NEW YORK AND NEW JERSEY HARBOR DEEPENING PROJECT

AQUATIC BIOLOGICAL SURVEY REPORT 2004

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Table of Contents

LIST OF APPENDICES

LIST OF TABLES

Table 3-3d. Monthly average ichthyoplankton density (Number / 1000 m^3) by species for all shallow/shoal stations in the Upper Bay during the 2004 Aquatic Biological Sampling Program.

Table 3-3e. Monthly average ichthyoplankton density (Number / 1000 m^3) by species for all navigation channel stations in the Lower Bay during the 2004 Aquatic Biological Sampling Program.

Table 3-3f. Monthly average ichthyoplankton density (Number / 1000 m^3) by species for all shallow/shoal stations in the Lower Bay during the 2004 Aquatic Biological Sampling Program.

LIST OF FIGURES

1.0 INTRODUCTION

1.1 BACKGROUND

This report presents and summarizes results of the 2004 Aquatic Biological Sampling Program conducted in the New York and New Jersey Harbor (Harbor) from January though July 2004. The program's focus was to collect spatial and temporal data on adult and early life stages of finfish in the Harbor, with an emphasis on winter flounder *(Pseudopleuronectes americanus).*

The 2004 Biological Sampling Program supplements data provided in the following reports: 1998–1999 New York and New Jersey Harbor Navigation (NYNJHN) Study, 2000–2001 Supplemental Sampling Program, 2001–2002 Aquatic Biological Sampling Program, and the 2002–2003 Biological Sampling Program. Collectively, these four studies comprise the biological database for the New York and New Jersey Harbor Deepening Project (NYNJHDP), a United States Army Corps of Engineers (USACE) and Port Authority of New York and New Jersey (PANYNJ) sponsored project to deepen navigation channels to 50-ft or more to accommodate today's larger commercial vessels. A primary goal of the NYNJHDP is to collect data on Harbor finfish, shellfish, macroinvertebrates, and water quality, with a focus on biological community structure, distribution patterns, and seasonal patterns of habitat use. The information collected is used in determining the potential biological impacts of deepening existing Harbor navigation channels, anchorages, and berthing areas to depths of 50 ft or greater.

The NYNJHDP is the culmination of several prior projects. In December 1999 the U.S. Army Corps of Engineers released their Final Feasibility Report and Environmental Impact Statement, a comprehensive report detailing existing conditions of the Harbor, evaluating alternative actions and recommending a plan for channel improvements in the Harbor. In December 2000 the U.S. Congress issued the Water Resources Development Act allowing the Harbor Navigation Study to commence. In 2002 Congress released the Conference Report on the Energy and Water Appropriations Act of 2002 which orders the USACE to consolidate each of its dredging projects into the Harbor Deepening Project. In June 2002 a Record of Decision was issued for the Final Environmental Impact Statement for the Harbor Navigation Study.

The 1998–1999 NYNJHN Study found that the Harbor finfish community consists of a variety of resident and migratory fish species typical of large coastal estuaries and inshore waterways along the Middle Atlantic Bight. The Harbor estuary serves as a spawning ground, migratory pathway and nursery/foraging area for many fish and macroinvertebrate species. To obtain more information on the use of Harbor habitats by early life stages of fish, particularly winter flounder, the NYNJHN Supplemental Sampling Program was conducted during 2000–2001.

Although both the 1998–1999 NYNJHN Study and the 2000–2001 Supplemental Sampling Program provided extensive information about adult and early life stages of winter flounder in the Harbor, it was determined that additional data were needed to better understand spatial and temporal occurrence patterns within the Harbor, their use of Harbor navigation channels and shallow/shoal areas, and the role Lower New York Bay plays in winter flounder overwintering and spawning. Furthermore, it was determined that data for multiple years are needed to establish whether the use of navigation channels and shallow/shoal areas by winter flounder is consistent over time. As a result, the 2001-2002 Aquatic Biological Sampling Program was conducted to meet this need for additional data.

The 2001-2002 Aquatic Biological Sampling Program provided additional support to the findings of the Supplemental Sampling Program (2000-2001) that winter flounder disperse throughout the Hudson-Raritan Estuary after hatching within the primary spawning areas in the Lower New York Bay. After hatching, winter flounder larvae move from the Lower Bay into the Upper Harbor. These movement patterns may be important to winter flounder population dynamics as larvae that move directly to the ocean without using the nursery habitat may be lost to the population, as they are unlikely to survive in the open ocean due to lack of nursery habitat and predation (Chant et al. 2000; Curran and Able 2002).

Although there is some indication from the 2000-2001 and 2001-2002 sampling programs, and to a lesser extent from the 1998-1999 program, that winter flounder in the Hudson-Raritan Estuary exhibit these movement patterns, more data are required to determine if this pattern is consistent among years. As a result, additional sampling was conducted during 2002-2003 and 2004 to expand the temporal coverage of the Biological Monitoring Program Database, especially with respect to the Lower Bay. To allow for direct comparisons among years, the sample objectives in the 2002-2003 and 2004 Aquatic Biological Sampling Programs remained the same as the 2001-2002 Aquatic Biological Sampling Program.

1.2 STUDY OBJECTIVES

During the 2004 Aquatic Biological Sampling Program data were collected on adult and early life stages of finfish in the Harbor with an emphasis on winter flounder – sampling was conducted during the period when winter flounder spawning and early lifestages occur in the Harbor. The specific objectives were to:

- Determine the utilization and significance of Harbor areas for adult winter flounder and other Essential Fish Habitat (EFH) species for the months of January through July.
- Determine the utilization and significance of Harbor areas for early life stages (eggs and larvae) of winter flounder and other EFH species from January through July.

To meet program objectives, two sampling methodologies were employed. Bottom trawling was conducted to address the objectives related to adult finfish, and an epibenthic sled-mounted plankton net was used to target early life stages.

1.3 REPORT ORGANIZATION

The remainder of this report, which describes the 2004 Aquatic Biological Sampling Program methodology and presents results, is organized as follows: Section 2 describes sampling stations and summarizes the sampling methods used; Section 3 presents the results of bottom-trawl and epibenthic-sled sampling; and Section 4 discusses how the data collected relate to 2004 program objectives and compare to previous years of the NYNJHDP.

2.0 METHODS

2.1 SAMPLING LOCATIONS

The same 26 locations sampled during the 2001–2002 and 2002-2003 Aquatic Biological Sampling Programs were sampled during 2004 (Table 2-1). Of these 26 stations, 14 were located in shallow/shoal or interpier areas, and 12 were located in navigation channels.

For data analysis purposes in this and the two previous Biological Sampling Programs, the Harbor was divided into three study areas based on geography: Arthur Kill/Newark Bay, Upper New York Bay, and Lower New York Bay (Figure 2-1). The 26 stations were distributed as follows among the three areas:

- Arthur Kill and Newark Bay
  Nine stations were located in this area. Of these, two were in Arthur Kill shallow/shoal areas (AK-1 and AK-4) and two were in channels at the Arthur Kill/Kill Van Kull confluence area (AK-2 and AK-3). Two other stations were located in the navigation channel in Newark Bay (NB-5, and NB-6), while the shallow/shoal areas were represented by three Arthur Kill/Newark Bay stations: NB-3, NB-4, and NB-7.

- Upper New York Bay ("Upper Bay")
  In the Upper Bay, which includes South Brooklyn (SB) and Port Jersey (PJ), 11 stations were sampled. Two were in the South Brooklyn interpier areas (shallow/shoal area stations SB-1 and SB-2) and one was on the Bay Ridge Flats (SB-3). Three stations were located in navigation channels—one in Bay Ridge Channel (SB-4) and two in the Anchorage Channel (SB-5 and SB-6). Three shallow/shoal area stations were located in Port Jersey (PJ-l, PJ-2, and PJ-3) and two were located in Port Jersey Channel (PJ-4 and PJ-5).

- Lower New York Bay ("Lower Bay")

  Six stations were located in this area—three in channels (LB-2, LB-4, and LB-6) and three in shallow/shoal areas (LB-1, LB-3, and LB-5). The Lower Bay sites were added in the 2001–2002 Biological Sampling Program to provide better spatial coverage for the evaluation of winter flounder and other EFH species in the Harbor.

2.2 ADULT FINFISH SAMPLING (BOTTOM TRAWLS)

Adult finfish were sampled via a single valid bottom trawl in bi-weekly surveys conducted from 18 January through 18 June 2004. Trawls were conducted on a stratified schedule bracketing the period when adult winter flounder historically are present in the Harbor to spawn. The 26 sampling stations were sampled twice monthly during February and March and once monthly during January and April through June.

Bottom trawl surveys were conducted using a 30-foot (9.1 m) otter trawl (Table 2-2), the same trawl used during previous years of the NYNJHN Study. A minimum ratio of tow cable length to maximum station water depth of 5:1 was maintained to ensure that the trawl was in contact with the bottom.

