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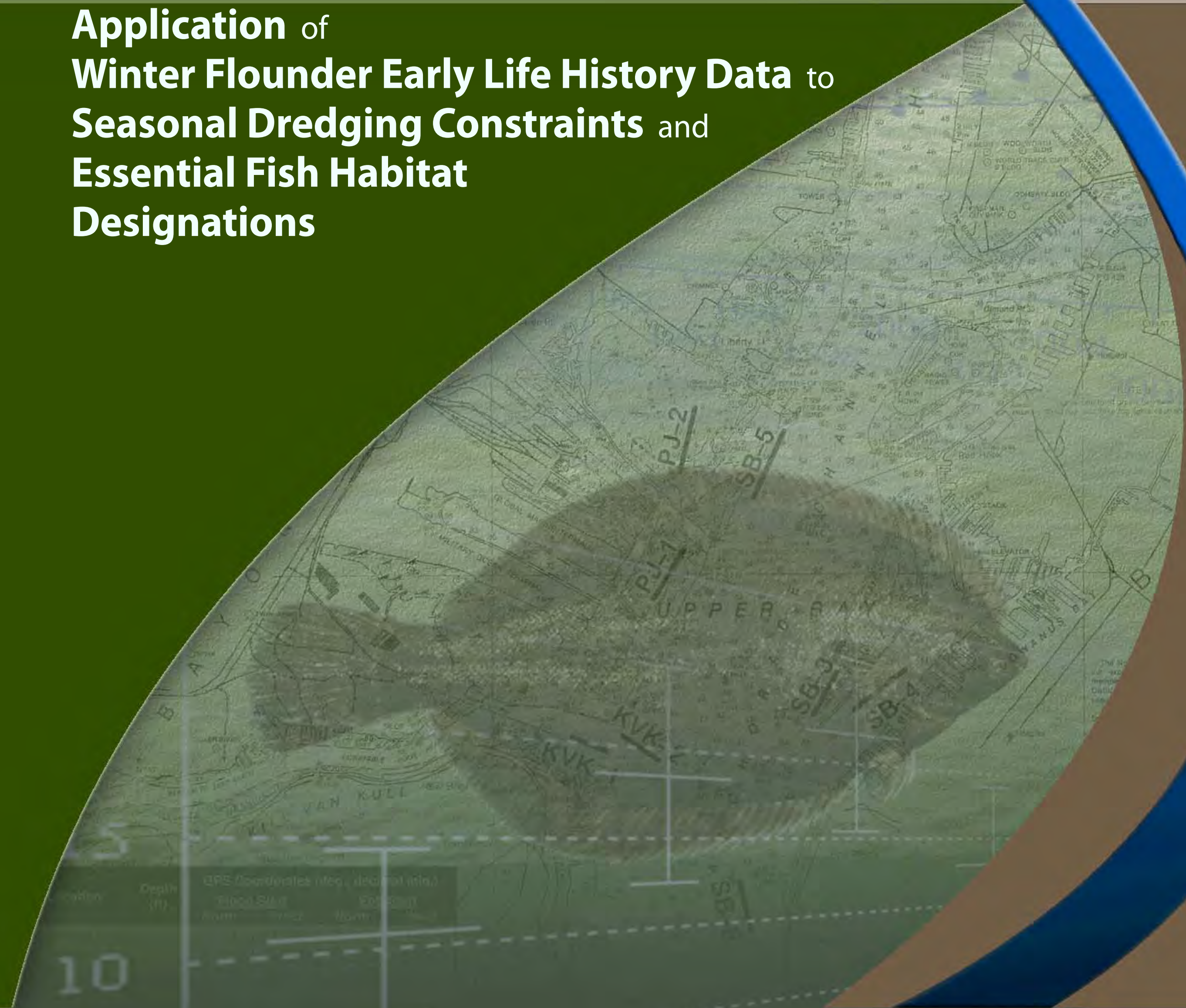
New York District

NEW YORK AND NEW JERSEY
HARBOR DEEPENING PROJECT

# Application of Winter Flounder Early Life History Data to Seasonal Dredging Constraints and Essential Fish Habitat Designations



**NEW YORK AND NEW JERSEY HARBOR DEEPENING PROJECT**

# APPLICATION of WINTER FLOUNDER EARLY LIFE HISTORY DATA to SEASONAL DREDGING CONSTRAINTS and ESSENTIAL FISH HABITAT DESIGNATIONS

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# 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Determinations of seasonal dredging restrictions throughout the United States are frequently based on outdated information or perceptions of the dredging process and in only a few instances on conclusive scientific evidence (National Research Council 2001).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 early life history stages of winter flounder, *Pseudopleuronectes americanus*.

Currently, the United States Army Corps of Engineers – New York District's (USACE-NYD) congressionally authorized Harbor Deepening Project (HDP) is under construction. The HDP is a multi-year Federal channel deepening program 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 migrant finfish species, shellfish and benthic macro-invertebrate species (USACE-NYD 1998). A systematic sampling program, 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.

Since its inception in 1998, the ABS has undergone a number of modifications and enhancements, such as the addition of new sampling locations in the Lower Bay (Figure 1), in order to provide the necessary and relevant data for essential fish habitat (EFH)[1] coordination with NMFS and state regulatory agencies as data needs and agency interests/concerns arose. Currently, the ABS program primarily focuses on winter flounder distribution and seasonal

[1] EFH is defined under section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCA) as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267) as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

patterns of habitat use. Winter flounder was selected as the target species because it is commercially and recreationally important in the Northeast and representative of other federally managed species.

Developing an understanding of when and where winter flounder eggs and larvae are present within the HDP area and how their presence is related to environmental factors greatly improves the ability to effectively manage dredging activities in the Harbor. The extensive database collected prior to and during the construction of the HDP has provided an opportunity for decision makers to apply management practices based on sound science that allow for both the protection of EFH species and the efficient and effective execution of navigational improvements. USACE-NYD is using this database to address the following local and regional EFH issues:

1. The application of the 2001 conservation recommendations (NMFS 2001) issued by National Marine Fisheries Service (Northeast Region) to the seasonal dredging restrictions as they pertain to existing and future construction contracts for the Harbor Deepening Project (HDP).

2. The potential re-designation[2] of winter flounder egg and larvae EFH from 5 and 6 meters (16 and 20 feet), respectively, to 20 meters (66 feet).

The following summary report primarily focuses on winter flounder early life stage (eggs and larvae) data as they pertain to winter flounder EFH utilization within the Harbor. Additional information regarding data analysis and methods for the ABS can be found in Appendix A. Summaries of additional water quality, sediment and hydrodynamic data collected from other HDP monitoring programs conducted by USACE-NYD can be found in Appendix B. Appendix C evaluates the impacts that the seasonal dredging restrictions have had on the overall construction of the HDP.

[2] New England Fishery Management Council is in the process of preparing a programmatic Environmental Impact Statement (EIS) and Omnibus EFH Amendment (draft expected during the Spring 2011) to reevaluate winter flounder egg and larvae depth designations.

# Application to the 2001 Conservation Recommendation – Seasonal Dredging Constraints

In 2001, National Marine Fisheries Service (NMFS) - Northeast Region - issued a conservation recommendation (CR) letter (NMFS 2001) regarding potential impacts of the HDP on federally managed EFH species. The potential project impacts identified in the letter included the re-deposition of sediment suspended during dredging, physical removal of bottom habitat, entrainment of eggs and larvae in dredging equipment, and loss of EFH function. To mitigate these potential project impacts, NMFS recommended seasonal dredging constraints (typically February 1 through May 31) for some navigation channels based on location, sediment characteristics, and the temporal use of the project area by early life stage (eggs and larvae) winter flounder. Specifically, the 2001 CR letter identified winter flounder as a species "that will be most affected by the deepening, or are representative of other federally managed species."

Due to data unavailability at the time, NMFS employed "a very conservative, risk-adverse approach." However, NMFS encouraged USACE-NYD to "revisit the consultation process during the pre and actual construction phases of the project if the information affects the basis for NMFS conservation recommendations (50 CFR 600.920(k))", including if "altered or new information become available regarding ESA or EFH issues."

Based on the extensive ABS dataset and other monitoring programs associated with the HDP, USACE-NYD has revisited the local consultation process regarding seasonal dredging restrictions as they pertain to existing and future construction contracts for the HDP. Based on the latest scientific data from these studies and the current HDP construction plans, the project related impacts identified in the 2001 CR letter may have limited application as they pertain to winter flounder EFH within the Harbor. The following sections discuss each of the potential project impacts identified in the 2001 CR and the relevant data sources as they apply including the spatial and temporal distribution data for early life stage winter flounder collected and available from the ABS.

## Re-deposition of Suspended Sediment

The 2001 CR letter identified the re-deposition of sediment suspended during dredging as a potential source of impact on EFH. For the past five years, USACE-NYD has conducted a Water Quality/Total Suspended Solids (TSS) monitoring program to measure the spatial extent and temporal dynamics of suspended sediment plumes associated with the mechanical dredging of fine-grained sediments. Plume surveys were conducted during dredging operations using an environmental bucket in the Arthur Kill and Newark Bay. The results of the TSS surveys from these waterbodies have showed that, similar to Bohlen *et al.* (1996), resuspended sediment plumes were largely confined to the bottom of the navigation channel with no evidence of plume excursion beyond the channel side slopes (USACE-NYD 2007 and USACE-NYD 2008). Therefore, potential project related impacts to nearby shallow water habitats in those waterbodies as a result of dredging with an environmental bucket would likely be minimal given that channel depths, prevailing water current patterns, and applied best management practices would effectively keep suspended sediment plumes within the channel.

## Entrainment of Early Life Stages

The 2001 CR letter identified the entrainment in the dredging equipment as a primary concern for "species with limited mobility including eggs and larvae of winter flounder, early life stages of lobsters and overwintering winter flounder, striped bass and blue crabs." However, the adverse impacts from entrainment are primarily associated with the use of hopper dredges which have had limited applications during the construction of the HDP.

## Physical Removal of Bottom Habitat

The 2001 CR letter identified the "physical removal of bottom habitat resulting from the blasting and dredging" as a primary concern because it would potentially "eliminate or reduce the ecological value of habitat used by a number of species including winter flounder…" The current winter flounder EFH designation does not include Harbor channels as water depths are greater than 6 meters. Therefore, dredging/blasting in channels does not have an impact on winter flounder EFH. In areas where the channels are being widened and there is an impact to the flats USACE-NYD are mitigating these impacts. In addition, USACE-NYD is conducting winter flounder habitat enhancement and restoration in Port Jersey.

<u>Loss of EFH Function</u>

Defined parameters for EFH function were not provided in the 2001 CR letter. However, functional EFH is described on the NMFS website to "include aquatic areas and their associated physical, chemical, and biological properties that are used by fish" as well as substrate that "includes sediment, hard bottom, structures underlying the waters, and associated biological communities."

The ABS program provides broad spatial and temporal data on the occurrence of early life stage winter flounder within the Harbor. The spatial data show the relative utilization of both channel and non-channel areas in each of the harbor regions by winter flounder and the potential relationship of the results to EFH function. The temporal data were used to demonstrate that newly available information can be used to reevaluate and refine the conservation recommendation through the timing of winter flounder egg and larvae occurrence in the Harbor; to establish a relationship between winter flounder life stage data and EFH function; and to present cumulative probability graphs that address concerns about yearly variability in the data.

## Spatial Occurrence of Winter Flounder Early Life Stages

In order to assess distinct and or discrete areas or habitats within or adjacent to HDP Federal channels, USACE- NYD analyzed nine years (2002-2010) of ABS winter flounder early life stage data. These data were used to determine the presence and location of winter flounder egg and larval occurrences throughout the project area, including Arthur Kill/Newark Bay, Upper Bay, and Lower Bay (Figures 2 and 3).

Winter flounder eggs are distributed throughout the Lower and Upper Bay areas of the Harbor, with significantly lower egg densities in the Arthur Kill/Newark Bay (AK/NB) area (Figure 4a, Kruskal-Wallis test statistic = 12.06, $p < 0.005$). Averaged over the nine year period, eggs collected in the AK/NB area accounted for less than 5% (based on density) of the total egg collection within the project area (Figure 4b). Winter flounder larval densities are highest in the Lower Bay and lowest in the AK/NB area where yolk-sac and post-yolk-sac larval collections averaged 10% and 14%, respectively, of the overall larval collections from 2002 to 2010 (Figure 5).

*Upper and Lower Bays*

Within the Upper and Lower Bays, shallow benthic habitat (typically less than 6 meters) is used as winter flounder spawning habitat. In some years, eggs were concentrated in either the Lower (2002, 2003 and 2004) or Upper (2005, 2006, and 2008) Bay areas (Figure 4a). Eggs occurred in relatively even densities in the Lower and Upper Bay areas in other years (2007, 2009, and 2010). Yolk-sac and post-yolk-sac larval densities were highest in the Lower Bay (Figure 5). There were no statistical associations (Appendix A) between egg and larval distributions among the Harbor areas and several environmental variables (river discharge, salinity, dissolved oxygen and temperature). *Because winter flounder egg and larval distributions are most highly concentrated in the Upper and Lower Bays, seasonal dredging restrictions in these areas should be carefully refined to encompass demonstrated periods of egg and larval occurrences.*

*Arthur Kill/Newark Bay*

Of the 2,643 eggs collected from 2002 to 2010, only six were collected in the Arthur Kill and these collections were confined to two of the five stations sampled in the Arthur Kill area (Table 1). Averaged over the nine-year study period, the percent contribution of eggs to the total collections within the study area was 1% for one Arthur Kill station and zero for the other four stations (Table 1). *These data strongly indicate that the Arthur Kill area is not utilized as a primary spawning habitat by winter flounder, and therefore, dredging restrictions in February that are designed to protect winter flounder eggs are not necessary for this area.* Low larval densities in the AK/NB area (Figure 5) reduce the risk of impact from dredging on the larval stage. Although larvae are more widely distributed into the AK/NB areas than eggs, larval densities in these areas are low compared to the Lower Bay ($F = 12.5$, $p < 0.001$; Table 2).

