US Army Corps
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New York District

NEW YORK AND NEW JERSEY
HARBOR DEEPENING PROJECT

Application of Adult and Juvenile Winter Flounder Data to Habitat Uses in New York/New Jersey Harbor

November 2012

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Executive Summary

Determinations of seasonal dredging restrictions throughout the United States are frequently based on outdated information or perceptions of the dredging process and in only a few instances on conclusive scientific evidence (National Research Council 2001). Within New York and New Jersey Harbor (the Harbor), an opportunity exists to use results of an extensive aquatic biological sampling program as a basis for informed dredging management practices and to promote the protection of winter flounder, *Pseudopleuronectes americanus*, from its earliest egg and larval stages (USACE-NYD Early Life Stage Application Report published November 2010) through the juvenile and adult spawning life stages (this report).

The following summary report focuses on juvenile and adult spawning winter flounder occurrence and essential fish habitat (EFH) utilization within the Harbor incorporating data collected as part of the Aquatic Biological Survey (ABS) bottom trawl program (2002 – 2010) by the USACE-NYD during the Harbor Deepening Project (HDP). Additional information regarding the field methodologies for the ABS (Appendix A) as well as a summary of existing sediment distribution and benthic invertebrate communities (Appendix B) placed within the context of winter flounder life history and EFH are also provided.

Previous studies within the Harbor, as well as in other northeastern U.S. estuaries indicate that habitat utilization by juvenile and adult winter flounder may not be consistent across habitat types and may be highly variable among systems and from year to year (Schultz et al 2007). This observation is consistent with the characterization of winter flounder as generalists in terms of habitat selection and food preferences (NMFS 1999).

The 2002 – 2010 ABS trawl survey results are consistent with these previous studies in that juvenile and adult winter flounder occurred throughout the Harbor, showing no indication of avoiding a particular area. The ABS trawl survey data also confirmed previous studies (Wilk *et al*. 1998) in showing that juvenile and adult winter flounder are relatively common in channels and that juveniles spend their first year in their natal estuary (Able and Fahay 2010). Site-specific results include the relatively high densities of Year-1 juveniles and low densities of adults in the Arthur Kill area, indicating this area is used for early grow out and is not of high value as spawning habitat, especially when taken in conjunction with the findings from USACE 2010 that showed very few eggs and larvae collected in this area.

There was no indication, in the ABS data, that revision of the current dredging restrictions that are in place to protect winter flounder egg and larval stages would provide more protection to juvenile and adult winter flounder, based on their distribution patterns within the Harbor. Importantly, this report's results confirm that the existing conservation recommendations and environmental window restrictions discussed in 2010 Early Life Stage Application Report should not apply to the more mobile juvenile and adult life stages of winter flounder, which can avoid potential impacts associated with dredging (i.e. physical disturbances and re-suspended sediments).

The major findings of this study include:

- Nine years (2002-2010) of bottom trawl sampling in the Harbor from the winter to early summer revealed winter flounder habitat use within the Harbor varied by size/age class Year-1 juvenile densities were significantly higher in the Arthur Kill/Newark Bay area and adult densities were significantly lower in this area compared to the Lower Bay and Upper Bay areas
- Combined juvenile and adult winter flounder densities did not differ significantly by Harbor area
- Juvenile and adult winter flounder densities were higher at channel than non-channel stations
- Adult densities peaked in April at Lower Bay and Upper Bay stations after the spawning season ended, which coincided with the time that adults typically forage inshore before emigrating from estuaries
- A condition index[1] calculated for both adult male and female winter flounder declined during the spawning season and increased in May consistent with depletion of energy reserves from spawning and the accumulation of energy post-spawning while feeding within the estuary

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[1] The condition index (K) was used to examine seasonal changes in energy accumulation and depletion (Burton and Idler 1984; Wuenschel et al. 2009) and is calculated as (weight/TL3) *105.

- Annual egg densities were positively correlated with Year-1 juvenile densities the following year, indicating these winter flounder spend their first year in their natal estuary.

Table of Contents

Appendices

List of Tables

List of Figures

1. Introduction

Determinations of seasonal dredging restrictions throughout the United States are frequently based on outdated information or perceptions of the dredging process and in only a few instances on conclusive scientific evidence (National Research Council 2001). Within New York and New Jersey Harbor (the Harbor), an opportunity exists to use results of an extensive aquatic biological sampling program as a basis for informed dredging management practices and to promote the protection of winter flounder, *Pseudopleuronectes americanus*, from its early life stages (egg and larval) through juvenile and adult life stages.

Currently, the United States Army Corps of Engineers – New York District's (USACE-NYD's) congressionally authorized Harbor Deepening Project (HDP) is under construction and is aimed at improving Harbor navigation and safety while minimizing impacts to the overall environment, as well as promoting environmental sustainability and improvements. Prior to construction, a comprehensive review of the literature related to the biological resources in the Harbor indicated that there were insufficient data available to evaluate the relative importance of aquatic habitats, including the use of the Harbor's navigation channels by resident and migratory finfish species, shellfish and benthic macro-invertebrate species (USACE-NYD 1998). The Aquatic Biological Survey (ABS) was developed in coordination with National Marine Fisheries Service (NMFS) and the state environmental regulatory agencies in New York and New Jersey, as well as the project sponsor, the Port Authority of New York and New Jersey (PANYNJ) to assess the seasonal distribution and abundance of these biotic resources.

In 2010, USACE-NYD published a report with multiple year data analysis (2002-2010) that focused on winter flounder early life stage utilization of the Harbor (USACE-NYD 2010). The findings of Early Life Stage Application report provided strong evidence consistent with existing literature that navigation channels are not high value spawning habitat (USACE-NYD 2010). In addition, the robust dataset has-been used to better define the timing of spawning activity in the Harbor, and thus, refine existing dredge windows associated with the HDP.

The following summary report focuses on juvenile and adult winter flounder occurrence and EFH utilization within the Harbor incorporating data collected for juveniles and adults as part of the extensive ABS bottom trawl program. Additional information regarding the field methodologies for the ABS can be found in Appendix A. Appendix B summarizes the existing data from sediment studies conducted in the Harbor, provides maps of sediment distributions, and provides a summary of the sediment data collected in 2011 at each of the ABS sampling locations. Benthic community information is also characterized in Appendix B. The occurrence and general abundance of the most common invertebrates are tabulated by major habitat type for each of the HDP contract areas within the harbor in order to relate juvenile and adult winter flounder habitat usage to benthic community distribution.

a. Winter Flounder Life History

As a valuable commercial and recreational species, winter flounder has remained a species of importance to local and regional resource managers. Recent assessments of the Southern New England/Mid-Atlantic stock have identified declines in commercial landings and recreational catches since the mid 1980s (ASMFC 1998; Vonderweidt *et al*. 2006). Other winter flounder surveys in the region, such as those conducted in the Niantic River estuary in Connecticut and Narragansett Bay in Rhode Island, have also shown steady declines in winter flounder abundances since the 1970s (Millstone 2008; Dominion 2009).

Except for the Georges Bank population, which may spawn at depths up to 45 meters, adult winter flounder have been documented to migrate inshore in the fall and early winter throughout most of its range (Able and Fahay 2010), typically spawning in very shallow water less than five meters (NMFS 1999; Brown *et al*. 2000; USACE-NYD 2010). A recent study on the New York Bight intercontinental shelf suggests that not all winter flounder move to estuaries to spawn and some spawning may occur in nearshore areas on the inner continental shelf (Wuenschel *et al.* 2009). DeCelles and Cadrin (2010) documented a similar pattern of coastal spawning in the southern Gulf of Maine in Plymouth Bay and pre-flexion (i.e. beginning of notochord development) winter flounder larvae were collected in nearshore and surf zone habitat in New Jersey (Able *et al.* 2010).

Spawning individuals that move to estuarine waters spawn in shallow waters where conditions favor limited movements of their eggs, which are demersal and adhesive. Schultz *et al.* (2007) found early stage eggs concentrated in low current areas. The yolk-sac larvae begin development in low current areas which is beneficial for a life stage with limited mobility (Schultz *et al.* 2007).

Young-of-the-year (YOY) winter flounder spend the majority of the first year in shallow inshore waters, tolerating higher water temperatures and lower salinities (5 ppt) than yearlings or adults (NMFS 1999). Comparisons of habitat-specific patterns of abundance and distribution of YOY winter flounder in Great Bay-Little Egg Harbor in New Jersey, Long Island Sound and the Hudson-Raritan estuary indicate that habitat utilization by YOY winter flounder may be highly variable across habitat types and among systems (NMFS 1999).

Winter flounder are omnivorous, opportunistic feeders, consuming a wide variety of prey based upon seasonal availability and changes in life history with polychaetes and crustaceans (mostly amphipods) constituting the bulk of the diet (NMFS 1999). Stehlik and Meise (2000) studied the stomach contents of juvenile and adult winter flounder collected from the Navesink River and Sandy Hook Bay, New Jersey, and found clear differences between size groups with YOY (<50 mm total length) preferring spionid polychaetes, calanoid copepods and ampeliscid amphipods. They noted the disappearance of copepods from the diets of the larger fish collected and an increase in the number of taxa consumed including siphons of the bivalve *Mya arenaria* as well as an increase in consumption of crangon shrimp during the summer and fall.

b. NY/NJ Harbor Habitat Summary

Appendix B provides a summary of Harborwide sediment and benthic studies within the Harbor. The following text briefly summarizes the data. Sediment distribution and benthic communities in estuarine environments such as the NY/NJ Harbor are characterized by a high level of temporal and spatial variability. This variability is caused by the interplay of many natural factors and human influences on estuarine environments. Despite this variability, there is a general pattern of benthic community distribution that is related to substrate type. Silt and sand commonly occur in various degrees of mixing throughout the Harbor and can have distinctive benthic communities depending on the relative amounts of silt and sand and organic matter. In 2011, USACE conducted a benthic survey throughout the NY/NJ Harbor to characterize the surficial sediments found at 38 ABS transect locations; the results provided grain size and TOC content of the surficial sediments of channels and non-channel areas. These data provide habitat data specific to the ABS Stations/Transects and winter flounder collections.

In general, the Lower Bay (LB) was primarily sand; the majority of the Upper Bay (UB) was transitional with a range from silt to gravelly sand and the Kill Van Kull was dominated by silts; Arthur Kill (AK) and Newark Bay (NB) were dominated by silty material in varying quantities. Total Organic Carbon values ranged from 0.07% to 5.5%, with the lowest values at the Lower Bay transects and the highest values at transect locations in the Arthur Kill, followed by Newark Bay and the Port Jersey (Table B-1). In general, the lower values were associated with sandy sediments and the higher values with silts and clays. In UB and NB, channels comprise approximately 35% and 25% of the total available substrate and in combination with the inshore shallow areas, which are subject to sedimentation of fine-grained materials, accounts for the relatively high percentage of soft substrates.

The benthic community in the Harbor consists of a wide variety of small aquatic invertebrates which live burrowed into or in contact with the bottom, such as worms, mollusks, and amphipods (Pearce 1974). Benthic invertebrate communities play an important role in the Harbor for winter flounder as they are an essential part of the winter flounder diet. The majority of species identified in grab samples collected during USACE Harborwide Benthic recovery program 2005 and 2009 benthic macro-invertebrate surveys were nematodes, annelids (oligochaetes and polychaetes), arthropods, and mollusks (bivalves and gastropods). These taxa are typically found in the Harbor, and vary considerably in occurrence and abundance both seasonally and spatially (BVA 1998, Cerrato *et al.* 1989, Dean 1975, Iocco *et al.* 2000, Gandarillas and Brinkhuis 1981).

2. ABS Bottom Trawl Data Analysis

Bottom trawl sampling for adult and juvenile finfish during the ABS was scheduled to bracket the period when adult winter flounder are historically present in the Harbor to spawn. Bottom trawl surveys were conducted from 2002 to 2010[2] beginning in December or January and ending in May or June at approximately 24 to 29 fixed location stations, which varied by year of sampling (Table 1). Overall, the sampling effort ranged from 194 to 286 bottom trawls per year, with the concentration of effort shifting increasingly toward LB non-channel stations in latter years as it became increasingly clear from the ichthyoplankton surveys that winter flounder do not commonly use the AK/NB area as spawning habitat and shallow, non-channel areas (more common in the LB) were favored as spawning sites.

The distribution of juvenile and adult winter flounder were analyzed with reference to their location in the Harbor (AK/NB, UB and LB, Figure 1), occurrence in channel vs. non-channel stations, and association with physical factors such as sediment type, dissolved oxygen, salinity, temperature, and station depth. In addition, analyses were conducted to determine whether annual abundances of different life history stages (e.g, eggs, larvae, juveniles, adults) were correlated once the appropriate time lag (i.e. time between developmental stages) was incorporated into the analyses. For instance, we investigated if there is a relationship between the relative annual densities of eggs and one-year-old juvenile winter flounder a year later.

The spatial distributions of juvenile and adult winter flounder were examined by Harbor area (AK/NB, LB, UB) and station type (channel vs. non-channel) across years with a two factor Analysis of Variance (ANOVA). Fish distributions were also examined by size classes, which were designated to roughly correspond to approximate age categories based on both fish size and the time of collection (Witherell and Burnett 1993, Able and Fahay 2010, McBride *et al.* 2010).

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[2] Bottom trawls were conducted during the night from the 1999 through 2004 sampling programs. In 2005, sampling was changed to daylight hours due to safety considerations.

The four size classes roughly corresponded to YOY (< 80 mm TL collected in May and June), year-1 juveniles (80 to 149 mm TL and < 80 mm TL collected before May), subadults (150 to 249 mm TL), and adults ($\geq$ 250 mm TL), and are respectively referred to as size classes 0 to 3. There are several caveats that pertain to these size/age class designations. Size class 0 appears as a new mode, or common size category, in June when size frequency histograms are plotted (USACE 2005, Figure 3-32). The Year-1 designation is a conservative estimate that may not include some faster growing individuals. The minimum size for the adult size class (250 mm TL) may include females that are not yet reproductively active and may not include some males that are reproductively active (Chris Chambers, NMFS, pers. comm.). All fish density data were log-transformed prior to analysis to reduce heteroscedasticity (i.e. random variability) (Levene's test, $p>0.05$; Sokal and Rohlf 1995). The size distributions of adult males and females were compared using a Kolmogorov-Smirnov test.

Three-factor ANOVAs were used to determine whether winter flounder densities differed by size class, Harbor area, or station type. The distribution of those adults identified by gender (Table 2) was analyzed by a three-factor ANOVA, using Harbor area, station type, and gender as factors. Fish abundance was standardized by the number of trawls conducted in each area x habitat type combination for each year. Pearson correlations were used to examine potential associations among winter flounder life history stages. The condition factor (K) was used to examine seasonal changes in energy accumulation and depletion (Burton and Idler 1984; Wuenschel *et al.* 2009) and is calculated as $(\text{weight}/\text{TL}^3) * 10^5$.

3. Results

a. Spatial Distributions

Juvenile and adult winter flounder densities were significantly greater at channel stations throughout the Harbor than at non-channel locations ($F = 39.81$, $p < 0.001$) and total densities did not differ by Harbor area (Figure 2). Stations with consistently high bottom trawl catches of winter flounder were located in all three Harbor areas (Table 3) and included AK-3, SB-5, PJ-5, and LB-6. Winter flounder densities were not significantly related to station depth within either the channel or non-channel station type categories. Dissolved oxygen concentrations and salinities measured at the time of sampling were well within the physical tolerances of the species and were not associated with any distribution patterns.

YOY individuals were not collected from 2008-2010 (Figure 3) most likely because sampling was not conducted in June for those years. YOY individuals collected from 2002 to 2007 were relatively abundant in some years, (e.g., 118 YOY fish collected at 15 stations in 2002) and uncommon in others (two and one YOY fish in 2005 and 2006, respectively). Nearly all of the YOY individuals collected were captured in the AK/NB (54%) and Upper Bay (44%) areas and a majority (69%) were collected at non-channel stations (Figure 3).