Bottom trawls were conducted during the night hours (from one hour after sunset to one hour before sunrise) against the prevailing current at a bottom speed of approximately 5.0 ft/sec (150 cm/sec). Target tow duration was ten minutes, although tow times were adjusted as needed to account for obstructions, limited interpier distances, commercial traffic, and several other factors.

A total of 201 bottom trawls where conducted —96 at navigation channel stations and 105 at shallow/shoal/interpier stations.

All fish were identified and enumerated on the research vessel immediately following collection. Total length of each winter flounder caught was recorded to the nearest millimeter (mm). When available, up to a total of 10 winter flounder per trawl that measured greater than 250 mm were preserved on ice and returned to the laboratory for sex determination. A 250-mm total length was established to limit the number of immature fish kept for analysis. Winter flounder typically exhibit adult gonad development at 250 mm total length and reach sexual maturity between 280 mm and 300 mm (Witherell 1993).

For all other species collected, total length was measured for a minimum of 25 individuals in each trawl sample. An unbiased selection of 25 specimens was made for non-target species when the number of fish collected exceeded 25. Except for winter flounder preserved for laboratory analysis, all fish collected were released after on-board examination.

2.3 ICHTHYOPLANKTON SAMPLING (EPIBENTHIC SLED TOWS)

Ichthyoplankton sampling was conducted from 18 January to 2 July 2004. The 26 stations were sampled twice monthly from February through June and once monthly during January and July.

Samples were collected with an epibenthic sled-mounted 0.5-m mouth diameter plankton net with 0.5-mm mesh (Table 2-3). Typically, a 4:1 ratio of cable length to station depth was used and an inclinometer was used to determine the warp angle from the boat to confirm that the sled was on the bottom. The net was fitted with a General Oceanics flowmeter (Model 2030R) to calculate sample volume.

All samples were collected during daylight hours (from one hour after sunrise to one hour before sunset). Whenever possible, each tow was conducted against the prevailing current or tide for ten minutes. Tow direction and duration were adjusted as needed to account for obstructions, limited transect distances and commercial traffic.

A total of 309 epibenthic sled tows were conducted—143 at navigation channel stations and 166 at shallow/shoal stations. Each sample was washed from the plankton net into containers and preserved with 5% buffered formalin containing the vital stain rose bengal. Samples were returned to the laboratory for sorting and identification.

All specimens were identified to the lowest taxonomic level practicable, assigned a life stage based on morphometric characteristics (egg, yolk-sack larvae, post yolk-sac larvae, or juvenile) and enumerated. Eggs and larvae that could not be identified to species were recorded as unidentified species. For some larvae, it was not possible to discern between yolk-sac and post yolk-sac life stages because specimens were damaged. Indiscernible larval life stages were combined with the yolk-sac larvae life stage during analysis.

Strict quality control procedures consisting of a continuous sampling plan to assure an average outgoing quality limit (AOQL) of ≥ 90% were followed during sample sorting, enumeration, life-stage designation, and identification.

2.4 WATER QUALITY MEASUREMENTS

Dissolved oxygen (DO), temperature, conductivity, and salinity were measured after each trawl and epibenthic sled tow (Table 2-4). Water quality parameters were recorded one foot (0.3 m) above the substrate using calibrated meters (YSI Model 85 Handheld Oxygen, Conductivity, Salinity and Temperature System).

2.5 DATA ANALYSIS

The names of all species identified to the lowest possible taxonomic level in both trawl and ichthyoplankton sampling are listed in Table 2-5 at the end of the report.

2.5.1 Trawl

Catch per unit effort (CPUE), defined as number of fishes per 10 minute trawl tow, was determined for each trawl tow based on the time each net sampled on the bottom. Catches were standardized to a 10-minute tow when tow times were less than 10 minutes. Standardization was performed by dividing 10 by the actual number of tow minutes

$$CPUE = Nx\frac{10}{T}$$

Where:

N equals the number of fishes collected during the tow.

T equals the actual tow time expressed in minutes.

2.5.2 Ichthyoplankton

Ichthyoplankton densities (number per 1000 cubic meters [number / 1000 m^3]) were determined for each epibenthic sled tow. The volume of water sampled was determined using the area of the net mouth and flowmeter revolutions recorded during each tow.

3.0 RESULTS

Adult finfish and ichthyoplankton data were analyzed for the two general habitat types (navigation channels and shallow/shoal areas) and the three Harbor areas (Arthur Kill/Newark Bay, Upper Bay, and Lower Bay). Following is a summary of results for all species combined and for winter flounder. Detailed station data for adult finfish, ichthyoplankton, and water quality are provided in Appendices A through C, respectively.

Note that the following data-unit definitions apply in the figures accompanying the main report text and in Appendices A and B:

- Trawl: Catch per unit effort (CPUE), defined as number caught per 10 minute trawl tow.
- Epibenthic sled tow: Ichthyoplankton density (number per 1000 cubic meters).

3.1 FINFISH

3.1.1 Adults (Trawl Sampling)

A total of 35 fish species were collected during the 2004 bottom trawl survey (Table 2-5). Thirty-one (31) species were collected from the channel stations (Table 3-1a) and 34 species were collected from the shallow/shoal stations (Table 3-1b). Tables 3-1a and 3-1b report average trawl CPUEs by species for all navigation channel stations combined and for all shallow/shoal stations combined for each month sampled (January-June) during 2004, respectively.

Bay anchovy, striped bass, white perch and Atlantic tomcod were the most abundant species collected in the Harbor during the 2004 sampling program. Overall, the total annual catch in the Harbor was similar among the shallow/shoal stations and the navigation channel stations; however species composition differed among station type.

When considering only the navigation channel stations, striped bass, white perch and blueback herring, respectively, were the most abundant species (Table 3-1a). At shallow/shoal stations bay anchovy was the most abundant species collected, with most of the individuals collected in June. Atlantic tomcod, alewife and striped bass were also abundant in the shallow/shoal stations throughout the Harbor (Table 3-1b).

When considering both shallow/shoal stations and navigation channel stations, greater numbers of fish were collected during the spring than during the winter in all of the sampling areas. The greatest collections occurred in June, and the smallest number of fish was collected during February. However, when considering only the navigation channel stations, more fish were collected during the winter months (January through March) than during the spring (Figure 3-1). The monthly average CPUE for the navigation channel stations ranged from 49 to 96 fish per 10-minute tow during the winter months, and from 20 to 39 fish per tow between April and June (Table 3-1a). The greatest numbers of fish were collected from the shallow/shoal stations during the spring (April through June), when the average monthly CPUE ranged between 65 and 135 fish per tow. Very few fish were collected from the shallow/shoal stations during the winter months. The monthly average CPUE for the shallow stations ranged from 9 to 11 fish per 10-minute tow for the months of January through March (Table 3-1b).

Species distribution varied among season and among station type (i.e. shallow/shoal vs. navigation channel stations). During the winter months (January through March), striped bass, white perch and winter flounder dominated the collections. This is the case for all stations combined, and for the shallow/shoal stations and the navigation channel stations considered separately (Tables 3-1a and 3-1b). Bay anchovy, Atlantic tomcod and alewife dominated the collections between April and June when all stations are combined, and when considering only the shallow/shoal stations (Tables 3-1a and 3-1b). However, when considering only the navigation channel stations, bay anchovy, spotted hake and blueback herring were the most abundant species collected during the spring. Few alewives were collected from the channel stations in the spring.

3.1.1.1 Arthur Kill/Newark Bay

A total of 26 species were collected from the Arthur Kill/Newark Bay sampling area, with 23 species collected from the navigation channel stations and 21 collected from the shallow/shoal stations. Catches were most diverse in April when 16 species were collected from the channel stations and 11 species were collected from the shallow/shoal stations (Table 3-2a).

Overall, the total annual catch in the Arthur Kill/Newark Bay sampling area was similar among the shallow/shoal stations and the navigation channel stations; however species composition differed among station type (Table 3-2a). White perch and striped bass were the most abundant species in the navigation channel stations, accounting for 36% and 33% of the total annual catch in these stations, respectively. Bay anchovy, alewife and white perch were the most abundant species in the shallow/shoal stations, making up 40%, 16% and 14% of the annual catch, respectively.

Of all the sampling areas, the greatest fish abundance occurred in the Arthur Kill/Newark Bay, with peak catches occurring in March (Figure 3-1). In general, finfish abundance in the Arthur Kill/Newark Bay sampling area was highest between January and March in the navigation channel stations and between April and June in the shallow/shoal stations (Tables 3-2a and 3-2b). The monthly average CPUE in the navigation channels ranged from 76 to 248 fish per 10-minute tow between January and March, with the peak abundance occurring in March (Table 3-2a). In the shallow/shoal stations abundance was greatest between April and June when the monthly average CPUE ranged from 97 to 207 fish per tow, with peak collections in June (Table 3-2b).