Egg collections at Newark Bay stations totaled 52 (out of 2,643 eggs collected for the nine-year study period) and 83% of these eggs were collected at a single station (NB-7) located directly north of Shooter's Island (Elizabeth Flats). *With the exception of the Elizabeth flats area, other areas sampled in Newark Bay were not consistently utilized as winter flounder spawning habitat and therefore dredging-related impacts on winter flounder eggs and larvae may be considered minimal for the Newark Bay area and the current seasonal restrictions adjusted accordingly.*

## Temporal Occurrence of Winter Flounder Early Life Stages (Seasonal Dredging Restrictions)

Current seasonal dredging restrictions within the Harbor associated with winter flounder early life stages is typically from February 1 to May 31 as recommended in NOAA's 2001 Conservation Recommendations and as issued for the HDP by the regulating states of New York and New Jersey are presented in Table 3. Subsequently, USACE-NYD has coordinated with and provided ABS data to resource managers, such as NOAA and the regulating states of New York and New Jersey, to assist in making informed decisions regarding seasonal dredging restrictions based on the latest available data. ABS data were used to determine if the seasonal dredging restriction could be modified to either better protect winter flounder or remove unnecessary restrictions on dredging. On a HDP contract by contract basis NYD has used the ABS data in this way and received some reduction in seasonal restrictions from the states of New York and New Jersey. *Based on existing ABS data, the current dredging restrictions for the Harbor can be reduced to the time period between mid-February and mid-May and remain a risk-adverse measure*.

ABS data indicate winter flounder eggs occur in the Harbor from early February to early April, with 90% of the annual egg collections obtained after 18 February in eight of nine years (Figure 6). In addition, 90% of yolk-sac larvae were collected during April and 90% of post-yolk sac larvae were collected by 16 May of each year (Figure 6).

Further reductions to the dredging restriction during May could be defensible in some years because of the inverse relationship between water temperature and the presence of post-yolk-sac larvae in May. Study results indicate that the two years in which the 90% collection of post-yolk-sac larvae occurred later in May (2003 and 2005) were years with the most extreme low water temperatures in March of less than 2°C (Figure 7). This finding is consistent with previous studies that have demonstrated extreme cold temperatures delay egg and larval development (Laurence 1975, Williams 1975, Sogard *et al.* 2001). Science based management decisions on dredging restrictions in May could therefore be assessed by NOAA and the States in coordination with USACE-NYD by reviewing March water temperatures (data available online, NOAA station ID 8518750) to estimate whether larvae would still be present in the Harbor during mid to late May.

## Application to the Potential EFH Depth Re-Designation

The New England Fishery Management Council (NEFMC) is in the process of preparing a programmatic Environmental Impact Statement (EIS) and Omnibus EFH Amendment (draft expected during the Spring 2011) to reevaluate winter flounder egg and larvae depth EFH designations. Under the current winter flounder EFH designation (Table 4), Federal navigation channels are not considered EFH as channels depths are typically greater than 12 meters (39 feet). However, a re-designation of winter flounder EFH from the current depth of 5 and 6 meters (16 and 20 feet) for eggs and larvae, respectively, to a depth of 20 meters (66 feet) would potentially include all existing and planned navigation channels in the Harbor. Dredged navigation channels are a distinct habitat maintained in a disturbed condition not suitable for winter flounder spawning and nursery habitat.

USACE-NYD has been coordinating with the NEFMC on the potential re-designation as it will have an impact on existing and future regional navigation channel maintenance and improvement projects. Coordination has included the sharing of available ABS data and the invitation to attend a regional Fishery Management Council Habitat Plan Development Team (HPDT) meeting to present the latest ABS results relevant to the potential depth re-designation (Table 5). During the HPDT meeting, the ABS dataset, containing spatial and temporal occurrence of early life stage winter flounder, was identified by the HPDT as one of the most robust data sets on the East Coast.

The ABS data were evaluated to determine if channels are used as spawning habitat by winter flounder. Egg densities at channel stations relative to non-channel stations varied annually over the nine-year study (Figure 8). Multiple regression analysis of this inter-annual variability in the relative abundance of eggs in channels revealed no significant associations with salinity, dissolved oxygen, or river discharge. Further examination of the relationship between eggs in the channels and water temperature revealed there was a significant positive correlation between the duration of extreme cold temperatures (number of weeks < $1^{o}$ C) and the annual percentage of eggs in the channels (Figure 9, $r^2 = 0.90$, $p < 0.001$). The highest incidences of winter flounder egg collections in the channels occurred in years with the lowest temperatures and most prolonged low temperatures. The annual percentage of eggs collected at channel stations was also positively correlated with the number of days elapsed between the first and last egg collection date of each year ($r^2 = 0.56$, $p < 0.05$). Eggs were collected over a longer time period in years with the most prolonged cold water temperatures ($r^2 = 0.54$, $p< 0.05$). The presence of eggs in the channels was significantly correlated with extreme low water temperatures. *Under extreme cold water conditions, winter flounder eggs develop more slowly (Williams 1975, Keller and Klein-MacPhee 2000) and therefore, are present in the Harbor longer and may be more susceptible to being transported from their spawning sites into the channels which are not high value spawning sites per existing literature and ABS data*. For the three years in which the average water temperature was below $1^{o}$ C for at least one week at the NOAA Battery gage, eggs were collected, on average, over an 80-day period compared to a 55-day period for other years with less extreme cold temperatures.

The existing literature (NMFS 1999, Shultz *et al.* 2007) provides supporting evidence consistent with the ABS findings that eggs appear not to be spawned in the channels. Among the non-channel stations sampled for the ABS, egg collections were highest at the shallowest stations. There was a significant negative correlation between non-channel station depth (Lower and Upper Bay stations) and the station's average percent contribution to overall egg collections ($r^2 = 0.68$, $p = 0.005$, Figure 10). Stations with the highest catches of eggs were at approximately three meters (10 feet) depth, whereas non-channel stations with low egg abundances were at depths of eight and nine meters (26 and 30 feet), respectively (Figure 10). In addition, nearly all (98%) newly spawned eggs (stages 1 and 2, less than 48 hours old) were collected at non-channel stations. Also, samples that contained multiple egg stages (presumably from multiple spawning events, which is indicative of spawning sites or sinks) were collected almost exclusively at non-channel stations (Table 1). *These results, therefore, strongly indicate that the Federal channels are not used as spawning habitat by winter flounder in the Harbor and the re-designation of winter flounder early life stage EFH to 20 meters (66 feet) may not be warranted.*

# Management Implications

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). The seasonal dredging constraints set nearly ten years ago, in the absence of site-specific data, provided broad guidelines to protect winter flounder eggs and larvae from potential dredging-related impacts. Despite the application of seasonal restrictions to dredging programs, winter flounder stock declines continue and no clear relationship between the near shore occurrence of eggs and larvae and offshore stock recruitment have been established. By taking into consideration the robust dataset collected over the ensuing nine years, refinements can be made in the existing broad temporal and spatial parameters, as related to the presence of essential fish habitat and winter flounder. An adaptive management application of the expansive scientific dataset collected as part of the HDP, in conjunction with a better understanding of EFH function and target species habitat requirements, can serve to justify revisions of existing seasonal dredging restrictions in a manner that supports more efficient regulation of dredging activities while still effectively maintaining a risk-adverse approach to protecting winter flounder resources.

Seasonal dredging constraints based on the 2001 conservation recommendation letter have had cost, schedule, navigation safety, environmental, and construction efficiency implications on the HDP. Seasonal dredging restrictions have the potential to impact construction in channels during an estimated 33% of a given calendar year (approximately 4 months) and thereby prolong construction, which delays critical navigation improvements and prolongs adverse effects on the environment. These delays have implications for navigation safety and Coast Guard imposed navigation restrictions, terminal and commercial vessel operations, and contractor's ability to allocate available resources most efficiently.

The aquatic biological data collected during the HDP can be used by both local and regional managers in addressing larger EFH questions such as the potential re-designation of winter flounder early life stage EFH to 20 meters (66 feet). *The ABS study provides strong scientific evidence and is consistent with existing literature in showing channels are not high value spawning habitat.* The preference for shallow spawning habitat is supported by the key findings that 1) the highest abundances of eggs occurred at the shallowest non-channel stations (approximately three meter (10 feet) depths), 2) nearly all (98%) newly spawned eggs (stages 1 and 2, less than 48 hours old) were collected at non-channel stations, and 3) samples that contained multiple egg stages (presumably from multiple spawning events, which is indicative of spawning sites or sinks) were collected almost exclusively at non-channel stations.

Integration of knowledge gained from extensive historical research on winter flounder biology and the ABS program can assist NOAA and the States to determine science-based restrictions on dredging and other activities in the Harbor such that winter flounder eggs and larvae can be reliably protected while regional and economically critical navigation improvements are ensured.

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**Table 1.** Percentage of annual egg collection at each station for each year of sampling (2002-2010). Empty cells indicate that the station was not sampled that year, whereas zero values indicate the station was sampled, but no eggs were collected. Habitat indicates whether the station was a channel (CH) or non-channel/shallow (NC) station. 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. Shaded cells indicate the stations (and years) in which multiple-stage egg collections were obtained.

| Station | Habitat | Area | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Ave. % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PJ-2 | NC | UB | 24 | 0 | 0 | 47 | 41 | 12 | 6 | 22 | 36 | 21 |
| PJ-3 | NC | UB | 1 | 3 | 0 | 0 | 31 | 25 | 80 | | | 20 |
| LB-5 | NC | LB | 31 | 26 | 6 | 0 | 0 | 24 | 0 | 1 | 2 | 10 |
| LB-1 | NC | LB | 23 | 2 | 21 | 1 | 0 | 6 | 0 | 10 | 2 | 7 |
| LB-4 | CH | LB | 9 | 28 | 10 | 10 | 0 | 0 | 0 | 3 | 1 | 7 |
| SB-6 | CH | UB | 1 | 27 | 0 | 9 | 0 | 2 | 2 | 0 | 0 | 5 |
| PJ-1 | NC | UB | 0 | 1 | 0 | 8 | 0 | 19 | 3 | 0 | 0 | 3 |
| LB-2 | CH | LB | 1 | 1 | 24 | 0 | 3 | 0 | 0 | 0 | 1 | 3 |
| NB-7 | NC | AKNB | 4 | 0 | 0 | 9 | | 1 | 7 | 2 | 1 | 3 |
| PJ-5 | CH | UB | 0 | 0 | 0 | 2 | 16 | 0 | | | | 3 |
| LB-6 | CH | LB | 3 | 1 | 18 | 0 | 0 | 0 | 0 | 2 | 0 | 3 |
| SB-3 | NC | UB | 0 | 5 | 0 | 2 | 1 | 10 | 0 | 4 | 0 | 2 |
| SB-4 | CH | UB | 1 | 5 | 7 | 4 | 1 | 0 | 0 | 3 | 0 | 2 |
| SB-5 | CH | UB | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 5 | 0 | 1 |
| LB-3 | NC | LB | 2 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| PJ-4 | CH | UB | 0 | 0 | 0 | 3 | 2 | 0 | 0 | | | 1 |
| AK-2 | CH | AKNB | 0 | 0 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 1 |
| SB-2 | NC | UB | 0 | 0 | 0 | 4 | 0 | 0 | | | | 1 |
| AK-1 | NC | AKNB | 0 | 0 | 2 | 0 | | | | | | 1 |
| NB-6 | CH | AKNB | 0 | 0 | 3 | 0 | 0 | 0 | | | 0 | 0 |
| SB-1 | NC | UB | 0 | 0 | 0 | 0 | 2 | 0 | | | | 0 |
| NB-3 | NC | AKNB | 1 | 0 | 0 | 0 | 0 | 0 | | | | 0 |
| AK-4 | NC | AKNB | 0 | 0 | 0 | 0 | | | | | | 0 |
| NB-5 | CH | AKNB | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 |
| NB-4 | NC | AKNB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AK-7 | NC | AKNB | | | | | 0 | | | | | 0 |
| AK-3 | CH | AKNB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NB-8 | CH | AKNB | | | | | | | | 0 | 0 | |
| LB-9 | NC | LB | | | | | | | 0 | 2 | 0 | |
| LB-8 | NC | LB | | | | | | | 1 | 1 | 1 | |
| LB-7 | NC | LB | | | | | | | 0 | 0 | 0 | |
| LB-14 | CH | LB | | | | | | | 0 | 1 | 2 | |
| LB-13 | NC | LB | | | | | | | 1 | 45 | 6 | |
| LB-12 | NC | LB | | | | | | | 0 | 0 | 8 | |
| LB-11 | NC | LB | | | | | | | 0 | | | |
| LB-10 | NC | LB | | | | | | | 0 | 0 | 0 | |
| LB-16 | NC | LB | | | | | | | | | 35 | |
| LBD-15 | NCdeep | LB | | | | | | | | | 1 | |
| LBD-17 | NCdeep | LB | | | | | | | | | 3 | |
| SB-7 | CH | UB | | | | | | | | | 1 | |

