs are distributed along the eastern and Gulf coasts of the U.S., ranging from the Gulf of St. Lawrence to Florida and into Texas (Grosslein and Azarovitz 1982, Eversole 1987). It is most abundant from Virginia to Massachusetts (Eversole 1987) and has also been introduced to California and Europe.

Northern quahogs are an important commercial fisheries species. They have a large population, estimated in the millions of bushels, with the leading production area in the mid-Atlantic region (Eversole 1987, MacKenzie 1990). The clams can be harvested in many ways and have one of the oldest fisheries in the United States. Both small clams and large clams are harvested and classified into one of four commercial size grades. These include 1) seed clams; less than 50 millimeters in length, 2) littlenecks; 50 to 65 millimeters, 3) cherrystones; 66 to 79 millimeters, and 4) chowders; greater than 80 millimeters (Eversole 1987). Northern quahogs have a long-standing history within the New York/New Jersey Harbor area as one of the staple foods of the native Americans and were a special food item consumed during celebrations. They were also a popular food item with the colonists (MacKenzie 1990). According to data collected by Grosslein and Azarovitz (1982), peak harvest of northern quahogs occurred during the late 1940s and early 1950s, averaging 9,500 metric tons (MT). By the 1960s it had dropped to 6,000 MT, where it remained until the mid-1970s. Data from the National Marine Fisheries Service (NMFS 1999) indicate that the fishery only brought in around 1,000+ MT per year in the 1980s and early 1990s. Grosslein and Azarovitz (1982) reported that production in the New York Bight increased from 2,700 MT in the 1950s to 5,000 MT in 1971, after which time the harvest began to decline. Possible explanations for this decline are poor monitoring of catches, harvesting of undersized clams, and the by-catch of seed clams. Recreational harvesting of northern quahogs does not appear to affect the commercial take (Eversole 1987).

Northern quahogs inhabit the subtidal regions of bays and estuaries to approximately 15 meters in depth (Eversole 1987). They are generally found in firm bottom areas consisting of sand or shell fragments (Chesapeake Bay Program 1987), optimal settling substrates for juveniles (Eversole 1987). Franz and Harris (1988) identified northern quahogs as fine-sand species in Jamaica Bay. Northern quahogs are an osmoconforming, euryhaline species generally occurring at salinities ranging 15 to 32 psu (Grosslein and Azarovitz 1982, Chesapeake Bay Program 1987). They have been found in salinities as low as 4 psu, but optimal growth occurs at 24 to 28 psu (Eversole 1987). At extreme salinities, clams can tightly close their shell valves and respire anaerobically, allowing them to survive up to a few weeks in harmful conditions. Adults are more tolerant of salinity extremes than are larvae and eggs (Eversole 1987), and normal egg development requires salinities of 20 to 35 psu. Below 17.5 psu, larvae fail to metamorphose and juvenile growth ceases (Chesapeake Bay Program 1987).

Northern quahog larvae, juveniles, and adults consume phytoplankton, zooplankton, and detrital material by trapping particles in the mucus lining of their gills (Grosslein and Azarovitz 1982, Chesapeake Bay Program 1987). They are also able to absorb dissolved organics directly from the water (Eversole 1987). Water is brought through the inhalant siphon and passed over the gills where the food particles are captured and transported to the mouth via cilia. The particles pass through the digestive system, and waste is released through the exhalant siphon in the shape of rod-shaped fecal pellets (Eversole 1987). Predation on juvenile northern quahogs is very high, especially below 15 to 20 millimeters in length (Grosslein and Azarovitz 1982). Larval clams are consumed by planktivores, and Eversole (1987) indicated that open areas often result in few adult clams, even if the set quantity is high, due to predation of young clams. Areas with vegetation and shell matter tend to be more conducive to survival of the young. Adult northern quahogs are preyed upon by gastropods, crabs, starfish, and some fish species (Eversole 1987). A predator exclusion experiment detailed by Grosslein and Azarovitz (1982) resulted in a 7- to 8-fold increase in northern quahog abundance. The distribution of northern quahogs may be affected by the existence of the competitors, such as the amethyst gem clam (*Gemma gemma*). One study showed that in muddy areas with high densities of *G. gemma*, newly settled northern quahogs were unable to effectively compete for food resources, resulting in high mortality (Ahn et al. 1993).

Spawning occurs when males and females release gametes into the water column during the summer months, as water temperatures reach approximately 22 to 24 ^{o}C (Chesapeake Bay Program 1987). Eggs are buoyant and have a diameter of 0.07 millimeters plus an outer envelope 0.03 to 0.1 millimeters thick. Fertilization occurs in the water column followed by development into planktonic larvae. The larvae pass through various developmental stages, marked by the formation of shell valves, umbo, and ciliated foot. After approximately four weeks of development, settlement occurs with the larvae attaching to sand grains and taking up a benthic lifestyle. During this stage, the siphons develop, the mantle fuses, and the shell develops ridges. As the juveniles grow, they burrow into the sediment, maintaining contact with the surface using only the siphon (Eversole 1987). Prior to sexual maturity, northern quahogs go through a hermaphroditic stage (occurring at 6 to 7 millimeters in length) having both male and female gonadal cells while functioning mostly as males (Eversole 1987). At the end of this stage they become either male or female and reach maturity by age two and at lengths of 3.2 to 3.8 centimeters. Northern quahogs in the south reach maturity in about one year, while their northern relatives mature in two years, thus sexual maturity in northern quahogs is dependent on size rather than age (Eversole 1987). In their first 5 to 6 years, quahogs can reach sizes of 5 to 6 centimeters (littleneck) and reach their maximum length of 15 centimeters at an estimated 20 years.

Northern quahogs are often found in very polluted habitats. Adults can tolerate wide ranges in water quality and can survive in changing concentrations of ammonia, nitrites, nitrates, phosphates, and sulfur compounds (Eversole 1987). Although they tend to survive in such habitats, these beds are unsafe for human consumption. One cause for concern is their ability to filter and concentrate harmful bacteria from domestic sewage leading to shellfish contamination. Contaminated shellfish can transfer typhoid, hepatitis, cholera, and other diseases. Oil pollution is also a concern, and can lead to closure of fisheries. Adult clams are also susceptible to inhibited growth, reduced feeding rates, and delayed sexual maturity from exposure to pollutants.

Planktonic larvae are more susceptible to harm from pollution than are adults, and improved conditions following clean-up of the Raritan River and Bay led to dramatic increases in northern quahog recruitment (Menzel 1979). Larvae have been experimentally shown to suffer from inhibition of growth and increased mortality as a result of exposure to various pesticides, herbicides, detergents, and heavy metals. Effluent waste from pulp mills has been determined to cause mortality during all northern quahog life stages. In areas with typically cold water, industrial plants are known to release warm water, which can affect the recruitment of non-native species (e.g., northern quahogs in the British Isles; Menzel 1979). Pollution also indirectly affects northern quahogs by inhibiting algal growth, thereby reducing the food supply (Grosslein and Azarovitz 1982).

Additionally, human activities, such as dredging and drainage of marshes and wetlands, have contributed to the reduction of active clam beds (Grosslein and Azarovitz 1982). Dredging of navigation channels destroys bottom habitat in the dredged areas, spoil placement alters the habitat at the disposal site, and resuspension of silts can smother shellfish. Besides navigational dredging, dredging for the purposes of shellfish harvesting has similar effects (Menzel 1979).

Blue mussel (*Mytilus edulis)*

Blue mussels have a large distribution, occurring in the Arctic, North Pacific, and North Atlantic, ranging from Labrador to Cape Hatteras. Blue mussels are commonly found in the littoral and sublittoral zones and in polyhaline portions of the Hudson River and New York/New Jersey Harbor (Ristich et al. 1977, Gosner 1971). Interest in blue mussels as a U.S. fishery species has begun only in the last few decades, although mussels have been an important seafood species in foreign markets for much longer. Recreational harvesting does occur, but little is known about the quantities, as blue mussels are not a regulated fishery species.

Adult blue mussels are most commonly observed in areas of rock and coarse gravel, although sand and mud can provide suitable habitat if there are surfaces for attachment. Large beds of blue mussels are found where wave and current energy is relatively low, but water flow must be high enough to facilitate feeding (Newell 1989). They are typically found in areas of fine sand in the New York/New Jersey Harbor (Franz and Harris 1988), but any area with a surface for attachment of the byssus threads can be suitable habitat (Newell 1989). Blue mussels are euryhaline and capable of living in oceanic salinities (35 psu) to mesohaline estuaries (5 to 18 psu; Newell 1989). It can remain active even in areas that vary by 10 psu during the daily tidal cycles. During significant salinity fluctuations, the mussel will stop flow from its excurrent siphon and close its shell for up to four days. If the salinity change is permanent, the mussel will adjust itself osmotically to the new conditions (Newell 1989).

All life stages are planktonic feeders, filtering particles from the water column. Their main food source is phytoplankton and possibly detrital bacteria. Different stages all use cilia to move particles along their oral groove and into their mouths by creating water flow. The labial palps in adult blue mussels are able to sort the particles, separating food from the indigestible material, which is then rejected through the gills. Blue mussels are able to change their filtration rate depending on current needs (Newell 1989). Blue mussel larvae are heavily preyed upon by species ranging from jellyfish to fishes. As mussels grow, they are preyed upon by fewer species, and adults are mostly at risk from large starfish, large crustaceans, and some birds (Newell 1989).