In most years, Year-1 juveniles were the most abundant size class collected. There was a significant three-way interaction among size class, Harbor area, and station type (F = 2.67, p <0.05), reflecting the higher abundance of year-1 winter flounder at channel stations in the AK/NB area and the near absence of adults (size class 3) in AK/NB (Figure 4). In particular, Year-1 juvenile winter flounder were abundant at station AK-3, especially in the latter years of sampling (Table 4). Adults were collected in high abundances at UB and LB stations with consistently high relative abundances at channel station SB-5 in the UB (Table 5). Winter flounder were usually collected in small numbers per trawl, for instance, two thirds of the 889 trawls that collected winter flounder contained less than five flounder in the sample over the nine year sampling period (Figure 5). There were two channel stations at which samples with 20 or more winter flounder were collected 10 or more times (AK-3 and SB-5). The high abundance collections at AK-3 all occurred from 2008 to 2010 and involved primarily Year-1 juveniles. High abundance collections at the UB station SB-5 frequently involved relatively large numbers of adults. Collections of five or more adults in a single sample occurred exclusively in the LB and UB areas primarily in April and May (Table 6).

From 2002-2010, the gender of 406 winter flounder > 250 mm TL was determined (290 females, 116 males). Among these adults > 250 mm TL, female densities were significantly greater than males (F = 13.0, p = 0.001). Female-biased sex ratios for adult winter flounder have also been observed in the Niantic River and Bay (DNC 2011). There was no difference in the size distributions of the measured males and females (D = 0.11, p = 0.47) with the median size of both sexes equal to 293 mm. The spatial pattern of lower adult densities in the AK/NB area and at non-channel stations did not differ by gender, indicating that males and females inhabit the Harbor areas and channels in similar ways.

b. Temporal Patterns

YOY winter flounder were collected almost exclusively in June, most probably because by this time they were large enough to be effectively sampled by the trawling gear (one-inch wing and body mesh down to 0.25-inch cod end liner mesh). Year-1 juveniles were most commonly collected in the early months of sampling (January to March) in the AK/NB and UB areas. Adult collections were highest in March and April (Figure 6). A seasonal decline in the adult condition index occurred in the spring followed by an increase in May for both males and females (Figure 7). Ripe individuals were collected in February and March and spent individuals were collected thereafter.

4. Discussion

a. General Abundance and Distribution Patterns

Nine years (2002-2010) of bottom trawl sampling in New York/New Jersey Harbor from the winter through early summer revealed a pattern of habitat use that varied by size/age class. Total juvenile and adult winter flounder abundance (across all size/age classes) did not differ among individual geographic regions of the Harbor surveyed (AK/NB, LB, UB), however size specific differences were apparent. Year-1 juvenile densities were significantly higher in the AKNB area and adult densities were significantly lower in this area compared to the LB and UB areas Overall, both adult and juvenile winter flounder densities were higher in channel stations relative to non-channel areas, which is consistent with the results from a previous extensive sampling effort (1992-1997) in the Harbor (Wilk *et al.* 1998).

The timing and location of relatively large collections of winter flounder in single trawls may indicate preferred spawning and foraging sites within the Harbor. Episodic collections of five or more adults in a single sample occurred exclusively in the LB and UB areas, primarily in April and May. Peak adult abundances and frequent observations of winter flounder “congregations” in April may indicate increased foraging activity at this time prior to the declining abundance in May and June as adults move out of the estuary in response to an increase in water temperatures (McCracken 1963, Phelan 1992, NMFS 1999). For example, UB Station SB-5 had consistently high abundances of adult winter flounder throughout the sampling program. Bottom conditions and benthic invertebrate community composition near SB-5 are typical of the UB, and likely represent a combination of adult winter flounder habitat requirements (i.e. appropriate hydrodynamics and sediment distribution, sufficient dissolved oxygen concentrations, and abundant prey resources).

Because both juvenile and adult winter flounder are nocturnal (Casterlin and Reynolds 1982, Stoner *et al.* 1999), the change from night to daytime sampling after the 2004 sampling season (Appendix A) may influence interannual comparisons of winter flounder abundances. Although substantial interannual variation in overall winter flounder abundance is apparent, there was no statistical difference or trend in abundance between the night (2002-2004) and day (2005-2010) sampling regimes. However, it should be acknowledged that a diurnal influence may have been obscured by interannual variation. The highest winter flounder densities observed throughout the monitoring program occurred in 2004 and 2008 when collections were dominated by Year-1 juveniles and the lowest densities occurred in 2005 and 2006 when Year-1 fish were considerably less abundant.

b. Age-Specific Abundance and Distribution

Although combined densities of juvenile and adult winter flounder did not differ across geographic regions within the Harbor, the distribution of YOY flounder did exhibit a spatial pattern. YOY individuals were collected almost exclusively in the UB and AK/NB areas. Although the AK/NB area is not used extensively as spawning habitat (USACE 2010), the relatively high abundances of YOY and Year-1 juveniles in this area indicate that it may function as an important nursery habitat where early grow-out occurs. This could be due to a combination of factors (i.e. water depth/hydrodynamics, prey availability, substrate type) that collectively produce favorable habitat conditions for this life stage. This region of the Harbor is predominantly non-channel habitat, and approximately 66% of the area is less than 15' deep (Appendix B). Substrates are dominated by fine silts, often in association with clay and fine sands, which may provide preferred foraging habitat for YOY flounder and substantial opportunity for predator avoidance (burial). The benthic assemblage is characterized by high abundances of opportunistic taxa and low species richness and diversity (Appendix B).

Analysis of winter flounder early life stage distribution/abundance supports the observed patterns of juvenile flounder abundance. There was a significant correlation between annual egg densities and juvenile densities the following year ($r = 0.87$, $p < 0.01$). The high Year-1 juvenile abundance (2004 and 2008) in years following high spawning activity (2003 and 2007; USACE 2010) is consistent with the theory that juveniles overwinter in their natal estuary (Bigelow and Schroeder 1953), although some dispersal may also occur into nearshore habitats (Phelan 1992, Able and Fahay 2010).

c. Gender-Specific Abundance and Distribution

Analysis of condition for both adult male and female winter flounder did not reveal any gender-specific patterns. For both sexes, condition declined during the spawning season and increased in May; this observation is consistent with depletion of energy reserves from spawning and the accumulation of energy post-spawning while feeding within the estuary. A similar trend in condition fluctuation was observed for females and males collected in the nearshore habitat of the New York Bight (Wuenschel 2009). Average monthly condition (K) values following spawning (Fig. 7) were close to the mean K values reported for females in March (1.02) and April (1.18) from the nearshore New Jersey habitat (Wuenschel 2009) and for females from Conception Bay, Newfoundland in the beginning of their summer feeding period (1.13; Maddock and Burton 1994).

d. Habitat

Linking juvenile and adult winter flounder occurrence to habitat use in the Harbor is complex as generally these life stages are opportunistic and take advantage of habitats that are suitable within each Harbor area. The widespread abundance of juvenile and adult winter flounder across the study areas shows that these life stages can find suitable habitat based on their life history needs throughout the Harbor.

The distribution of substrate types throughout the Harbor provides perspective on the potential for habitat use by juvenile and adult winter flounder. Figures 8 through 10 plot average winter flounder CPUE from the ABS 2002-2010 data set for juveniles (< 150 mm), adults (≥ 250 mm), and all lengths combined over the existing sediment types within the Harbor. Overall, these results reflect a pattern of habitat use within the Harbor with both life stages tending towards the sand and gravelly sand habitats of the LB and the silty sand and sandy silt areas of the UB and AK/NB. This finding of generalized habitat use is consistent with the existing literature (NMFS 1999). Several studies of newly settled winter flounder reported higher densities on muddy substrates, although it would seem unlikely that newly metamorphosed flounder (typically less than 10mm) would actively seek out a specific habitat but would instead be deposited in these areas by currents (NMFS 1999). Other studies (NMFS 1999) found that higher catches of YOY winter flounder occurred on muddy substrates, muddy substrates covered by leaf or bivalve beds, and in depositional areas with low current speeds (NMFS 1999; USACE 2010). The relatively high abundances of Year-1 juveniles in AKNB channel habitat that has a high silt/clay and % total organic carbon content are consistent with these studies.

In a study conducted in the Great Bay-Little Egg Harbor estuary in New Jersey, YOY winter flounder were more abundant on sandy, unvegetated substrates conducive to burial and escape from predators (Able and Fahay 2010). Although they were also collected in macroalgae and marsh creek habitats, the results supported the conclusion that habitat utilization by juvenile winter flounder is not consistent across habitat types and may be highly variable among systems and from year to year (NMFS 1999). These findings support the position that winter flounder are generalist species.

The benthic community distributions in the Harbor vary spatially and seasonally. Changes in species richness and numerical abundance are in contrast to the relatively stable conditions in the substrates. Benthic communities associated with tube dwelling amphipods (Amelisca mats) and bivalves (mussels and clams) have been mapped for Lower Bay (Iocco *et al.* 2000), but such stable spatial distributions are uncommon in the Harbor and involve areas generally beyond the influence of harbor deepening. In addition, previous studies of benthic communities rely on benthic grab samples and sediment profiling images that do not provide representative samples of mobile epibenthic invertebrates. Small shrimp, mobile gammarids, and mobile early life stages of decapods are known to be important prey for juvenile and adult winter flounder.

The benthic communities throughout UB, LB and AK/NB are diverse and at their densities are comparable to other benthic densities of east coast estuarine systems. Although water and sediment quality conditions have improved in recent decades, these communities continue to be dominated by many species characterized as tolerant of pollution and organic enrichment. These species are suitable prey for juvenile and adult winter flounder and are accessible throughout the Harbor.

Preferred food is often related to winter flounder life stage and the relative abundance, availability and size of prey in the habitat in which winter flounder are living (Frame 1974; Keats 1990). Stoner *et al.* (2001) in their evaluation of habitat factors found that prey abundance was not a significant factor for juvenile winter flounder less than 55 mm total length. This finding suggests that there would be little relationship between dominant benthic organisms and winter flounder abundance and distribution in many situations. This observation is consistent with the characterization of winter flounder as generalists in terms of habitat and food preferences. At times prey availability may be a factor in winter flounder distribution, but its importance would probably be limited to short intervals and small areas.

The distribution of sediment types and the taxonomic composition of benthic assemblages throughout the Harbor (Appendix B) may provide perspective on the potential for habitat use by juvenile and adult winter flounder. However, relatively high spatial and seasonal variability of benthic species richness and numerical abundance in the Harbor makes specific conclusions about habitat preference and therefore EFH difficult. Furthermore, winter flounder are known to be opportunistic predators and at times may engage in positive selection for prey based on abundance of benthic organisms (Stelhick *et al.* 2000). Previous studies within the harbor, as well as in other northeastern U.S. estuaries indicate that habitat utilization by juvenile and adult winter flounder may not be consistent across habitat types and may be highly variable among systems and from year to year (Schultz *et al*. 2007).

The recent dredging associated with the Harbor Deepening Project represents an incremental change to a physical habitat in the Harbor that has occurred for decades. Winter flounder have accommodated this altered physical habitat as they do for natural changes to physical habitat, through their use of a broad range of habitats and food resources. Importantly, these results confirm that the existing conservation recommendations and environmental window restrictions should not apply to the more mobile juvenile and adult life stages of winter flounder which can avoid potential impacts associated with dredging (i.e. localized and short term physical disturbances and re-suspended sediments). There was no indication that revision of the current dredging restrictions that are in place to protect winter flounder egg and larval stages would provide more protection to juvenile and adult winter flounder, based on their distribution patterns within the Harbor.

5. Summary

As a valuable commercial and recreational species, winter flounder has remained a species of importance to local and regional resource managers. Recent assessments of the Southern New England/Mid-Atlantic stock have identified declines in commercial landings and recreational catches since the mid 1980s (ASMFC 1998 and Vonderweidt et al. 2006). Within the NY/NJ Harbor, the seasonal dredging constraints for early life stages set nearly ten years ago by the NMFS 2001 Conservation Recommendations, in the absence of site-specific data, provided broad guidelines to protect winter flounder eggs and larvae from potential dredging-related impacts. Over the last ten years, management decisions associated with dredging and protection of winter flounder life stages have been reviewed based on the aquatic biological survey (ABS) data collected as part of the HDP and some spatial and temporal changes to early life state seasonal windows has occured. In USACE-NYD's report, Early Life Stage Application Report published November 2010 (USACE_NYD 2010), the ABS study provided strong scientific evidence that is consistent with existing literature in showing channels are not high value spawning habitat.

Currently, as outlined in the NMFS 2001 Conservation Recommendations, there are no existing environmental window recommendations associated with juvenile and adult life stages. The results of this report confirm that an environmental window restriction should not apply to the more mobile juvenile and adult winter flounder life stages that can avoid potential short – term and localized impacts associated with dredging (i.e. physical disturbances and re-suspended sediments). The findings of this report documents how juvenile and adult winter flounder utilize habitats within the Harbor and helps to contribute to the overall effort in how scientific data can be used during the planning process for future maintenance dredging and regulatory management decisions. By overlapping the winter flounder habitat uses and dredging needs within the Harbor, we can be confident that the existing measures, as pertains to the early life stages, are protective and make adjustments if necessary at site specific locations rather than Harborwide.

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Table 1. Bottom trawl sampling effort from 2002 through 2010 in New York / New Jersey Harbor. Bay areas are abbreviated as Arthur Kill/Newark Bay (AKNB), Lower Bay (LB), and Upper Bay (UB).

Year	Begin Sampling Period	End Sampling Period	# of Stations	# Trawls AKNB		# Trawls LB		# Trawls UB	
				CH	NC	CH	NC	CH	NC
2002	12/18/01	6/20/02	26	40	49	28	28	50	60
2003	12/17/02	6/20/03	26	39	50	30	30	49	60
2004	1/19/04	6/17/04	26	31	33	24	24	37	45
2005	1/10/05	6/16/05	24	32	32	27	27	45	45
2006	1/17/06	6/14/06	24	36	25	27	27	45	53
2007	1/22/07	6/21/07	24	36	27	27	27	45	50
2008	2/5/08	5/30/08	25	16	16	32	77	30	32
2009	12/15/08	5/7/09	24	30	20	40	90	30	30
2010	12/14/10	5/7/10	29	38	20	40	120	38	30

Table 2. Number of adult (> 250 mm TL) winter flounder collected and the number for which sex determinations were made each year.

Year	# adults collected	# adults per trawl	# adults w/ sex ID	% sex ID	% ID by March 30
2002	75	0.29	66	88	95
2003	122	0.47	110	90	88
2004	19	0.10	19	100	100
2005	43	0.21	16	37	40
2006	43	0.20	41	95	100
2007	59	0.28	42	71	100
2008	64	0.32	41	64	100
2009	22	0.09	21	95	100
2010	102	0.36	43	42	100

Table 3. Percentage of the annual juvenile and adult winter flounder collection at each station for each year. Empty cells indicate that station was not sampled that year, whereas zero values indicate the station was sampled, but no winter flounder were collected. Station type is indicated as channel (CH) or non-channel (NC). Stations sampled three or fewer years are listed at the bottom.