**Table 2.** Percentage of annual larval (yolk-sac and post-yolk-sac) collections at each station for each year of sampling (2002-2010). Empty cells indicate that station was not sampled that year, whereas zero values indicate the station was sampled, but no larvae were collected. Habitat indicates whether the station was a channel (CH) or non-channel/shallow (NC) station. Stations listed at the bottom were sampled only from 2008 to 2010; these stations were added later in the ABS program to address specific agency interests or questions.

| Station | Habitat | Area | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Ave. % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LB-3 | NC | LB | 4 | 16 | 20 | 5 | 20 | 53 | 15 | 15 | 7 | 17 |
| LB-1 | NC | LB | 4 | 19 | 5 | 18 | 9 | 3 | 4 | 2 | 16 | 9 |
| LB-4 | CH | LB | 12 | 7 | 11 | 5 | 16 | 2 | 5 | 11 | 3 | 8 |
| LB-5 | NC | LB | 7 | 6 | 9 | 8 | 8 | 10 | 6 | 5 | 6 | 7 |
| LB-6 | CH | LB | 20 | 2 | 7 | 2 | 2 | 4 | 11 | 6 | 3 | 6 |
| SB-6 | CH | UB | 4 | 6 | 4 | 4 | 7 | 1 | 7 | 2 | 6 | 5 |
| SB-1 | NC | UB | 7 | 5 | 1 | 4 | 3 | 2 | | | | 4 |
| SB-4 | CH | UB | 5 | 5 | 4 | 6 | 3 | 1 | 2 | 4 | 2 | 4 |
| LB-2 | CH | LB | 7 | 3 | 5 | 3 | 4 | 1 | 2 | 2 | 1 | 3 |
| SB-3 | NC | UB | 3 | 5 | 2 | 6 | 3 | 0 | 1 | 2 | 1 | 3 |
| SB-2 | NC | UB | 4 | 2 | 1 | 4 | 2 | 2 | | | | 2 |
| PJ-5 | CH | UB | 3 | 1 | 2 | 3 | 4 | 1 | | | | 2 |
| SB-5 | CH | UB | 2 | 3 | 5 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| PJ-1 | NC | UB | 2 | 1 | 2 | 3 | 3 | 4 | 1 | 2 | 1 | 2 |
| PJ-4 | CH | UB | 2 | 1 | 4 | 2 | 2 | 2 | 0 | | | 2 |
| PJ-3 | NC | UB | 1 | 1 | 1 | 6 | 2 | 2 | 1 | | | 2 |
| NB-6 | CH | AKNB | 1 | 0 | 4 | 4 | 1 | 0 | | | 1 | 2 |
| PJ-2 | NC | UB | 1 | 1 | 1 | 2 | 3 | 3 | 1 | 2 | 3 | 2 |
| NB-3 | NC | AKNB | 1 | 1 | 0 | 4 | 1 | 2 | | | | 2 |
| AK-2 | CH | AKNB | 1 | 1 | 4 | 3 | 1 | 1 | 0 | 1 | 1 | 2 |
| AK-4 | NC | AKNB | 1 | 4 | 2 | 1 | | 0 | | | | 2 |
| AK-3 | CH | AKNB | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 |
| NB-4 | NC | AKNB | 2 | 2 | 0 | 2 | 1 | 1 | 0 | 1 | 1 | 1 |
| NB-7 | NC | AKNB | 1 | 1 | 1 | 1 | | 1 | 1 | 2 | 1 | 1 |
| NB-5 | CH | AKNB | 1 | 0 | 2 | 1 | 1 | 1 | | | | 1 |
| AK-7 | NC | AKNB | | | | | 1 | | | | | 1 |
| AK-1 | NC | AKNB | 1 | 2 | 1 | 0 | 0 | | | | | 1 |
| NB-8 | CH | AKNB | | | | | | | | 1 | 1 | |
| LB-7 | NC | LB | | | | | | | 3 | 7 | 4 | |
| LB-8 | NC | LB | | | | | | | 10 | 3 | 4 | |
| LB-9 | NC | LB | | | | | | | 3 | 1 | 4 | |
| LB-10 | NC | LB | | | | | | | 4 | 3 | 3 | |
| LB-11 | NC | LB | | | | | | | 2 | | | |
| LB-12 | NC | LB | | | | | | | 7 | 11 | 11 | |
| LB-13 | NC | LB | | | | | | | 8 | 7 | 5 | |
| LB-14 | CH | LB | | | | | | | 3 | 4 | 7 | |
| LB-16 | NC | LB | | | | | | | | | 3 | |
| LBD-15 | NCdeep | LB | | | | | | | | | 2 | |
| LBD-17 | NCdeep | LB | | | | | | | | | 1 | |
| SB-7 | CH | UB | | | | | | | | | 1 | |

**Table 3.** Summary of environmental windows by contract area for the Harbor Deepening Project.

| Channel Reach | Letter Date | State Issued | Window Dates | Reason | Specific Location |
|---|---|---|---|---|---|
| S-NB-1 | 8-Sep-06 | NJ | 1 February - 31 May | Dredging of soft, fine-grained material is prohibited in any given year | Acceptance Areas A1, A2, B1 and B2 |
| | | | 31 March - 31 May | Dredging of all other material in any given year to protect the early life stages of winter flounder | Acceptance Areas A1, A2, B1 and B2 |
| | 29-Nov-07 | NJ | 1 February - 31 May | Dredging of soft, fine-grained material is prohibited in any given year | Outer Side Slope Acceptance Area |
| | | | 31 March - 31 May | Dredging of all other material in any given year to protect the early life stages of winter flounder | within the Outer Side Slope Acceptance Area |
| S-NB-2 | 10-May-10 | NJ | 15 February - 20 May | Dredging is prohibited in any given year to protect the early life stages of winter flounder | 500' from the top of slope of the federal navigation channels in proximity to the intertidal flats adjacent to Bayonne, NJ and adjacent to the intertidal flats in Elizabeth, NJ |
| | | | 15 March - 15 August | No blasting and/or dredging activity shall occur & the NY District shall use marker buoys every 200 ft or less to indicate the 1,000 ft restricted area | within 1,000 ft of any osprey nest |
| S-E-1 | 26-Sep-08 | NJ | None | | |
| S-AK-1 | 10-May-10 | NJ | 15 February - 20 May | Dredging is prohibited in any given year to protect the early life stages of winter flounder | |
| | | | 1 April - 31 July | If nesting is confirmed, no blasting and/or dredging activity shall occur & the NY District shall use marker buoys every 200 ft or less to indicate the 1,000 ft restricted area | within 1,000 ft of Shooter's Island |

| Channel Reach | Letter Date | State Issued | Window Dates | Reason | Specific Location |
|---|---|---|---|---|---|
| S-AK-2&3 | 5-Mar-10 | NY | | Authorized excavator test digs to determine the dredgeability of a shale and sandstone bedrock outcropping | |
| | 9-Apr-10 | NJ | | Allowing 10 test digs | |
| S-KVK-1 | 30-Nov-07 | NJ | 1 February - 31 May | Dredging is prohibited for the following sediment types: Holocene sand, Holocene black silt and Pleistocene sand and gravel to protect the early life stages of winter flounder | Acceptance Areas east of the line 611.000 (Station 32+00 to Station 0+00) |
| | 18-Dec-07 | NY | | | |
| | 18-Apr-08 | NY | | | |
| S-KVK-2 | 15-Oct-04 | NY | 15 November - 31 May | Dredging of non-Hars material is prohibited for protection of winter flounder | NY waters west of the Bayonne Bridge |
| | | | 1 April - 31 July | If nesting is confirmed on Shooters Island, dredging and/or blasting activity is prohibited & Permittee shall use marker buoys every 200 ft or less to indicate the 1,000 ft restricted area | within 1,000 feet of the island |
| | 17-Nov-04 | NJ | 1 April - 31 July | If nesting is confirmed on Shooters Island, dredging and/or blasting activity is prohibited | within 1,000 feet of the island |
| | 21-Apr-05 | NY | 1 February - 31 May | Dredging of non-Hars material is prohibited for protection of winter flounder | NY waters west of the Bayonne Bridge |
| S-PJ-1 | 24-May-05 | NJ | 1 February - 31 May | Dredging is prohibited of any given year to protect winter flounder early life stages | within the lateral extent of the contract areas 2A and 2B |
| PJ-3 | | | | | |

| Channel Reach | Letter Date | State Issued | Window Dates | Reason | Specific Location |
|---|---|---|---|---|---|
| S-AN-1 | 25-Jul-06 | NY | 1 February - 31 May | Dredging is prohibited | In the area between stations 105+00 and 140+00 |
| | 9-May-07 | NY | | Allow use of an open clamshell bucket to dredge areas that contain greater than 50% sand-sized particles | |
| S-AN-1A | 22-May-08 | NY | 1 February - 22 May | Dredging is prohibited | In the area between stations 105+00 and 140+00 |
| S-AN-1B | 6-May-08 | NY | | | |
| S-AN-2 | 7-Aug-09 | NY | | | Reach 3 |
| | 19-Nov-09 | NY | | | Reaches 1 & 2 |
| | 23-Nov-09 | NJ | 1 February - 31 May | Dredging is prohibited to protect the early life stages of winter flounder | Any portion of Reach 1 & Reach 2 above the confluence of the Kill Van Kull |
| | 24-Nov-09 | NY | 1 February - 31 May | Dredging is prohibited | Reaches 1 & 2 |
| S-AM-1 | 17-Mar-05 | NJ | None | | |
| | 28-Mar-05 | NY | None | Material is >90% sand; there are no operational or seasonal restrictions | |
| S-AM-2 | 6-May-08 | NY | | | |

**Table 4.** Summary of winter flounder EFH parameters.

| Life Stage | EFH General Habitat Parameters | | | | |
|---|---|---|---|---|---|
| | **Water Temp (°C)** | **Salinity (‰)** | **Water Depth (m)** | **Seasonal Occurrence/Peak Abundance** | **Comments** |
| **Eggs** | <10 | 10-30 | <5 | Feb-June | Inshore areas from Gulf of Maine to Mid-Atlantic in bottom habitats with a substrate of sand, mud or gravel. |
| **Larvae** | <15 | 4-30 | <6 | Mar-July | Pelagic and bottom waters inshore from Gulf of Maine to Mid-Atlantic. |
| **Juveniles** | <25 | 10-30 | 1-50 | * | Bottom habitats with a substrate of mud or fine-grained sand. |
| **Adults** | <25 | 15-33 | 1-100 | * | Bottom habitats including estuaries with mud, sand or gravel substrate. |
| **Spawning Adults** | <15 | 5.5-36 | <6 | Feb-June | Bottom habitats including estuaries with mud, sand or gravel substrate. |
| Source: New England Fishery Management Council EFH Amendment document accessed at http://www.nero.noaa.gov/hcd/winter.pdf | | | | | |

* Note the NEFMC EFH Amendment document does not specify a seasonal occurrence/peak abundance for Juveniles and adults

**Table 5.** Harbor Deepening Project and EFH coordination timeline.

| | |
|---|---|
| **1996** | The Water Resources Development Act (WRDA) authorizes USACE to investigate alternatives for navigation improvement in the Harbor. |
| **1998** | Baseline biological sampling (bottom trawls and ichthyoplankton tows) begins as a systematic program that eventually develop into the Aquatic Biological Survey (ABS). |
| **1999** | The Feasibility Report for the Harbor Navigation Study (HNS) and Final Environmental Impact Statement (FEIS) are published which includes a harborwide EFH assessment. |
| **2001** | National Marine Fisheries Service (NMFS) issues its EFH conservation recommendations (CR) for the proposed Harbor Navigation Project that includes seasonal work constraints for certain channels based on location, sediment characteristics, and the temporal use of the project area by early life stage (eggs and larvae) winter flounder. |
| **2002** | ABS sampling locations are added to the Lower Bay to provide a comprehensive survey of the entire project area. |
| **2003** | NMFS reviews the Limited Reevaluation Report (LRR) and the draft Environmental Assessment (EA) and issues a CR for the Consolidated Implementation of the Harbor Deepening Project (HDP). |
| **2007** | New England Fishery Management Council (NEFMC) releases a draft EIS for the proposed re-designation of winter flounder EFH from the current 5 and 6 meters for eggs and larvae, respectively, to 20 meters. |
| | Staging of winter flounder larvae based on developmental characteristics is added to the laboratory methodology of the ABS. |
| **2008** | New ABS sampling stations are added in the KVK to address seasonal dredge constraints added to the water quality certifications of the HDP contract area S-KVK-1.<br><br>ABS technical team presents ABS data at Flatfish Biology Conference in Plymouth, MA. |
| **2009** | ABS technical team meets with NMFS (Gloucester, MA) and the NEFMC Habitat PDT to present ABS data for further review and consideration regarding the draft EIS. |
| | Three new sampling locations are added in the Lower Bay to address NEFMC Habitat PDT questions about egg and larval densities at natural deep versus channelized deep water. |
| | USACE-NYD submits a Technical Memorandum (Depth vs. Density analysis) to NMFS. |
| | NEFMC files NOI to prepare one final EIS that combines both phases of the Omnibus Amendment. |
| **2010** | USACE-NYD meets with NMFS to discuss reinitiating formal EFH coordination for revised HDP Conservation Recommendations, in light of the extensive ABS dataset and to re-establish proper coordination and collaboration processes. |
| | NYD ABS technical team prepares an EFH Summary Report to summarize ABS dataset, and other data sources, for use in adaptive management applications to support the NAD navigation program. |