An increase in water temperature, change in salinity or wave action, desiccation, or increases in phytoplankton concentrations can trigger spawning in blue mussels. Eggs and sperm are released through the excurrent siphon into the water column, at a ratio of 10,000:1 spermatozoa to egg, and sperm are released first, stimulating the release of eggs. The eggs are spherical with diameters of approximately 0.07 millimeters. The larval period ranges 15 to 35 days depending on environmental conditions, and is marked by development of the shell valves, umbo, photosensitive eyespots and elongated foot. The larvae then settle onto hard substrates, fix their locations via byssus threads, and metamorphose into plantigrades. They remain in this juvenile state until they reach 1 to 1.5 millimeters in length. Following this growth period, the plantigrades detach from the substrate and move with the currents into an adult blue mussel bed. Here they secrete new byssus threads and attach to the substrate or other mussels. Sexual maturity occurs in one to two years, and adult blue mussels grow to approximately 100 millimeters and live up to 20 years (Newell 1989). Blue mussel sexes are separate, but individuals can undergo periods of hermaphroditism.

Responses of blue mussels to pollutant exposure can include delay of maturation, inhibition of growth, and increased mortality, which make this species a useful indicator of ecosystem health (Newell 1989). As with many filter-feeding bivalves, blue mussels can filter and concentrate harmful bacteria from sewage, uptake metals from industrial waste, and concentrate petrochemicals from oil pollution. These forms of contamination not only compromise the health of blue mussel populations but they can result in fishery closure. Dredging activities can also adversely affect blue mussel populations. Dredging for channel maintenance or shellfish harvest can destroy mussel beds (Menzel 1979), and resuspension of silts and sediment-bound pollutants can hinder feeding and renew exposure to contaminants.

American oyster (*Crassostrea virginica*) (a.k.a., Eastern oyster)

American or eastern oyster occur along the east coast of North America from the Gulf of St. Lawrence to Key Biscayne, Florida and south through the Caribbean to the Yucatan Peninsula of Mexico and Venezuela.

The American oyster are found attached to hard substrate such as rock or shells on the floor of brackish bays, coves and estuaries, sometimes in great clusters. The highestgrade (best quality) oysters from areas where the bottom is firm and non-shifting. Their preferred range of water salinity lies between 20 to 27 psu, which include bays into which rivers flow, as well as river estuaries, into which salty tides ebb and flow. Oysters are filter feeders, consuming phytoplankton and improving water quality by filtering the water. Reef forming creatures, oysters provide structured habitat for many fish species and crabs by attaching (or setting) to existing oyster reefs and other hard substrates. Material put out for oysters to attach to is called *cultch*. The process of becoming cemented to the cultch is termed *setting* or *spatting,* and the young oyster after setting, *seed* or *spat*. Oyster larvae will attach themselves to many types of cultch but seem to prefer mollusc shells and materials which contain chalky substances. The newly attached oysters – called spat – begin to grow at the rate of about an inch per year. Growth rates can be affected by temperature, food quantity, salinity, and parasitic infection. Shell growth usually occurs in the spring and soft body tissue growth occurs after spawning. Oysters usually enter the market three to five year after spat settlement.

The separate sexes of the American oyster ripen in early summer. When the water warms above a minimum temperature of 20 ^{o}C *(68^{o}F)*, they release eggs and sperm into the water. The spawn is not released all at once but at intervals over a period of four to six weeks. During the spawning season, a single female, by clapping her shells gently, will puff out many millions of buoyant eggs and a male will release an even greater number of sperm. Fertilization takes place in the open water and cell division begins. The fertilized egg develops into a microscopic larva. Within 24 hours it forms a shell and develops a swimming and feeding organ consisting of a disc covered with vibrating hairs which can be thrust out and withdrawn at will, allowing free movement. For about three weeks, the little larva swims and drifts in the tidal currents and may travel far from the spawning area. It feeds on microscopic plants of the plankton community of which it is a part. The mortality rate is very high and only a small fraction of 1 percent of the young larvae reaches the next stage of development. When its length reaches about 300 microns, or the size of a grain of pepper, each larva extends a probing foot and seeks a place of attachment. Once it finds a suitable, clean, hard surface, the foot gland ejects a tiny pool of cement-like adhesive. The little oyster then turns on its left side, cements itself to the object, and remains immobile for the rest of its life. Henceforth, it can feed only on what food the water brings and is unable to escape overcrowding, or flee from enemies.

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APPENDIX B

BENTHIC ANALYSIS SUMMARY TABLES

Table B-1: Average Benthos Density (No./m^2) at West Bank ATN.

Phylum	Class	Order	Family	GenusSpecies	WB4	WB5	WB7	WB8	WB9	WB10
Annelida	Oligochaeta	---	---	---	2,924	2,945	9,941	0	292	5,555
	Polychaeta	---	---	---	2,924	0	0	0	0	0
		Archiannelida	Polygordiidae	Polygordius sp.	0	0	0	0	292	0
		Ariciida	Orbiniidae	---	0	0	0	0	0	0
				Haploscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos Fragilis	0	0	877	0	292	1,170
				Leitoscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos sp.	0	0	0	0	0	0
		Capitellida	Capitellidae	---	0	0	0	0	0	0
				Capitella sp.	0	0	585	920	0	0
			Maldanidae	Asychis elongata	0	0	0	0	11	21
		Cirratulida	---	---	0	0	0	10	0	0
			Cirratulidae	---	0	43	0	0	0	0
		Eunicida	Arabellidae	Arabella iricolor	0	0	0	0	0	0
			Onuphidae	Diopatra cuprea	0	0	0	0	0	0
		Phyllodocida	Glyceridae	Glycera sp.	292	4,971	877	150	0	292
			Goniadidae	---	1,170	0	0	0	0	0
			Nephtyidae	Nephtys sp.	1,462	2,047	0	0	303	292
			Nereidae	Nereid succinea	0	0	0	0	0	0
				Nereis sp.	0	0	292	10	0	0
				Nereis virens	0	0	0	0	0	0
			Phyllodocidae	---	0	0	0	0	0	0
				Eteone sp.	0	0	0	30	292	0
				Eumida Sanguinea	0	0	0	0	0	0
				Phyllodoce sp.	0	0	0	0	0	0
			Polynoidae	Harmothoe sp.	0	0	0	0	0	0
				Lepidametria commensalis	0	0	0	30	0	0
			Syllidae	---	877	0	0	0	0	0
		Spionida	Chaetopteriadae	---	292	0	0	0	0	0
			Paraonidae	---	3,509	2,674	0	0	2,924	30,408
				Paraonis sp.	0	0	3,509	0	0	0
			Sabellariidae	Sabellaria vulgaris	0	0	0	0	0	0
			Spionidae	Polydora ligni	1,170	0	0	0	0	0
				Streblospio benedicti	6,432	1,191	19,882	0	0	0
		Terebellida	---	---	0	0	0	0	0	0
			Pectinariidae	Pectinaria gouldii	0	0	0	10	0	0
				Pectinaria sp.	0	0	877	0	0	0
Arthropoda	Crustacea	Amphipoda			0	0	0	0	0	0
			Ampeliscidae	Ampelisca abdita	0	292	6,432	0	292	2,967
				Ampelisca sp.	0	0	0	0	0	0
				Ampelisca Vadorum	0	43	0	0	0	0
				Byblis Serrata	0	0	0	0	0	0
			Ampithoidae		0	0	0	10	0	0
			Aoridae	Unciola irrorata	0	0	0	0	0	0
				Unciola sp.	0	292	0	20	0	0
			Caprellidae	Caprella penantis	0	0	0	10	0	0
			Corophiidae		0	0	0	0	0	0
				Corophium sp.	0	0	0	0	0	0
			Gammaridae		0	0	292	0	0	1,462
				Gammarus sp.	292	0	0	10	0	0
			Ischyroceridae	Jassa falcata	0	0	0	0	0	0
			Melitidae		0	0	0	0	0	0
				Melita netida	0	0	0	0	0	0
			Photidae		0	0	0	0	0	0
			Phoxocephalidae		0	0	292	70	0	0
				Paraphoxus sp	0	0	0	0	0	0
			Stenothoidae		0	0	0	0	0	0
		Decapoda	Cancridae	Cancer irroratus	11	0	0	0	0	0
			Crangonidae	Crangon septemspinosa	0	0	0	30	0	0
			Magidae	Libinia emarginata	0	0	0	0	0	0
			Paguridae	Pagurus sp.	0	0	0	20	0	0
			Portunidae	Ovalipes ocellatus	0	0	11	0	0	0
			Xanthidae	Panopeus herbstii	0	0	0	30	0	0
				Rhithropanopeus harrisii	0	0	0	0	0	0
		Isopoda	Anthuridae	Cyathura polita	0	292	1,754	0	0	0
		Ostracoda			0	0	0	0	0	0
Mollusca	Bivalvia	Eudesmodontida	Pandoridae	Pandora Gouldiana	0	0	0	0	21	303
		Myoida	Myidae	Mya arenaria	292	585	0	0	0	585
		Mytioida	Mytilidae	Mytilus edulis	0	6,733	11	0	0	0
		Nuculoida	Nuculanidae	Nucula sp.	0	0	0	0	8,479	0
		Ostreoida	Anomiidae	Anomia sp.	0	0	0	10	0	0
		Veneroida	Astartidae	Astarte sp.	0	292	888	0	0	303
			Mactridae	Mulinia lateralis	0	86	0	0	5,848	10,526
				Spisula Solidissima	11	0	0	0	0	0
			Solenidae	Ensis directus	0	0	0	0	0	0
			Tellinidae	Tellina agilis	0	0	0	0	1,462	0
			Veneridae	Mercenaria mercenaria	0	0	0	10	0	303
	Gastropoda				0	0	0	0	0	0
		Archaeogastropoda	Naticidae	Neverita Duplicata	0	0	0	0	0	292
		Cephalaspidea			0	0	0	0	0	0
			Acteonidae	Rictaxis puntcostriatus	0	0	0	0	0	0
			Scaphandridae	Acteocina canaliculata	0	0	0	0	4,093	1,170
		Mesogastropoda	Calyptraeidae	Crepidula fornicata	0	0	11	330	0	0
				Crepidula plana	0	0	0	0	0	0
			Rissoidae		0	0	0	0	0	0
		Neogastropoda	Melongenidae	Busycon carica	0	0	0	0	292	0
			Muricidae	Eupleura caudata	0	0	0	0	0	0
				Urosalpinx cinereus	0	0	0	0	0	0
			Nassariidae	Ilyanassa obsoleta	0	0	0	0	0	0
				Ilyanassa trivittata	0	0	0	20	0	292
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius parma	0	0	0	0	0	0
Nematoda					0	0	2,339	0	0	0
Nemertea					0	0	0	0	0	0