Station	Area	Station Type	2002	2003	2004	2005	2006	2007	2008	2009	2010	Ave. %
AK-3	AKNB	CH	2.5	2.5	4.4	1.1	0.9	7.7	45.8	33.5	31.8	14.5
SB-5	UB	CH	11.8	6.7	1.1	16.4	21.6	14.4	15.4	28.0	4.7	13.3
PJ-5	UB	CH	6.8	7.5	14.6	0.4	12.0	21.8				10.5
LB-6	LB	CH	4.6	4.0	1.7	35.4	3.5	7.0	2.7	0.7	4.4	7.1
SB-4	UB	CH	1.9	3.1	6.3	1.1	10.6	17.7	3.2	6.0	4.5	6.0
AK-2	AKNB	CH	1.9	10.3	8.4	0.9	3.0	3.4	6.2	7.4	11.7	5.9
LB-2	LB	CH	14.1	1.3	1.2	17.0	5.7	1.4	4.0	3.9	1.6	5.6
PJ-1	UB	NC	8.9	11.7	7.2	1.1	2.2	3.0	2.4	3.7	5.7	5.1
NB-6	AKNB	CH	9.2	3.8	6.9	0.7	8.6	3.4			0.5	4.7
PJ-4	UB	CH	2.2	2.8	1.5	0.0	10.5	3.4	5.1			3.6
SB-3	UB	NC	3.6	7.7	2.3	2.2	4.2	8.6	0.7	0.0	2.0	3.5
NB-7	AKNB	NC	9.7	9.6	3.8	1.9	0.0	0.3	0.3	2.0	0.9	3.2
SB-6	UB	CH	3.3	1.4	6.4	10.4	1.4	0.2	0.7	1.1	0.7	2.9
NB-5	AKNB	CH	1.9	1.6	4.3	4.6	2.5	1.1				2.7
PJ-2	UB	NC	0.7	6.8	3.9	0.8	2.1	1.8	0.5	2.8	0.7	2.2
LB-4	LB	CH	3.6	3.6	3.7	1.1	2.1	1.6	1.5	0.5	0.4	2.0
SB-1	UB	NC	0.9	2.1	0.0	0.0	4.6	1.8				1.6
NB-3	AKNB	NC	3.3	2.9	1.0	1.2	0.7	0.2				1.6
AK-4	AKNB	NC	2.6	0.2	2.0	0.8						1.4
PJ-3	UB	NC	1.0	3.7	0.7	0.7	0.4	0.5	0.3			1.0
SB-2	UB	NC	0.5	0.6	0.9		2.8	0.0				0.9
LB-1	LB	NC	0.9	2.7	1.9	0.6	0.4	0.2	0.0	0.0	0.4	0.8
NB-4	AKNB	NC	2.0	1.8	0.7	0.5	0.0	0.0	0.0	0.2	0.1	0.6
LB-3	LB	NC	0.6	0.5	1.1	1.1	0.0	0.2	0.2	0.2	1.2	0.6
LB-5	LB	NC	0.5	0.2	3.0	0.0	0.0	0.2	0.1	0.0	1.0	0.6
LBD-15	LB	NC									8.0	8.0
LB-14	LB	CH							7.3	3.9	4.9	5.4
AK-1	AKNB	NC	1.1	1.0	11.0							4.4
SB-7	UB	CH									6.5	3.3
NB-8	AKNB	CH								3.2	2.6	2.9
LB-10	LB	NC							2.2	0.9	3.3	2.1
LB-12	LB	NC							0.1	1.4	1.0	0.8
LB-7	LB	NC							0.1	0.2	0.5	0.3
LBD-17	LB	NC									0.3	0.3
LB-9	LB	NC							0.6	0.0	0.1	0.2
LB-13	LB	NC							0.4	0.2	0.0	0.2
LB-16	LB	NC									0.2	0.2
LB-8	LB	NC							0.1	0.0	0.3	0.1

Table 4. Percentage of Year-1 winter flounder (80 to 149 mm TL) collection at each station for each year. Empty cells indicate that station was not sampled that year, whereas zero values indicate the station was sampled, but no fish were collected. Station type is indicated as channel (CH) or non-channel (NC). Stations sampled three or fewer years are listed at the bottom.

Station	Area	Station Type	2002	2003	2004	2005	2006	2007	2008	2009	2010	Ave. %
AK-3	AKNB	CH	2.01	2.25	4.56	2.52	1.60	13.17	57.31	40.60	25.44	16.61
PJ-5	UB	CH	7.22	9.00	15.63	0.75	6.39	13.17				8.69
LB-2	LB	CH	16.05	0.90	1.30	32.15	12.77	0.00	2.43	4.51	1.90	8.00
SB-5	UB	CH	4.41	2.70	0.98	8.22	4.79	11.97	8.91	19.92	3.04	7.22
SB-3	UB	NC	7.22	8.10	2.28	3.74	15.96	14.37	1.01	0.00	3.42	7.01
AK-2	AKNB	CH	1.20	8.50	9.49	1.68	9.58	2.99	7.49	4.89	13.48	6.59
NB-6	AKNB	CH	17.66	5.85	7.33	2.52	3.19	5.99			0.24	6.11
PJ-1	UB	NC	11.24	9.90	7.81	2.24	1.60	5.99	2.83	3.76	8.54	5.99
SB-4	UB	CH	0.80	1.80	6.51	0.75	11.17	13.17	2.02	7.52	2.47	5.14
NB-5	AKNB	CH	3.61	2.25	5.05	12.62	1.60	2.99				4.69
PJ-4	UB	CH	3.61	3.15	1.04	0.00	9.58	3.59	6.48			4.58
PJ-2	UB	NC	0.80	14.84	3.26	1.50	9.58	2.99	0.81	3.76	1.33	4.32
LB-6	LB	CH	5.80	0.00	1.95	14.95	0.00	5.99	0.81	1.13	2.09	3.64
NB-3	AKNB	NC	7.22	6.30	0.81	3.36	1.60	0.00				3.22
NB-7	AKNB	NC	2.81	11.70	2.44	0.00	0.00	0.60	0.20	2.63	0.76	2.64
SB-6	UB	CH	0.80	2.00	7.16	3.74	1.60	0.00	0.00	0.75	0.57	1.85
SB-1	UB	NC	0.40	0.00	0.00	0.00	4.79	0.60				1.45
PJ-3	UB	NC	2.01	4.50	0.49	1.50	0.00	1.20	0.20			1.41
LB-4	LB	CH	2.68	0.45	4.40	1.50	0.00	1.20	0.61	0.00	0.57	1.27
AK-4	AKNB	NC	0.40	0.45	2.12	1.68						1.16
NB-4	AKNB	NC	0.80	3.15	0.81	0.84	0.00	0.00	0.00	0.38	0.19	1.03
LB-3	LB	NC	0.00	0.45	1.30	3.74	0.00	0.00	0.40	0.38	1.90	1.02
LB-5	LB	NC	0.45	0.00	3.42	0.00	0.00	0.00	0.00	0.00	1.71	0.93
SB-2	UB	NC	0.00	0.45	0.43		1.80	0.00				0.67
LB-1	LB	NC	0.80	0.90	1.63	0.00	0.00	0.00	0.00	0.00	0.00	0.48
LBD-15	LB	NC									11.20	11.20
LB-14	LB	CH							3.85	4.51	7.97	5.44
SB-7	UB	CH									5.22	5.22
AK-1	AKNB	NC	0.00	0.45	7.81							2.75
LB-10	LB	NC							2.83	1.13	4.18	2.71
NB-8	AKNB	CH								2.63	1.71	2.17
LB-12	LB	NC							0.00	1.13	0.38	0.50
LB-7	LB	NC							0.00	0.38	0.95	0.44
LB-9	LB	NC							0.61	0.00	0.19	0.40
LB-8	LB	NC							0.20	0.00	0.57	0.39
LB-13	LB	NC							0.00	0.00	0.00	0.00
LBD-17	LB	NC									0.00	0.00
LB-16	LB	NC									0.00	0.00

Table 5. Percentage of Year 3 winter flounder (mm TL) collection at each station for each year. Empty cells indicate that station was not sampled that year, whereas zero values indicate the station was sampled, but no fish were collected. Station type is indicated as channel (CH) or non-channel (NC). Sampling at stations listed at the bottom occurred only in 2008 to 2010; these stations were added later in the ABS program to address specific agency interests or questions.

Station	Area	Station Type	2002	2003	2004	2005	2006	2007	2008	2009	2010	Ave. %
SB-5	UB	CH	15.77	8.16	5.25	46.10	44.07	16.94	27.61	31.82	15.49	23.47
SB-4	UB	CH	1.31	4.89	21.01	2.31	6.96	32.18	1.53	0.00	11.62	9.09
LB-6	LB	CH	4.38	14.68	0.00	2.31	11.60	6.78	13.80	0.00	16.46	7.78
SB-6	UB	CH	17.08	0.00	0.00	23.05	4.64	1.69	3.07	13.64	0.97	7.13
PJ-1	UB	NC	2.63	19.58	10.50	4.61	4.64	3.39	1.53	13.64	2.90	7.05
LB-1	LB	NC	7.88	10.60	15.76	6.92	2.32	1.69	0.00	0.00	2.90	6.87
LB-4	LB	CH	7.30	13.05	0.00	0.00	6.96	1.69	10.74	4.55	0.00	4.92
LB-2	LB	CH	23.65	0.00	0.00	0.00	4.64	1.69	3.07	0.00	5.81	4.32
PJ-5	UB	CH	5.26	0.00	5.25	0.00	2.32	11.86				4.11
SB-3	UB	NC	5.26	9.79	0.00	4.61	0.00	8.47	0.00	0.00	1.94	3.76
PJ-2	UB	NC	0.00	0.82	15.76	2.31	0.00	3.39	0.00	4.55	0.00	2.98
PJ-3	UB	NC	0.00	3.26	10.50	0.00	2.32	0.00	0.00			2.30
AK-2	AKNB	CH	1.31	4.53	0.00	0.00	0.00	1.69	0.00	9.09	0.97	1.96
NB-7	AKNB	NC	0.00	4.08	5.25	5.19	0.00	0.00	0.00	0.00	0.97	1.94
PJ-4	UB	CH	1.31	1.63	0.00	0.00	4.64	1.69	0.00			1.55
AK-3	AKNB	CH	0.00	0.00	0.00	0.00	0.00	5.08	1.53	4.55	0.97	1.35
NB-6	AKNB	CH	1.31	0.00	5.25	0.00	2.32	0.00			0.00	1.27
NB-3	AKNB	NC	0.00	0.00	5.25	0.00	0.00	0.00				0.88
LB-3	LB	NC	1.46	1.63	0.00	0.00	0.00	0.00	0.00	0.00	2.90	0.75
LB-5	LB	NC	0.00	0.00	0.00	0.00	0.00	1.69	1.53	0.00	0.97	0.70
SB-2	UB	NC	0.00	0.00	0.00		2.61	0.00				0.65
NB-4	AKNB	NC	1.31	0.00	0.00	2.59	0.00	0.00	0.00	0.00	0.00	0.65
AK-4	AKNB	NC	1.31	0.00	0.00	0.00						0.33
SB-1	UB	NC	0.00	0.82	0.00	0.00	0.00	0.00				0.20
NB-5	AKNB	CH	0.00	0.82	0.00	0.00	0.00	0.00				0.14
LBD-15	LB	NC									10.65	10.65
LB-14	LB	CH							21.47	0.00	1.94	7.80
SB-7	UB	CH									6.05	6.05
LB-13	LB	NC							4.60	4.55	0.00	4.57
LB-12	LB	NC							1.53	9.09	2.90	4.51
NB-8	AKNB	CH								4.55	1.94	3.24
LB-10	LB	NC							3.07	0.00	5.81	2.96
LBD-17	LB	NC									2.90	2.90
LB-16	LB	NC									1.94	1.94
AK-1	AKNB	NC	1.46	1.63	0.00							1.03
LB-7	LB	NC							0.00	0.00	0.97	0.32
LB-8	LB	NC							0.00	0.00	0.00	0.00
LB-9	LB	NC							0.00	0.00	0.00	0.00

Table 6. Timing and stations where five or more adult winter flounder were collected in a single sample.

Year	Month	Station	Station Type	# of flounder in sample
2003	April	LB-1	NC	15
2010	April	LB-10	NC	5
2010	April	LB-15	NC	5
2008	April	LB-14	CH	13
2002	May	LB-2	CH	8
2003	May	LB-4	CH	12
2003	May	LB-6	CH	7
2008	April	LB-6	CH	5
2010	April	LB-6	CH	5
2010	April	LB-6	CH	5
2003	April	PJ-1	NC	11
2003	May	PJ-1	NC	8
2003	April	SB-3	NC	9
2003	April	SB-4	CH	5
2007	April	SB-4	CH	19
2005	March	SB-5	CH	10
2006	April	SB-5	CH	14
2008	April	SB-5	CH	16
2009	April	SB-5	CH	5
2010	April	SB-5	CH	12
2005	April	SB-6	CH	17

Figure 1. ABS sampling locations from 2002-2010 with HDP contract areas.

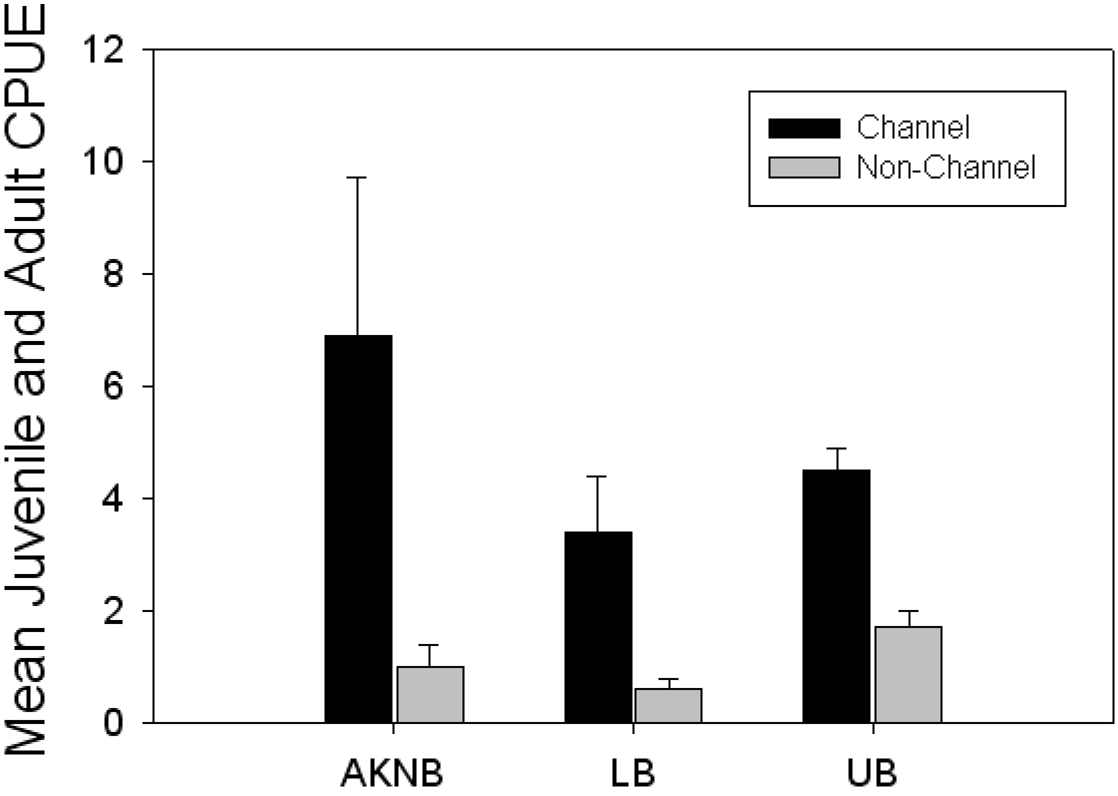

Figure 2. Mean overall densities of juvenile and adult winter flounder collected at channel and non-channels stations in three areas of New York/New Jersey Harbor (AKNB – Arthur Kill/Newark Bay, LB – Lower Bay, and UB – Upper Bay) from 2002-2010.