**Figure 1.** Ichthyoplankton sampling locations during the 2002-2010 ABS with HDP contract areas.

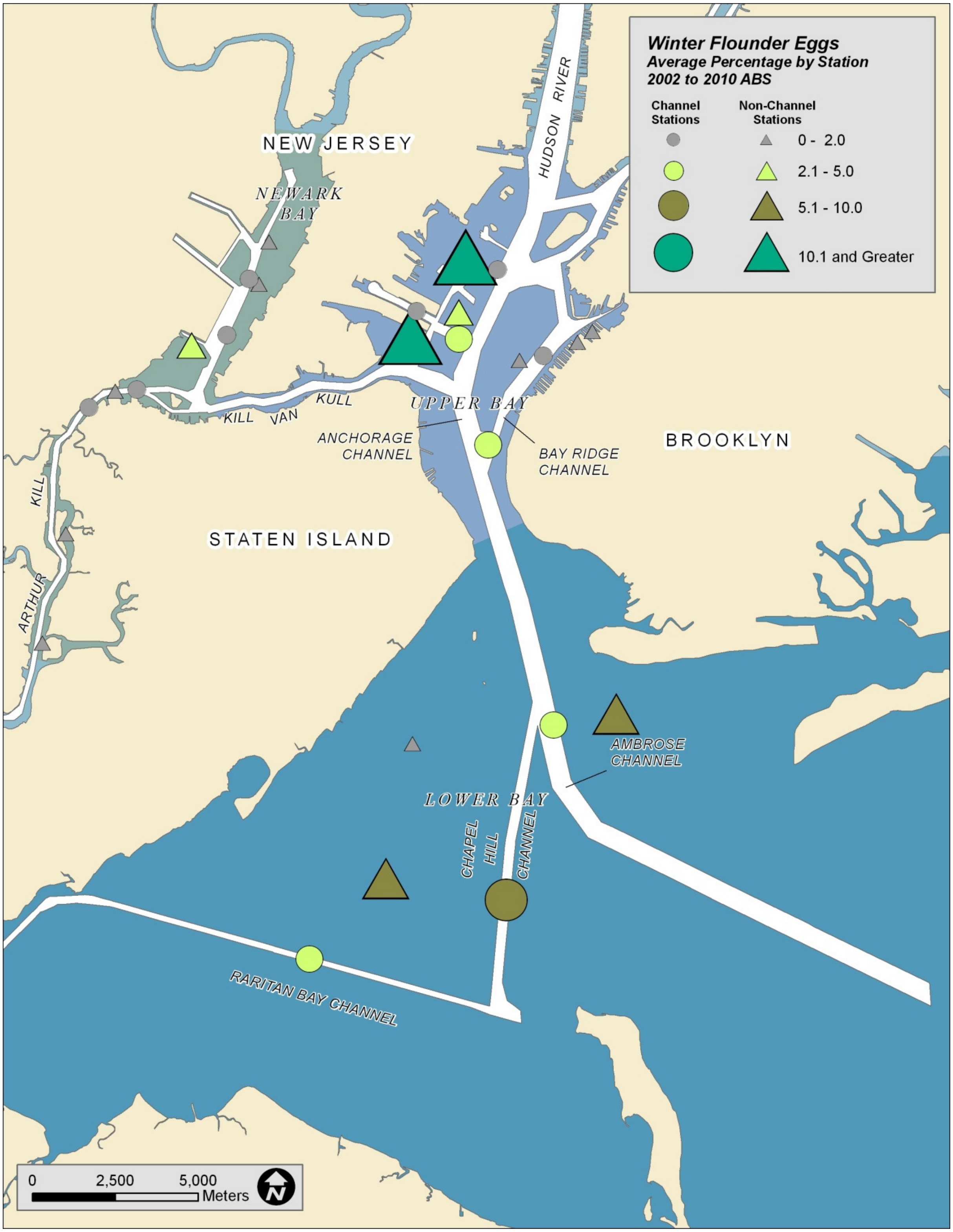



**Figure 2.** Average percentage of collection by station for winter flounder eggs during the 2002-2010 ABS for channel (circles) and non-channel (triangles) stations based on the all year average shown in Table 1.

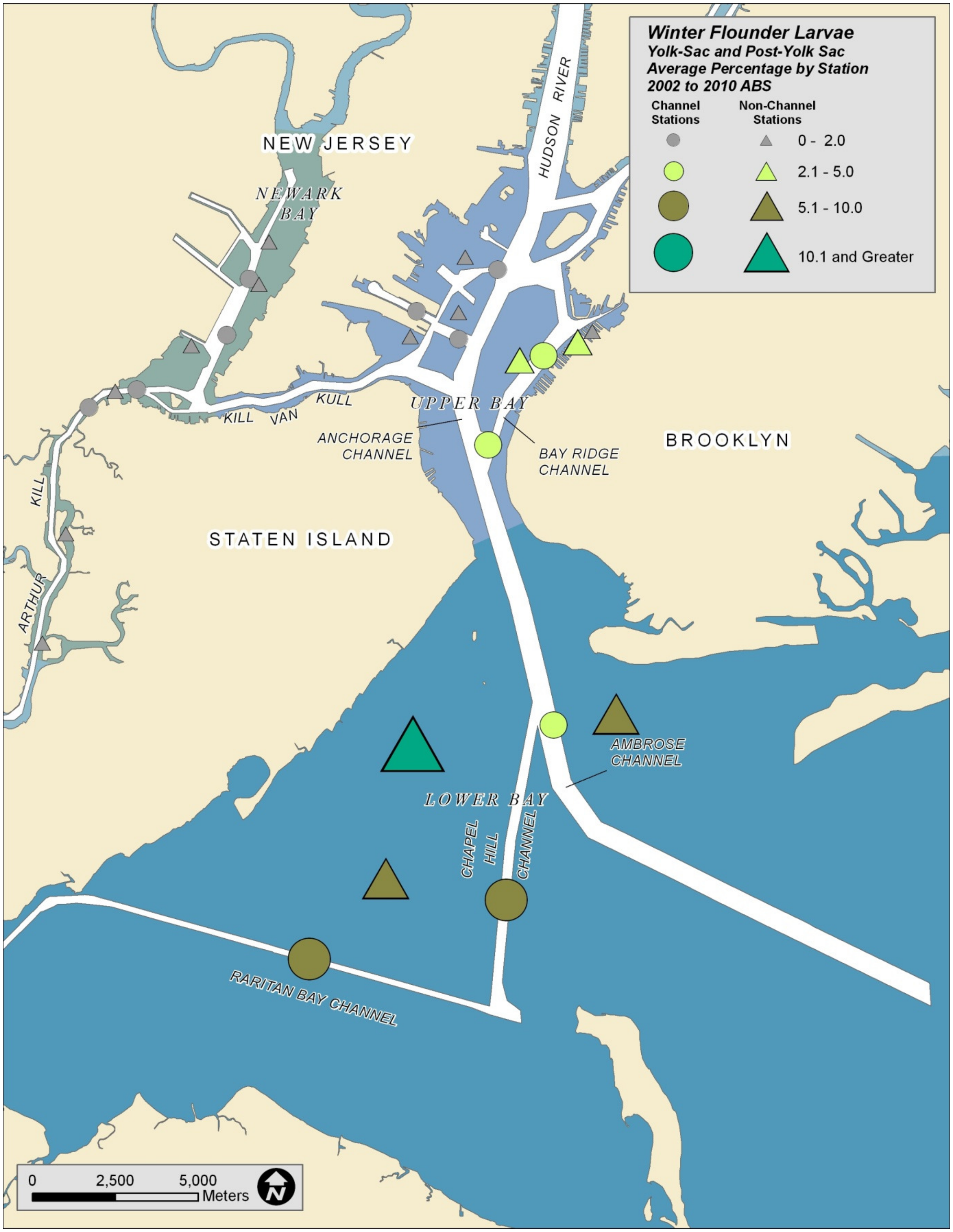
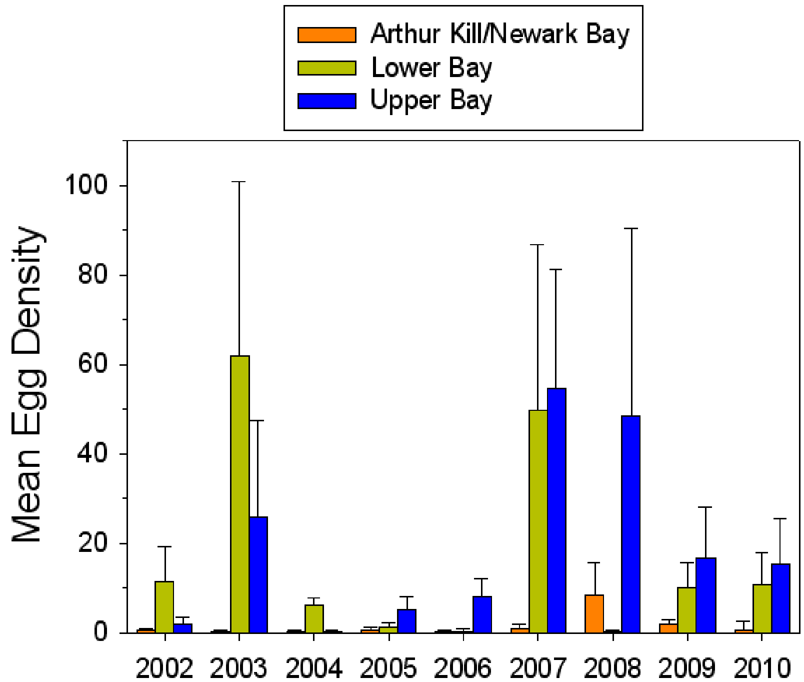
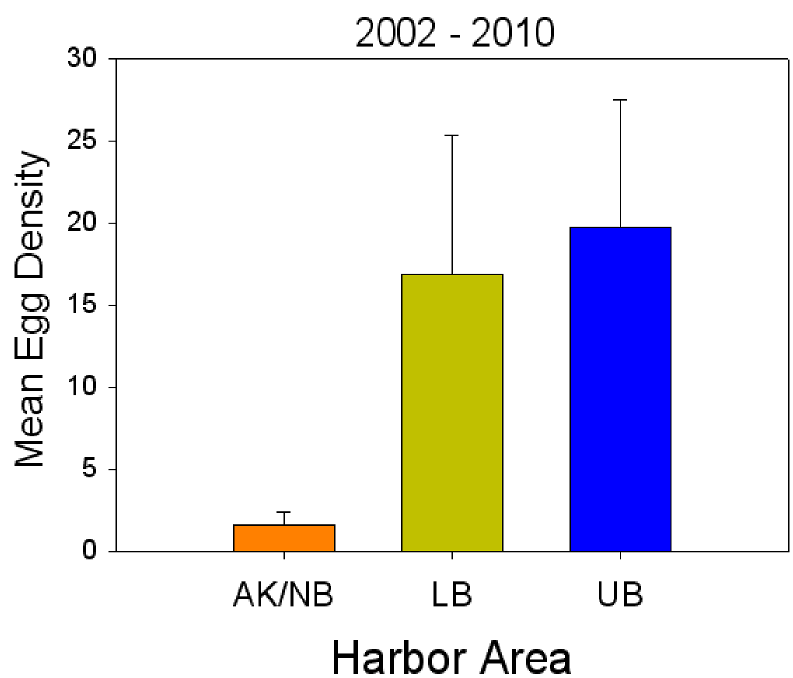



**Figure 3.** Average percentage of collection by station for winter flounder larvae (yolk-sac and post-yolk-sac) during the 2002-2010 ABS for channel (circles) and non-channel (triangles) stations based on the all year average shown in Table 2.




a.




b.

**Figure 4**. Average (± standard error) egg densities (per 1,000 $m^3$) collected in Arthur Kill/Newark Bay, Lower Bay, and Upper Bay for (a) each year and (b) for the nine year study period (2002-2010).