Figure 3-2 presents the monthly species composition for the Arthur Kill/Newark Bay sampling area. Striped bass and white perch were the most abundant species collected from the Arthur Kill/Newark Bay sampling area, with peak collections occurring in the winter when they accounted for 78% to 85% of the fish collected. Alewife was the most abundant species collected in April, accounting for 32% of the catch. Atlantic herring accounted for 48% of May collections, and June collections were dominated by bay anchovy which made up 95% of the catch.

3.1.1.2 Upper Bay

A total of 27 species were collected from the Upper Bay sampling area, with 20 species collected from the navigation channel stations and 26 collected from the shallow/shoal stations (Table 3-3a).

Striped bass, winter flounder and blueback herring were the most abundant species collected during the winter in the Upper Bay sampling area (Figure 3-3). Striped bass and winter flounder were collected from both navigation and shallow/shoal stations, and blueback herring was collected mainly from the shallow/shoal stations (Tables 3-3a and 3-3b). Peak collections occurred in May and June, when Atlantic tomcod and bay anchovy dominated the catch. These species made up 84% of May collections and 97% of June collections (Figure 3-3). While bay anchovy was collected from both channel and shallow/shoal stations, Atlantic tomcod was mainly collected from shallow/shoal stations (Tables 3-3a and 3-3b).

3.1.1.3 Lower Bay

Collections from the Lower Bay sampling area were the lowest in diversity and abundance when compared to the other sampling areas. A total of 23 species were collected from the Lower Bay, with 20 species collected from the navigation channel stations and 18 collected from the shallow/shoal stations (Table 3-4a). Peak collections occurred in January, and most of the fish were collected from the channel stations (Figure 3-1).

Atlantic herring and bay anchovy were the most abundant species in the Lower Bay. Atlantic herring was collected only from navigation channels, and only in January when they accounted for 62% of the total catch (Tables 3-4a and 3-4b). Bay anchovy was collected during May and June, accounting for 53% and 90% of the collections, respectively (Figure 3-4). Although collected from both station types, bay anchovy were more abundant in the navigation channels (Tables 3-4a and 3-4b).

3.1.2 Ichthyoplankton (Epibenthic Sled Sampling)

Among the eggs, larvae, and juveniles collected throughout the 2004 Aquatic Biological Sampling Program, 34 species were identified. Fish eggs were the most abundant ichthyoplankton life stage collected during the sampling program, followed by post yolk-sac larvae. The highest egg densities were collected in the Arthur Kill/Newark Bay at shallow/shoal stations, and the highest post yolk-sac larvae densities were collected in the Lower Bay at navigation channel stations. Regardless of station depth, the greatest ichthyoplankton densities were recorded during June and July in all three study areas. (Tables 3-3a through 3-3f).

3.1.2.1 Eggs

The highest egg densities (all species included) were collected throughout the Harbor during June and July – predominantly bay anchovy. The greatest weekly egg densities (85,241/1000 m^3) were collected at the Lower Bay navigation channel stations during this period, i.e. early-June (Figure 3-5). No eggs were collected during January in the Arthur Kill/Newark Bay, during January and February in the Upper Bay and during February in the Lower Bay (Figures 3-6 through 3-8), but were present through after March. Egg densities were typically higher in the Lower Bay and Upper Bay navigation channel stations than in the Lower Bay and Upper Bay shallow/shoal stations. Whereas egg densities were greater at Arthur Kill/Newark Bay shallow/shoal stations than in the Arthur Kill/Newark Bay navigation channel stations.

With exception to the Lower Bay where winter flounder dominated the catch, winter flounder was the only species collected as eggs prior to April, regardless of Harbor area. Weakfish dominated catches during April throughout the Harbor and Atlantic menhaden was the dominant species during May, especially in the Upper Bay and Lower Bay. Labridae was the most dominant family collected during May in the Arthur Kill/Newark Bay. Bay anchovy was the most common species collected as eggs in the later months of the program ranging from 40%-52% of the catch.

3.1.2.2 Yolk-sac Larvae

Yolk-sac larvae were collected in the Harbor throughout the sampling program and ranged in density (all species included) from 0.9/1000 m^3 to 66/1000 m^3 (Figure 3-9). The highest average yolk-sac larvae density (66/1000 m^3) was observed at shallow/shoal stations in the Upper Bay during early June. Peaks in yolk-sac larvae abundance in the Arthur Kill/Newark Bay occurred at navigation channel stations and at shallow/shoal stations in the Lower Bay during late March.

Yolk-sac larvae were not collected during January, except for one American sandlance collected in the Lower Bay (Figures 3-10 through 3-12). During February, three species (grubby, winter flounder and American sandlance) were collected in the Arthur Kill/Newark Bay, winter flounder was the only species collected in the Upper Bay and American sandlance was the only species collected in the Lower Bay. Grubby dominated catches throughout the Harbor during March and in the Arthur Kill/Newark Bay during April. Winter flounder was the dominant species in April catches in the Upper and Lower Bay. No yolk-sac larvae were collected during May in the Arthur Kill/Newark Bay and the Lower Bay, and one winter flounder was collected in the Upper Bay. During June, Atlantic silverside was the only species collected in the Arthur Kill/Newark Bay, Atlantic menhaden dominated the catch in the Upper Bay and no yolk-sac larvae were collected in the Lower Bay. One Gobiid species was collected during July in the Upper Bay and no other yolk-sac larvae were collected throughout the Harbor during July.

3.1.2.3 Post Yolk-sac Larvae

Post yolk-sac larvae (all species included) were collected in each of the three areas of the harbor during the entire 2004 sampling program. The highest post yolk-sac larvae densities were collected during June and July – predominantly bay anchovy. Post yolk-sac larvae densities were relatively low (<500/1000 m^3) from January through March (Figure 3-13). Densities increased throughout the Harbor, especially in the Lower Bay, during late March and early April. After a slight decrease in densities in post yolk-sac larvae during May (<660/1000 m^3), densities increased again by early June. Although, post yolk-sac larvae densities fluctuated, the highest densities were recorded in the Lower Bay (8742/1000 m³) the Arthur Kill/Newark Bay (1829/1000 m³) and the Upper Bay (5869/1000 m³) during June and July.

Post yolk-sac larvae were the most species-rich lifestage (20 species) collected during the 2004 ichthyoplankton sampling. Few species were collected during January - Atlantic croaker was the only species collected in the Arthur Kill/Newark Bay and Lower Bay and one summer flounder was collected in the Upper Bay (Figures 3-14 through 3-16). Species diversity increased from January to February with the occurrence of winter flounder, American sandlance, rock gunnel, Atlantic tomcod and grubby. The highest post yolk-sac larvae densities were collected throughout the Harbor during June and July – predominantly bay anchovy. Winter flounder (34%) dominating February catches in the Arthur Kill/Newark Bay and rock gunnel dominated catches in the Upper and Lower Bay (38% and 56%, respectively). During March, grubby dominated catches in the Arthur Kill/Newark Bay (58%) and the Lower Bay (82%). Winter flounder dominated the catch during March in the Upper Bay and throughout the Harbor (>73% of the catch) during April and May. Species composition shifted from May to June with bay anchovy dominating the catches throughout the Harbor during June and in the Upper and Lower Bay during July.

3.1.2.4 Juveniles

Juveniles represented the lowest densities of all the life stages collected. Average weekly juvenile density of all species combined ranged up to a peak of 12.5/1000 m³ during the week of 26 April in the channels of the Lower Bay (Figure 3-17). In general, juveniles were more common at navigation channel stations, particularly in the Lower Bay where no juveniles were collected at shallow/shoal stations (Figure 3-17).

Species composition of juveniles in each of the three Harbor areas is shown in Figures 3-18 through 3-20. No juveniles were collected throughout the Harbor during January and February. Only one juvenile was collected in March samples (a windowpane flounder in the Lower Bay). Grubby dominated juvenile densities during April throughout the

Harbor; in the Upper and Lower Bay, grubby (80% and 83%, respectively) and winter flounder (20% and 17%, respectively) were the only species collected, while grubby (52%), winter flounder (26%) and Atlantic herring (22%) juveniles were collected in the Arthur Kill/Newark Bay. Three Atlantic tomcod were collected during May in the Arthur Kill/Newark Bay while no juveniles were collected in either the Upper or Lower Bays. No juveniles were collected during June, except in the Lower Bay where one northern pipefish juvenile was reported. No juveniles were collected in the Arthur Kill/Newark Bay during July. July catch in the Upper Bay was represented by three species: northern pipefish (72%), *Prionotus* spp. (14%) and butterfish (14%). Grubby (83%) and winter flounder (17%) were the only two species reported in the Lower Bay during July.