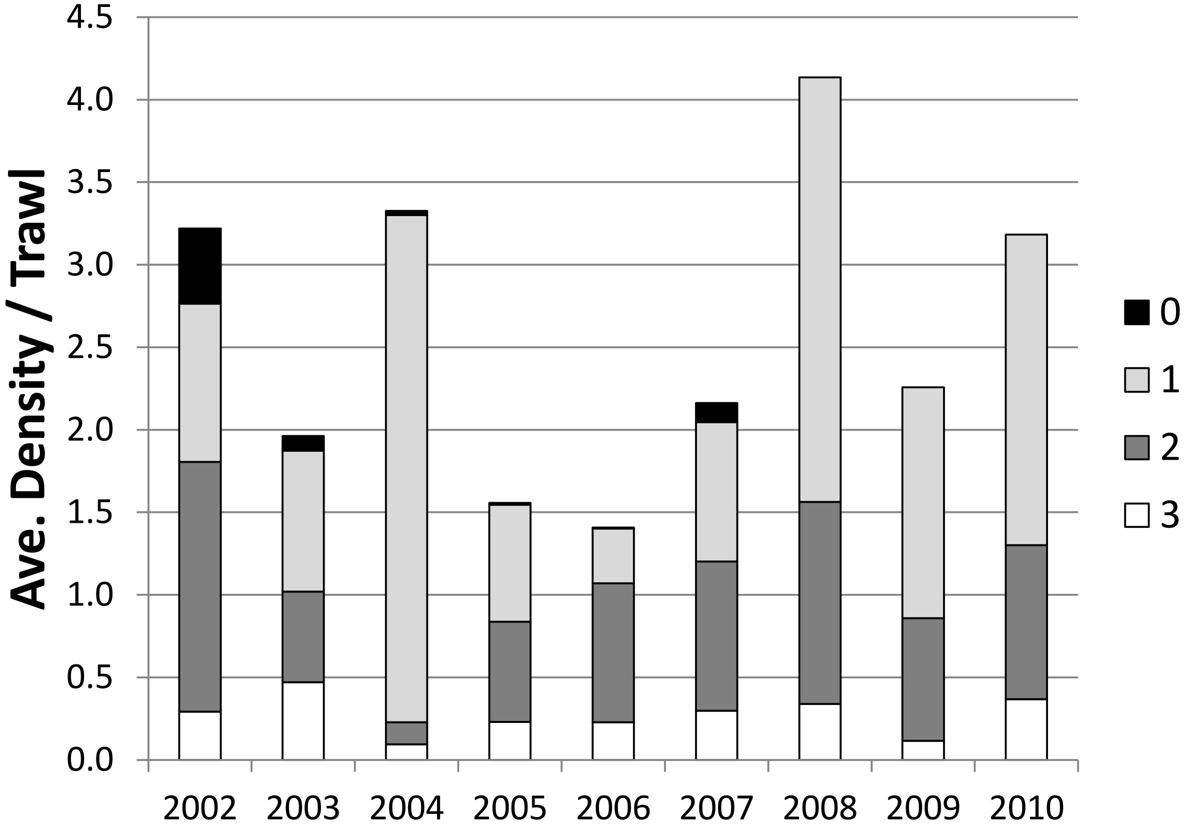

Figure 3. Annual average density of winter flounder collected by bottom trawl in four size class categories (0 to 3). Sampling was not conducted in June 2008 to 2010, which is the month that most YOY (size class 0) were collected in other years.

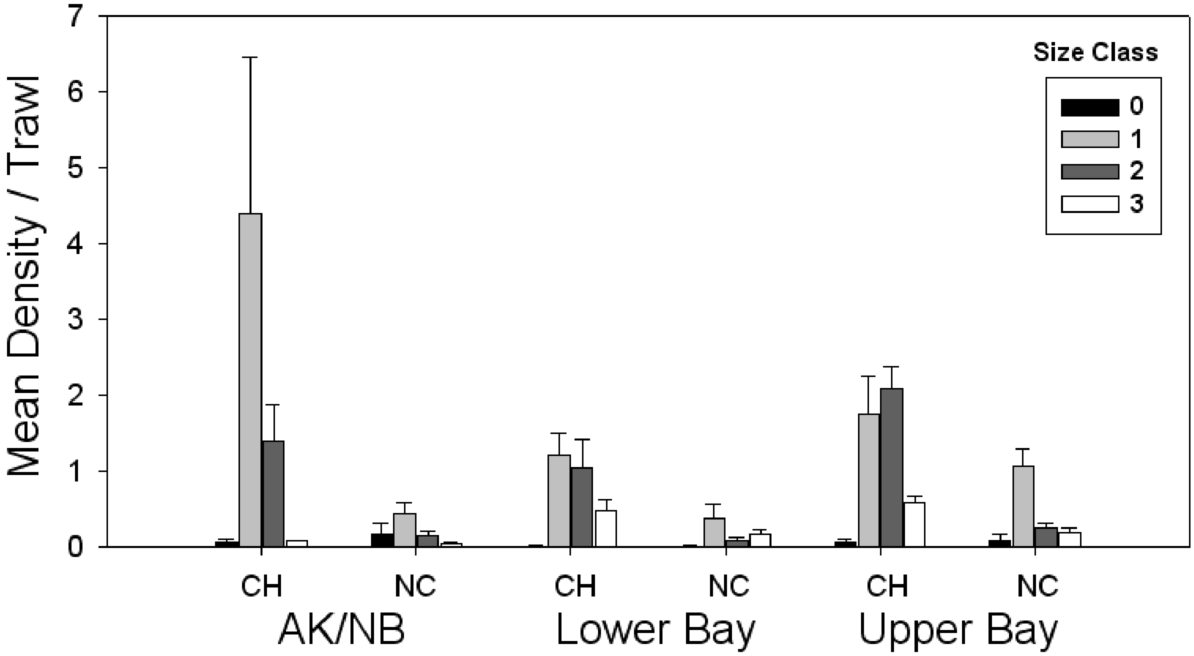

Figure 4. Mean (+ se) density of winter flounder in size classes 0 – YOY, 1- Year-1 juveniles, 2 – subadults, 3 – adults at channel (CH) and non-channel (NC) stations in the three areas of the Harbor.

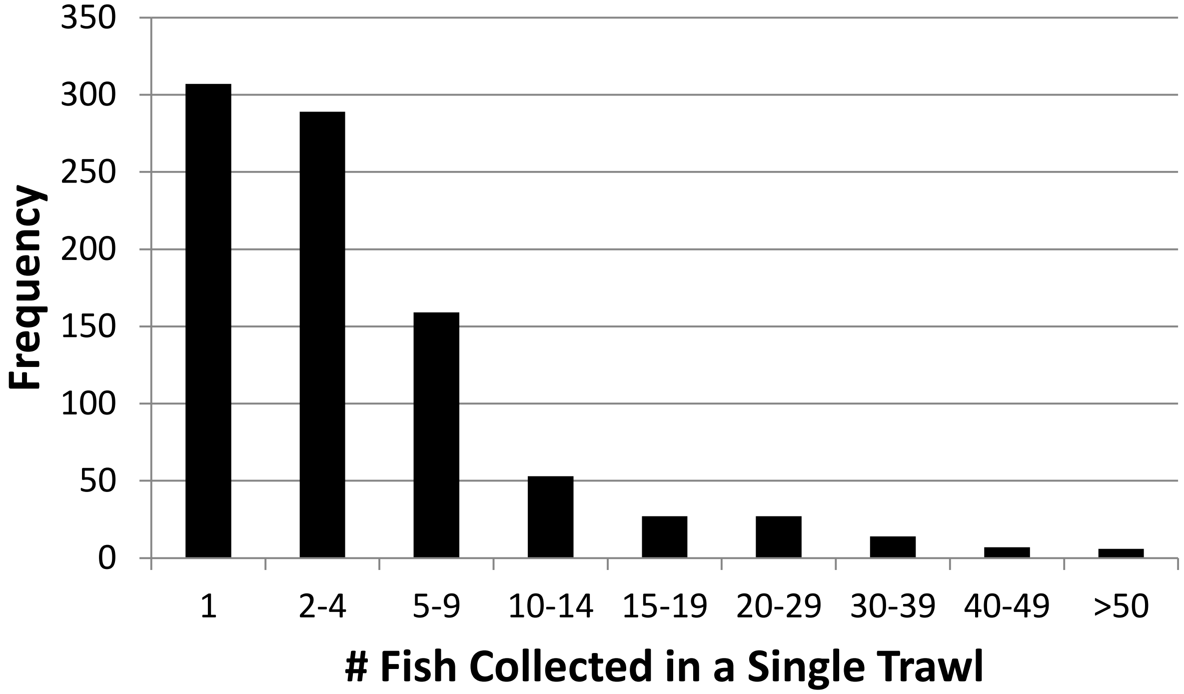

Figure 5. Frequency of bottom trawl samples that contained winter flounder in various abundance categories.

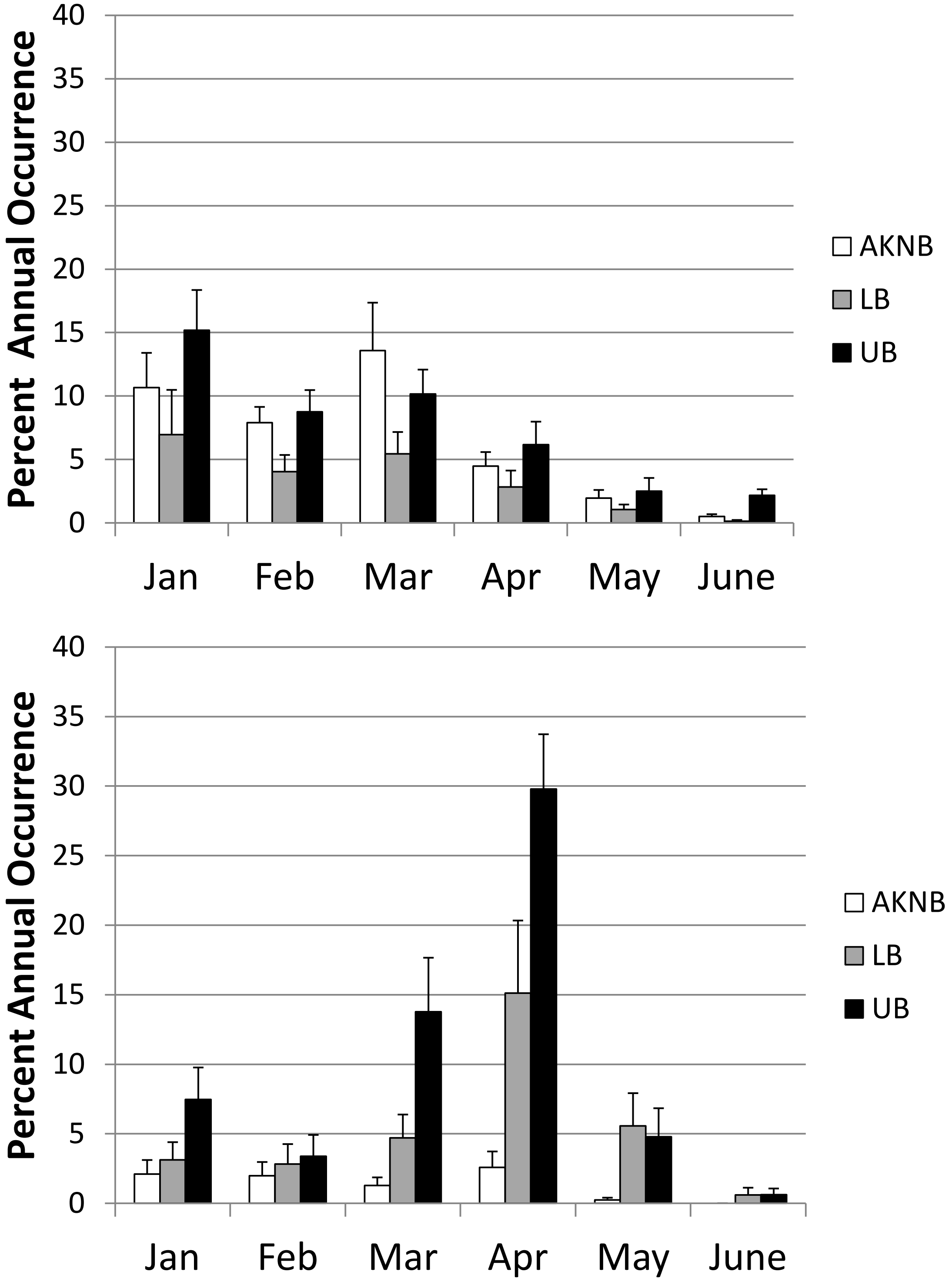

Figure 6. Average (+ se) percentage of the annual catch of (a) Year-1 juvenile and (b) adult (>250 mm TL) winter flounder collected in each Harbor area for each month of sampling.

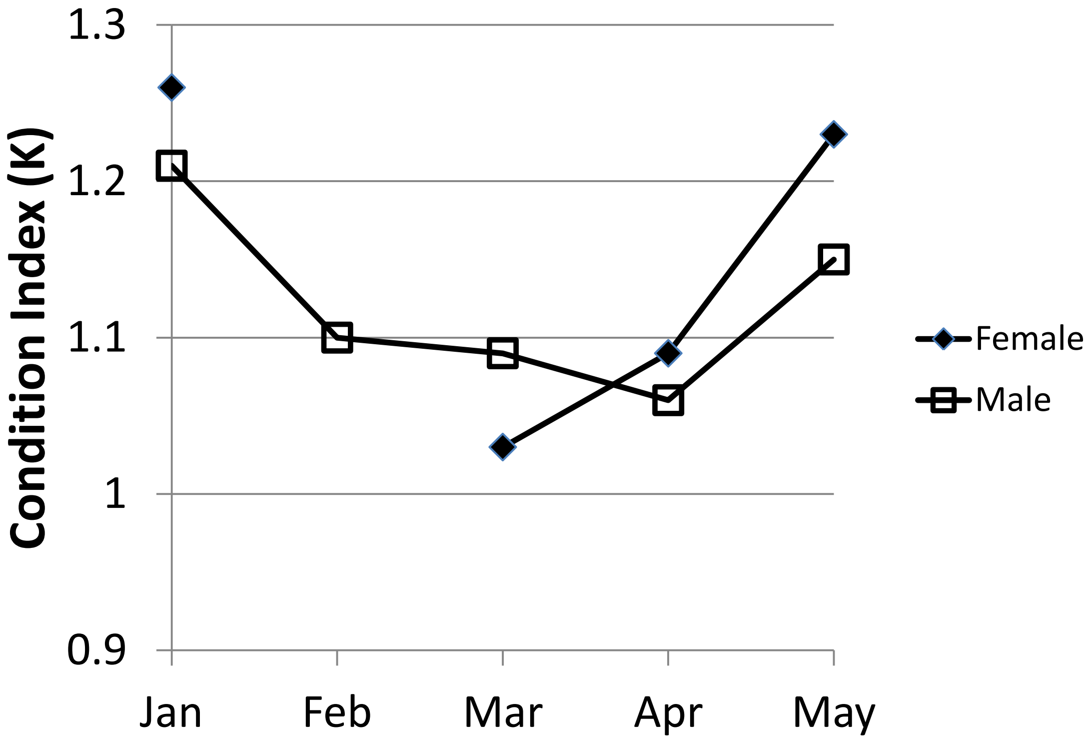

Figure 7. Average condition index (K) of adult female (solid diamond) and male (open square) winter flounder (> 250 mm TL) collected from 2008 to 2010 for each month of sampling. Weight data were not taken on any female winter flounder collected in February.