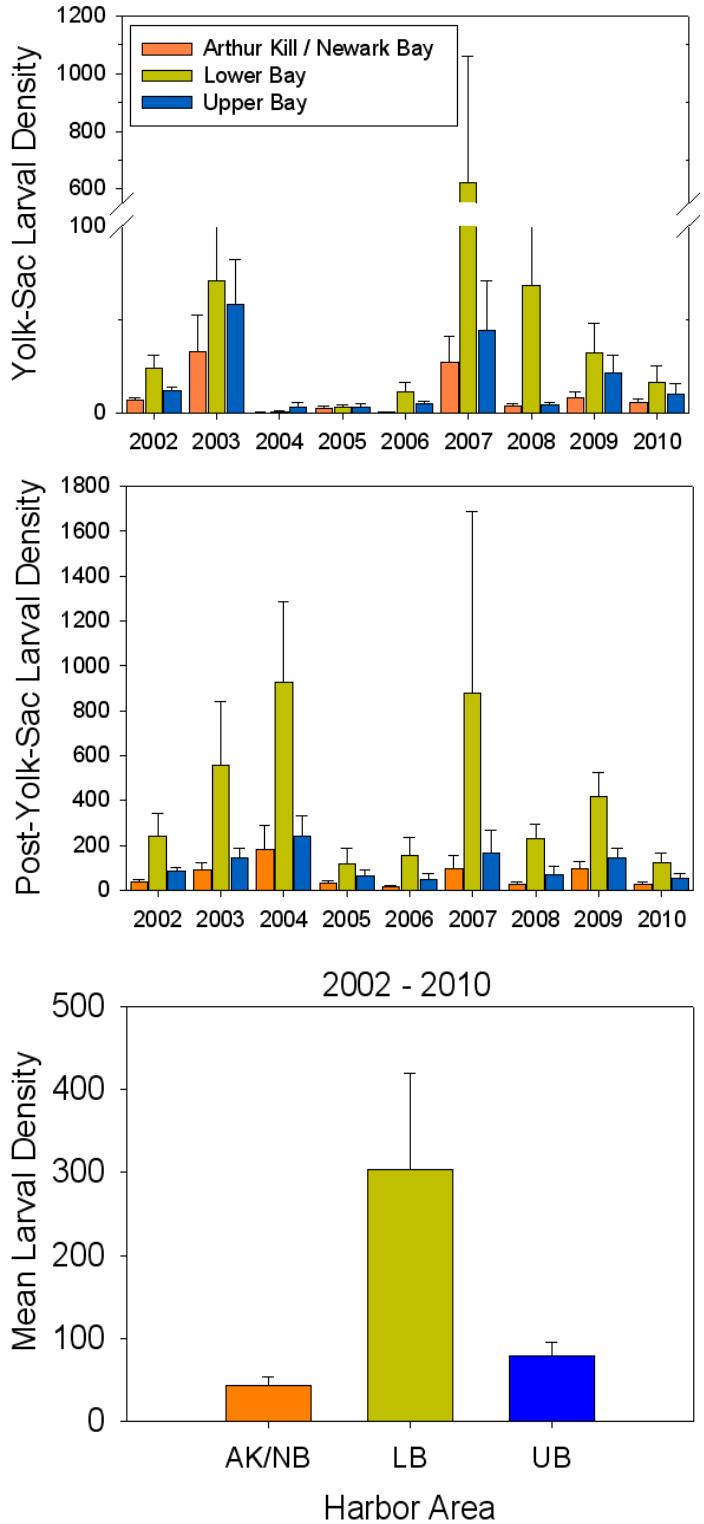



**Figure 5.** Average (± standard error) densities (per 1,000 $m^3$) of (a) yolk-sac and (b) post-yolk-sac larvae, and (c) total larvae collected in Arthur Kill/Newark (AK/NB) Bay, Lower Bay (LB), and Upper Bay (UB) for 2002 to 2010.

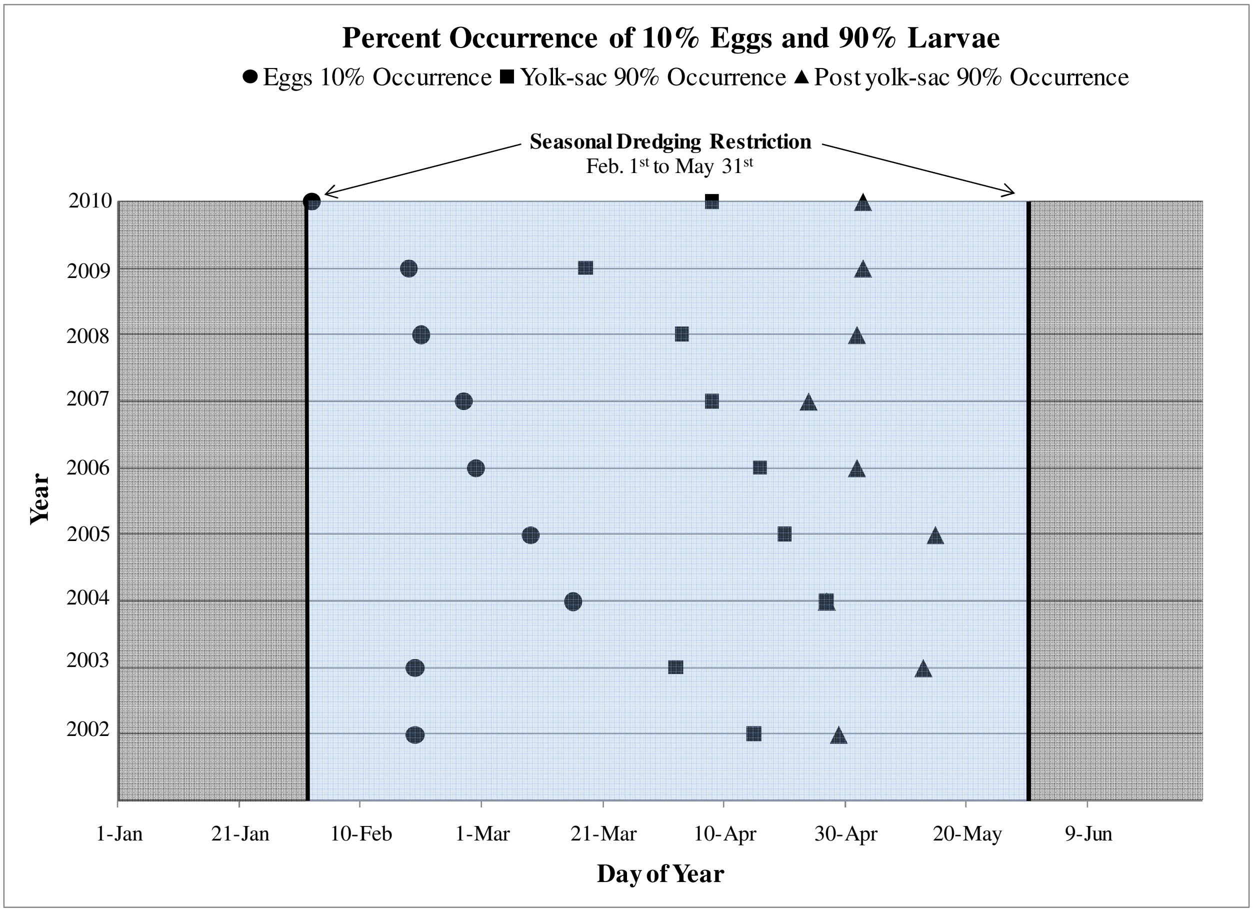



**Figure 6.** Dates by which 10% of eggs (circles) and 90% of yolk-sac (squares) and post-yolk-sac (triangles) larvae were collected from 2002 to 2010 for all Harbor stations.

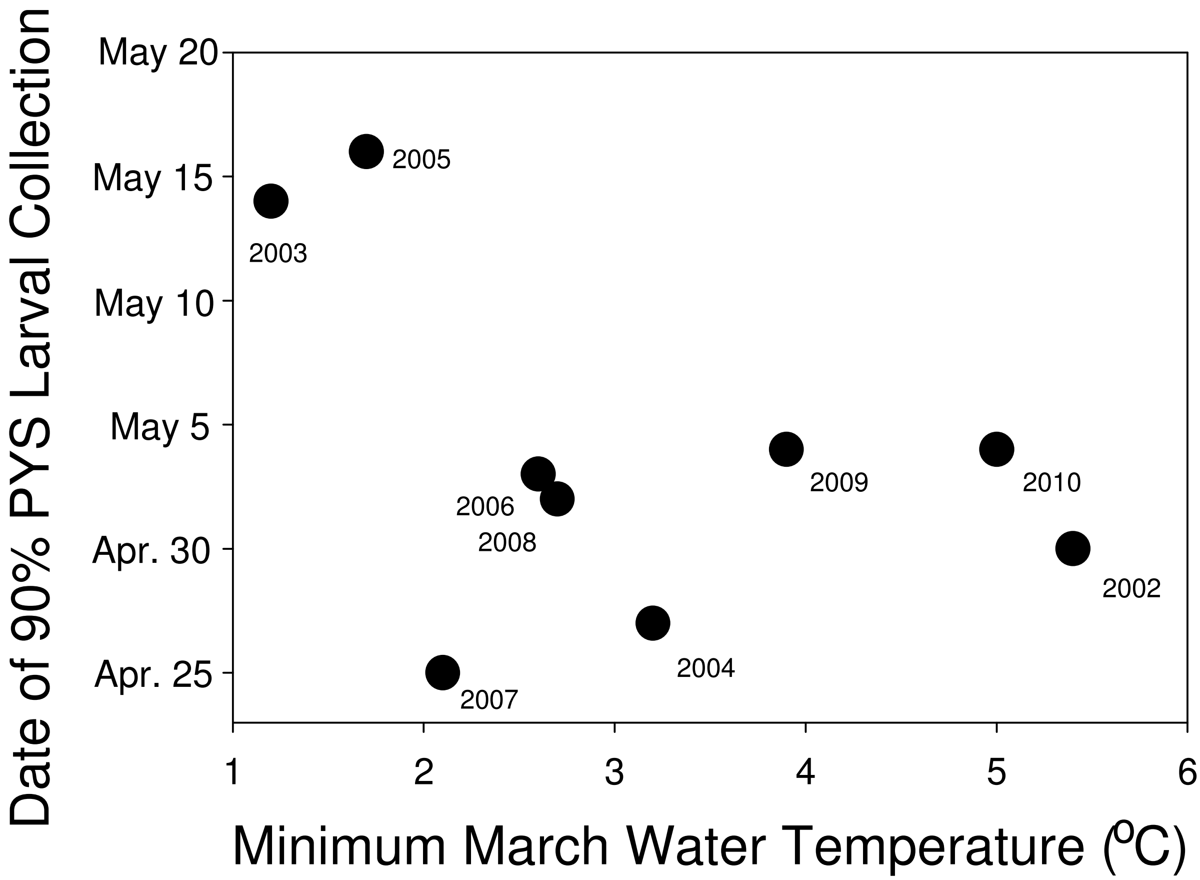



**Figure 7.** Correlation between minimum March water temperatures (NOAA station 8518750 located at the Battery) and the date at which 90% of post-yolk-sac larvae were collected each year.

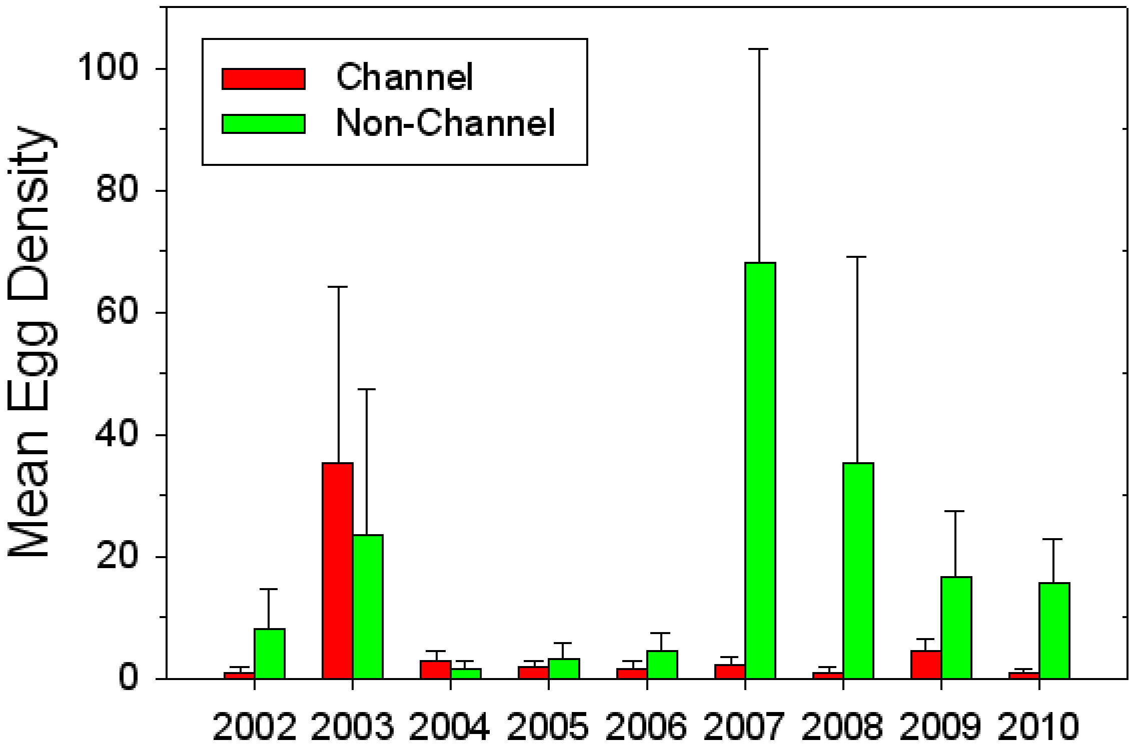



**Figure 8.** Mean (+ standard error) densities (per 1,000 $m^3$) of eggs collected at channel (red bars) and non-channel (green bars) stations for all years of sampling.