3.2 WINTER FLOUNDER

3.2.1 Adults (Trawl Sampling)

3.2.1.1 Catch Per Unit Effort (CPUE)

Winter flounder were collected in trawls at shallow/shoal stations during all sampling months (January to June) in each of the three Harbor areas (Table 3-2a to 3-2c). At navigation channel stations, winter flounder were also collected during every month of sampling in the Arthur Kill/Newark Bay, but only during January through March and in June in the Upper Bay, and January through March in the Lower Bay. The highest monthly average winter flounder CPUE (17) was recorded during January at navigation channel stations in the Upper Bay. Overall winter flounder CPUEs were higher at navigation channel stations in the Arthur Kill/Newark Bay and Upper Bay, while CPUEs were similar among the shallow/shoal stations in all three Harbor areas and navigation channel stations in the Lower Bay. When CPUE data were analyzed temporally (by sampling week), there is some indication that winter flounder transition from deep-water to shallow-water habitats over the January to June sampling period, particularly in the Arthur Kill/Newark Bay and Upper Bay. (Figure 3-21).

3.2.1.2 Size Distribution

A total of 612 winter flounder were collected during 2004 and all were measured for total length. Lengths ranged from 9 to 371 mm, with the majority of fish measuring between 60 to 160 mm (Figure 3-22).

In the three Harbor areas, most winter flounder were collected from January to April while few were collected during May and June (Figures 3-23 through 25). Most winter flounder collected in the Upper Bay were typically less than 160 mm. Larger individuals (greater than 160 mm) were more abundant during January, March and April in the Upper Bay. In the Lower Bay, most winter flounder were collected during February and March, and were typically less than 140 mm. The few winter flounder greater than 140 mm in the Lower Bay were collected during April.

3.2.2 Ichthyoplankton (Epibenthic Sled Sampling)

Winter flounder eggs, yolk-sac and post yolk-sac larvae were collected throughout the Harbor during the 2004 sampling (Figure 3-27). A majority of the ichthyoplankton (all life stages combined) were collected from the Lower Bay (68%), followed by the Upper Bay (19%) and then the Arthur Kill/Newark Bay (13%). Most of the winter flounder eggs were collected in the Lower Bay (90%), followed by the Arthur Kill/Newark Bay (6%). Yolk-sac larvae were collected mostly in the Upper Bay (75%), then the Lower Bay (19%). Post yolk-sac larvae and juveniles distribution patterns were similar, with most occurring in the Lower Bay (68% and 41%, respectively), followed by the Upper Bay (19% and 31%, respectively). Post yolk-sac larvae were the most common life stage collected (99.12%), followed by yolk-sac larvae (0.43%), eggs (0.42%) and then juveniles (0.03%).

Winter flounder eggs were collected in the Harbor from late January through mid-April (Figure 3-28). Peak egg densities (16.7/1000 m^3) were collected in late March at the Lower Bay navigation channel stations; high egg densities were also collected at both navigation channel and shallow/shoal stations in the Lower Bay during mid March and mid April. In the Upper Bay, winter flounder eggs were only collected at the navigation channel stations during mid March.

Winter flounder yolk-sac larvae densities were greatest in the Upper Bay, where a peak density of nearly 40/1000 m^3 was observed at the navigation channel stations during mid April (Figure 3-29). Yolk-sac larvae were collected in the lowest densities in the Arthur Kill/Newark Bay area. In general, yolk-sac larvae were collected sporadically throughout the Harbor with the highest densities occurring in the Upper Bay, followed by the Lower Bay, during April.

As mentioned earlier, post yolk-sac larvae were the most abundant winter flounder life stage in ichthyoplankton collections. This larval life stage was collected in the Harbor mostly from mid-March to mid-May (Figure 3-30). Densities were highest in the Lower Bay, where the peak densities occurred at shallow/shoal stations during mid April (3,219.5/1000 m^3) and late April (3,100.1/1000 m^3). High post-yolk sac larvae densities also occurred in the Lower Bay at navigation channel stations during mid April (1,998.5/1000 m^3) and late April (1,786.7/1000 m^3). Post yolk-sac larvae densities were similar to each other in the Arthur Kill/Newark Bay and Upper Bay. The highest post yolk-sac larvae densities in the Arthur Kill/Newark Bay (1,301.8/1000 m^3) and the Upper Bay (1,212.7/1000 m^3) were reported at navigation channel stations during late April.

Winter flounder juveniles were collected during late April at navigation channel stations in the Upper Bay and Lower Bay, and at shallow/shoal stations in the Arthur Kill/Newark Bay (Figure 3-31). Winter flounder juveniles comprised 0.03% of the total winter flounder catch during the 2004 sampling program and average weekly densities ranged from 1.3/1000 m^3 (Arthur Kill/Newark Bay) to 2.2/1000 m^3 (Lower Bay).

3.3.3 Comparison with Previous Years

In this section, comparisons are made between the winter flounder CPUE and density data presented above and data from the 2001-2002 and 2002-2003 Biological Monitoring

Programs (USACE 2002, USACE 2003) to identify trends across years. Direct comparisons were made by month since the three sampling programs were conducted during the same time of year at the same sampling stations using the same gear.

Winter flounder CPUE was generally lower during 2002-2003 than in 2001-2002 and in 2004 (Figure 3-32). This was especially true in the Arthur Kill/Newark Bay and Lower Bay areas. The highest abundance of winter flounder in the Arthur Kill/Newark Bay occurred during June 2001-2002. This catch was dominated by small (<90 mm), likely young-of-year fish (Figure 3-33). Winter flounder were collected in greatest abundance in the Upper Bay during January 2004 and the catch was dominated by small fish mostly between 60 mm and 120 mm total length, representing young-of-year (Figure 3-34). During the three program years, the winter flounder that are expected to be sexually mature (>250 mm) were collected throughout the Harbor from January through May (Figure 3-33 to 3-35). The majority of these sexually mature fish were collected in the Upper Bay and Lower Bay.

Egg densities were greater throughout the Harbor in 2002-2003 than in the 2001-2002 and 2004 sampling programs, especially in the Upper Bay and Lower Bay (Figure 3-36). In all three program years, few eggs were collected in the Arthur Kill/Newark Bay, while the highest egg densities occurred during February and March in the Lower Bay and during March in the Upper Bay.

Larval densities (yolk-sac and post yolk-sac combined) in April were generally greater in 2004 than in 2001-2002 and 2002-2003 sampling programs in all three areas, while densities in May were greater during 2002-2003 (Figure 3-37). In 2001-2002 and then again in 2004, larvae were first collected in February and March, whereas larvae were generally not collected until April in 2002-2003. The highest larval densities collected during all three program years were in the Lower Bay.

3.3 WATER QUALITY

During 2004 water quality sampling, average near bottom water temperatures in the Harbor ranged from a low of 0.4°C in the Arthur Kill/Newark Bay during January to a high of 22.7°C during July also in the Arthur Kill/Newark Bay (Figure 3-38). At the onset of the winter flounder spawning period in February, water temperatures were similar throughout the three areas of the Harbor. During the peak spawning period in March, warmer temperatures (5.6°C) were measured at the Arthur Kill/Newark Bay than in the Upper Bay and Lower Bay.

Salinity recorded from near bottom depth during ichthyoplankton surveys ranged between 17.7 ppt and 27.9 ppt over the course of the program (Figure 3-38). Salinities were consistently lowest in the Arthur Kill/Newark Bay and highest in the Lower Bay throughout the 2004 sampling season.

Dissolved oxygen concentration in water is largely dependent on water temperature, and to a lesser degree, salinity. As temperature increases, the amount of oxygen capable of being held in solution decreases. Similarly, as salinity increases, the amount of oxygen that can be held in solution decreases. Trends in dissolved oxygen levels were similar across the three Harbor areas, remaining between 10.6 mg/L and 11.6 mg/L from January through March and decreasing throughout the program to between 5.7 mg/L and 6.3 mg/L during July (Figure 3-38). From May through July, dissolved oxygen levels were inversely proportional to temperatures throughout the Harbor, that is, when temperatures were highest in the Arthur Kill/Newark Bay and lowest in the Lower Bay, then dissolved oxygen levels were low in the Arthur Kill/Newark Bay and highest in the Lower Bay.

All water quality sampling data are presented in Appendix C.

4.0 DISCUSSION

The water quality and habitat characteristics of the areas sampled may affect the spatial and temporal occurrence of finfish in the Harbor, particularly winter flounder. As previously demonstrated the Lower Bay is more characteristic of the marine/oceanic environment (i.e., this area exhibits the least variability suggesting a more stable environment) than the Arthur Kill/Newark Bay and the Upper Bay while the Arthur Kill/Newark Bay and Upper Bay areas are more characteristic of a nearshore, estuarine environment (USACE 2002). Based on the water quality data it appears that the Upper Bay may be more ocean-like than the Arthur Kill/Newark Bay by virtue of the relatively broad connection between Lower Bay and Upper Bay through The Narrows. As identified in previous reports (USACE 2002, USACE 2003) the predominance of fine bottom sediments in the Arthur Kill/Newark Bay area suggests that there is limited tidal exchange resulting in a depositional area with a greater potential for high biological, chemical, and sediment oxygen demand.