Table B-2: Average Benthos Density (No./m^2) at Gravesend Bay.

Phylum	Class	Order	Family	GenusSpecies	GB4	GB5	GB6	GB7	GB8	GB10
Annelida	Oligochaeta	---	---	---	1,170	0	0	877	0	2,047
	Polychaeta	---	---	---	292	0	0	0	0	0
		Archiannelida	Polygordiidae	Polygordius sp.	0	0	0	0	0	0
		Ariciida	Orbiniidae	---	0	0	0	0	0	0
				Haploscoloplos robustus	0	0	0	292	0	0
				Leitoscoloplos Fragilis	0	3,509	8,771	1,462	4,971	5,263
				Leitoscoloplos robustus	0	0	0	0	585	0
				Leitoscoloplos sp.	13,157	0	0	0	0	0
		Capitellida	Capitellidae	---	0	0	0	0	0	0
				Capitella sp.	585	0	0	0	585	0
			Maldanidae	Asychis elongata	11	0	0	0	0	0
		Cirratulida	---	---	0	0	0	0	0	0
			Cirratulidae	---	0	0	0	0	0	0
		Eunicida	Arabellidae	Arabella iricolor	0	0	0	0	0	0
			Onuphidae	Diopatra cuprea	0	0	0	0	0	0
		Phyllodocida	Glyceridae	Glycera sp.	899	877	2,631	11	595	585
			Goniadidae	---	0	0	0	0	0	0
			Nephtyidae	Nephtys sp.	585	585	0	1,170	0	585
			Nereidae	Nereid succinea	0	0	0	0	0	0
				Nereis sp.	0	0	0	0	0	0
				Nereis virens	0	0	0	0	0	0
			Phyllodocidae	---	0	0	0	292	0	0
				Eteone sp.	0	11	292	11	0	0
				Eumida Sanguinea	0	0	0	292	0	0
				Phyllodoce sp.	0	606	877	292	0	0
			Polynoidae	Harmothoe sp.	0	0	0	0	0	0
				Lepidametria commensalis	0	0	0	0	0	0
			Syllidae	---	0	0	0	0	0	0
		Spionida	Chaetopteriadae	---	0	0	0	292	0	0
			Paraonidae	---	29,238	5,912	57,015	8,771	11,111	17,543
				Paraonis sp.	0	0	0	0	0	0
			Sabellariidae	Sabellaria vulgaris	0	11	0	0	0	0
			Spionidae	Polydora ligni	0	0	0	0	0	0
				Streblospio benedicti	0	0	0	0	0	0
		Terebellida	---	---	0	0	0	0	0	0
			Pectinariidae	Pectinaria gouldii	11	303	292	0	303	0
				Pectinaria sp.	0	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda			0	0	0	292	0	0
			Ampeliscidae	Ampelisca abdita	292	0	292	585	292	0
				Ampelisca sp.	0	0	0	0	0	0
				Ampelisca Vadorum	0	0	0	0	0	0
				Byblis Serrata	0	0	0	0	0	0
			Ampithoidae		0	0	0	0	0	0
			Aoridae	Unciola irrorata	0	0	0	0	0	0
				Unciola sp.	0	0	0	0	0	0
			Caprellidae	Caprella penantis	0	0	0	0	0	0
			Corophiidae		0	0	0	0	0	0
				Corophium sp.	0	0	0	0	0	0
			Gammaridae		0	0	0	0	0	0
				Gammarus sp.	0	0	0	0	0	0
			Ischyroceridae	Jassa falcata	0	0	0	0	0	0
			Melitidae		0	0	0	0	0	0
				Melita netida	0	0	0	0	0	0
			Photidae		0	0	0	0	0	0
			Phoxocephalidae		0	0	0	0	0	0
				Paraphoxus sp	0	0	0	0	0	0
			Stenothoidae		0	0	0	0	0	0
		Decapoda	Cancridae	Cancer irroratus	0	0	0	0	0	0
			Crangonidae	Crangon septemspinosa	0	0	0	0	0	0
			Magidae	Libinia emarginata	0	0	0	0	0	0
			Paguridae	Pagurus sp.	0	0	0	0	0	0
			Portunidae	Ovalipes ocellatus	0	0	0	0	0	0
			Xanthidae	Panopeus herbstii	0	0	0	0	0	0
				Rhithropanopeus harrisii	0	0	0	0	0	0
		Isopoda	Anthuridae	Cyathura polita	0	0	0	0	0	0
		Ostracoda			0	0	0	0	0	0
Mollusca	Bivalvia	Eudesmodontida	Pandoridae	Pandora Gouldiana	0	0	585	0	0	0
		Myoida	Myidae	Mya arenaria	585	1,462	585	585	1,462	0
		Mytioida	Mytilidae	Mytilus edulis	0	11	0	0	0	0
		Nuculoida	Nuculanidae	Nucula sp.	877	0	0	0	0	0
		Ostreoida	Anomiidae	Anomia sp.	0	0	0	0	0	0
		Veneroida	Astartidae	Astarte sp.	11	292	585	0	0	0
			Mactridae	Mulinia lateralis	9,356	5,263	5,263	3,801	4,093	10,233
				Spisula Solidissima	0	0	0	0	0	0
			Solenidae	Ensis directus	0	0	0	0	0	0
			Tellinidae	Tellina agilis	0	0	0	0	0	0
			Veneridae	Mercenaria mercenaria	0	0	11	11	21	0
	Gastropoda				0	0	0	0	0	292
		Archaeogastropoda	Naticidae	Neverita Duplicata	0	0	0	0	0	0
		Cephalaspidea			0	0	3,216	0	5,848	292
			Acteonidae	Rictaxis puntcostriatus	0	585	0	0	877	0
			Scaphandridae	Acteocina canaliculata	1,462	2,339	3,801	292	5,848	11,988
		Mesogastropoda	Calyptraeidae	Crepidula fornicata	0	0	0	0	0	0
				Crepidula plana	0	0	0	0	0	0
			Rissoidae		0	0	0	0	292	0
		Neogastropoda	Melongenidae	Busycon carica	0	0	0	0	0	0
			Muricidae	Eupleura caudata	0	0	0	0	0	0
				Urosalpinx cinereus	0	0	0	0	0	0
			Nassariidae	Ilyanassa obsoleta	0	0	0	0	0	0
				Ilyanassa trivittata	0	0	0	0	0	0
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius parma	0	0	0	0	0	292
Nematoda					0	11	0	0	0	0
Nemertea					0	0	0	0	0	0

Table B-3: Average Benthos Density (No./m^2) at Hoffman-Swinburne Islands.