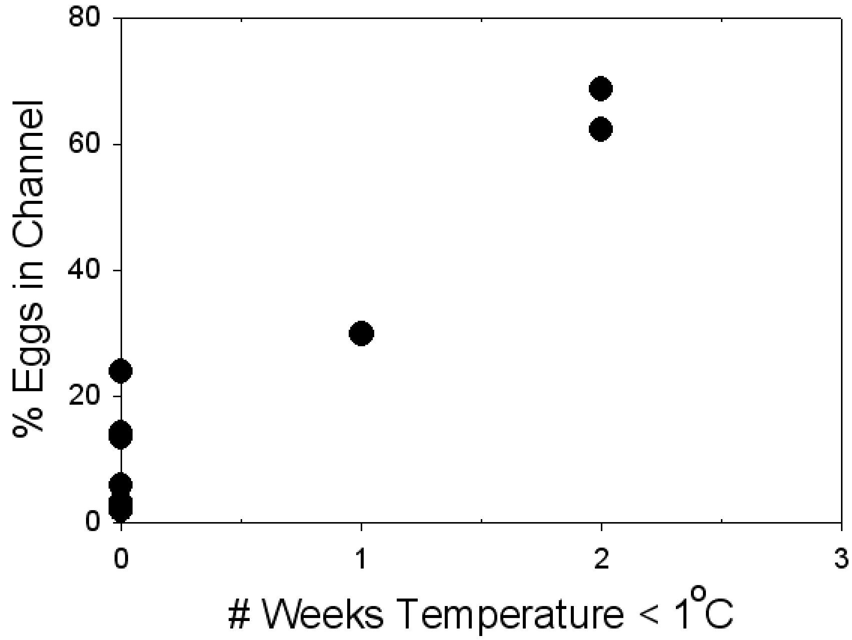



**Figure 9.** Annual % of eggs collected at channel stations (2002 – 2010) vs. the number of weeks that year in which the average water temperature was below 1° C ($r^2 = 0.90$, $p < 0.001$).

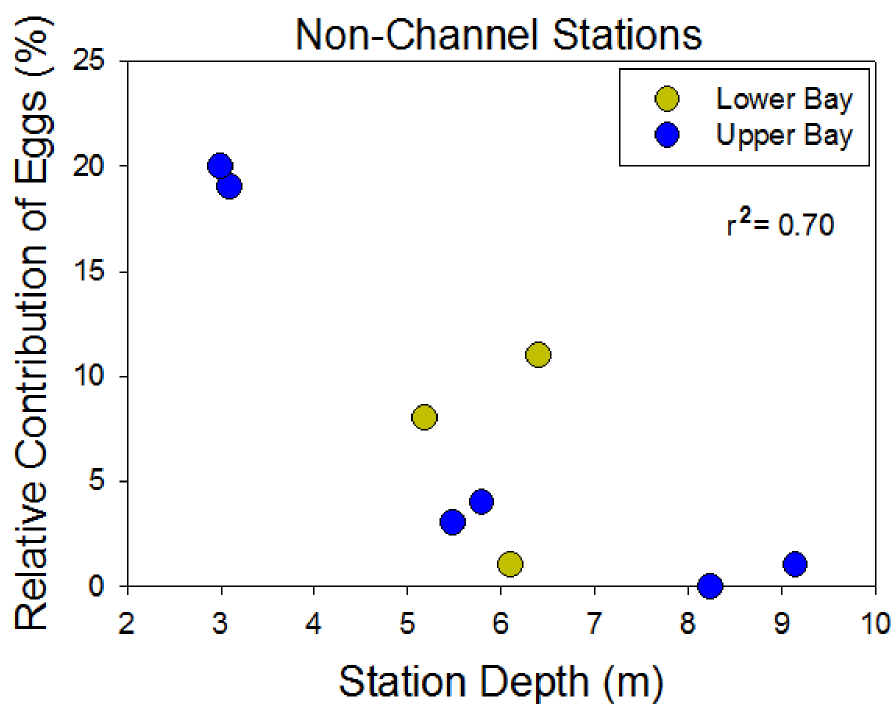



**Figure 10.** Inverse relationship between the average percentage of eggs collected at non-channel stations and station depth ($r^2 = 0.68$, $p < 0.005$). Upper and Lower Bay stations are shaded blue and green, respectively.

# APPENDIX A

# Aquatic Biological Survey (ABS) Methods & Data Analysis
# 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.

# 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 standard set of approximately 26 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.

In 2010, through coordination with the New England Fisheries Management Council (NEFMC), new sampling stations were added to the ABS program in order to examine winter flounder use of naturally deep (i.e. non-channel) areas. Data collected at these non-channel deep stations will be used by USACE-NYD and NEFMC to help determine if and when winter flounder are using deeper waters within the Harbor. Ichthyoplankton sampling has been scheduled to bracket the established period when winter flounder eggs and larvae are present in the Harbor with surveys generally conducted twice each month (approximately every other week) from January to June.

***Field Sampling***

Ichthyoplankton samples were collected using a 0.5-m² diameter plankton net with 0.5-mm mesh mounted on an aluminum epibenthic sled (Figure A-1). The plankton net was fitted with a General Oceanics (GO) Model 2030R flow meter to calculate sample volume. Samples were collected during daylight hours from one hour after sunrise to one hour before sunset. Tows were conducted against the prevailing current at a bottom speed of approximately 3.0 to 3.6 ft/sec (90 to 110 cm/sec). Boat speed was measured using a GO Model 2031 electronic flow meter coupled to GO Model 2135 deck readout. GPS coordinates were recorded at the beginning and end of each tow to ensure proper station maintenance. Target tow duration was ten minutes, although tow times were occasionally adjusted as needed to account for obstructions, limited transect distance, vessel traffic, and other safety considerations in the field. A minimum ratio of 3:1 tow cable length to maximum station water depth was maintained to ensure that the sled was in contact with the bottom throughout each tow.

Upon retrieval of the epibenthic sled, the flow meter reading was checked to ensure that enough water volume had been sampled and that the net had not been ripped or filled with sediment or debris. The net was then washed down from the outside concentrating the sample in the cod-end bucket. Each ichthyoplankton sample was then transferred to an appropriately sized container(s) and the remaining volume filled with 10% buffered Formalin containing the vital stain Rose Bengal. Samples were then returned to the laboratory for sorting and identification.

***Laboratory Methodology***

All specimens collected during the ABS ichthyoplankton surveys were identified to the lowest taxonomic level practicable, and assigned a life stage based on morphometric characteristics (i.e., egg, yolk-sac larvae, post yolk-sac larvae, or juvenile). For some larvae, it was not possible to discern between yolk-sac and post yolk-sac life stages because the specimens were damaged by natural causes and/or during sample collection.

Quality control procedures consisted of a continuous sampling plan to assure an average outgoing quality limit (AOQL) of <0.10 (≥90% accuracy) during sample sorting, enumeration, life stage designation, and identification.

Beginning in 2008, to further identify and describe the embryonic development of viable[1] winter flounder eggs (Figure A-2) collected during the ichthyoplankton survey, the following sequential staging methodology was developed based upon the winter flounder egg development described by Martin and Drury (1978).

**<u>Egg Stages</u>:**

**Stage 1 or Early Cleavage Stage:** 1-64 cells, age equals < 24 hours.

**Stage 2 or Blastula Stage:** Final product of cleavage, formation of blastocoel, age equals approximately 24-48 hours.

**Stage 3 or Gastrula Stage:** Between formation of blastocoel and formation of embryonic axis, age equals approximately 2-3 days.

**Stage 4 or Early Embryo Stage:** Formation of embryonic axis, age equals approximately 4-15 days.

**Stage 5 or Late Embryo Stage:** After formation of embryonic near hatching, age equals approximately >15 days.

Knowing the developmental stage of eggs may be useful in discriminating between the locations of possible spawning sites (areas where early stage eggs are collected) and non-spawning sites that contain eggs (in latter developmental stages) that may have been relocated from their site of deposition by currents (Schultz *et al.* 2007). Another indicator of potential spawning site location is the presence of both early (Egg Stage 1/Egg Stage 2) and late (Egg Stage 5) stage eggs in the same sample, thus indicating the presence of eggs from multiple spawning events. Although egg development rates can vary within a single clutch, the range in development times does not span two weeks, thus mixed stage samples indicate either a commonly used spawning site or a sink for eggs drifting in the

[1] Viable eggs were fertilized eggs showing various stages of development at the time of preservation. Non-viable eggs include those that were unfertilized as well as those fertilized but obviously dead: an egg that has become opaque in appearance or has signs of fungus and/or other types of deterioration.

area. In 2008 through 2010, the number of non-viable eggs was also recorded. Non-viable eggs include those that are unfertilized as well as those that are opaque, or exhibiting some form of deterioration.

In addition, all winter flounder yolk-sac and post yolk-sac larvae were further classified (beginning in 2007) into the following developmental stages (Figure A-3):

**Larval Stages**:

**Stage 1:** Yolk-sac present or eyes not pigmented.

**Stage 2:** Eyes pigmented, no loop or coil formed in the gut, no flexion of the notochord, and no yolk-sac present or minimal traces of yolk may remain.

**Stage 3:** Loop or coil formed in gut and/or flexion of the notochord has begun, but left eye has not migrated past the midline.

**Stage 4:** Left eye has migrated past the midline, but juvenile characteristics not present.

# Statistical Analysis

# ABS Ichthyoplankton Data 2002-2010

The spatial distribution of winter flounder eggs and larvae were examined with reference to dredging management issues of concern in New York/New Jersey Harbor. Winter flounder egg and larval distributions are examined as they relate to:

- Harbor area, i.e., the location of high and low value spawning habitats,
- Channel vs. non-channel areas, and
- Physical characteristics of high value spawning habitat.

Winter flounder populations throughout their range are cyclical, with adult abundances fluctuating as much as seven-fold within a decade (Jeffries and Terceiro 1985). This high degree of variation in annual abundance was evident in the nine years of sampling reviewed in this study.

Egg abundance data were not normally distributed, therefore, non-parametric Kruskal-Wallis tests were used to test for differences in abundance among areas (Arthur Kill/Newark Bay, Lower Bay, and Upper Bay) and station types (channel vs. non-channel). The dependent variables used in these analyses were the average percent contribution to overall egg collections. Multiple regression analyses were used to test whether annual variation in physical factors such as river discharge, salinity, dissolved oxygen, and temperature was related to annual differences in the spatial distribution of eggs among Harbor areas and station types (channel vs. non-channel). Salinity, dissolved oxygen, and temperature variables used in these analyses were calculated from ABS data for Upper Bay stations during the peak egg collection periods (late February through March) each year. This combination of factors was selected to maximize the potential of finding significant associations. Physical factors (especially salinity) were more variable within sampling events among stations in the Upper Bay, compared to more uniform conditions in the Lower Bay.

The independent variables were the average minimum salinity at channel stations, average minimum salinity at non-channel stations, average minimum dissolved oxygen, average temperature, and February and March Hudson River discharge (analyzed as separate variables). The dependent variables were the annual percentage of eggs collected in the Upper Bay and the average percentage of eggs collected at channel stations. Regression analyses were used to further explore associations between temperature and egg distributions using temperature data from the Battery station (NOAA gage, station ID 8518750).

The relationship between relative egg abundance and station depth for Lower and Upper Bay stations was examined through regression analysis. Stations in Arthur Kill and Newark Bay were not included in this analysis because egg collections in general were very low in these areas. An Analysis of Covariance test was conducted to determine whether egg densities differed by sediment type using station depth as the covariate. Sediment types were assigned based on station proximity to known sediment types described later in this data appendix.

Yolk-sac and post-yolk-sac larval densities were tested with two factor ANOVAs using harbor area and station type as independent variables. Larval abundance data were log-transformed to satisfy the normality and homogeneity of variance assumptions of the ANOVA tests. Tests were conducted separately for each year. Multiple regression analyses of the larval data included the aforementioned factors used in the analysis of egg distributions as well as April Hudson River discharge.

***Station Type (Channel vs. Non-Channel)***

Egg densities at channel stations relative to non-channel stations varied by year (Figure A-4). In some years (2003 and 2004), egg densities at channel stations exceeded those of non-channel stations, although there was no statistically significant difference. In other years, egg densities at non-channel stations far exceeded that of channel stations (2007, 2008, and 2009). Multiple regression analysis of this inter-annual variability in the relative abundance of eggs in channels revealed no significant correlations with salinity, dissolved oxygen, temperature or river discharge. Years in which the percentage of eggs collected at channel stations were relatively high were also years with relatively low water temperatures (Figure A-4).

***Sediment Type***

Egg density did not differ by sediment type (ANCOVA using depth as covariate). Because sediment type differs between the Upper and Lower Bay areas, i.e. primarily silty sands in the Upper Bay and coarser sands in the Lower Bay, any potential difference related to sediment type would be confounded with Harbor area. Sediment type, within the range of types that occur within the study area (see later section) was unrelated to egg density.

***Developmental Stage***

Stage 1 eggs were collected in 2008, 2009 and 2010 in sufficient numbers to examine distribution patterns, which are hereafter discussed based on density (eggs/1,000 m³). In 2008, 87% of all eggs collected were in stage 1 of development and 98% of the stage 1 eggs were collected at non-channel stations, due in large part, to a very large collection at station PJ-3 on February 20th. Stage 1 eggs were collected at three other non-channel stations (PJ-1, PJ-2, and NB-7) and one channel station (SB-6) in 2008 (Table A-1). In 2009, stage 1 eggs comprised 22% of the eggs collected and 100% of the stage 1 eggs were collected at three non-channel stations (NB-7, LB-13, and PJ-2). A single collection at PJ-2 on February 18th accounted for 70% of the stage 1 eggs. Thirty percent of the eggs collected in 2010 were stage 1 and 2% of these eggs were collected at channel stations.