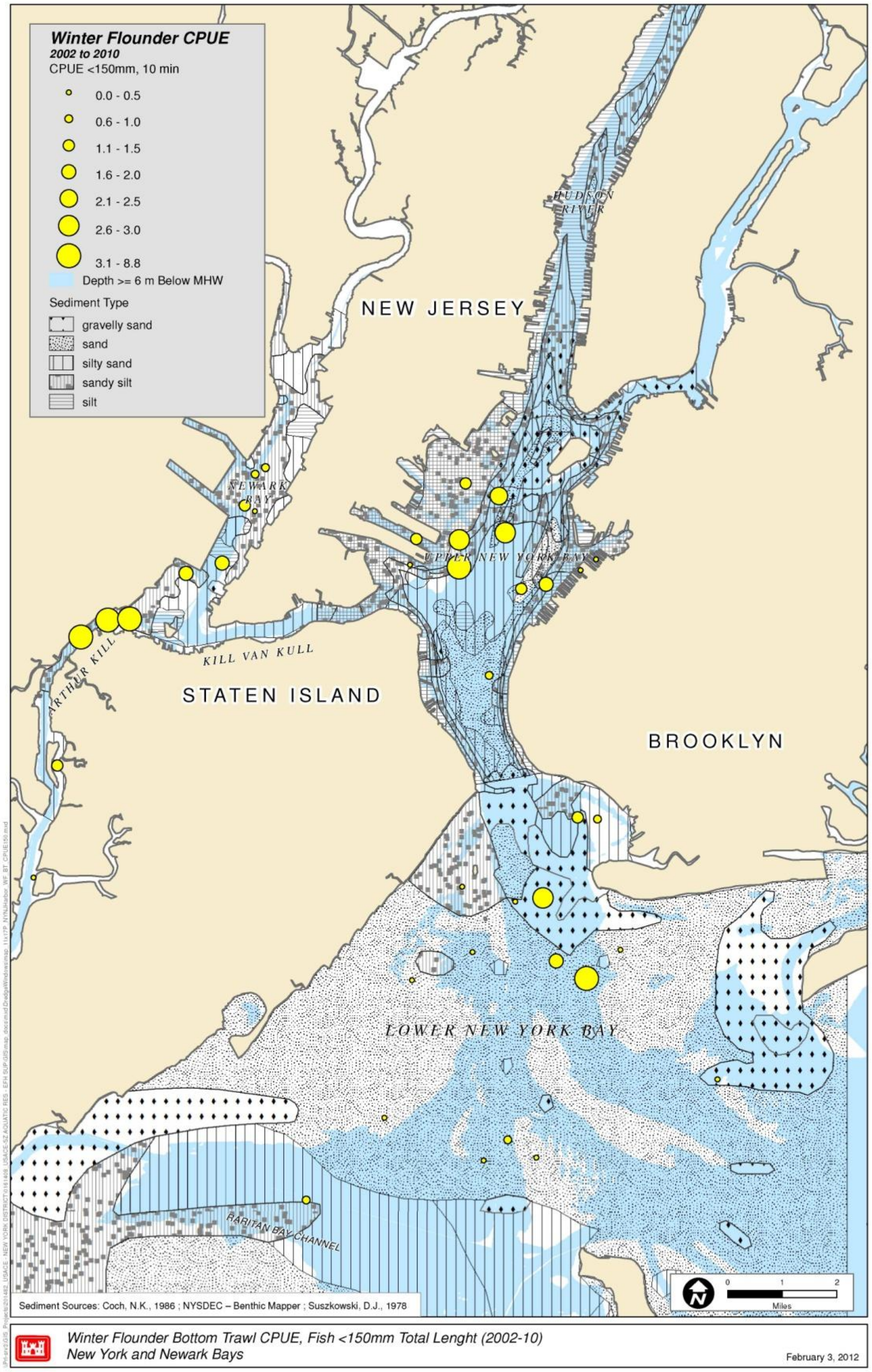

Figure 8. Winter flounder bottom trawl CPUE (2002-2010); juveniles total length <150mm.

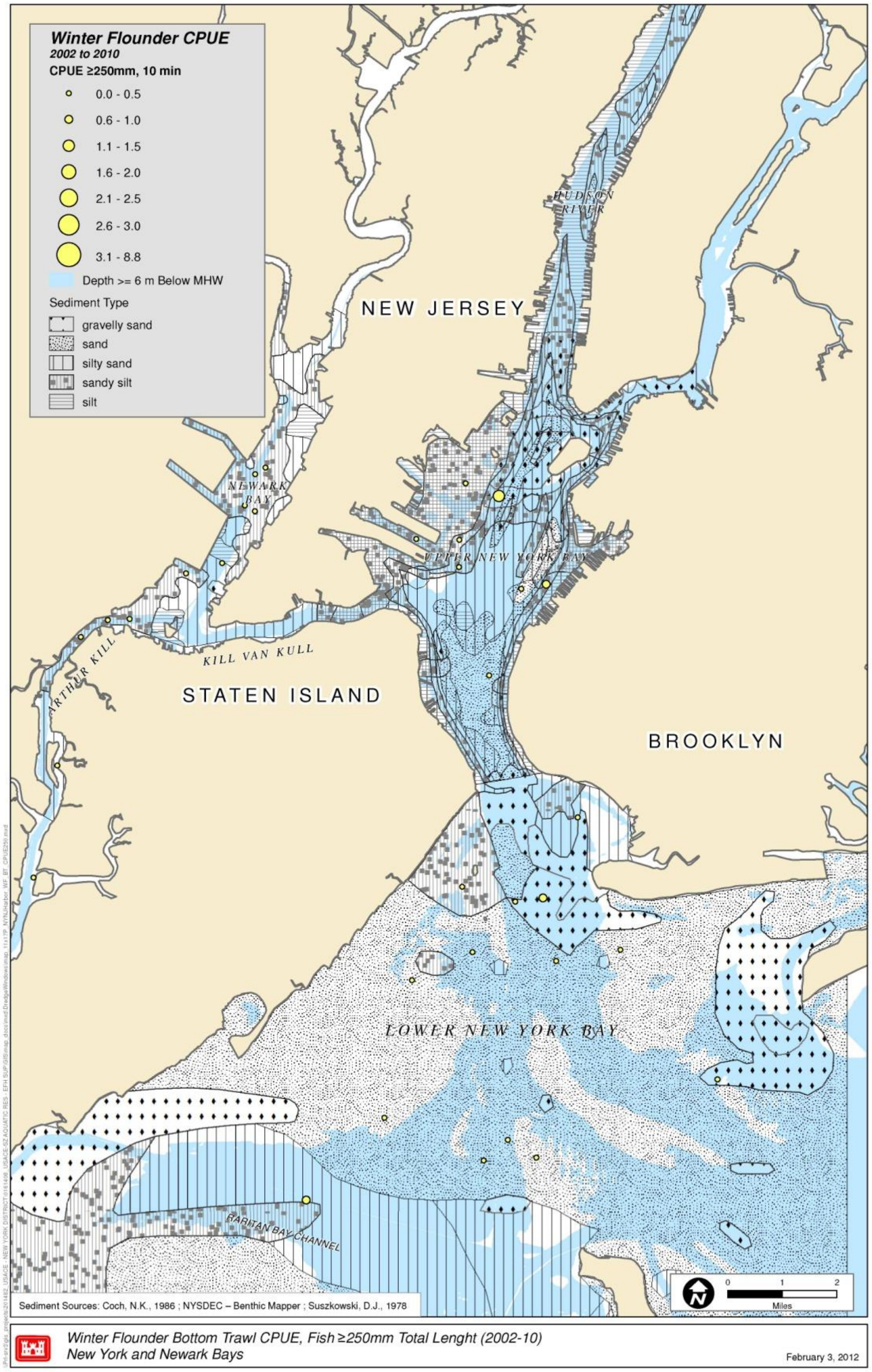

Figure 9. Winter flounder bottom trawl CPUE (2002-2010); adults total length ≥250mm.

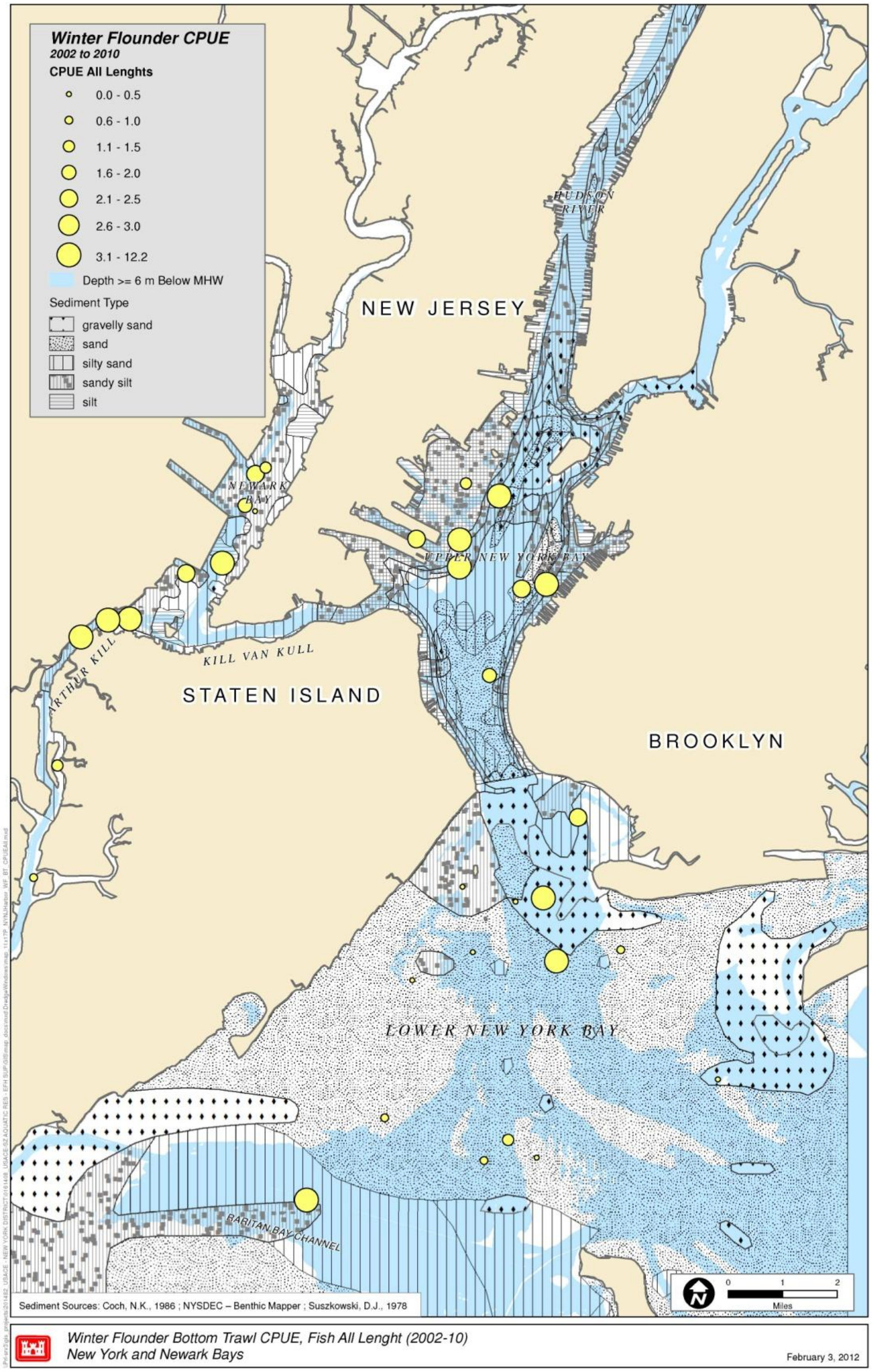

Figure 10. Winter flounder bottom trawl CPUE (2002-2010); all lengths.

APPENDIX A

Aquatic Biological Survey (ABS)

Bottom Trawl Methods

2002 - 2010

Introduction

The primary objective of the Aquatic Biological Survey (ABS) has been to collect both spatial and temporal data on the distribution and seasonal patterns of habitat use (spawning and nursery habitat utilization) of winter flounder as well as other essential fish habitat (EFH) designated species within the Harbor. The information collected has been used in determining the potential project related impacts of deepening existing navigation channels, anchorages, and berthing areas as well as to address local and regional EFH issues. Chapter 1, Application of Winter Flounder Early Life History Data to Seasonal Dredging Constraints and Essential Fish Habitat Designations, focused on winter flounder early life stages collected with an epibenthic sled equipped with a fine mesh net and flow meter. Chapter 2 is focused on juvenile, sub-adult, and adult winter flounder collected in 30 foot bottom trawls.

ABS Methodology

Since 2002, when ABS sampling began in the Lower Bay, the study objectives, survey areas (Upper Bay, Lower Bay and Arthur Kill/Newark Bay), and sampling gear have remained relatively consistent among sampling years to allow for inter-annual comparisons. Consistency embedded in the ABS sampling design allows the cumulative 2002 through 2010 dataset to serve as a foundation for analyses in this technical assessment. Throughout the survey, a set of approximately 24 to 29 sampling locations have been used, but some adjustments have been made from year to year to accommodate Harbor Deepening Project (HDP) construction and changes in station bathymetry. Sample locations are divided into channel and non-channel areas through the three survey areas.

Bottom trawl sampling has been scheduled from early winter (pre-spawning) to late spring (post-spawning) with the most frequent sampling generally conducted twice each month (approximately every other week) from January to March (no January surveys were conducted in 2008) in order to bracket the primary spawning period when adult winter flounder are present and spawning in the Harbor.

Field Sampling

Bottom trawls were conducted using a 30-ft (9.1-m) otter trawl with 1 inch square mesh wings and body and a 0.75 square mesh cod end with a 0.25 square mesh liner (Figure A-1). Bottom trawls were conducted during the night from 1999 through 2004 sampling programs. In 2005, sampling was changed to daylight hours due to safety considerations. Trawls were towed against the prevailing current at a bottom speed of approximately 5.0 ft/sec (150 cm/sec); however, interpier transects and some non-channel transects could only be towed in set directions. Boat speed was measured using a General Oceanics (GO) Model 2031 electronic flow meter coupled to a GO Model 2135 or similar on board readout. Station coordinates were recorded at the beginning and end of each tow. Trawls were towed for ten minutes; infrequently, the duration was adjusted as needed to account for obstructions, limited transect distance, commercial traffic, and other safety considerations in the field. A minimum ratio of 5:1 tow cable length to maximum station water depth was maintained to ensure that the trawl was in contact with the bottom throughout each tow.

On retrieval, all fish and invertebrates were placed in a collection tub or buckets filled with ambient water. All fish, blue crab, and American lobster were identified and enumerated following collection. All winter flounder were measured and total length (TL) was recorded to the nearest millimeter (mm). For all other fish, blue crab, and lobster, up to 25 specimens of each species was measured. If more than 25 of any one species was present, a subsample of 25 was selected. Except for winter flounder preserved for laboratory analysis, as described below, all fish collected were released into back into the water.

Laboratory Methodology

For winter flounder (≥ 250mm TL), gender was determined in the field by exerting gentle pressure to extrude either eggs or milt. If gender could not be determined in the field by this method, up to a total of five winter flounder (≥ 250mm TL) per trawl were preserved on ice and returned to the laboratory for further analysis. Since winter flounder typically exhibit adult gonad development at 250 mm TL and reach sexual maturity between 280 mm and 300 mm TL (Witherell and Burnett 1993), a 250-mm TL requirement was established to limit the number of immature fish returned to the laboratory for analysis. The total number of adult winter flounder returned to the lab for gender determination was set by collector’s license restrictions and was generally limited to 30-50 each program year. Spawning condition (ripe, partially spent, and spent) (Schmidt and St. Pierre 1997; Wyanski and Brown-Peterson 2010) was also recorded in the laboratory to provide additional information on spawning period.

Water Quality Measurements

Dissolved oxygen (DO), temperature, conductivity, and salinity were measured during each survey at each station location using a calibrated YSI Model 85 Handheld Oxygen, Conductivity, Salinity and Temperature System meter with a known degree of accuracy. Measurements were recorded from the bottom strata of the water column at approximately one foot (0.3 m) above the substrate. Field instruments were calibrated each day before sampling. At least once per sampling day, the accuracy of the YSI Model

85 instrument was verified using an ASTM certified thermometer, a laboratory conductivity/salinity meter, and at least three water samples collected in the field and analyzed for DO using the Winkler titration method.