4.1 ALL SPECIES

The finfish composition collected in the 2004 sampling program is typical of Atlantic seaboard estuaries and consistent with the species composition observed in previous years of the project. Composition of dominant species shifted slightly between the 2003 and the 2004 programs with striped bass replacing white perch and spotted hake as dominant species. Bay anchovy remained the most dominant species collected, while white perch, Atlantic herring and Atlantic tomcod were also collected in notable numbers throughout the Harbor. These species are common in estuaries and known to rely on the Harbor for spawning, nursery and foraging habitat (Able and Fahay 1998).

Many species spawn in the harbor seasonally, while others spawn offshore on the continental shelf or in the Harbor tributaries. This seasonality and preference for different spawning habitat influenced the occurrence and relative density of species collected during the sampling program. Species that spawn in the Harbor, such as bay anchovy, windowpane flounder, and winter flounder, were present in higher densities during their seasonal spawning periods.

4.2 WINTER FLOUNDER

The occurrence of adult winter flounder during the peak spawning period and the subsequent occurrence of eggs and larvae were used to identify where and when winter flounder are spawning in the Harbor. Because winter flounder produce demersal eggs that adhere to the substrate it is assumed that the location in which the eggs are collected is primary spawning habitat.

Adult winter flounder were most common in the Arthur Kill/Newark Bay and Upper Bay during January to March. In the NJ, NY, CT, RI waters, winter flounder spawn from late January to early April at temperatures of 1 to 10 °C and salinities of 10 to 35 ppt (Scarlett and Allen 1992, Pearcy 1962, Crawford and Carey 1985). In the NY/NJ Harbor area, peak spawning occurs from February to March (Able and Fahay 1998, Stoner et. al 1999) with optimum temperatures generally ranging from 3 to 8 °C and salinities from15 to 25 ppt. The incubation period to hatching varies with temperature and reports range from 11 to 63 days at 8 to 1.8 °C, respectively. Adults are believed to reach maturity in 2 to 3 years at 200 to 250 mm (Witherell and Burnett 1993) and spawn in shallow and conservative hydrodynamic areas of estuaries to retain larvae in spawning and nursery habitat (Pearcy 1962, Crawford and Carey 1985). In previous program years more spawning size (>250 mm) adults were collected in the Lower Bay than the other areas of the Harbor. Although winter flounder adults were collected in both the shallow/shoals and navigation channel habitats, adults were more abundant at navigation channel habitats, especially from January through March in the Arthur Kill/Newark Bay and Upper Bay. No consistent pattern in a depth preference of winter flounder adults has been identified in the NYNJHN Studies (USACE 1999 USACE 2003) or the NYNJHD Project (USACE 2004). There is little indication that winter flounder spawn in the channels, during the expected peak of the spawning season (late February to mid March for the Harbor area), few WFL 250 mm in total length or larger are collected prior to late March or April (Reference & Data - Figures 3.23-25). Channels are likely the primary migration route for adult winter flounder moving to and from spawning areas. (The presence of winter flounder in early life stages (eggs and yolk-sac larvae) suggest some spawning had occurred near the channel stations, however this may not be the case as bottom disturbance caused by traffic in some areas which in combination with strong currents may result in the displacement and transport of eggs and yolk sac larvae from adjacent non-channel areas to areas where spawning may not have occurred.)

Sampling conducted as part of NYNJHN Study 2001-2004 has consistently demonstrated the importance of the Lower Bay of New York/New Jersey Harbor to winter flounder. The predominance of winter flounder eggs in the Lower Bay during the peak spawning period (i.e. February to March) coupled with the relatively high densities of post yolk-sac larvae supports that the Lower Bay provides important winter flounder spawning habitat. Although, winter flounder spawning does occur in the Upper Bay and Arthur Kill/Newark Bay areas of the Harbor, the intensity is notably less than in the Lower Bay and is potentially the result of less preferential habitat (e.g. water quality and sediment quality) in these areas.

The previous sampling programs have identified that young winter flounder move from the primary spawning area in the Lower Bay and the lower reaches of the Upper Bay to areas further into the Harbor estuary (USACE 2001, USACE 2002, USACE 2003) based on the increase in winter flounder juveniles collected in the Arthur Kill/Newark Bay during June. This pattern of juvenile migration into the estuary was not evident in the results of the 2004 trawl program, suggesting that the relatively high densities of post yolk-sac larvae collected in 2004 as compared to previous program years did not result in a strong year class of early summer juveniles.

As demonstrated in previous program years (USACE 2003; USACE 2004), the spatial and temporal trends observed in winter flounder occurrence as adults, eggs and larvae during the 2004 sampling program further supports that winter flounder use the different

Harbor areas for different stages of their life history. These sampling programs have consistently demonstrated the importance of the Lower Bay for winter flounder spawning and the Arthur Kill/Newark Bay and Upper Bay as nursery habitat.

5.0 LITERATURE CITED

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Table 2-1 Description of stations sampled during the 1999–2004 Aquatic Biological Sampling Programs.

Area	Station Name	Type	Station Location	Average Depth (ft)	GPS Coordinates (deg., min., sec.)			
					Start		End	
					North	West	North	West
South Brooklyn/ Upper Bay	SB–1*	Shallow/shoal	Gowanus Bay Interpier South	27	40:39.45	74:00.86	40:39.56	74:01.05
	SB–2 **	Shallow/shoal	Gowanus Bay Interpier	30	40:39.60	74:00.48	40:39.75	74:00.75
	SB–3*	Shallow/shoal	Bay Ridge Flats	22	40:39.36	74:02.26	40:38.91	74:02.36
	SB–4 **	Navigation Channel	Bay Ridge Channel	42	40:39.28	74:01.52	40:38.98	74:01.79
	SB–5*	Navigation Channel	Anchorage Channel Middle	57	40:39.53	74:03.30	40:39.69	74:03.19
	SB–6 **	Navigation Channel	Anchorage Channel South	49	40:38.76	74:03.11	40:38.48	74:02.98
Port Jersey	PJ–1 **	Shallow/shoal	Jersey Flats	12	40:39.91	74:03.57	40:40.17	74:03.45
	PJ–2*	Shallow/shoal	Caven Point	10	40:40.62	74:03.44	40:41.02	74:03.35
	PJ–3 **	Shallow/shoal	Constable Hook	13	40:39.75	74:04.75	40:39.53	74:04.19
	PJ–4 **	Navigation Channel	Port Jersey Channel	39	40:39.91	74:04.11	40:40.07	74:04.51
	PJ–5*	Navigation Channel	Port Jersey Channel East	42	40:39.48	74:03.64	40:39.78	74:03.96
Newark Bay	NB–3*	Shallow/shoal	Newark Bay Flats Middle	10	40:41.06	74:07.61	40:41.40	74:07.44
	NB–4*	Shallow/shoal	Newark Bay Flats South	16	40:40.72	74:07.76	40:40.38	74:07.92
	NB–5 **	Navigation Channel	Newark Bay Middle Reach	42	40:40.59	74:07.96	40:40.19	74:08.26
	NB–6 **	Navigation Channel	Newark Bay South Reach	46	40:39.44	74:08.52	40:39.15	74:08.75
	NB–7*	Shallow/shoal	Elizabeth Flats North	13	40:39.62	74:09.29	40:39.51	74:08.99
Lower Bay	LB–1	Shallow/shoal	East Bank	13	40:33.45	74:00.24	40:33.94	74:00.52
	LB–2	Navigation Channel	North End Ambrose Channel	50	40:33.23	74:01.54	40:33.40	74:01.55
	LB–3	Shallow/shoal	Swash Channel Range	17	40:33.34	74:04.46	40 33.00	74 04.44
	LB–4	Navigation Channel	Chapel Hill South Channel	30	40:31.06	74:02.41	40:30.64	74:02.39
	LB–5	Shallow/shoal	Old Orchard Shoals	13	40:30.59	74:04.72	40:30.75	74:05.22
	LB–6	Navigation Channel	Raritan Bay East Reach	41	40 29.41	74 06.39	40 29.53	74 06.90
Arthur Kill	AK-1	Shallow/shoal	Elizabeth Flats South	19	40:38.84	74:10.58	40:38.85	74:10.13
	AK-2	Navigation Channel	North of Shooter Island Reach	39	40:38.80	74:10.75	40:38.77	74:10.26
	AK-3	Navigation Channel	Elizabeth Reach	42	40:38.32	74:11.59	40:38.53	74:11.30
	AK-4	Shallow/shoal	Prall's Island	20	40:36.83	74:11.91	40:36.24	74:11.82

* Also sampled during the 2000 - 2001 Supplemental Sampling Program
** Also sampled during the NYNJHN 1998 – 1999 Baseline Program and 2000-2001 Supplemental Sampling Program

Table 2-2. Specifications of the bottom trawl used to collect adult finfish during the 2004 Aquatic Biological Sampling Program

Part	Specification
Headrope	25.9 ft. (7.9 m)
Footrope	27.9 ft (8.5 m)
Wing height	3.6 ft. (1.1 m)
Total length	35.1 ft (10.7 m)
Wing mesh (square)	2.0-in. (5.1 cm)
Body mesh (square)	2.0-in. (5.1 cm)
Cod end mesh (square)	0.75-in. (1.9 cm)
Cod end liner mesh (square)	0.25-in. (0.6 cm)
Trawl doors	32.0 x 17.0 x 1.0-in (81.3 x 43.2 x 2.5 cm)
Tow line length	5 times maximum station water depth

Table 2-3. Specifications of the epibenthic sled and plankton net used to collect early life stages of finfish during the 2004 Aquatic Biological Sampling Program.