Phylum	Class	Order	Family	GenusSpecies	HSI3	HSI4	HSI5	HSI6	HSI7	HSI8
Annelida	Oligochaeta	---	---	---	0	585	0	0	0	8,187
	Polychaeta	---	---	---	0	0	0	0	0	0
		Archiannelida	Polygordiidae	Polygordius sp.	0	0	0	0	0	0
		Ariciida	Orbiniidae	---	0	0	0	0	380	0
				Haploscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos Fragilis	0	585	0	0	0	1,170
				Leitoscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos sp.	0	0	0	0	0	0
		Capitellida	Capitellidae	---	0	0	0	0	0	0
				Capitella sp.	0	0	0	0	80	0
			Maldanidae	Asychis elongata	0	0	0	0	0	0
		Cirratulida	---	---	0	0	0	0	0	0
			Cirratulidae	---	0	0	0	0	0	0
		Eunicida	Arabellidae	Arabella iricolor	0	0	0	0	0	0
			Onuphidae	Diopatra cuprea	0	0	0	10	0	0
		Phyllodocida	Glyceridae	Glycera sp.	0	0	11	30	60	0
			Goniadidae	---	0	0	0	0	0	0
			Nephtyidae	Nephtys sp.	0	0	292	130	140	2,631
			Nereidae	Nereid succinea	0	0	0	0	0	0
				Nereis sp.	0	0	0	0	40	0
				Nereis virens	0	0	0	0	0	0
			Phyllodocidae	---	0	0	0	0	0	0
				Eteone sp.	0	0	0	0	0	0
				Eumida Sanguinea	0	0	0	0	0	0
				Phyllodoce sp.	0	0	0	0	0	0
			Polynoidae	Harmothoe sp.	0	0	0	0	0	0
				Lepidametria commensalis	0	0	0	0	0	0
			Syllidae	---	0	0	0	0	0	0
		Spionida	Chaetopteriadae	---	0	0	0	0	0	0
			Paraonidae	---	0	4,386	1,462	50	0	1,462
				Paraonis sp.	0	0	0	0	0	0
			Sabellariidae	Sabellaria vulgaris	0	0	0	0	0	0
			Spionidae	Polydora ligni	0	0	0	0	0	0
				Streblospio benedicti	0	0	0	10	0	0
		Terebellida	---	---	0	0	0	0	0	0
			Pectinariidae	Pectinaria gouldii	0	0	0	0	0	0
				Pectinaria sp.	0	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda			0	0	0	0	0	0
			Ampeliscidae	Ampelisca abdita	0	292	0	0	0	0
				Ampelisca sp.	0	0	0	0	0	0
				Ampelisca Vadorum	0	0	0	0	0	0
				Byblis Serrata	0	0	0	0	0	0
			Ampithoidae		0	0	0	0	0	0
			Aoridae	Unciola irrorata	0	0	0	0	0	0
				Unciola sp.	0	0	0	0	0	0
			Caprellidae	Caprella penantis	0	0	0	0	0	0
			Corophiidae		0	0	0	0	0	0
				Corophium sp.	0	0	0	0	0	0
			Gammaridae		0	0	0	0	80	0
				Gammarus sp.	0	0	0	0	0	0
			Ischyroceridae	Jassa falcata	0	0	0	0	0	0
			Melitidae		0	0	0	0	0	0
				Melita netida	0	0	0	10	0	0
			Photidae		0	0	0	0	0	0
			Phoxocephalidae		0	0	0	0	0	0
				Paraphoxus sp	0	0	0	0	340	0
			Stenothoidae		0	0	0	0	0	0
		Decapoda	Cancridae	Cancer irroratus	0	0	0	10	0	0
			Crangonidae	Crangon septemspinosa	0	0	0	0	0	0
			Magidae	Libinia emarginata	0	0	0	0	40	11
			Paguridae	Pagurus sp.	0	0	0	10	0	0
			Portunidae	Ovalipes ocellatus	0	0	0	0	0	0
			Xanthidae	Panopeus herbstii	0	0	0	0	20	0
				Rhithropanopeus harrisii	0	0	0	0	0	0
		Isopoda	Anthuridae	Cyathura polita	0	0	0	0	0	0
		Ostracoda			0	0	0	0	0	0
Mollusca	Bivalvia	Eudesmodontida	Pandoridae	Pandora Gouldiana	0	0	0	0	0	0
		Myoida	Myidae	Mya arenaria	0	0	0	130	140	877
		Mytioida	Mytilidae	Mytilus edulis	0	0	0	530	0	0
		Nuculoida	Nuculanidae	Nucula sp.	0	0	0	0	0	0
		Ostreoida	Anomiidae	Anomia sp.	0	0	0	0	0	0
		Veneroida	Astartidae	Astarte sp.	0	0	0	0	0	0
			Mactridae	Mulinia lateralis	292	2,924	0	0	60	0
				Spisula Solidissima	0	0	0	0	0	11
			Solenidae	Ensis directus	0	0	0	0	0	0
			Tellinidae	Tellina agilis	0	0	0	0	0	0
			Veneridae	Mercenaria mercenaria	0	0	0	20	0	0
	Gastropoda				0	0	0	0	0	0
		Archaeogastropoda	Naticidae	Neverita Duplicata	0	11	0	0	0	0
		Cephalaspidea			0	0	0	0	0	0
			Acteonidae	Rictaxis puntcostriatus	0	0	0	0	0	0
			Scaphandridae	Acteocina canaliculata	0	0	0	0	0	0
		Mesogastropoda	Calyptraeidae	Crepidula fornicata	0	0	0	60	720	0
				Crepidula plana	0	0	0	0	40	0
			Rissoidae		0	0	0	0	0	0
		Neogastropoda	Melongenidae	Busycon carica	0	0	0	0	0	0
			Muricidae	Eupleura caudata	0	0	0	0	0	0
				Urosalpinx cinereus	0	0	0	0	0	0
			Nassariidae	Ilyanassa obsoleta	0	0	0	0	0	0
				Ilyanassa trivittata	0	0	0	10	40	292
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius parma	0	0	0	0	0	0
Nematoda					0	0	0	0	0	0
Nemertea					0	0	0	0	0	0

Table B-4: Average Benthos Density (No./m^2) at Verrazano-Narrows.

Phylum	Class	Order	Family	GenusSpecies	VN1	VN2	VN4	VN5	VN6	VN9
Annelida	Oligochaeta	---	---	---	1,765	0	0	0	5,848	3,801
	Polychaeta	---	---	---	0	0	75	0	0	0
		Archiannelida	Polygordiidae	Polygordius sp.	0	0	0	0	0	0
		Ariciida	Orbiniidae	---	0	0	0	0	0	0
				Haploscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos Fragilis	0	1,462	0	0	2,924	585
				Leitoscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos sp.	0	0	0	0	0	0
		Capitellida	Capitellidae	---	0	2,047	0	1,170	0	0
				Capitella sp.	4,093	0	585	0	0	0
			Maldanidae	Asychis elongata	0	0	0	0	0	0
		Cirratulida	---	---	0	0	0	0	0	0
			Cirratulidae	---	0	0	0	0	0	0
		Eunicida	Arabellidae	Arabella iricolor	0	0	0	0	0	0
			Onuphidae	Diopatra cuprea	0	0	0	292	0	0
		Phyllodocida	Glyceridae	Glycera sp.	0	0	1,170	1,170	292	0
			Goniadidae	---	0	0	0	0	0	0
			Nephtyidae	Nephtys sp.	0	0	0	0	0	0
			Nereidae	Nereid succinea	292	0	0	0	0	0
				Nereis sp.	0	0	0	292	0	0
				Nereis virens	0	0	0	0	0	0
			Phyllodocidae	---	0	0	0	0	0	0
				Eteone sp.	585	0	0	0	0	0
				Eumida Sanguinea	0	0	32	0	0	0
				Phyllodoce sp.	0	0	0	0	0	0
			Polynoidae	Harmothoe sp.	0	0	0	0	0	0
				Lepidametria commensalis	0	0	0	0	0	0
			Syllidae	---	292	0	0	0	0	0
		Spionida	Chaetopteriadae	---	0	11	0	0	0	0
			Paraonidae	---	0	0	23,391	0	5,263	0
				Paraonis sp.	0	0	0	0	0	0
			Sabellariidae	Sabellaria vulgaris	0	0	0	292	0	0
			Spionidae	Polydora ligni	0	0	0	0	0	0
				Streblospio benedicti	2,642	0	0	0	0	877
		Terebellida	---	---	0	0	0	292	0	0
			Pectinariidae	Pectinaria gouldii	0	43	0	585	877	11
				Pectinaria sp.	0	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda			0	0	0	0	0	0
			Ampeliscidae	Ampelisca abdita	11	0	0	585	585	1,462
				Ampelisca sp.	0	0	0	0	0	0
				Ampelisca Vadorum	0	0	0	0	0	0
				Byblis Serrata	0	0	0	0	0	0
			Ampithoidae		0	0	0	0	0	0
			Aoridae	Unciola irrorata	0	0	0	0	0	0
				Unciola sp.	0	0	0	292	0	0
			Caprellidae	Caprella penantis	0	0	0	0	0	0
			Corophiidae		0	0	0	0	0	0
				Corophium sp.	0	0	0	292	0	0
			Gammaridae		0	0	0	0	0	0
				Gammarus sp.	0	0	0	0	0	0
			Ischyroceridae	Jassa falcata	0	0	0	0	0	0
			Melitidae		0	0	0	0	0	0
				Melita netida	0	0	0	0	0	0
			Photidae		0	0	0	0	0	0
			Phoxocephalidae		0	0	292	0	0	0
				Paraphoxus sp	0	0	0	0	0	0
			Stenothoidae		0	0	0	0	0	0
		Decapoda	Cancridae	Cancer irroratus	0	0	0	0	0	0
			Crangonidae	Crangon septemspinosa	0	0	0	0	0	0
			Magidae	Libinia emarginata	0	0	0	0	0	0
			Paguridae	Pagurus sp.	0	0	0	0	0	0
			Portunidae	Ovalipes ocellatus	0	0	0	0	0	0
			Xanthidae	Panopeus herbstii	0	0	0	0	0	0
				Rhithropanopeus harrisii	0	0	0	0	0	0
		Isopoda	Anthuridae	Cyathura polita	0	0	0	0	0	0
		Ostracoda			0	0	0	0	0	0
Mollusca	Bivalvia	Eudesmodontida	Pandoridae	Pandora Gouldiana	0	11	0	0	0	0
		Myoida	Myidae	Mya arenaria	0	0	292	2,924	292	0
		Mytioida	Mytilidae	Mytilus edulis	11	0	0	0	0	0
		Nuculoida	Nuculanidae	Nucula sp.	0	0	0	0	0	0
		Ostreoida	Anomiidae	Anomia sp.	0	0	0	0	0	0
		Veneroida	Astartidae	Astarte sp.	0	11	0	0	21	0
			Mactridae	Mulinia lateralis	0	3,552	0	0	5,587	17,618
				Spisula Solidissima	0	0	0	0	0	0
			Solenidae	Ensis directus	0	0	0	0	0	0
			Tellinidae	Tellina agilis	0	0	0	0	0	0
			Veneridae	Mercenaria mercenaria	0	0	0	3,216	0	0
	Gastropoda				0	0	0	0	0	0
		Archaeogastropoda	Naticidae	Neverita Duplicata	0	0	11	0	0	0
		Cephalaspidea			0	0	0	0	0	0
			Acteonidae	Rictaxis puntcostriatus	0	0	0	0	0	0
			Scaphandridae	Acteocina canaliculata	292	0	0	0	0	877
		Mesogastropoda	Calyptraeidae	Crepidula fornicata	0	0	43	5,263	0	0
				Crepidula plana	0	0	0	0	0	0
			Rissoidae		0	0	0	0	0	0
		Neogastropoda	Melongenidae	Busycon carica	0	0	0	0	0	0
			Muricidae	Eupleura caudata	0	0	0	0	0	0
				Urosalpinx cinereus	0	0	0	0	0	0
			Nassariidae	Ilyanassa obsoleta	0	0	0	0	0	0
				Ilyanassa trivittata	0	0	0	0	292	0
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius parma	0	0	0	0	0	0
Nematoda					0	0	292	0	0	0
Nemertea					0	0	0	0	0	0