References

Schmitt, C.C. and G. St. Pierre. 1997. Evaluation of Two Methods to Determine Maturity of Pacific Halibut. International Pacific Halibut Commission. Technical Report No. 35. 24 pp. Seattle, Washington.

Witherell, D.B. and J. Burnett. 1993. Growth and maturation of winter flounder, *Pleuronectes americanus*, in Massachusetts. Fishery Bulletin 91:816-820.

Wyanski, D.M. and N.J. Brown-Peterson (Editors). 2010. Proceedings of the 4th Workshop on Gonadal Histology of Fishes. El Puerto del Santa Maria, Spain. 228 pp. http//htl.handle.net/10261/24937.

Figure A-1. 30-ft bottom trawl used during the 2002-2010 ABS.

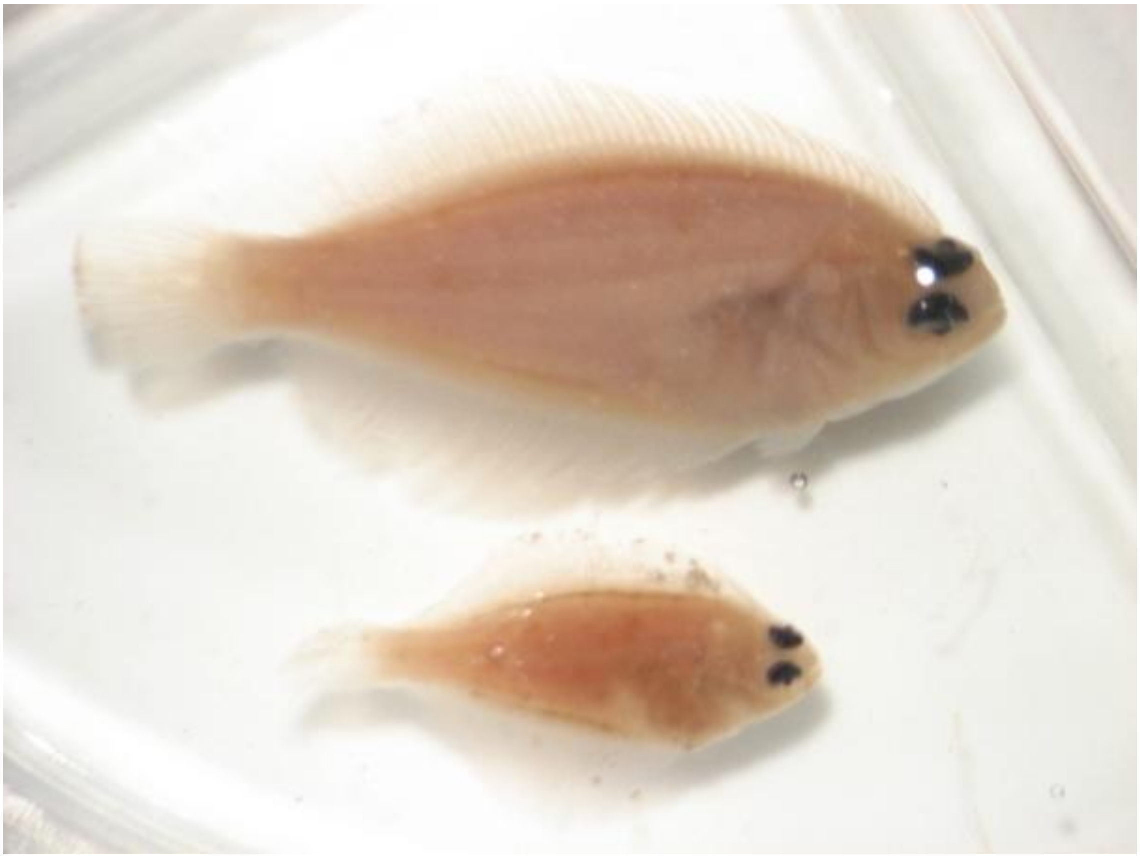

Figure A-2. Young-of-the-year winter flounder collected during the ABS.

Appendix B

Sediment Distribution and Benthic Community Characterization in New York/New Jersey Harbor

Introduction

Benthic communities in temperate estuarine environments are characterized by a high level of temporal and spatial variability. This variability involves both species richness and relative abundance, and occurs on a seasonal basis as well as from year to year. This variability is caused by the interplay of many natural factors and human influences on estuarine environments. Despite this variability, there is a general pattern of benthic community distribution that is related to substrate type. Benthic communities in silt, sand and rocky substrates can be expected to be similar in terms of major invertebrate groups throughout the Harbor. Where the organic content is relatively high in silty substrates, species tolerant of organic matter will predominate, but these species can be expected to be less abundant in silt that has limited organic loading. Silt and sand commonly occur in various degrees of mixing throughout the Harbor and can have distinctive benthic communities depending on the relative amounts of silt and sand and organic matter.

The Narrows tends to be a dividing line between silt dominated substrate and sand dominated substrate on the ocean side of the Narrows. Sand occurs in the center of Upper Bay and in scattered locations in Newark Bay. Silt occurs in the upper part (close to the Narrows) of Lower Bay, particularly in the sand borrow pits that are deeper than the surrounding bay bottom. In the southern part of Lower Bay in the areas designated Raritan Bay and Sandy Hook Bay there is an extensive band of muddy substrate. This area is generally beyond the influence of Harbor Deepening Project and had limited spatial coverage during the ABS program.

An important factor in the availability of benthic communities as food resources for fish including winter flounder is the enhancement of water quality in the Harbor that has taken place since the mid-1900s. Studies discussed below have shown improvements in benthic communities in such areas as Newark Bay and Raritan Bay and other parts of the Harbor associated with improvements in water quality, notably dissolved oxygen (D.O.). Organically enriched substrates occur throughout the Harbor, which can be utilized by invertebrates tolerant of both low D.O. and relatively high T.O.C. Dissolved oxygen is now adequate to permit benthic feeding fish to take advantage of the relatively high productivity associated with the benthic communities that thrive in organically enriched substrates. For benthic feeding species such as winter flounder, the improvement in D.O. expands the area where winter flounder can find food resources and the general improvement in benthic communities provides more food resources for fishes in recent decades.

Sediment Distribution in NY/NJ Harbor

Existing Harborwide Data

Surficial sediments and sedimentation rates for the NY/NJ Harbor have been studied in limited areas and in different years by a number of investigators. Only a few studies have documented the sediments in large areas of the Harbor. Suszkowski (1978) studied the sedimentology and dispersal patterns in Newark Bay and provided maps with polygons containing various sediment types. Coch (1986) studied harbor-wide sediments between August 1977 and August 1981; providing the percent fine fractions (silts and clays) and percents coarse fractions (sands and gravels) for the Upper Bay and Lower Bay. The NYSDEC created contours of the Upper Bay that were based on sediment types collected in grab and core samples (NYSDEC 2011).

Adams and Benyi (1998 REMAP Study) determined percentages of fines throughout the Upper and Lower bays and total organic carbon (TOC) values for the sediments in 1993 and in a resurvey conducted in 1998. The Final Environmental Impact Statement (FEIS) for the New York and New Jersey Harbor Study (USACE 1999b) includes descriptions of sediments collected in core samples from some of the navigation channels. The Feasibility Report (USACE 1999a) Appendix F provides sediment information on the percentage of sediment types along and across some of the navigation channels.

Iocco *et al.* (2000) used both a Shipek grab sampler (0.04 m^2) for sediment collections and Sediment Profile Imagery (SPI) camera. Plan-view images of the sediment surface were obtained with a PhotoSea underwater camera and strobe light mounted to the SPI camera frame. The SPI data was visually interpreted and SPI data were interpreted with the supplemental benthic grab sampling. Sediment types were mapped in a GIS to show sediment distribution of the Lower Bay and Upper Bay. This study found that the widest range in benthic habitat types was present in the Upper Bay. Figure B-1 shows the sediment grain size characterizations for the (a) Upper and (b) Lower Bay areas of NY/NJ Harbor. These characterizations made by Bob Diaz (Virginia Institute of Marine Science) follow the Wentworth classification as described in Folk (1974) and represent the major modal classes for each layer identified in a sediment profile image. Grain size was determined by comparison of collected images with a set of standard images for which mean grain size had been determined in the laboratory (Iocco *et al*. 2000).

2011 Sediment Survey of ABS Stations

In 2011, the USACE sampled throughout the NY/NJ Harbor to characterize the surficial sediments found at 38 ABS transect locations; the results provided grain size and TOC content of the surficial sediments of channels and non-channel areas. These data provide habitat data specific to the ABS Stations/Transects.

The 2011 sediment data was collected near the center of each ABS bottom trawl transect using a 0.1 m^2 Smith McIntyre Dredge. The upper 10 centimeters of each grab sample was removed using large stainless steel spoons and placed in a stainless steel pan and thoroughly mixed. The mixed sample was placed into two one liter labeled sample bottles (one for grain size and the other for TOC), capped, added to the chain of custody, and placed in a cooler with ice for transport to the laboratory for analysis. The samples were analyzed using standard methods for percent grain size (ASTM D422) and TOC (SW846 9060).

The percent grain size data was used to classify the sediments collected at the 38 ABS locations into the following 5 primary sediment types:

- Gravelly Sand = primarily sands with lesser amounts of gravel; may have some silt and clay fractions.
- Sand = primarily sand (> 90% sand)
- Silty Sand = primarily sand with lesser amounts of silt; may have some clay fractions.
- Sandy Silt = primarily silt with lesser amounts of sand; may have some clay fractions.
- Silt / "Clayey" = Primarily silt with varying amounts of clay. In general, this classification includes sediments that are primarily silt with lesser amounts of clay; however, their may be a higher percentage of clay in some samples and these sediments may have some sand fractions possibly with some gravel.

Results

The distribution of sediment type among the 38 samples and among the Harbor sub-areas is shown in Table B-1. The Lower Bay was primarily sand; Upper Bay was transitional with a range from silt to gravelly sand; and Kill Van Kull, Arthur Kill and Newark Bay were dominated by silty material in varying quantities. Total Organic Carbon values ranged from 0.07% to 5.5%, with the lowest values at the Lower Bay transects and the highest values at transect locations in the Arthur Kill, followed by Newark Bay and the Port Jersey (Table B-1). In general, the lower values were associated with sandy sediments and the higher values with silts and clays.

The substrate conditions in the major subareas of the Harbor are presented in three figures that show a composite of broad sediment polygons, sediment type at the ABS sampling stations in 2011 (Figures B-2, B-3 and B-4). The Polygons were derived from

Coch (1986) for Lower Bay, from Suskowski (1978) for Newark Bay, from the New York Benthic Mapper (NYSDEC 2011) for Upper Bay, and from other studies, such as the EIS (USACE 1999b) for the Harbor Deepening Project, for Arthur Kill and Kill Van Kull. These studies provided the boundaries between sediment types and existing surficial sediment conditions.

Newark Bay, Kill Van Kull and Arthur Kill are dominated by fine-grained sediments consisting of silts, often in association with clay and fine sands. Upper Bay is dominated by silt in the inshore areas, silty sand north of the Kill Van Kull, with sand dominating south of Kill Van Kull to the Narrows. Gravelly sand occurs in a few central areas of Upper Bay. Lower Bay contains a high percentage of coarser-grained particles, including gravelly sand in the vicinity of the contract areas in Ambrose Channel. The silty sand and silt that occurs in Lower Bay occurs beyond the bounds of the channel dredging activities. Where silty sand and silt occur in Lower Bay, they are beyond the influence of channel dredging. Lower Bay is primarily sand substrates, particularly in the area where Ambrose Channel passes through the Bay. Sand predominates in much of Ambrose Channel from the longshore currents which transport sand along the South Shore of Long Island and the north coast of New Jersey into the Lower Bay. Within Lower Bay, sand borrow pits have a mix of substrates, but silty substrates predominate in the larger, deeper pits.

Table B-2 provides a summary of the areas in the Harbor categorized by non-channel and channel, and by depth increment. Lower Bay has a relatively even distribution of depth over its total area, whereas Upper Bay is predominantly deepwater (>25ft) and Newark bay is dominated by shallow water (<15ft). Kill Van Kull and Arthur Kill are narrow waterbodies dominated by major channels, thus they also have a high percentage of soft substrates.

In Upper Bay and Newark Bay, channels are a significant portion of the total available substrate and in combination with the inshore shallow areas, which are subject to sedimentation of fine-grained materials, accounts for the relatively high percentage of soft substrates in these subareas.

Table B-1. Sediment Data for 38 Grab Sample sites Collected Near the Mid Point of ABS Transect Locations during April/May 2011.

Station	Sediment Type[1]	Sediment Analysis				
		Percent				Percent
		Gravel	Sand	Silt	Clay	TOC
LB-1	Sand	2	96	0	2	0.13
LB-2	Sand	0	99	0	1	0.07
LB-3	Silty Sand	5	78	11	7	0.7
LB-4	Silty Sand	8	41	40	11	2.7
LB-5	Sand	0	98	0	2	0.15
LB-6	Sand	0	93	2	5	0.5
LB-7	Silt/Clayey Silt	0	13	72	16	2.8
LB-8	Sand	1	98	0	2	0.24
LB-9	Silty Sand	24	44	28	4	2.1
LB-10	Sandy Silt	1	31	44	23	1.4
LB-12	Sand	0	97	0	3	0.28
LB-13	Sand	3	95	1	2	0.18
LB-14	Silty Sand	11	60	24	5	2.4
LB-16	Sand	5	94	0	1	0.08
LB-18	Sand	0	98	1	1	0.06
LB-19	Sand	1	97	1	2	0.09
LB-20	Gravelly Sand	11	85	2	3	3.5
LB-21	Sand	1	96	1	2	0.30
SB-3	Sand	1	94	1	4	0.36

SB-4	Silt/Clayey Silt	0	4	67	28	2.9
SB-5	Sandy Silt	2	30	52	18	2.1
SB-6	Sand	0	98	1	1	0.16
PJ-1	Gravelly Sand	31	42	16	11	2.3
PJ-2	Sandy Silt	0	32	46	22	2.0
PJ-4	Silt/Clayey Silt	0	3	71	26	3.1
PJ-5	Silt/Clayey Silt	0	5	75	20	3.4
KVK-1	Sandy Silt	0	36	48	16	2.1
KVK-2	Silty Sand	2	63	24	11	0.92
AK-2	Silt/Clayey Silt	0	12	61	27	2.8
AK-3	Sandy Silt	3	43	47	7	4.3
AK-4	Sandy Silt	0	7	87	7	5.5
AK-8	Silt/Clayey Silt	0	10	73	17	3.2
NB-3	Silty Sand	3	58	27	13	2.2
NB-4	Silt/Clayey Silt	1	4	61	35	3.0
NB-5	Silt/Clayey Silt	0	5	69	26	3.8
NB-6	Silt/Clayey Silt	0	13	68	19	2.7
NB-7	Sandy Silt	0	20	73	7	2.9
NB-8	Silt/Clayey Silt	0	5	70	26	4.5

Table B-2. Summary of the aquatic habitat areas in the Harbor categorized by non-channel and channel, and by depth increment.

Subarea[1]	**Area (millions m^2) Percentage (%)**				
	Non-channel	**Channel**	**< 15' Depth**	**15-25' Depth**	**>25' Depth**
Lower Bay	152.3 (90.9)	15.5 (9.1)	63.5 (37.8)	65.6 (39.2)	38.7 (23.0)
UpperBay	28.7 (65.4)	15.2 (34.6)	9.2 (20.9)	5.4 (12.2)	29.4 (66.9)
Newark Bay	11.9 (78.1)	3.3 (21.9)	10.2 (66.9)	0.6 (4.0)	4.4 (29.1)

[1] Kill Van Kull and Arthur Kill were not quantified; both subareas are dominated by channels with relatively little 15-25' depths and generally a narrow edge of shallow water.