Part	Specification
Mouth height x width	0.5 x 0.5 m
Overall length	3.0 m
Mesh size	0.5 mm
Cod-end diameter	10.1 cm
Cod-end mesh	0.5 mm (PVC cod-end bucket)
Distance from sled base	Bottom of net is 17.8 cm above the bottom of the sled runners
Epibenthic sled	Constructed of aluminum pipe

Table 2-4. Water quality measurements made during the 2004 Aquatic Biological Sampling Program.

Water Quality Parameter	Units and Accuracy	Sample Depths
Temperature	+/- 0.2	Bottom
Dissolved oxygen	+/- 0.5 mg/L	Bottom
Conductivity	+/- 100 microseimens	Bottom
Salinity	+/- 0.1 ppt	Bottom

Table 2-5. Species identified in trawl and epibenthic sled (ichthyoplankton) samples collected during the 2004 Aquatic Biological Survey Report. (page 1 of 3)

Common Name	Scientific Name	Sled	Trawl
Alewife	*Alosa pseudoharengus*		x
American eel	*Anguilla rostrata*		x
American shad	*Alosa sapidissima*		x
American sandlance	*Ammodytes americanus*	x	
Atlantic cod	*Gadus morhua*	x	
Atlantic Croaker	*Micropogonias undulatus*	x	
Atlantic Herring	*Alosa sapidissima*	x	x
Atlantic Mackerel	*Scomber scombrus*	x	
Atlantic menhaden	*Brevoortia tyrannus*	x	x
Atlantic silverside	*Menidia menidia*	x	x
Atlantic tomcod	*Microgadus tomcod*	x	x
Bay anchovy	*Anchoa mitchilli*	x	x
Blueback herring	*Alosa aestivalis*		x
Bluefish	*Pomatomus saltatrix*		x
Butterfish	*Peprilus triacanthus*	x	x
Cunner	*Tautogolabrus adspersus*	x	x
Fourbeard Rockling	*Enchelyopus cimbrius*	x	
Fourspot flounder	*Hippoglossina oblonga*	x	
Gadid spp.	*Gadid* spp.	x	
Gizzard shad	*Dorosoma cepedianum*		x
Gobiid spp.	*Gobiid* spp.	x	
Goosefish	*Lophius americanus*	x	

Table 2-5. Species identified in trawl and epibenthic sled (ichthyoplankton) samples collected during the 2004 Aquatic Biological Survey Report. (page 2 of 3)

Grubby	*Myoxocephalus aenaeus*	x	x
Labridae	*Labridae* spp.	x	
Little skate	*Raja erinacea*		x
Hogchoker	*Trinectes maculatus*	x	
Longhorn sculpin	*Myoxocephalus octodecemspinosus*	x	
Naked goby	*Gobiosoma bosc*	x	x
Northern Kingfish	*Menticirrhus saxatilis*	x	
Northern pipefish	*Syngnathus fuscus*	x	x
Northern puffer	*Sphoeroides maculatus*	x	x
Prionotus sp.	*Prionotus* sp.	x	
Red hake	*Urophycis chuss*		x
Rock gunnel	*Pholis gunnellus*	x	x
Scup	*Stenotomus chrysops*		x
Silver hake	*Merluccius bilinearis*		x
Smallmouth flounder	*Etropus microstomus*	x	x
Spotted hake	*Urophycis regia*		x
Striped bass	*Morone saxatilis*		x
Striped killifish	*Fundulus majalis*		x
Striped searobin	*Prionotus evolanis*	x	x
Summer flounder	*Paralichthys dentatus*	x	x
Tautog	*Tautoga onitis*	x	x
Threespine stickleback	*Gasterosteus aculeatus*		x
Weakfish	*Cynoscion Regalis*	x	x

Table 2-5. Species identified in trawl and epibenthic sled (ichthyoplankton) samples collected during the 2004 Aquatic Biological Survey Report. (page 3 of 3)

White perch	*Morone americana*		x
Windowpane flounder	*Scopthalmus aquosus*	x	x
Winter flounder	*Pleuronectes americanus*	x	x
Winter skate	*Raja ocellata*		x

Table 3-1a Monthly average trawl CPUE by species for all navigation channel stations combined during the 2004 Aquatic Biological Sampling Program.

Species	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04
Alewife	3.89	0.80	2.56	2.75	0.17	0.08
American Shad		0.38	2.23	0.38	0.08	
Atlantic Herring	12.51	0.04	0.04	2.18	1.08	0.08
Atlantic Menhaden	0.84					
Atlantic Silverside	0.33	0.17				
Atlantic Tomcod	1.04	0.46	2.23	1.69	6.06	0.67
Bay Anchovy				0.09	6.11	19.82
Blueback Herring	0.58	10.35	6.01	10.45	0.50	
Butterfish						0.08
Clupeid unidentified					0.42	
Cunner		0.04				
Gizzard Shad	0.42	0.04				
Grubby	0.77	0.87	0.61	0.17		
Little Skate	1.98	0.13	0.29	0.25		
Northern Pipefish		0.05		0.27	0.08	
Northern Puffer			0.04		0.08	
Red Hake	0.85	0.08	0.67	1.00	0.08	
Rock Gunnel		0.05	0.04			
Silver Hake	0.17	0.08	0.75	0.08		
Smallmouth Flounder			0.13	0.10		
Spotted Hake	0.42		0.30	12.05	4.56	0.17
Striped Bass	18.97	14.11	37.39	3.21		0.08
Striped Killifish		0.04				
Striped Searobin					0.08	
Summer Flounder				0.08		
Threespine Stickleback	0.19				0.25	
Weakfish						0.08
White Perch	13.82	15.76	35.43	2.96	0.08	
Windowpane	0.38	0.30	0.33	0.25	0.08	
Winter Flounder	9.76	5.30	7.01	0.92	0.08	0.25
Winter Skate			0.08			

Table 3-1b Monthly average trawl CPUE by species for all shallow/shoal stations combined during the 2004 Aquatic Biological Sampling Program.

Species	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04
Alewife	0.28	0.07	1.19	26.45	0.96	0.08
American Eel				0.09		
American Shad		0.04	1.01	2.57	0.36	0.92
Atlantic Herring	0.22		0.08	0.48	21.03	
Atlantic Menhaden	0.07					
Atlantic Silverside		0.21	1.19	0.19		
Atlantic Tomcod	0.07			0.24	29.42	14.69
Bay Anchovy	0.31			0.08	14.62	116.59
Blueback Herring		0.33	0.92	5.58	0.15	
Bluefish						1.08
Cunner			0.08		0.19	
Gizzard Shad	0.29					
Grubby	1.19	0.19	0.08	0.66		
Little Skate		0.30	0.08	0.23		
Mummichog		0.06				
Naked Goby		0.04				
Northern Pipefish				0.08		
Northern Puffer			0.04			
Red Hake			0.08	0.15	0.27	
Rock Gunnel			0.04			
Scup						0.46
Silver Hake	0.30	0.09	0.04	0.15	0.08	
Smallmouth Flounder				0.38		
Spotted Hake			0.08	1.15	3.35	0.38
Striped Bass	7.66	2.12	3.74	12.08	2.32	0.38
Striped Killifish	0.08	0.04				
Summer Flounder				0.08	0.65	0.46
Tautog	0.07			0.09		
Threespine Stickleback		0.04			0.08	
White Perch	0.66	5.83	2.03	14.60	0.15	
Windowpane	0.59	0.30	0.34	0.84	0.58	
Winter Flounder	3.86	2.16	1.08	4.18	0.82	0.77
Winter Skate			0.04			
Yellowtail Flounder				0.08		

Table 3-2 a Monthly average CPUE by species for all navigation channel and shallow/shoal stations combined at Arthur Kill/Newark Bay during the 2004 Aquatic Biological Sampling Program.