Stage 1 eggs have been collected at twelve stations. The non-channel stations were in the Upper Bay (PJ-1, PJ-2, and PJ-3), Lower Bay (LB-1, LB-12, LB-13, LB-16, LBD-17) and Newark Bay (NB-7). Stage 1 eggs were collected at three channel station (LB-4, LB-14, and SB-6; Table A-1). Egg collections at many of the non-channel stations with stage 1 eggs also contained eggs in later stages of development (stage 4 and/or stage 5). The presence of both recently spawned eggs (stages 1 and 2) and late stage eggs (stages 4 and

5) in the same collection suggests eggs from several spawning events were collected. Collections at one channel station with stage 1 eggs (LB-14) also contained latter stage eggs (Table A-1). The sediment type at the non-channel stations where early stage eggs were collected was fine-grained, either sandy silt or silt, which is indicative of low current conditions.

In 2009, eggs in each stage of development were collected at non-channel stations. Eggs collected within 2 days of deposition (stages 1 and 2) comprised 31% of the catch. Eggs collected at the channel stations were exclusively in latter stages of development (stages 3, 4 and 5; Figure A-5).

Non-viable eggs were collected at both non-channel and channel stations in frequencies consistent with the collection of viable eggs in 2009 (Table A-1, Chi-square = 0.03, $p > 0.05$). Eggs were only collected at one channel station in 2008, therefore, preventing statistical analysis for this year. The largest collection of non-viable eggs (n = 936, February 20, 2008) was dominated by non-fertilized eggs.

***Larval Densities***

Yolk-sac larval densities differed significantly among Harbor areas in only one year (2008), in which larval densities were significantly higher in the Lower Bay than in either Arthur Kill/Newark Bay or the Upper Bay ($F = 6.8$, $p < 0.005$). Yolk-sac larval densities did not differ significantly by station type (channel vs. non-channel) in any year. Analysis of post-yolk-sac larvae yielded similar results. The only significant differences reflected higher post-yolk-sac larval densities in the Lower Bay than other areas in 2008 ($F = 5.4$, $p < 0.01$) and 2009 ($F = 3.5$, $p < 0.05$).

Multiple regression analyses revealed no significant associations between yolk sac larval distributions by Harbor area and environmental factors such as salinity, dissolved oxygen, temperature, and sediment type. The proportion of post-yolk-sac larvae in the Upper Bay was negatively correlated with net April inflows from the Hudson River ($r^2$ =

0.63, $p < 0.05$), suggesting that spring flood events transport larval winter flounder out of the Upper Bay.

***Temporal Analyses***

Seasonal occurrences of winter flounder eggs and larvae in New York/New Jersey Harbor are described and examined in association with fluctuations in environmental variables such as temperature, salinity, and Hudson River discharge. Two factor ANOVAs were used to test for differences in larval densities by week of year and station type (channel vs. non-channel) following log transformations of the data. The dates at which 90% of post-yolk sac larvae were collected among harbor areas were examined with a one-factor ANOVA. A similar test to determine whether the timing of egg collections differed by harbor area was not conducted due to small sample sizes caused by both the consistently low egg collections in the Arthur Kill/Newark Bay area and low egg collections in either the Upper Bay or Lower Bay in years in which spawning activity was concentrated in one area or the other. Dates at which 10% of eggs and 90% of post-yolk sac larvae were collected were examined for associations with annual variation in river discharge, temperature (NOAA station 8518750 located at the Battery) and salinity.

The timing of when 10% of the annual egg collections were made was not significantly associated with monthly Hudson River discharge, water temperature, or salinity. The date at which 90% of post-yolk sac larvae were collected did not differ by harbor area ($F = 0.49$, $p > 0.5$), however, there was a significant difference in the timing of 90% post-yolk sac larval collections among years ($F = 6.2$, $p = 0.001$), with larval collection occurring later in 2003 and 2005 than in other years (Figure A-6).

The timing of egg occurrences at channel and non-channel stations did not differ within years of sampling, i.e., there was no evidence that eggs were initially more common in non-channel areas and increasingly collected at channel stations later the same year. For instance, in 2003, the only year in which a relatively large number of eggs were collected from channel stations, high percentages of eggs were collected at channel stations during sampling periods in early February, early March and early April (Figure A-4). Other years with relatively high percentages of eggs at channel stations (2004 and 2005) had very low overall samples sizes, thus percentages were highly influenced by the collection of very few eggs. There were no significant interactions in the two factor ANOVAs testing whether post-yolk-sac larval densities differed by week and station type, thus temporal trends in post-yolk-sac larval occurrences are similar for channel and non-channel areas.

In a study conducted in Great Bay, New Jersey, Sogard *et al.* (2001) found a significant correlation ($r^2 = 0.58$, $p < 0.05$) between peak winter flounder larval densities and average March air temperatures between 1989 and 1999 (Figure A-6). Sogard *et al.* (2001) attributed this inverse relationship to delayed metamorphosis to settlement in colder years. The relationship between larval abundances in New York/New Jersey Harbor and March water temperatures is similar (Figure A-6). The long time period (19 years over the two studies combined) and consistency of findings strengthens the case that March water temperature can be used as a reliable tool for estimating a time at which most metamorphosis from the larval to juvenile stage can be presumed to have already occurred for the New York/New Jersey Harbor. In this study, winter flounder larval occurrences were examined in terms of the date at which 90% of post-yolk-sac larvae were collected. The significant correlations between this parameter and both mean and minimum March water temperatures provides alternative tools for management purposes, although the mechanism by which temperature affects larval occurrences is most probably related to minimum temperatures. Laurence (1975) studied winter flounder larval development at three temperatures ($2^o$, $5^o$ and $8^o$ C) and found that larval development was delayed up to six weeks at $2^oC$, which is consistent with the later larval residency times in the two years when March temperatures fell below $2^o$ C (2003 and 2005).

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Sogard, S.M., Able, K.W. and S.M. Hagan. 2001. Long-term assessment of settlement and growth of juvenile winter flounder (*Pseudopleuronectes americanus*) in New Jersey estuaries. Journal of Sea Research 45:189-204.

**Table A-1.** Viable egg (by stage E1 - E5) and non-viable egg densities (eggs/1,000 $m^3$) listed by station and sampling date. Stations with multiple-stage egg collections that are indicative of spawning habitat (i.e., include both early and late stage eggs) are shaded.

| Area | Station Type | Station | Date | Densities by Egg Stage (eggs/1,000 $m^3$) | | | | | Sum of Viable Egg Densities | Total Viable Eggs | Non-Viable Egg Densities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | E1 | E2 | E3 | E4 | E5 | | | |
| **2008** | | | | | | | | | | | |
| UB | CH | SB-6 | 2/20 | 35 | 0 | 0 | 0 | 0 | 35 | 4 | 35 |
| | NC | PJ-1 | 3/4 | 46 | 0 | 5 | 5 | 0 | 56 | 11 | 41 |
| | | PJ-2 | 2/20 | 60 | 0 | 0 | 35 | 10 | 105 | 21 | 973 |
| | | PJ-2 | 3/17 | 0 | 0 | 0 | 0 | 9 | 9 | 2 | 5 |
| | | PJ-3 | 2/20 | 1489 | 0 | 0 | 29 | 0 | 1518 | 311 | 4570 |
| | | PJ-3 | 3/7 | 0 | 0 | 6 | 0 | 0 | 6 | 1 | 0 |
| LB | NC | LB-13 | 2/25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| | | LB-13 | 3/18 | 0 | 0 | 0 | 10 | 0 | 10 | 2 | 5 |
| | | LB-8 | 3/24 | 0 | 0 | 0 | 0 | 6 | 6 | 1 | 0 |
| | | LB-8 | 4/3 | 0 | 0 | 0 | 0 | 6 | 6 | 1 | 0 |
| AKNB | NC | NB-7 | 2/19 | 0 | 96 | 11 | 0 | 23 | 130 | 23 | 6 |
| | | NB-7 | 3/7 | 7 | 0 | 0 | 0 | 0 | 7 | 1 | 0 |
| **2009** | | | | | | | | | | | |
| UB | CH | SB-4 | 3/9 | 0 | 0 | 0 | 0 | 35 | 35 | 4 | 167 |
| | | SB-5 | 4/10 | 0 | 0 | 11 | 32 | 0 | 43 | 4 | 0 |
| | | SB-5 | 2/25 | 0 | 0 | 0 | 4 | 4 | 8 | 2 | 0 |
| | | SB-5 | 3/9 | 0 | 0 | 0 | 7 | 0 | 7 | 1 | 0 |
| | | SB-6 | 3/9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| | NC | PJ-1 | 4/9 | 0 | 0 | 0 | 4 | 0 | 4 | 1 | 0 |
| | | PJ-2 | 2/18 | 190 | 0 | 17 | 17 | 39 | 263 | 47 | 436 |
| | | PJ-2 | 3/16 | 0 | 0 | 5 | 0 | 0 | 5 | 1 | 0 |
| | | SB-3 | 3/9 | 0 | 0 | 24 | 0 | 24 | 48 | 8 | 89 |
| LB | CH | LB-2 | 2/18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 |
| | | LB-14 | 2/6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| | | LB-14 | 4/9 | 0 | 0 | 0 | 7 | 0 | 7 | 2 | 0 |
| | | LB-14 | 3/6 | 0 | 0 | 7 | 0 | 0 | 7 | 1 | 22 |
| | | LB-4 | 4/8 | 0 | 0 | 0 | 19 | 0 | 19 | 4 | 0 |
| | | LB-4 | 3/18 | 0 | 0 | 10 | 0 | 5 | 14 | 3 | 0 |
| | | LB-6 | 4/8 | 0 | 0 | 0 | 17 | 0 | 17 | 2 | 0 |
| | | LB-6 | 3/5 | 0 | 0 | 0 | 10 | 0 | 10 | 1 | 0 |
| | SH | LB-1 | 3/6 | 0 | 0 | 6 | 28 | 68 | 102 | 18 | 181 |
| | | LB-1 | 3/19 | 0 | 0 | 0 | 22 | 0 | 22 | 2 | 11 |
| | | LB-1 | 2/25 | 0 | 0 | 0 | 7 | 0 | 7 | 1 | 0 |
| | | LB-13 | 3/18 | 62 | 50 | 67 | 162 | 162 | 503 | 90 | 212 |
| | | LB-13 | 3/5 | 10 | 0 | 10 | 0 | 10 | 30 | 3 | 10 |
| | | LB-13 | 4/8 | 0 | 0 | 0 | 24 | 0 | 24 | 5 | 5 |
| | | LB-5 | 3/18 | 0 | 0 | 0 | 8 | 0 | 8 | 1 | 0 |
| | | LB-8 | 3/6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71 |
| | | LB-8 | 4/8 | 0 | 10 | 0 | 0 | 0 | 10 | 2 | 0 |
| | | LB-9 | 3/6 | 0 | 0 | 0 | 0 | 16 | 16 | 3 | 0 |
| | | LB-9 | 4/9 | 0 | 0 | 0 | 6 | 0 | 6 | 1 | 0 |
| AKNB | NC | NB-7 | 3/4 | 9 | 0 | 0 | 0 | 13 | 22 | 5 | 9 |
| | | NB-7 | 3/17 | 0 | 0 | 6 | 0 | 0 | 6 | 1 | 0 |