Benthic Community Characterization

A variety of benthic grab samplers have been used in the NY/NJ Harbor benthic surveys reported herein. The NOAA survey of Newark Bay during 1993-1994 used a 0.04 m^2 Young-modified Van Veen grab. The USACE-NYD's 1998-1999 study used a 0.1 m^2 Smith McIntyre grab for infaunal collections while, larger, natant macrofauna (e.g. blue crabs) were sampled using a commercial crab dredge. The USACE-NYD used a Smith McIntyre grab for the 2005 (baseline) and 2009 (post-dredging) surveys within NY/NJ Harbor. Steimle and Caracciolo-Ward (1989) and Chang *et al.* (1992) also used a Smith McIntyre grab for their benthic surveys of Raritan Bay. Iocco *et al.* (2000) used a Shipek sampler (0.04 m^2) for sediment collections; however the primary sampling for this study was collection of photographic images via a Hulcher Sediment Profile Camera. Plan-view images of the sediment surface were obtained with a PhotoSea underwater camera and strobe light mounted to the SPI camera frame.

SPI Surveys

SPI data were collected, visually interpreted, and mapped in a GIS to depict the distribution of major benthic habitat types in these areas. SPI images were supplemented by sediment plan-view images and benthic grab sampling. This study found that the widest range in benthic habitat types was present in the Upper Bay and Jamaica Bay, including shellfish beds, amphipod mats, and both sand and silt substrates. Benthic communities throughout NY/NJ Harbor are dominated by opportunistic or pollution-tolerant taxa; overall, few differences in habitat quality are discernable among the various embayments.

The major habitat classes documented by Iocco *et al*. (2000) were:

Shell Beds – keyed on the presence of live bivalves including American oyster (*Crassostrea virginica*), blue mussels (*Mytilus edulis*), surf clams (*Spisula* *solidissima*), hard clams (*Mercenaria mercenaria*) or softshell clams (*Mya arenaria*).

***Ampelisca* mats** – three subclasses identified based upon sediment type underlying the mats (sand, sandy-silt and silt). Relatively unstable with regard to season in contrast to shellfish beds which tend to persist among seasons.

Sandy bottom – bare sand substrate lacking shellfish or *Ampelisca* mats.

Silt bottom – three subclasses were identified but they are not mutually exclusive. They include 1) those with high pollutant and/or organic loads (evidenced by gas voids); 2) soft silts indicating high sediment rates; and 3) silts overlain by algae and/or high infaunal densities.

Oligozoic – associated with silts and sandy silts. Includes azoic, which denotes a complete absence of infauna, epifauna or organism trails. There is a bacterial at subclass, which designates the presence of *Begiattoa* spp. mats on the sediment surface. *Beggiattoa* is a chemolithotrophic microbe, and metabolizes reduced sulfur compounds in anoxic sediments/waters. This subclass may be encountered at the bottom of deep, perpetually anoxic borrow pits, for example those located adjacent to the Edgemere Landfill in Jamaica Bay.

Existing Harbor-Wide Surveys

Several previous sampling programs have attempted to characterize the benthic community of NY/NJ Harbor. Some of the earliest of these, spanning a 20-year time period (e.g. Dean and Haskin 1964, McGrath 1974, Stainken 1984) characterize the benthic community of the Harbor, in particular the Raritan Estuary and lower New York Bay, as degraded from decades of industrial pollution and cultural eutrophication. However, successive studies (e.g. Steimle 1985) determined benthic productivity and biomass values within the New York Bight Apex, including Lower New York Bay, and reported similar or higher values in comparison to other NW Atlantic Estuaries.

Steimle and Caracciolo-Ward (1989) conducted a re-evaluation of McGrath's (1974) study, including the analysis of an additional 224 samples in an attempt to better describe trends in the degradation of benthic communities in the lower Harbor since baseline surveys conduced in the 1950s. The findings of this study were that the benthic community of the Lower New York Bay was not as degraded as previously reported, and was in many ways similar to other relatively unpolluted mid-Atlantic estuaries. The Lower Bay generally supports a greater taxonomic diversity relative to the other areas of the NY/NJ Harbor, with benthic organism abundance and taxa diversity negatively correlated with sediment contaminant levels and silt-clay content (Cerrato 1986, Cerrato and Scheier 1984).

Cerrato *et al.* (1989) conducted a broad survey of benthic invertebrates throughout lower New York Bay during 1986-1987. A total of 84 stations were sampled from Raritan Bay across to Sandy Hook and extending up to the Verrazano Narrows and Rockaway Point. The lower Bay assemblage was dominated by the tubiculous amphipod *Ampelisca abdita* (>55%) and blue mussels (*Mytilus edulis*) represented >17%. Additional numerical dominants in the Lower Bay assemblage included the polychaetes *Asabellides oculata* and *Heteromastus filiformis*, softshell clam (*Mya arenaria*), eastern slipper shell (*Crepidula fornicata*), and the amphipods *Corophium tuberculatum* and *Elasmopus levis*.

Chang *et al.* (1992), working in the New York Bight, used factor and canonical analyses to identify species assemblages associated with varying degrees of habitat quality. They determined that a small group of species, previously deemed accurate indicators of habitat quality in the Bight (*Ceriantheopsis americanus*, *Nephthys incisa*, *Capitella spp.*, *Nucula proxima* and *Ampelisca agassizi*) were, in fact, valid indicators. They also described a species assemblage representative of minimally impacted habitats in the Bight, including the sand dollar *Echinarachnius parma*; the amphipods *Byblis serrata*, *Corophium crassicorne*, and *A. abdita;* and the polychaetes *Goniadella gracilis* and *Exogene hebes*. Invertebrate taxa that were typically associated with contaminated/dredged sediments in the Bight included the polychaetes *Tharyx acutus*, *N. incisa*, *Pherusa affinis*, and Capitella spp.; the ribbon worm *Cerabratulus lacteus*; the anemone *Ceriantheopsis americanus*; and the bivalve *Nucula proxima*.

The USACE-NYD conducted a benthic invertebrate survey of NY/NJ Harbor during 1998-1999, with emphasis on inter-pier and shoal habitats and navigation channels (USACE 1999). Marine terminal inter-pier areas and shoal areas were characterized during Fall and Winter by a few species of polychaetes (44% of total), primarily *Streblospio benedicti*. *Nereis* sp. and Paraonidae, along with oligochaetes and the gastropod *Lacuna vincta*. During Spring and Summer, a shift to dominance by blue mussel and the dwarf surf clam (*Mulinia lateralis*) was noted, along with the bivalve *Tellina* sp., sea grapes (*Molgula manhattensis*), oligochaetes and the polychaete *Leitoscoloplos fragilis* (Table B-3).

TABLE B-3. Mean density (number/ 0.1m^2) of 10 most abundant taxa at Interpier/ Shoal Areas, November 1998 - September 1999**.**

Taxon	**Total**	**%**
Mulinia lateralis	45.6	21.6
Streblospio benedicti	40.9	19.3
Mytilus edulis	23.9	11.3
Leitoscoloplos fragilis	13.5	6.4
Nereis sp.	9.6	4.5
Paraonidae	7.8	3.7
Oligochaeta	7	3.3
Molgula manhattansis	6.3	3
Crepidula plana	4.7	2.2
Phyllodocidae	4.5	2.1

In general, navigation channels were dominated by a few species of eurytopic polychaetes including *Scolecolepides viridis*, and *S. benedicti*. These two species represented 40% of all organisms collected within deep channels. The dwarf surf clam represented 28% of all organisms collected among all channel stations. While there was considerable variation in relative abundance among seasons, overall dominance by these few species persisted year-round (Table B-4).

TABLE B-4 Mean density (number/ $0.1m^2$) of 10 most abundant taxa at Channel Stations areas.November 1998 - September 1999.

Taxon	**Total**	**%**
Mulinia lateralis	405.6	39.2
Scolecolepides viridis	139.3	13.5
Streblospio benedicti	101.6	9.8
Tellina sp.	53.6	5.2
Ampharetidae	44.9	4.3
Nephtys sp.	28.9	2.8
Leitoscoloplos fragilis	25.2	2.4
Ampelisca abdita	20.4	2
Mytilus edulis	16.5	1.6
Glycera sp	14.7	1.4

Shallow stations (0-20 ft.) were located on the Jersey Flats, Constable Hook , and the Global Marine Terminal. In this depth range, *S. benedicti* represented >25% of total invertebrates collected), followed by *L. fragilis* (>10%) and dwarf surf clam at >8%.

Additional common taxa included the polychaetes *Nereis* sp., *Glycera* sp., Paraonidae, Phyllodocidae and Orbiniidae as well as the gastropods *Crepidula plana* and *C. fornicate* (Table B-5).

TABLE B- 5. Mean density (number/ 0.1m^2) of 10 most abundant taxa at Shallow-water (<20 ft MLW) Stations, November 1998 - September 1999.

Taxon	**Total**	**%**
Streblospio benedicti	125.3	25.2
Leitoscoloplos fragilis	52.8	10.6
Mulinia lateralis	44.1	8.9
Paraonidae	37.7	7.8
Molgula manhattansis	30.5	6.1
Nereis sp.	26.5	5.3
Phyllodocidae	18	3.6
Crepidula plana	17.5	3.5
Glycera sp.	15	3
Orbiniidae	14.6	2.9

Mid-depth (15-30 ft.) stations included the Port Jersey Pierhead Channel, Claremont Terminal Channel and the Gowanus Bay inter-pier area. The two most abundant species in this depth range were the blue mussel (>29%) and dwarf surf clam (> 29%). The third most abundant species was *S. benedicti* (>10%). Additional common species included *Nereis* sp., *L. fragilis*, and *Glycera* sp.; amphipods (*A. abdita* and Gammaridae), the bivalve *Tellina* sp. and gastropods (*C. plana* and *Acteocina canaliculata*) (Table B-6).

TABLE B- 6. Mean density (number/ 0.1m^2) of 10 most abundant taxa at Mid-depths (shallow channel) Stations, November 1998 - September 1999.

Taxon	Total	%
Mulinia lateralis	179	29.3
Mytilus edulis	119.5	29.5
Streblospio benedicti	52.7	10.9
Oligochaeta	15	0.9
Nereis sp.	13.5	3.4
Tellina sp.	11.7	2.6
Ampelisca abdita	11.3	1.9
Leitoscoloplos fragilis	9.8	2.3
Acteocina canaliculata	9.7	2
Glycera sp.	6.1	1.6

Stations located in the 30-40 ft depth range were dominated by dwarf surf clam, accounting for >33% of the total. Additional dominants included the polychaetes *S. viridis*, *S. benedicti* and *L. fragilis*, together representing >29% of the total. Additional taxa which were common at this depth range included *Tellina* sp., *A. abdita* and the polychaetes *Nephtys* sp., *Glycera* sp. and Orbiniidae (Table B-7).

TABLE B-7 Mean density (number/ 0.1m^2) of 10 most abundant taxa at 30 - 40 ft (MLW) Stations, November 1998 - September 1999

Taxon	**Total**	**%**
Mulinia lateralis	347.2	33.3
Scolecolepides viridis	139.2	13.3
Streblospio benedicti	127.5	12.2
Ampharetidae	92.5	8.9
Leitoscoloplos fragilis	44.5	4.3
Tellina sp.	32.2	3.1
Leucon americanus	29.5	2.8
Ampelisca abdita	22	2.1
Orbiniidae	19	1.8
Nephtys sp.	17	1.6

Very deep stations (>40 ft.) included North Ambrose Channel and Anchorage Channel. The three most abundant species at these stations included dwarf surf clam (>49%), Tellina spp. (11%). and blue mussel (>5%). Additional common species included the polychaetes Nephtys sp., S. benedicti, Pectinaria gouldi, Glycera sp., Ampharetidae, Spionidae. Paranoidae and Phyloccidae and amphipods (A. abdita and Gammarus spp.) (Table B-8).

TABLE B-8 Mean density (number/ 0.1m^2) of 10 most abundant taxa at Deep-water (>20 ft MLW) Stations, November 1998 - September 1999.

Taxon	**Total**	**%**
Mulinia lateralis	211.2	49.3
Tellina sp.	47.5	11.1
Mytilus edulis	23.8	5.6
Nephtys sp.	19.3	4.5
Streblospio benedicti	13.8	3.2
Ampharetidae	13.2	3.1
Pectinaria gouldii	6.8	1.6
Ampelisca abdita	6.2	1.4
Strongylocentrotida	5.5	1.3
Spionidae	5.3	1.2

Channel Subareas

Lower Bay - Ambrose Channel

During the USACE-NYD’s 2005 baseline (pre-dredging) benthic monitoring program, a total of 33 benthic taxa were recorded from grab samples collected in Ambrose Channel. This area exhibited a moderate level of invertebrate density (2325 organisms m^2) and was dominated by mollusks (51%) and annelids (32%). Blue mussels dominated the assemblage accounting for 41% of the total. Additional taxa of significance included amphipods (Gammaridae), the polychaetes *Nephtys* sp. and *Magelona* sp. and the northern dwarf tellin (*Tellina agilis*).

During the USACE-NYD's 2009 post-dredging survey (contract area S-AM-1), a total of 28 benthic taxa were collected. The assemblage was dominated by annelids (73%) and arthropods (18%). Additional major taxa collected included mollusks, echinoderms and nemerteans. Among the annnelids, the most abundant taxa were *Magelona* sp. and Paraonidae. The amphipod *Parahaustorius* sp. was also numerically dominant. In contrast to the general survey of Ambrose channel in 2005, blue mussels were absent from the S-AM-1 reach in 2009.

Upper Bay - Anchorage Channel

During the USACE-NYD's 2005 baseline (pre-dredging) monitoring program, Anchorage Channel exhibited relatively high levels of benthic taxa diversity with over 42 taxa reported. Benthic invertebrate density was high (15,040 organisms m^2. As with Ambrose channel in 2005 blue mussels dominated the benthic assemblage, accounting for 79% of total organisms collected. Additional numerical dominants included tubiculous amphipods (*Ampelisca spp.*) northern dwarf tellin, and the polychaete *Spio setosa*.

During the 2009 post-dredging surveys a total of 28 taxa were collected (S-AN-1a contract area). The assemblage was dominated by arthropods (53%) and annelids (44%), with *A. abdita* and the polychaete *Capitella spp.* dominating collections. Mean benthic invertebrate density was higher in 2009 (6913 m^2) than in 2005.

Newark Bay

A number of benthic invertebrate surveys have been conducted in Newark Bay since the mid-1980s. During 1985, 30 stations throughout the western and southern portion of Newark Bay were sampled by USACE-NYD, and these stations were evenly distributed among shallow (7-18 ft) and deep 3-40 ft) areas. Overall, benthic abundance was deemed moderate, and the assemblage was dominated by the polychaetes *S. benedicti* and *S.*

vulgaris. Softshell clam were also abundant. Seasonal shifts in the assemblage were noted with the polychaetes *S. viridis*, *Nereis succinea* and *Polydora ligni* dominating in the Spring, and *S. setosa*, the barnacle *Balanus balanoides* and the sea grape (*Molgula manhattensis*) dominating summer assemblages. While there was considerable variation in species composition among shallow and deep stations, there was no discernible difference in abundance (USACE-NYD 1987).

NOAA conducted a benthic macroinvertebrate survey of Newark Bay during 1993-1994. The findings of this study were similar to that of the 1987 USACE-NYD study in that polychaetes dominated the assemblages and exhibited discernible shifts in species composition among seasons (Stehlik *et al*. 1994).

The Port Authority of New York/New Jersey conducted a benthic sampling program in Newark Bay from 1995-1996, with particular emphasis on siting a proposed confined disposal facility (LMS 1996). This study further corroborated the initial USACE-NYD findings with dominance by polychaetes including *S. viridis*, *S. benedicti*, Paraonidae and Phyllodocidae. Additional common invertebrates included softshell clam, dwarf surf clam, the isopod *Cyathura polita*, and the cumacean *Oxyurostylis smithii* (Table B-9).