Table B-5: Average Benthos Density (No./m^2) at Old Orchard Shoal.

Phylum	Class	Order	Family	GenusSpecies	OOS1	OOS2	OOS3	OOS4	OOS5	OOS6
Annelida	Oligochaeta	---	---	---	325	0	0	1,462	0	0
	Polychaeta	---	---	---	11	4,678	0	0	0	0
		Archiannelida	Polygordiidae	Polygordius sp.	0	0	0	0	0	0
		Ariciida	Orbiniidae	---	0	0	0	0	0	0
				Haploscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos Fragilis	0	0	0	0	0	0
				Leitoscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos sp.	0	0	0	0	0	0
		Capitellida	Capitellidae	---	0	0	0	0	0	0
				Capitella sp.	0	0	0	585	0	0
			Maldanidae	Asychis elongata	0	0	0	0	0	0
		Cirratulida	---	---	0	0	0	0	0	0
			Cirratulidae	---	0	0	0	0	0	0
		Eunicida	Arabellidae	Arabella iricolor	0	0	0	11	0	0
			Onuphidae	Diopatra cuprea	0	0	0	0	0	0
		Phyllodocida	Glyceridae	Glycera sp.	1,462	0	0	2,339	70	100
			Goniadidae	---	0	0	0	0	0	0
			Nephtyidae	Nephtys sp.	877	0	1,754	0	0	0
			Nereidae	Nereid succinea	0	0	0	0	0	0
				Nereis sp.	0	0	0	0	110	0
				Nereis virens	11	0	0	0	0	0
			Phyllodocidae	---	0	0	0	0	0	0
				Eteone sp.	21	877	0	0	0	10
				Eumida Sanguinea	0	0	0	0	0	0
				Phyllodoce sp.	0	0	0	0	0	0
			Polynoidae	Harmothoe sp.	0	0	0	0	0	0
				Lepidametria commensalis	0	0	0	0	0	0
			Syllidae	---	11	0	0	0	0	0
		Spionida	Chaetopteriadae	---	11	0	0	0	0	0
			Paraonidae	---	877	0	0	0	20	0
				Paraonis sp.	0	0	0	0	0	0
			Sabellariidae	Sabellaria vulgaris	0	0	0	0	0	0
			Spionidae	Polydora ligni	0	0	0	0	0	0
				Streblospio benedicti	1,526	11	0	0	20	80
		Terebellida	---	---	0	0	0	0	0	0
			Pectinariidae	Pectinaria gouldii	11	0	0	11	0	0
				Pectinaria sp.	0	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda			0	0	0	0	0	0
			Ampeliscidae	Ampelisca abdita	0	0	0	0	0	10
				Ampelisca sp.	0	0	0	0	0	0
				Ampelisca Vadorum	0	0	0	0	0	0
				Byblis Serrata	0	0	0	0	0	0
			Ampithoidae		0	0	0	0	0	0
			Aoridae	Unciola irrorata	21	0	0	0	0	0
				Unciola sp.	0	0	0	0	10	350
			Caprellidae	Caprella penantis	0	0	0	0	0	20
			Corophiidae		0	0	0	0	0	50
				Corophium sp.	0	0	0	0	0	0
			Gammaridae		0	0	0	0	0	0
				Gammarus sp.	0	0	0	0	0	0
			Ischyroceridae	Jassa falcata	0	0	0	0	0	50
			Melitidae		0	0	0	0	10	0
				Melita netida	0	0	0	0	0	0
			Photidae		0	0	0	0	0	0
			Phoxocephalidae		0	0	0	292	0	10
				Paraphoxus sp	0	0	0	0	0	0
			Stenothoidae		0	0	0	0	0	10
		Decapoda	Cancridae	Cancer irroratus	0	0	11	0	0	0
			Crangonidae	Crangon septemspinosa	0	0	0	0	0	0
			Magidae	Libinia emarginata	0	0	0	0	0	0
			Paguridae	Pagurus sp.	0	0	11	0	20	0
			Portunidae	Ovalipes ocellatus	0	0	0	0	0	0
			Xanthidae	Panopeus herbstii	0	0	11	0	50	70
				Rhithropanopeus harrisii	21	0	0	11	0	0
		Isopoda	Anthuridae	Cyathura polita	0	0	0	0	10	0
		Ostracoda			0	0	0	0	0	0
Mollusca	Bivalvia	Eudesmodontida	Pandoridae	Pandora Gouldiana	952	1,317	1,449	0	10	0
		Myoida	Myidae	Mya arenaria	292	292	877	292	40	60
		Mytioida	Mytilidae	Mytilus edulis	11	0	0	0	0	0
		Nuculoida	Nuculanidae	Nucula sp.	0	0	0	0	0	0
		Ostreoida	Anomiidae	Anomia sp.	0	0	0	0	10	0
		Veneroida	Astartidae	Astarte sp.	11	0	0	0	0	10
			Mactridae	Mulinia lateralis	292	877	9,356	0	0	0
				Spisula Solidissima	0	0	0	0	0	0
			Solenidae	Ensis directus	0	0	11	0	0	0
			Tellinidae	Tellina agilis	0	0	0	0	0	0
			Veneridae	Mercenaria mercenaria	292	0	303	11	30	0
	Gastropoda				0	0	0	0	0	0
		Archaeogastropoda	Naticidae	Neverita Duplicata	0	0	0	0	0	0
		Cephalaspidea			0	0	0	0	0	0
			Acteonidae	Rictaxis puntcostriatus	0	0	0	0	0	0
			Scaphandridae	Acteocina canaliculata	0	0	0	0	0	0
		Mesogastropoda	Calyptraeidae	Crepidula fornicata	11	0	585	1,781	710	20
				Crepidula plana	303	0	0	679	20	0
			Rissoidae		0	0	0	0	0	0
		Neogastropoda	Melongenidae	Busycon carica	0	0	0	0	0	0
			Muricidae	Eupleura caudata	0	0	11	0	0	0
				Urosalpinx cinereus	0	0	0	0	30	0
			Nassariidae	Ilyanassa obsoleta	0	0	0	0	0	0
				Ilyanassa trivittata	0	0	0	0	70	0
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius parma	0	0	0	0	0	0
Nematoda					0	0	0	0	0	0
Nemertea					11	0	0	0	0	0