Navigation Channel Stations

Species	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04
Alewife	0.56	0.14	2.79	2.75	0.50	0.25
American Shad		0.13	2.06	0.31	0.25	
Atlantic Herring				4.10	2.42	
Atlantic Silverside	0.25	0.13				
Atlantic Tomcod	0.25	0.78	6.69	5.06	16.75	2.00
Bay Anchovy					4.08	17.81
Blueback Herring		1.64	14.40	15.71	1.50	
Gizzard Shad	1.25	0.13				
Grubby	0.56	0.79	0.94	0.25		
Northern Pipefish				0.56	0.25	
Red Hake	1.00		0.25	2.25		
Rock Gunnel		0.14				
Silver Hake	0.31	0.25	0.25	0.25		
Smallmouth Flounder				0.31		
Spotted Hake			0.63	29.81	12.42	0.50
Striped Bass	24.19	38.44	111.81	9.31		0.25
Striped Killifish		0.13				
Summer Flounder				0.25		
Threespine Stickleback	0.31				0.75	
Weakfish						0.25
White Perch	40.50	47.15	106.28	8.88	0.25	
Windowpane	0.50	0.26	0.13	0.25	0.25	
Winter Flounder	7.31	8.60	6.78	2.75	0.25	0.50

Shallow/Shoal Stations

Species	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04
Alewife	0.78	0.22	1.13	84.12	1.25	
American Eel				0.28		
American Shad			1.38	6.67	1.17	0.25
Atlantic Herring	0.22			0.53	62.83	
Atlantic Silverside		0.19	1.33	0.61		
Atlantic Tomcod					3.75	1.75
Bay Anchovy					18.75	199.25
Blueback Herring		0.33	1.88	15.87	0.25	
Bluefish						2.50
Cunner			0.13			
Gizzard Shad	0.62					
Grubby	1.00	0.11		0.36		
Mummichog		0.19				
Silver Hake	0.40					
Striped Bass	1.22	4.30	7.75	23.60	6.92	1.00
Striped Killifish	0.22	0.11				
Summer Flounder						1.00
Threespine Stickleback					0.25	
White Perch	1.11	17.37	6.21	47.45	0.50	
Windowpane				0.71		
Winter Flounder	2.67	1.56	1.13	4.88	1.17	0.75

Table 3-2 b Monthly average CPUE by species for all navigation channel and shallow/shoal stations combined at Upper Bay during the 2004 Aquatic Biological Sampling Program.

Navigation Channel Stations

Species	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04
Alewife	0.80	0.80	2.50	4.01		
American Shad		0.50	3.41	0.65		
Atlantic Herring	0.20	0.10	0.10	1.94	0.65	0.20
Atlantic Silverside	0.20					
Atlantic Tomcod	2.29	0.48			1.15	
Bay Anchovy				0.22	8.20	18.53
Blueback Herring	0.20	20.83	2.80	8.31		
Clupeid unidentified					0.60	
Cunner		0.10				
Grubby	1.00	1.05	0.40	0.20		
Little Skate	0.20		0.10			
Northern Pipefish		0.11				
Northern Puffer			0.10		0.20	
Red Hake	0.89		0.40			
Silver Hake			0.80			
Spotted Hake	1.00		0.21	1.07	0.40	
Striped Bass	26.17	3.10	0.30	0.25		
Threespine Stickleback	0.20					
White Perch	0.77	0.11				
Windowpane		0.10	0.60	0.20		
Winter Flounder	17.23	4.94	7.70			0.20

Shallow/Shoal Stations

Species	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04
Alewife			1.42	0.72	1.08	0.17
American Shad			1.12	0.79		1.83
Atlantic Herring			0.18	0.69	3.67	
Atlantic Silverside		0.17	1.73			
Atlantic Tomcod	0.17			0.52	61.25	30.67
Bay Anchovy	0.71			0.17	17.83	116.44
Blueback Herring			0.73	0.52	0.17	
Bluefish						0.67
Cunner			0.09		0.42	
Gizzard Shad	0.17					
Grubby	1.77	0.35	0.18	1.19		
Naked Goby		0.08				
Northern Pipefish				0.17		
Northern Puffer			0.09			
Red Hake					0.42	
Rock Gunnel			0.09			
Scup						0.17
Silver Hake	0.38	0.21		0.33	0.17	
Spotted Hake				1.17	5.42	0.33
Striped Bass	16.85	1.55	2.86	10.44	0.42	0.17
Summer Flounder					1.25	0.33
Tautog	0.17			0.19		
Threespine Stickleback		0.08				
White Perch	0.61	0.08	0.09			
Windowpane	1.38	0.09	0.59	0.85	1.25	
Winter Flounder	6.29	1.36	1.27	4.63	0.83	1.00

Table 3-2 c Monthly average CPUE by species for all navigation channel and shallow/shoal stations combined at Lower Bay during the 2004 Aquatic Biological Sampling Program.

Navigation Channel Stations

Species	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04
Alewife	13.46	1.67	2.33	0.67		
American Shad		0.50	0.50			
Atlantic Herring	49.72					
Atlantic Menhaden	3.36					
Atlantic Silverside	0.67	0.50				
Bay Anchovy					5.33	24.67
Blueback Herring	2.00	4.50	0.17	7.00		
Butterfish						0.33
Clupeid unidentified					0.67	
Grubby	0.67	0.67	0.50			
Little Skate	7.59	0.50	1.00	1.00		
Northern Pipefish				0.33		
Red Hake	0.59	0.33	1.67	1.00	0.33	
Rock Gunnel			0.17			
Silver Hake	0.26		1.33			
Smallmouth Flounder			0.50			
Spotted Hake				6.67	1.00	
Striped Searobin					0.33	
Windowpane	0.85	0.67	0.17	0.33		
Winter Flounder	0.59	1.50	6.17			
Winter Skate			0.33			

Shallow/Shoal Stations

Species	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04
Alewife			0.83	1.00	0.33	
American Shad		0.17	0.33	0.67		
Atlantic Herring	0.67					
Atlantic Menhaden	0.33					
Atlantic Silverside		0.33				
Bay Anchovy					2.67	6.67
Blueback Herring		1.00		2.00		
Grubby	0.33					
Little Skate		1.33	0.33	1.00		
Red Hake			0.33	0.67	0.33	
Scup						1.67
Silver Hake			0.17			
Smallmouth Flounder				1.67		
Spotted Hake			0.33	2.67	3.67	1.00
Summer Flounder				0.33	0.33	
Windowpane		1.17	0.33	1.00		
Winter Flounder	1.00	4.67	0.67	2.33	0.33	0.33
Winter Skate			0.17			
Yellowtail Flounder				0.33		

Table 3-3 a Monthly average ichthyoplankton density (Number/1000 m³) by species for all navigation channel stations in Arthur Kill/Newark Bay, 2004 Aquatic Biological Sampling Program.

Egg

Species	January	February	March	April	May	June	July
Atlantic menhaden					4.89	1026.46	
Bay anchovy						19661.38	50568.81
Fourbeard rockling					1.81		
Gadid unidentified				1.80			
Labridae					30.52	1812.39	2557.48
Prionotus sp.							160.21
Weakfish				44.04	8.72		
Windowpane						579.16	235.95
Winter flounder		0.79	0.61				

Yolk-sac Larvae

Species	January	February	March	April	May	June	July
Atlantic silverside						3.34	
Atlantic tomcod			2.23				
Grubby			19.75	3.48			
Winter flounder		0.79					

Post-yolk sac Larvae

Species	January	February	March	April	May	June	July
Atlantic herring				0.93	9.28		
Atlantic menhaden						69.40	
Atlantic silverside						1.76	
Atlantic tomcod			1.84	0.93			
Bay anchovy						969.51	655.87
Gobiid unidentified						29.44	354.22
Grubby		0.82	162.29	172.97	4.00		
Longhorn sculpin				3.15			
Northern pipefish						5.69	19.93
Rock gunnel				4.30			
Summer flounder	1.13						
Tautog						2.50	
Unidentified				1.01		234.96	
Weakfish						29.97	10.99
Windowpane						2.39	
Winter flounder		0.70	30.17	819.90	45.97	13.70	

Juvenile

Species	January	February	March	April	May	June	July
Atlantic herring				0.79			
Atlantic tomcod					3.91		
Grubby				1.92			

Table 3-3 b Monthly average ichthyoplankton density (Number/1000 m³) by species for all shallow/shoal stations in Arthur Kill/Newark Bay, 2004 Aquatic Biological Sampling Program.