TABLE B-9 Mean density (number/ 0.05m^2) of 10 most abundant taxa, Newark Bay, 1995 - 1996 (LMS 1996).

Taxon	**Total**	**%**
Scoloplos sp.	1261	29.18
Streblospio benedicti	1049	24.27
Mulinia lateralis	681	15.76
Paraonidae	308	7.13
Cyathura polita	254	5.88
Mya arenaria	196	4.53
Phyllodocidae	77	1.78
Glycera sp.	73	1.69

Polydora ligni	69	1.6
Nemertea	56	1.3

Arthur Kill

Coincident with the PANY/NJ's 1995-1996 Newark Bay surveys, benthic sampling was also conducted in the Arthur Kill (LMS 1996). The polychaete *S. benedicti* accounted for >80% of all organisms collected. Additional numerical dominants included *S. vulgaris*, *Scolecolepides* sp., *N. succinea*, Paraonidae, and Phyllodocidae. Oligochaetes, Aorid amphipods, cumaceans, softshell clam and dwarf surf clam were also abundant in the Arthur Kill (Table B-10).

TABLE B-10 Mean density (number/ 0.05m^2) of 10 most abundant taxa, Arthur Kill, 1995 - 1996 (LMS 1996)..

Taxon	**Total**	**%**
Streblospio benedicti	4055	79
Phyllodocidae	245	4.77
Scoloplos sp.	186	3.62
Mya arenaria	107	2.08
Paraonidae	102	1.99
Oligochaeta	84	1.64
Polydora ligni	56	1.09
Mulinia lateralis	43	0.84
Leucon americanus	40	0.78
Edotea triloba	35	0.68

Kill Van Kull

Coincident with the PANY/NJ's 1995-1996 Newark Bay surveys, benthic sampling was also conducted in the Kill Van Kull (LMS 1996). The polychaete *S. benedicti* accounted for >49% of all organisms collected. Additional numerical dominants included *S. vulgaris*, *Scoloplos* sp., *N. succinea*, Paraonidae, Phyllodocidae and Oligochaetes. Aorid amphipods, softshell clam and dwarf surf clam were also abundant in the Kill Van Kull (Table B-11).

TABLE B- 11. Mean density (number/ 0.05m^2) of 10 most abundant taxa, Kill Van Kull, 1995 - 1996 (LMS 1996).

Taxon	**Total**	**%**
Streblospio benedicti	3703	49.14
Sabellaria vulgaris	2221	29.47
Paraonidae	419	5.56
Mulinia lateralis	137	1.82
Scoloplos sp.	129	1.71
Mya arenaria	126	1.67
Phyllodocidae	118	1.57
Oligochaeta	83	1.1
Nereis succinea	55	0.73
Amphipoda	49	0.65

During the USACE-NYD pre-dredging (2005) surveys a total of 32 benthic taxa were collected within the Kill Van Kull. Mean benthic invertebrate density was very high, at 21,972 m^2). The assemblage was dominated by pollution-tolerant taxa, indicating degraded conditions in the waterway overall. Dominant taxa included the polychaetes *Sabellaria vulgaris* and *S. benedicti*, as well as amphipods (Aoridae) and blue mussels. Nematodes were also abundant in most samples from this area.

During post-dredging (2009) surveys of the Kill Van Kull a total of 32 taxa were recorded. Polychaetes (*S. vulgaris, S. viridis* and Capitellidae) dominated post-dredging collections (64% of total). As in 2005, high densities of nematodes were reported. Very few pollution-sensitive species were encountered in 2009 Kill Van Kull samples.

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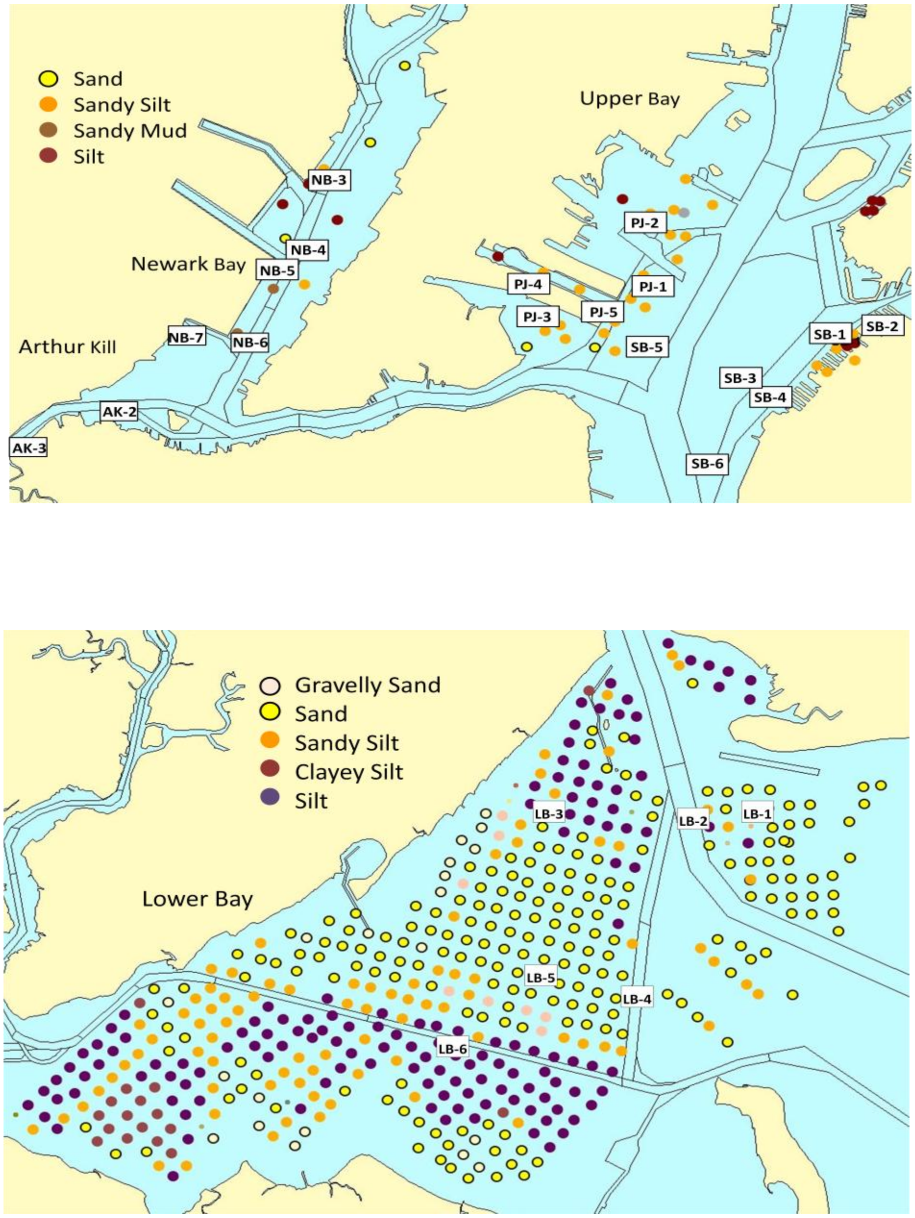

a)

b)

Figure B-1. Sediment grain size characterizations for the (a) Upper and (b) Lower Bay areas.[1]

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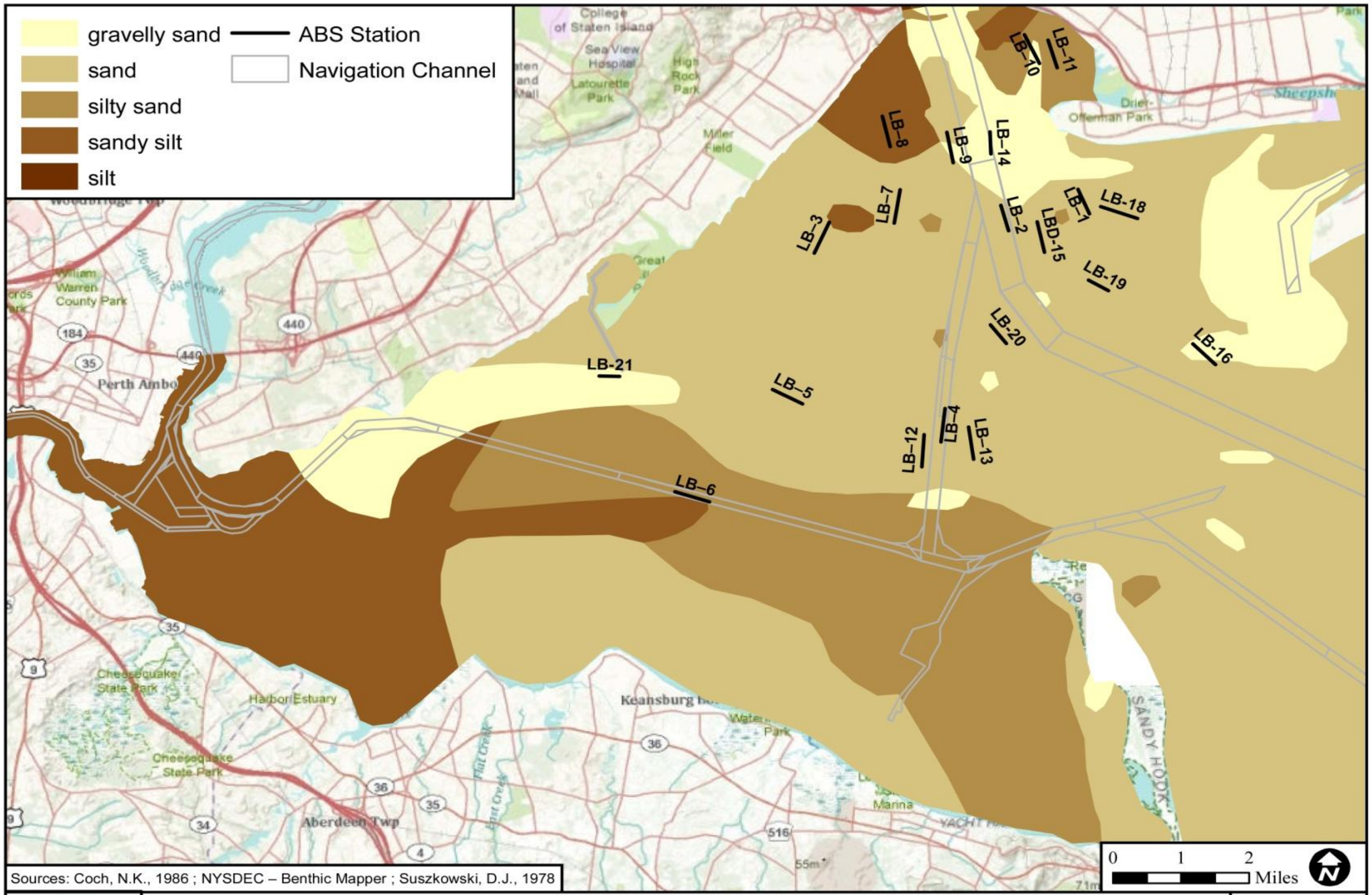
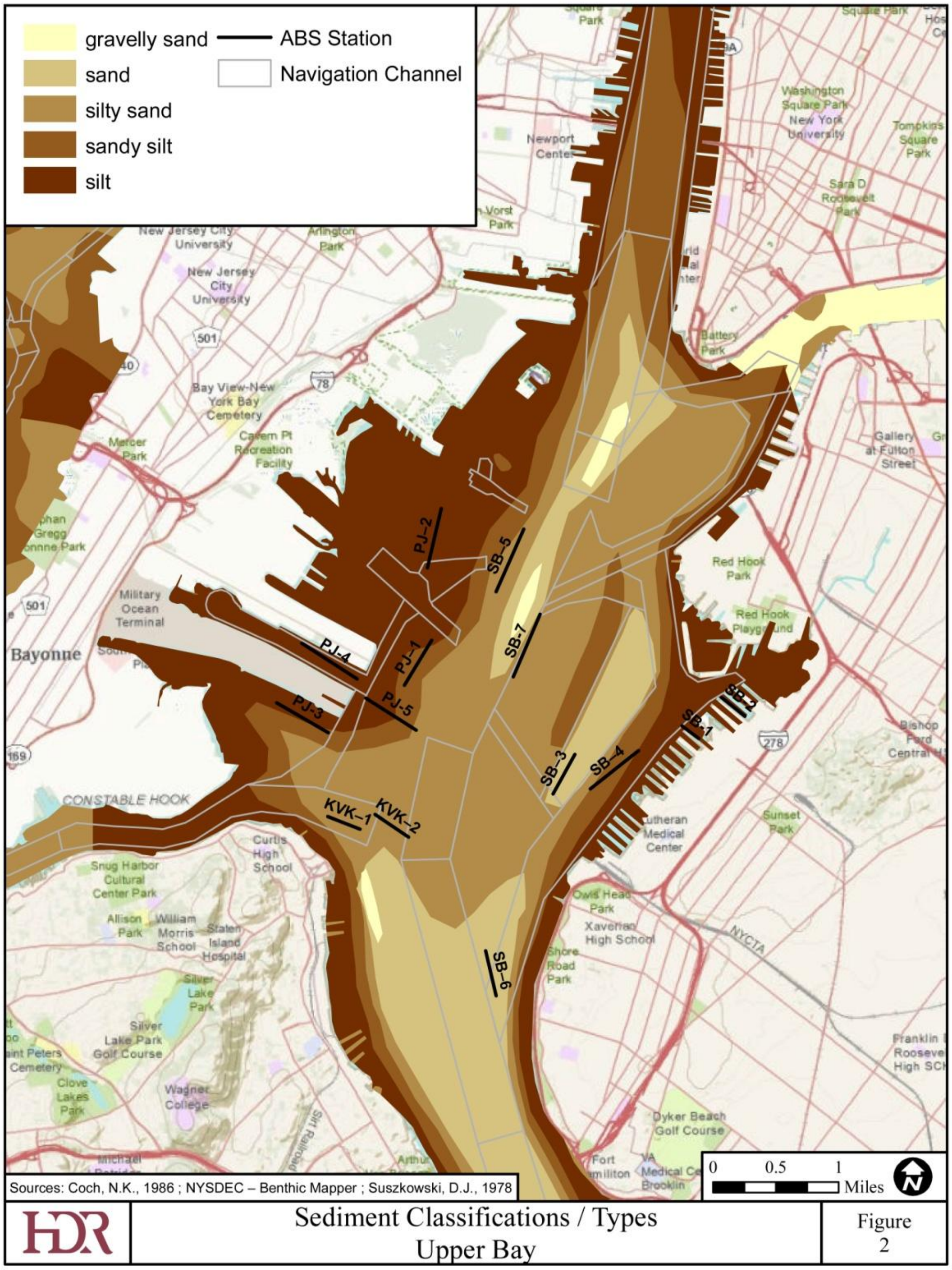
[1] These characterizations made by Bob Diaz (Virginia Institute of Marine Science) follow the Wentworth classification as described in Folk (1974) and represent the major modal classes for each layer identified in a sediment profile image. Grain size was determined by comparison of collected images with a set of standard images for which mean grain size had been determined in the laboratory (Iocco *et al.* 2000).



Sources: Coch, N.K., 1986 ; NYSDEC – Benthic Mapper ; Suszkowski, D.J., 1978

Sediment Classifications / Types
Lower Bay

Figure
1



Sources: Coch, N.K., 1986 ; NYSDEC – Benthic Mapper ; Suszkowski, D.J., 1978

Figure B-3. Sediment distribution in the Upper Bay.

Sources: Coch, N.K., 1986 ; NYSDEC – Benthic Mapper ; Suszkowski, D.J., 1978

Figure B-5. Sediment distribution in Arthur Kill/Newark Bay.