Table B-6: **Average Benthos Density (No./m^2) at Raritan Bay Rock Berm.**

Phylum	Class	Order	Family	GenusSpecies	RBRB1	RBRB2	RBRB3	RBRB4	RBRB5	RBRB6
Annelida	Oligochaeta	---	---	---	0	0	585	0	2,047	0
	Polychaeta	---	---	---	0	0	0	0	0	0
		Archiannelida	Polygordiidae	Polygordius sp.	0	0	0	0	0	0
		Ariciida	Orbiniidae	---	0	0	0	0	0	0
				Haploscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos Fragilis	20	30	0	0	1,170	292
				Leitoscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos sp.	0	0	0	0	0	0
		Capitellida	Capitellidae	---	0	0	0	0	0	0
				Capitella sp.	460	0	2,339	690	0	0
			Maldanidae	Asychis elongata	0	0	0	0	0	0
		Cirratulida	---	---	0	0	0	0	0	0
			Cirratulidae	---	0	0	0	0	0	0
		Eunicida	Arabellidae	Arabella iricolor	0	0	0	0	0	0
			Onuphidae	Diopatra cuprea	0	0	0	0	0	0
		Phyllodocida	Glyceridae	Glycera sp.	30	100	0	80	0	292
			Goniadidae	---	0	0	0	0	0	0
			Nephtyidae	Nephtys sp.	0	0	0	0	877	1,462
			Nereidae	Nereid succinea	0	0	0	20	0	0
				Nereis sp.	0	50	0	0	0	0
				Nereis virens	0	0	0	0	0	0
			Phyllodocidae	---	0	0	0	0	0	0
				Eteone sp.	0	0	1,170	0	0	0
				Eumida Sanguinea	0	0	0	0	0	0
				Phyllodoce sp.	10	0	0	0	0	0
			Polynoidae	Harmothoe sp.	0	0	0	0	0	0
				Lepidametria commensalis	0	0	0	0	0	0
			Syllidae	---	0	0	0	0	0	0
		Spionida	Chaetopteriadae	---	0	0	0	0	0	0
			Paraonidae	---	0	350	23,391	200	0	0
				Paraonis sp.	0	0	0	0	0	0
			Sabellariidae	Sabellaria vulgaris	0	0	0	0	0	0
			Spionidae	Polydora ligni	0	0	0	0	0	0
				Streblospio benedicti	0	0	2,631	0	292	0
		Terebellida	---	---	0	0	0	0	0	0
			Pectinariidae	Pectinaria gouldii	0	40	0	0	0	0
				Pectinaria sp.	0	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda			10	0	0	0	0	0
			Ampeliscidae	Ampelisca abdita	0	0	0	1,000	0	0
				Ampelisca sp.	0	0	0	0	0	0
				Ampelisca Vadorum	0	0	0	0	0	0
				Byblis Serrata	0	0	292	0	0	0
			Ampithoidae		0	0	0	0	0	0
			Aoridae	Unciola irrorata	0	0	0	0	0	0
				Unciola sp.	0	0	0	0	0	0
			Caprellidae	Caprella penantis	0	0	0	0	0	0
			Corophiidae		0	0	0	0	0	0
				Corophium sp.	0	0	0	10	0	0
			Gammaridae		0	0	585	0	0	0
				Gammarus sp.	0	0	0	0	0	0
			Ischyroceridae	Jassa falcata	0	0	0	0	0	0
			Melitidae		0	0	0	0	0	0
				Melita netida	0	0	0	0	0	0
			Photidae		20	0	0	0	0	0
			Phoxocephalidae		0	0	0	0	0	0
				Paraphoxus sp	0	0	0	0	0	0
			Stenothoidae		0	0	0	0	0	0
		Decapoda	Cancridae	Cancer irroratus	0	0	0	0	0	0
			Crangonidae	Crangon septemspinosa	0	0	0	0	0	0
			Magidae	Libinia emarginata	0	0	0	0	0	0
			Paguridae	Pagurus sp.	0	10	0	0	0	292
			Portunidae	Ovalipes ocellatus	0	0	0	0	11	0
			Xanthidae	Panopeus herbstii	20	60	0	10	0	0
				Rhithropanopeus harrisii	0	0	0	0	0	0
		Isopoda	Anthuridae	Cyathura polita	0	0	0	0	0	0
		Ostracoda			0	0	0	0	0	0
Mollusca	Bivalvia	Eudesmodontida	Pandoridae	Pandora Gouldiana	0	0	0	0	0	0
		Myoida	Myidae	Mya arenaria	0	270	0	20	0	585
		Mytioida	Mytilidae	Mytilus edulis	0	0	0	0	0	0
		Nuculoida	Nuculanidae	Nucula sp.	0	0	0	0	0	0
		Ostreoida	Anomiidae	Anomia sp.	0	0	0	0	0	0
		Veneroida	Astartidae	Astarte sp.	0	0	0	0	0	0
			Mactridae	Mulinia lateralis	10	0	0	0	0	0
				Spisula Solidissima	0	0	0	0	0	0
			Solenidae	Ensis directus	0	0	0	0	0	0
			Tellinidae	Tellina agilis	0	0	0	0	0	0
			Veneridae	Mercenaria mercenaria	100	130	11	10	0	0
	Gastropoda				0	0	0	0	0	0
		Archaeogastropoda	Naticidae	Neverita Duplicata	0	0	0	0	0	0
		Cephalaspidea			0	0	0	0	0	0
			Acteonidae	Rictaxis puntcostriatus	0	0	0	0	0	0
			Scaphandridae	Acteocina canaliculata	0	0	0	0	292	0
		Mesogastropoda	Calyptraeidae	Crepidula fornicata	1,190	700	0	0	0	0
				Crepidula plana	0	0	0	0	0	0
			Rissoidae		0	0	0	0	0	0
		Neogastropoda	Melongenidae	Busycon carica	0	0	0	0	0	0
			Muricidae	Eupleura caudata	0	0	0	0	0	0
				Urosalpinx cinereus	0	0	0	0	0	0
			Nassariidae	Ilyanassa obsoleta	0	0	0	0	0	0
				Ilyanassa trivittata	0	0	0	0	292	1,170
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius parma	0	0	0	0	0	0
Nematoda					0	0	0	20	0	0
Nemertea					0	0	0	0	292	0

Table B-7: **Average Benthos Density (No./m²) at Raritan Bay Shellfish Bed.**

Phylum	Class	Order	Family	GenusSpecies	RBSB1	RBSB2	RBSB3	RBSB4	RBSB5	RBSB6
Annelida	Oligochaeta	---	---	---	2,047	0	1,754	0	2,924	2,047
	Polychaeta	---	---	---	0	0	0	0	0	0
		Archiannelida	Polygordiidae	Polygordius sp.	0	0	0	0	0	0
		Ariciida	Orbiniidae	---	0	0	0	0	0	0
				Haploscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos Fragilis	292	877	0	0	292	292
				Leitoscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos sp.	0	0	0	0	0	0
		Capitellida	Capitellidae	---	0	0	0	0	0	0
				Capitella sp.	1,754	11,111	3,509	930	877	585
			Maldanidae	Asychis elongata	0	0	0	0	0	0
		Cirratulida	---	---	0	0	0	0	0	0
			Cirratulidae	---	0	0	0	0	0	0
		Eunicida	Arabellidae	Arabella iricolor	0	0	0	0	0	0
			Onuphidae	Diopatra cuprea	0	0	0	0	0	0
		Phyllodocida	Glyceridae	Glycera sp.	292	877	1,170	20	0	0
			Goniadidae	---	0	0	0	0	0	0
			Nephtyidae	Nephtys sp.	0	0	0	80	0	0
			Nereidae	Nereid succinea	0	0	0	0	292	0
				Nereis sp.	0	585	0	0	0	0
				Nereis virens	0	0	0	0	0	0
			Phyllodocidae	---	0	0	0	0	0	0
				Eteone sp.	292	0	3,509	10	877	585
				Eumida Sanguinea	0	0	0	0	0	0
				Phyllodoce sp.	0	0	0	0	0	0
			Polynoidae	Harmothoe sp.	0	0	585	0	0	0
				Lepidametria commensalis	0	0	0	0	0	0
			Syllidae	---	0	0	0	0	0	0
		Spionida	Chaetopteriadae	---	0	0	0	0	0	0
			Paraonidae	---	6,432	10,818	12,280	0	1,462	4,386
				Paraonis sp.	0	0	0	0	0	0
			Sabellariidae	Sabellaria vulgaris	0	0	0	0	0	0
			Spionidae	Polydora ligni	0	0	0	0	0	0
				Streblospio benedicti	0	0	0	0	292	0
		Terebellida	---	---	0	0	0	0	0	0
			Pectinariidae	Pectinaria gouldii	0	292	0	10	292	0
				Pectinaria sp.	0	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda			0	0	0	0	0	0
			Ampeliscidae	Ampelisca abdita	12,572	23,098	115,199	70	39,472	585
				Ampelisca sp.	0	0	0	0	2,924	0
				Ampelisca Vadorum	0	0	0	0	0	0
				Byblis Serrata	0	0	0	0	0	0
			Ampithoidae		0	0	0	0	0	0
			Aoridae	Unciola irrorata	0	0	0	0	0	0
				Unciola sp.	0	0	0	0	0	0
			Caprellidae	Caprella penantis	0	0	0	0	0	0
			Corophiidae		0	0	0	0	0	0
				Corophium sp.	0	0	0	0	0	0
			Gammaridae		4,386	0	0	50	0	0
				Gammarus sp.	0	292	0	0	0	0
			Ischyroceridae	Jassa falcata	0	0	0	0	0	0
			Melitidae		0	0	0	0	0	0
				Melita netida	0	0	0	0	0	0
			Photidae		0	0	0	0	0	0
			Phoxocephalidae		0	0	0	0	0	0
				Paraphoxus sp	0	0	0	0	0	0
			Stenothoidae		0	0	0	0	0	0
		Decapoda	Cancridae	Cancer irroratus	0	0	0	0	0	0
			Crangonidae	Crangon septemspinosa	0	0	0	0	0	0
			Magidae	Libinia emarginata	0	0	0	0	0	0
			Paguridae	Pagurus sp.	0	0	0	0	0	0
			Portunidae	Ovalipes ocellatus	0	0	0	0	0	0
			Xanthidae	Panopeus herbstii	0	0	0	10	0	0
				Rhithropanopeus harrisii	0	0	0	0	0	0
		Isopoda	Anthuridae	Cyathura polita	0	0	0	0	0	0
		Ostracoda			0	0	1,170	0	0	0
Mollusca	Bivalvia	Eudesmodontida	Pandoridae	Pandora Gouldiana	0	0	0	0	0	0
		Myoida	Myidae	Mya arenaria	0	0	0	0	0	0
		Mytioida	Mytilidae	Mytilus edulis	0	0	0	0	0	0
		Nuculoida	Nuculanidae	Nucula sp.	0	0	0	0	0	0
		Ostreoida	Anomiidae	Anomia sp.	0	0	0	0	0	0
		Veneroida	Astartidae	Astarte sp.	0	0	0	0	0	0
			Mactridae	Mulinia lateralis	0	0	0	0	0	0
				Spisula Solidissima	0	0	0	0	0	0
			Solenidae	Ensis directus	0	0	0	0	0	0
			Tellinidae	Tellina agilis	0	0	0	0	0	0
			Veneridae	Mercenaria mercenaria	0	292	0	40	0	0
	Gastropoda				0	0	0	0	0	0
		Archaeogastropoda	Naticidae	Neverita Duplicata	0	0	0	0	0	0
		Cephalaspidea			0	0	0	0	0	0
			Acteonidae	Rictaxis puntcostriatus	0	0	0	0	0	0
			Scaphandridae	Acteocina canaliculata	0	0	0	0	0	0
		Mesogastropoda	Calyptraeidae	Crepidula fornicata	0	0	0	10	0	0
				Crepidula plana	0	0	0	0	0	0
			Rissoidae		0	0	0	0	0	0
		Neogastropoda	Melongenidae	Busycon carica	0	0	0	0	0	0
			Muricidae	Eupleura caudata	0	0	0	0	0	0
				Urosalpinx cinereus	0	0	0	0	0	0
			Nassariidae	Ilyanassa obsoleta	0	0	0	0	0	0
				Ilyanassa trivittata	0	0	0	0	0	0
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius parma	0	0	0	0	0	0
Nematoda					585	0	1,170	0	1,462	0
Nemertea					0	0	0	0	0	0