Egg

Species	January	February	March	April	May	June	July
Atlantic menhaden					3.93	70.69	
Bay anchovy						12202.21	67296.97
Labridae					30.57	347.83	473.12
Prionotus sp.							49.64
Weakfish				1.41	1.97		74.14
Windowpane						44.53	99.27
Winter flounder		0.54					

Yolk-sac Larvae

Species	January	February	March	April	May	June	July
American sandlance		0.63					
Atlantic tomcod			2.75				
Grubby		1.12	3.03	0.60			
Winter flounder				1.25			

Post-yolk sac Larvae

Species	January	February	March	April	May	June	July
American sandlance		0.54					
American shad						1.12	
Atlantic cod				0.58			
Atlantic croaker	4.75						
Atlantic menhaden					1.19	55.24	
Atlantic silverside					1.19	1.80	
Atlantic tomcod		0.67	1.56				
Bay anchovy						1066.13	626.17
Gobiid unidentified						31.47	922.07
Grubby		0.67	22.16	32.76			
Northern pipefish						15.76	42.79
Northern puffer							1.13
Rock gunnel		0.67		0.59			
Summer flounder	1.87						
Tautog						2.81	2.78
Unidentified						163.44	
Weakfish						12.89	12.09
Windowpane					1.14	1.29	
Winter flounder		1.08	85.77	151.72	3.16		

Lifestage: Juvenile

Species	January	February	March	April	May	June	July
Winter flounder				0.65			

Table 3-3 c Monthly average ichthyoplankton density (Number/1000 m³) by species for all navigation channel stations in Upper Bay, 2004 Aquatic Biological Sampling Program.

Egg

Species	January	February	March	April	May	June	July
Atlantic menhaden					137.52	2394.43	
Bay anchovy						8127.35	2098.97
Fourbeard rockling				6.05	7.43		
Gadid unidentified				10.28		18.67	8.42
Goosefish							17.13
Labridae					19.47	1884.56	1367.32
Prionotus sp.						199.18	732.94
Weakfish				121.12	93.13	56.01	136.33
Windowpane				1.14		767.31	441.97
Winter flounder			1.02				

Yolk-sac Larvae

Species	January	February	March	April	May	June	July
Grubby			4.88	5.39			
Rock gunnel			0.23				
Windowpane						0.62	
Winter flounder		0.69		18.95			

Post-yolk sac Larvae

Species	January	February	March	April	May	June	July
American sandlance		1.20	0.32	6.20			
Atlantic herring				0.99			
Atlantic menhaden						684.91	15.15
Atlantic tomcod		1.38	0.62				
Bay anchovy						1268.29	455.48
Butterfish							18.20
Cunner							6.52
Fourspot flounder							4.53
Gobiid unidentified							53.02
Grubby		2.26	66.37	279.66	3.78		
Longhorn sculpin				10.79			
Northern pipefish						1.40	8.21
Prionotus sp.							3.19
Rock gunnel		2.23	2.14	13.08			
Smallmouth flounder							3.21
Summer flounder	1.07						
Tautog						7.50	11.10
Unidentified						1333.41	20.28
Weakfish						8.58	16.50
Windowpane					2.59	13.53	
Winter flounder			64.23	974.45	235.19	1.00	

Juvenile

Species	January	February	March	April	May	June	July
Grubby				1.73			
Northern pipefish							2.11
Prionotus sp.							1.07
Winter flounder				0.86			

Table 3-3 d Monthly average ichthyoplankton density (Number/1000 m³) by species for all shallow/shoal stations in Upper Bay, 2004 Aquatic Biological Sampling Program.

Egg

Species	January	February	March	April	May	June	July
Atlantic menhaden				13.19	127.20	2257.02	
Bay anchovy						12238.41	4506.74
Fourbeard rockling				3.59	3.74		
Gadid unidentified				6.89		8.82	
Goosefish							7.02
Labridae					10.99	906.50	2639.72
Prionotus sp.						21.00	291.01
Weakfish				68.34	77.26	27.64	62.79
Windowpane				0.52		341.97	575.03

Yolk-sac Larvae

Species	January	February	March	April	May	June	July
Atlantic menhaden						36.21	
Gobiid unidentified							0.95
Grubby			4.84	1.93			
Rock gunnel			0.36				
Winter flounder				8.01	0.94		

Post-yolk sac Larvae

Species	January	February	March	April	May	June	July
American sandlance		0.51	0.57				
Atlantic menhaden						347.15	
Atlantic tomcod			0.78				
Bay anchovy						1808.01	276.92
Butterfish							4.94
Cunner						1.07	12.73
Gobiid unidentified							89.46
Grubby		0.43	40.98	52.16			
Longhorn sculpin				1.79			
Northern pipefish						3.92	14.53
Northern puffer						2.22	
Rock gunnel		1.28	0.83				
Tautog						22.05	39.52
Unidentified						490.02	5.26
Weakfish						18.74	13.28
Windowpane					2.01	12.55	
Winter flounder			84.99	275.46	10.36		

Juvenile

Species	January	February	March	April	May	June	July
Butterfish							0.88
Grubby				1.64			
Northern pipefish							2.85

Table 3-3 e Monthly average ichthyoplankton density (Number/1000 m³) by species for all navigation channel stations in Lower Bay, 2004 Aquatic Biological Sampling Program.

Egg

Species	January	February	March	April	May	June	July
Atlantic mackerel					15.48	3.39	
Atlantic menhaden				4.32	477.24	2370.95	
Bay anchovy						27899.91	1018.61
Cunner						379.45	
Fourbeard rockling			0.72				
Gadid unidentified			0.72			60.63	
Goosefish							14.94
Hogchocker						700.01	
Labridae					25.85	5182.40	365.57
Prionotus sp.						8920.58	761.09
Weakfish				300.73	194.46	1542.05	
Windowpane				27.12		4147.42	44.81
Winter flounder	2.01		8.40	5.11			

Yolk-sac Larvae

Species	January	February	March	April	May	June	July
American sandlance	2.22						
Grubby			3.96				
Winter flounder				5.02			

Post-yolk sac Larvae

Species	January	February	March	April	May	June	July
American sandlance				2.77			
Atlantic croaker	4.02						
Atlantic menhaden						289.45	154.17
Atlantic silverside						3.37	
Bay anchovy						1031.81	7614.96
Butterfish							52.55
Cunner						2.19	39.46
Fourspot flounder							5.12
Gobiid unidentified						1.70	81.72
Grubby			35.31	213.15	13.95		
Longhorn sculpin				15.70			
Morone sp.						2.19	
Northern pipefish						22.44	54.30
Rock gunnel		0.93	1.41	14.61			
Smallmouth flounder							7.42
Tautog							14.35
Unidentified						717.87	1.87
Weakfish						8.15	392.34
Windowpane						58.23	6.51
Winter flounder			5.99	1892.61	644.22	4.07	

Juvenile

Species	January	February	March	April	May	June	July
Butterfish							3.73
Fourspot flounder							3.73
Grubby				5.18			
Northern pipefish						1.68	
Smallmouth flounder							1.39
Windowpane			1.41				
Winter flounder				1.08			

Table 3-3 f Monthly average ichthyoplankton density (Number/1000 m³) by species for all shallow/shoal stations in Lower Bay, 2004 Aquatic Biological Sampling Program.

Egg

Species	January	February	March	April	May	June	July
Atlantic menhaden				43.98	614.15	291.33	
Bay anchovy						30213.09	955.44
Fourbeard rockling					4.25		
Gadid unidentified			3.95	10.76		47.75	
Goosefish							5.26
Labridae					43.16	1414.90	425.96
Prionotus sp.						276.63	1185.72
Weakfish				384.21	530.53	248.58	103.63
Windowpane						546.94	44.69
Winter flounder			3.70	6.18			

Yolk-sac Larvae

Species	January	February	March	April	May	June	July
American sandlance		2.56					
Grubby			15.58				
Rock gunnel			0.59				
Winter flounder				1.55			

Post-yolk sac Larvae

Species	January	February	March	April	May	June	July
American sandlance			0.74				
Atlantic croaker	2.11						
Atlantic menhaden						80.27	2.63
Atlantic silverside						1.80	
Bay anchovy						2049.42	162.08
Butterfish							2.63
Cunner						7.77	5.65
Fourspot flounder							4.17
Gobiid unidentified						1.80	169.33
Grubby		4.55	96.66	44.62	4.25		
Longhorn sculpin				7.53			
Northern kingfish							2.83
Northern pipefish						13.39	41.38
Prionotus sp.							2.09
Rock gunnel		4.82	7.53				
Smallmouth flounder							2.63
Tautog						1.69	12.46
Unidentified						1110.01	
Weakfish						19.99	18.46
Windowpane					4.25	65.63	11.91
Winter flounder			12.58	3159.81	291.18		

Juvenile

Species	January	February	March	April	May	June	July