Table B-8: **Average Benthos Density (No./m^2) at Bowery Bay.**

Phylum	Class	Order	Family	GenusSpecies	BB1	BB2	BB4	BB5	BB9	BB10
Annelida	Oligochaeta	---	---	---	0	1,754	4,093	585	19,882	0
	Polychaeta	---	---	---	0	0	0	17,543	0	1,462
		Archiannelida	Polygordiidae	Polygordius sp.	0	0	0	0	0	0
		Ariciida	Orbiniidae	---	0	0	0	0	0	0
				Haploscoloplos robustus	0	0	0	0	0	0
				Leitoscoloplos Fragilis	2,339	0	0	0	585	0
				Leitoscoloplos robustus	0	585	0	0	0	0
				Leitoscoloplos sp.	0	0	52,629	0	0	0
		Capitellida	Capitellidae	---	0	0	0	0	0	0
				Capitella sp.	0	6,725	0	43,857	18,712	0
			Maldanidae	Asychis elongata	0	0	0	0	0	0
		Cirratulida	---	---	0	0	0	0	0	0
			Cirratulidae	---	0	0	0	0	0	0
		Eunicida	Arabellidae	Arabella iricolor	0	0	0	0	0	0
			Onuphidae	Diopatra cuprea	0	0	0	0	0	0
		Phyllodocida	Glyceridae	Glycera sp.	11	0	0	0	0	0
			Goniadidae	---	0	0	0	0	0	0
			Nephtyidae	Nephtys sp.	0	0	0	0	0	0
			Nereidae	Nereid succinea	0	0	0	11	0	11
				Nereis sp.	0	0	0	0	0	0
				Nereis virens	0	0	0	0	0	0
			Phyllodocidae	---	0	0	0	0	0	0
				Eteone sp.	0	1,170	1,170	877	0	0
				Eumida Sanguinea	0	0	0	0	0	0
				Phyllodoce sp.	0	0	0	0	0	0
			Polynoidae	Harmothoe sp.	0	0	0	0	0	0
				Lepidametria commensalis	0	0	0	0	0	0
			Syllidae	---	0	0	0	0	0	0
		Spionida	Chaetopteriadae	---	0	0	0	0	0	0
			Paraonidae	---	0	0	0	0	0	0
				Paraonis sp.	0	0	0	0	0	0
			Sabellariidae	Sabellaria vulgaris	0	0	0	0	0	0
			Spionidae	Polydora ligni	0	585	0	3,216	1,170	0
				Streblospio benedicti	0	12,280	5,848	4,093	8,187	0
		Terebellida	---	---	0	0	0	0	0	0
			Pectinariidae	Pectinaria gouldii	0	0	0	0	0	0
				Pectinaria sp.	0	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda			0	0	0	0	0	0
			Ampeliscidae	Ampelisca abdita	0	0	0	0	0	0
				Ampelisca sp.	0	0	0	0	0	0
				Ampelisca Vadorum	0	0	0	0	0	0
				Byblis Serrata	0	0	0	0	0	0
			Ampithoidae		0	0	0	0	0	0
			Aoridae	Unciola irrorata	0	0	0	0	0	0
				Unciola sp.	0	0	0	0	0	0
			Caprellidae	Caprella penantis	0	0	0	0	0	0
			Corophiidae		0	0	0	0	0	0
				Corophium sp.	0	0	0	0	0	0
			Gammaridae		0	0	0	0	0	0
				Gammarus sp.	0	0	0	0	0	0
			Ischyroceridae	Jassa falcata	0	0	0	0	0	0
			Melitidae		0	0	0	0	0	0
				Melita netida	0	0	0	0	0	0
			Photidae		0	0	0	0	0	0
			Phoxocephalidae		0	0	0	0	0	0
				Paraphoxus sp	0	0	0	0	0	0
			Stenothoidae		0	0	0	0	0	0
		Decapoda	Cancridae	Cancer irroratus	0	0	0	0	0	0
			Crangonidae	Crangon septemspinosa	0	0	0	0	0	0
			Magidae	Libinia emarginata	0	0	0	0	0	0
			Paguridae	Pagurus sp.	0	0	0	0	0	0
			Portunidae	Ovalipes ocellatus	0	0	0	0	0	0
			Xanthidae	Panopeus herbstii	0	0	0	0	0	0
				Rhithropanopeus harrisii	0	0	0	0	0	0
		Isopoda	Anthuridae	Cyathura polita	0	0	0	0	0	0
		Ostracoda			0	0	0	0	0	0
Mollusca	Bivalvia	Eudesmodontida	Pandoridae	Pandora Gouldiana	0	0	0	0	0	0
		Myoida	Myidae	Mya arenaria	0	0	0	0	0	0
		Mytioida	Mytilidae	Mytilus edulis	0	0	0	0	0	0
		Nuculoida	Nuculanidae	Nucula sp.	0	0	0	0	0	0
		Ostreoida	Anomiidae	Anomia sp.	0	0	0	0	0	0
		Veneroida	Astartidae	Astarte sp.	0	0	0	0	0	0
			Mactridae	Mulinia lateralis	585	0	0	0	0	0
				Spisula Solidissima	0	0	0	0	0	0
			Solenidae	Ensis directus	0	0	0	0	0	0
			Tellinidae	Tellina agilis	0	0	0	0	0	0
			Veneridae	Mercenaria mercenaria	0	0	0	0	0	0
	Gastropoda				0	0	0	0	0	0
		Archaeogastropoda	Naticidae	Neverita Duplicata	0	0	0	0	0	0
		Cephalaspidea			585	0	0	0	0	0
			Acteonidae	Rictaxis puntcostriatus	0	0	0	0	0	0
			Scaphandridae	Acteocina canaliculata	0	0	0	0	0	0
		Mesogastropoda	Calyptraeidae	Crepidula fornicata	0	0	0	0	0	0
				Crepidula plana	0	0	0	0	0	0
			Rissoidae		0	0	0	0	0	0
		Neogastropoda	Melongenidae	Busycon carica	0	0	0	0	0	0
			Muricidae	Eupleura caudata	0	0	0	0	0	0
				Urosalpinx cinereus	0	0	0	0	0	0
			Nassariidae	Ilyanassa obsoleta	0	0	0	32	11	0
				Ilyanassa trivittata	0	0	0	0	0	0
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius parma	0	0	0	0	0	0
Nematoda					0	0	0	0	0	0
Nemertea					0	0	0	0	0	0

APPENDIX C

DEFINITIONS AND TECHNICAL INFORMATION

Side-Scan Sonar (SSS)

The side-scan sonar (SSS) is a remote sensing technique that can provide a description of bottom morphology and the possibility to indicate substrate type over large areas for habitat characterization purposes. The SSS imagery provides a picture of the sea-floor by transmitting a series of acoustic pulses that are reflected off the sea-floor surface. Side-scan sonar data is interpreted by the shade or amplitude of the reflection. Fine-grain (e.g. silt and mud) will appear very light or low amplitude, whereas coarse grain areas (e.g. sand) are dark or high amplitude. Hard bottom areas (e.g. bedrock outcroppings) and bottom structures are also characterized by high amplitude returns (the SSS imagery of the Hoffman Swinburne Islands site is a good example).

Apparent Redox Potential Discontinuity (RPD)

The apparent Redox Potential Discontinuity (RPD) layer is the depth below the sediment-water interface marking the transition from chemically oxidative to reducing processes. The term “apparent” is used because the method is based on visual observation and no actual measurement is made of the Redox potential. It is generally marked by a change in color (light gray to black anoxic) that is easily and visually detectable. Below this layer, all chemical reactions in the sediment are anaerobic and primarily carried out by bacteria. This parameter has been determined to be an important estimator of the quality of benthic habitat, providing an estimate of the depth that sediments are oxidized (Rhoads and Germano 1986, Diaz and Schaffner 1988). The apparent RPD is typically found within the first centimeters of the sediment-water interface. Controlling for differences in sediment type, habitats with thinner RPD's (mm's) tend to be associated with some type of environmental stress, while habitats with deeper RPD's (cm's) usually have flourishing epibenthic and infaunal communities.

Grain-Size Analysis

Grain size is an important parameter for determining the nature of the physical forces acting on a habitat as well as determining the size and amount of interstitial habitat available. This can affect not only the bacterial and macroinvertebrate fauna, but also chemical composition because metals and other pollutants adsorb readily to small clay particles. It is also a major factor in determining benthic community structure (Rhoads 1974). As a result, grain size is a major factor affecting the faunal assemblage to be found in an area. Additionally, grain size is a controlling factor in the adsorption of contaminants onto sediments. Fine sediments typically accumulate higher levels of contaminants than coarse sediments, due to a higher surface area to volume ratio and surface charges that cause these particles to be more chemically and biologically reactive than coarser particles (Power and Chapman, 1995). Depositional areas, which accumulate fine particles, frequently have higher levels of contaminants than coarse sediment zones. The sediment type descriptors used in this study followed the Wentworth classification as described in Folk (1974) and represent the major modal class for each sample.

Organic detritus has been reported to be one of the most important food sources in estuaries. The measurement of organic contents in sediments not only helps determine the trophic state of the water body but will afford clues to the geomorphology and types of habitats available. High organic content would be typical of a low-gradient, low-energy, whereas high-flow, high-energy conditions would provide sandy, low-organic sediment.

Benthic Macroinvertebrates Analysis

Benthic macroinvertebrates provide useful indication of biological response to environmental conditions because they are relatively sedentary and present throughout the year. Benthic macroinvertebrates are also relatively long-lived and, as an essential component of the food web, are an important link between primary producers and higher trophic levels including the EFH-designated species. Annelids (Oligochaeta, Polychaeta), arthropods (Crustacea), and mollusks (Bivalvia, Gastropoda) are typically the three dominant groups of benthic macroinvertebrates from nearshore communities. Unlike the arthropods and mollusks, many of the most opportunistic species are annelids.

Benthic Community and Assemblage Structure Analysis

Species richness is one of the oldest and most basic diversity measurements, based directly on the total number of taxa (or species) at a site. In counting the number of taxa present in a sample, general taxonomic designations at the generic, familial, and higher taxonomic levels were dropped if there was one valid lower-level designation for that group. For example, if *Leitoscoloplos sp.*, *Leitoscoloplos fragilis*, and *Leitoscoloplos robustus* have all been identified in one sample, then *Leitoscoloplos* sp. was skipped when counting the number of taxa. In this event the number of taxa would be two.

The **Shannon-Wiener Diversity Index (H')** is one of the most widely used species diversity indices for examining overall benthic community characteristics as it is indicative of the species utilizing the available habitat. It provides more information about the benthic community composition than simply species richness since it takes into account the relative abundance of each different species. The diversity index H' can range between 0 (indicating low community complexity) and 4 (indicating high community complexity). Typically, a healthy benthic macroinvertebrate community should have a higher Shannon-Wiener Diversity Index. The index is computed as follows:

$$H' = -\sum_{i=1}^{s} (p_i)(Log_2\, p_i)$$

Where S is the total number of species per sample (i.e., species richness) and p_i is the proportion of total individuals in the i^{th} species. The value p_i is also defined as $p_i = n_i/N$ where n_i is the number of individuals of a species in sample and N is the total number of individuals of all species in sample.

The **Evenness E** (or equitability) measures the distribution among species within the community by scaling one of the heterogeneity measures relative to its maximal value when each species in the sample is represented by the same number of individuals. The evenness can range from 0 (low diversity) to 1 (high diversity). It is computed as follows”

$$E = \frac{H'}{H'_{\max}}$$

where H’ is the observed species diversity (as cited above) and H'_{max} is the logarithm of the total number of species (S) in the sample ($H'_{max} = Log_2 S$).

The use of **indicator species** that are pollution-tolerant or pollution-sensitive was also used in this study in order to determine the ecological health of each site. A review of indicator species shows that species present in most polluted areas, such as the polychaete *Capitella sp*., are typical of the first stage of infaunal succession. Although such species could also in high densities in areas other than those polluted areas showing organic enrichment, certain groups of species characterizing various stages of enrichment do occur in local areas. Pollution-tolerant taxa are species or higher taxonomic level designations that are indicative of pollution. Many pollution-tolerant species display opportunistic life-history characteristics, such as small size, rapid growth, high reproductive potential, and short-life spans; however not all opportunist species are classified as pollution-tolerant. Pollution-sensitive species are often called “equilibrium” species because they grow slowly and are relatively long-lived, and thus they tend to characterize undisturbed, mature communities. According to a literature review (Adams et al., 1998; Llansó et al., 2003; Pearson and Rosenberg, 1978), the main pollution-tolerant and pollution-sensitive taxa that are most likely found in the NY/NJ Harbor are listed in the table below.

Typical Pollution-Tolerant and Pollution Sensitive Taxa of the NY/NJ Harbor.

Pollution-tolerant taxa	Pollution-sensitive taxa	
ANNELIDA : Polychaeta	ANNELIDA : Polychaeta	MOLLUSCA : Bivalvia
Capitella sp.	*Chaetopterus variopedatus*	*Ensis directus*
Eteone heteropoda	*Diopotra cuprea*	*Mercenaria mercenaria*
Leitoscoloplos fragilis	*Glycera americana*	*Mya arenaria*
Streblospio benedicti	*Nephtys picta*	*Spisula solidissima*
		Tellina agilis
ANNELIDA : Oligochaeta	ARTHROPODA : Amphipoda	
Oligochaetes	*Ampelisca agassizi*	MOLLUSCA : Gastropoda
	Ampelisca verrilli	*Acteocina canaliculata*
	Byblis serrata	
	ARTHROPODA : Isopoda	
	Cyathura polita	

The percent abundance contribution of taxa classified as pollution-tolerant and pollution-sensitive taxa to the total abundance of species in each sample was calculated in order to evaluate the level of benthic community disturbance at each sampling station and project site. For the purpose of this study, it is assumed that a larger proportion of pollution-tolerant taxa than pollution-sensitive taxa would be indicative of a disturbed benthic community possibly due to pollution. Reciprocally, a larger proportion of pollution-sensitive taxa than pollution-tolerant taxa would be indicative of an undisturbed and mature benthic community. A similar proportion would be inconclusive.

Benthic Habitat Classification

As described in more details in Iocco, et al. (2000), this strategy focused primarily on economically important bivalves, species that build substantial biogenic structures or control important physical processes, and sediment characteristics that likely correlate with the diversity and biomass of the benthic infauna. This meant focusing on clams like the EFH-managed surf clams (*Spisula solidissima*) but also the non EFH-managed species like northern quahogs (*Mercenaria mercenaria*) (a.k.a. hard clam), soft clams (*Mya arenaria*), blue mussels (*Mytilus edulis*), and American oysters (*Crassostrea virginica*) (a.k.a. eastern oyster). Amphipods and polychaetes that build extensive tube mats and sediments with bacteria mats were also included in this strategy.

A total of five habitat classes were typically found through prior benthic surveys of the NY/NJ Harbor (Iocco et al., 2000). They were (1) shells beds (i.e., soft/hard clams, blue mussels, oysters), (2) mats of tube-dwelling amphipod *Ampelisca abdita*, (3) sandy bottoms (no shellfish or A*mpelisca* beds but dominated by sand fraction), (4) silty bottoms (no shellfish or A*mpelisca* beds but dominated by silt/clay fraction), and (5) bottoms with no discernable infauna and/or bacterial mats (oligozoic with sandy/silty sediments, high organic content, high hydrogen sulfide smell, and low RPD depths).

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