**Table A-1 continued**

| **Area** | **Station Type** | **Station** | **Date** | **Densities by Egg Stage (eggs/1,000 m$^3$)** E1 | E2 | E3 | E4 | E5 | **Sum of Viable Egg Densities** | **Total Viable Eggs** | **Non-Viable Egg Densities** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2010** | | | | | | | | | | | |
| UB | CH | SB-4 | 2/19 | 0 | 0 | 0 | 5 | 0 | 5 | 1 | 0 |
| | | SB-7 | 2/4 | 0 | 0 | 0 | 14 | 0 | 14 | 1 | 0 |
| | NC | PJ-1 | 1/4 | 0 | 0 | 0 | 0 | 7 | 7 | 1 | 5 |
| | | PJ-1 | 3/17 | 0 | 0 | 0 | 0 | 7 | 7 | 1 | 0 |
| | | PJ-2 | 2/17 | 19 | 19 | 0 | 0 | 0 | 38 | 6 | 19 |
| | | PJ-2 | 3/4 | 298 | 275 | 34 | 63 | 6 | 676 | 118 | 178 |
| | | PJ-2 | 3/16 | 0 | 0 | 0 | 0 | 5 | 5 | 1 | 20 |
| | | SB-3 | 2/19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| LB | CH | LB-2 | 2/23 | 0 | 6 | 6 | 0 | 0 | 12 | 2 | 12 |
| | | LB-14 | 2/23 | 6 | 12 | 6 | 12 | 0 | 36 | 6 | 12 |
| | | LB-4 | 1/19 | 0 | 9 | 0 | 9 | 0 | 18 | 2 | 0 |
| | | LB-4 | 3/18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| | | LB-4 | 4/22 | 5 | 0 | 0 | 0 | 0 | 5 | 1 | 0 |
| | NC | LB-1 | 2/23 | 12 | 12 | 0 | 12 | 0 | 36 | 6 | 41 |
| | | LB-1 | 3/22 | 0 | 0 | 5 | 0 | 0 | 5 | 1 | 0 |
| | | LB-10 | 4/5 | 0 | 0 | 0 | 0 | 6 | 6 | 1 | 0 |
| | | LB-12 | 1/19 | 0 | 0 | 0 | 6 | 0 | 6 | 1 | 6 |
| | | LB-12 | 2/2 | 60 | 42 | 18 | 0 | 0 | 120 | 20 | 42 |
| | | LB-12 | 2/22 | 0 | 9 | 0 | 0 | 0 | 9 | 1 | 0 |
| | | LB-12 | 3/2 | 0 | 15 | 0 | 0 | 0 | 15 | 3 | 0 |
| | | LB-12 | 4/6 | 0 | 0 | 0 | 0 | 13 | 13 | 2 | 0 |
| | | LB-13 | 1/19 | 0 | 0 | 0 | 7 | 0 | 7 | 1 | 0 |
| | | LB-13 | 2/2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| | | LB-13 | 2/22 | 0 | 14 | 0 | 0 | 0 | 14 | 2 | 0 |
| | | LB-13 | 3/18 | 0 | 38 | 11 | 5 | 5 | 59 | 11 | 0 |
| | | LB-13 | 4/22 | 12 | 0 | 6 | 18 | 0 | 36 | 6 | 0 |
| | | LB-16 | 1/11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| | | LB-16 | 1/19 | 37 | 26 | 11 | 5 | 5 | 84 | 16 | 42 |
| | | LB-16 | 2/2 | 5 | 20 | 0 | 10 | 0 | 35 | 7 | 20 |
| | | LB-16 | 2/22 | 0 | 17 | 0 | 0 | 0 | 17 | 3 | 11 |
| | | LB-16 | 3/18 | 113 | 173 | 60 | 93 | 100 | 540 | 81 | 320 |
| | | LB-16 | 4/20 | 0 | 0 | 0 | 5 | 0 | 5 | 1 | 0 |
| | | LB-5 | 3/17 | 0 | 24 | 0 | 6 | 6 | 36 | 6 | 0 |
| | | LB-8 | 2/17 | 0 | 6 | 0 | 0 | 0 | 6 | 1 | 0 |
| | | LB-8 | 3/5 | 0 | 5 | 0 | 0 | 0 | 5 | 1 | 0 |
| | | LB-9 | 3/5 | 0 | 0 | 0 | 4 | 0 | 4 | 1 | 0 |
| | | LBD-15 | 2/23 | 0 | 5 | 0 | 11 | 0 | 16 | 3 | 27 |
| | | LBD-17 | 2/2 | 0 | 23 | 0 | 0 | 0 | 0 | 3 | 23 |
| | | LBD-17 | 2/22 | 22 | 0 | 0 | 0 | 0 | 22 | 4 | 42 |
| | | LBD-17 | 3/18 | 0 | 0 | 0 | 0 | 6 | 6 | 1 | 0 |
| AKNB | NC | NB-7 | 3/1 | 6 | 22 | 0 | 0 | 0 | 28 | 5 | 0 |

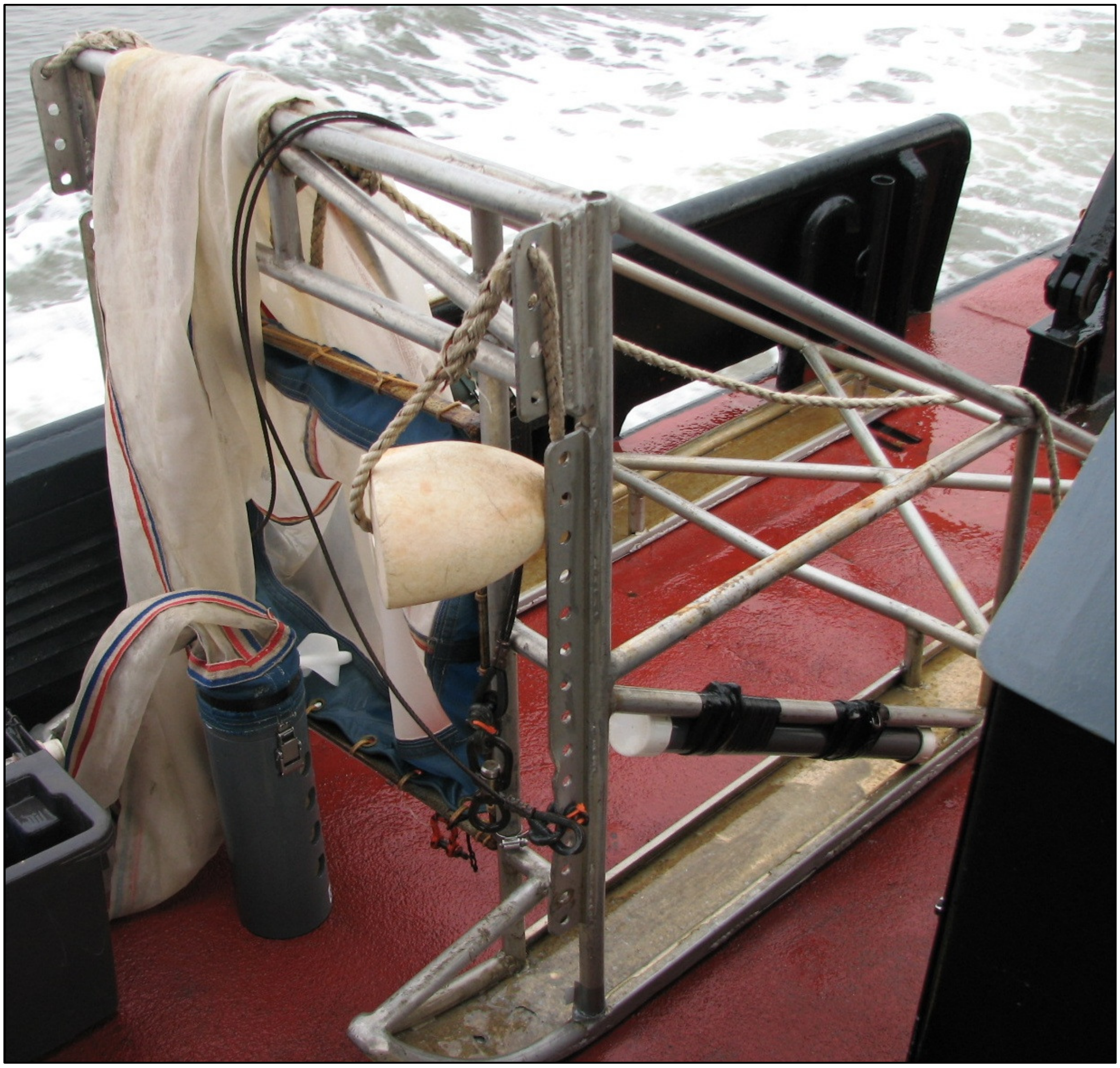
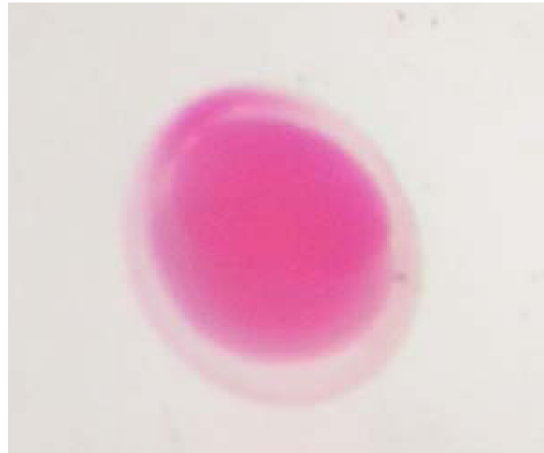
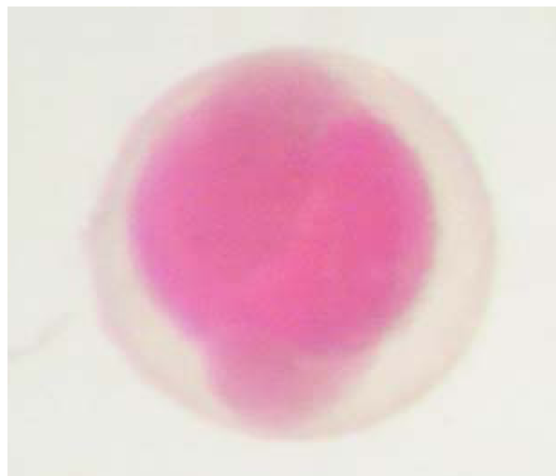


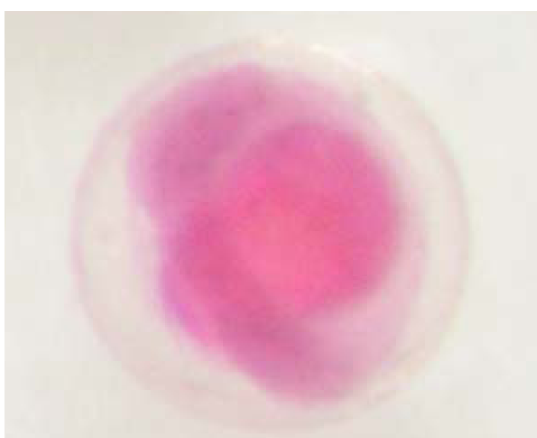
**Figure A-1.** Ichthyoplankton sampling gear used during the 2002-2010 ABS: 0.5-$m^2$ diameter plankton net with 0.5-mm mesh mounted on an aluminum epibenthic sled.



**Stage 1** **Stage 2**



**Stage 3** **Stage 4**



**Stage 5.**

**Figure A-2.** Winter flounder egg stages.

**Stage 1**

**Stage 2**

**Stage 3**

**Stage 3 – close up of gut**

**Stage 4**

**Figure A-3.** Winter flounder larvae stages.

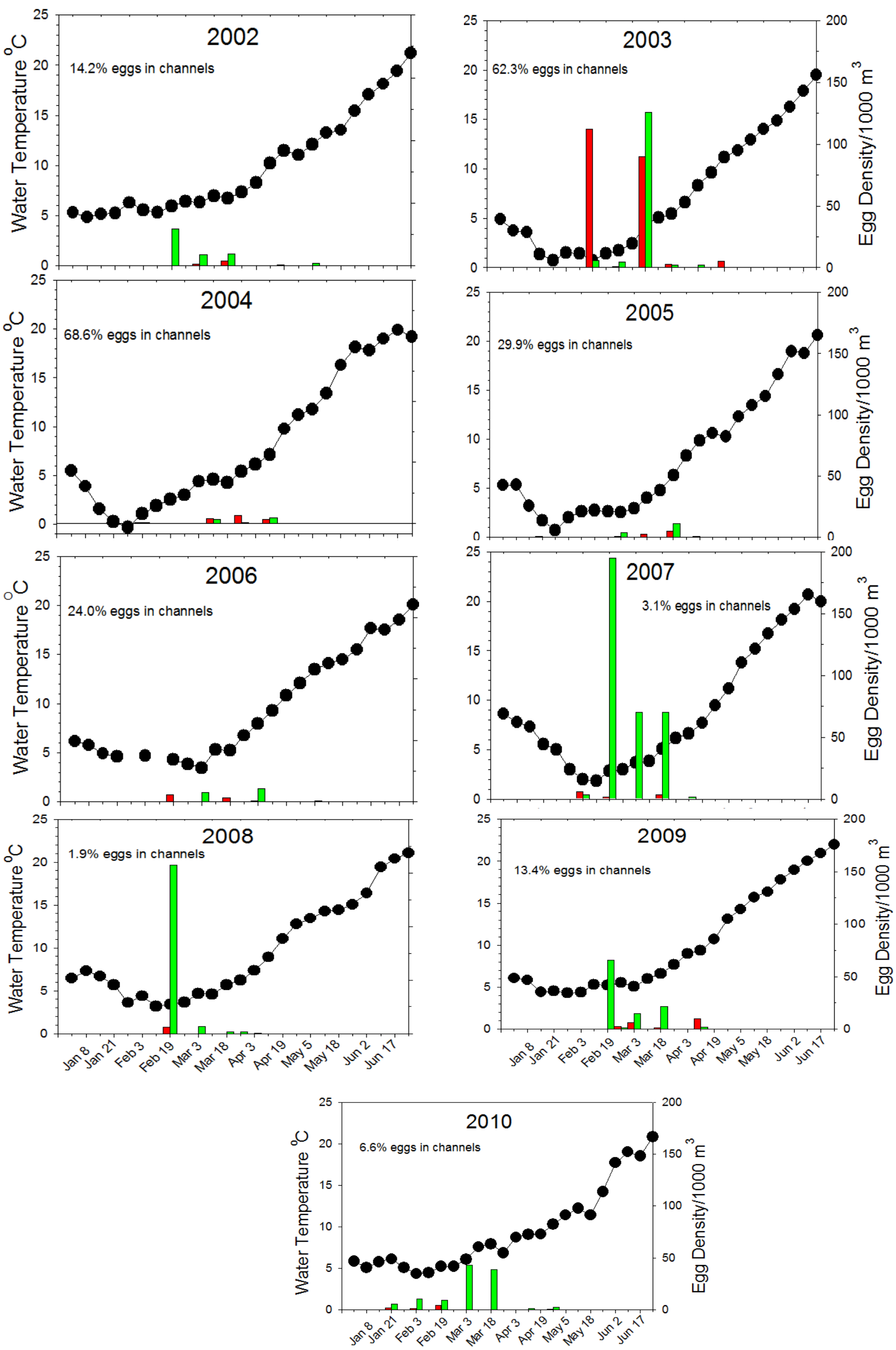



**Figure A-4.** Average weekly water temperatures (black circles) recorded at the Battery, NOAA station ID 8518750, along with the average egg densities collected at two week intervals at channel (red bars) and non-channel (green bars) stations.

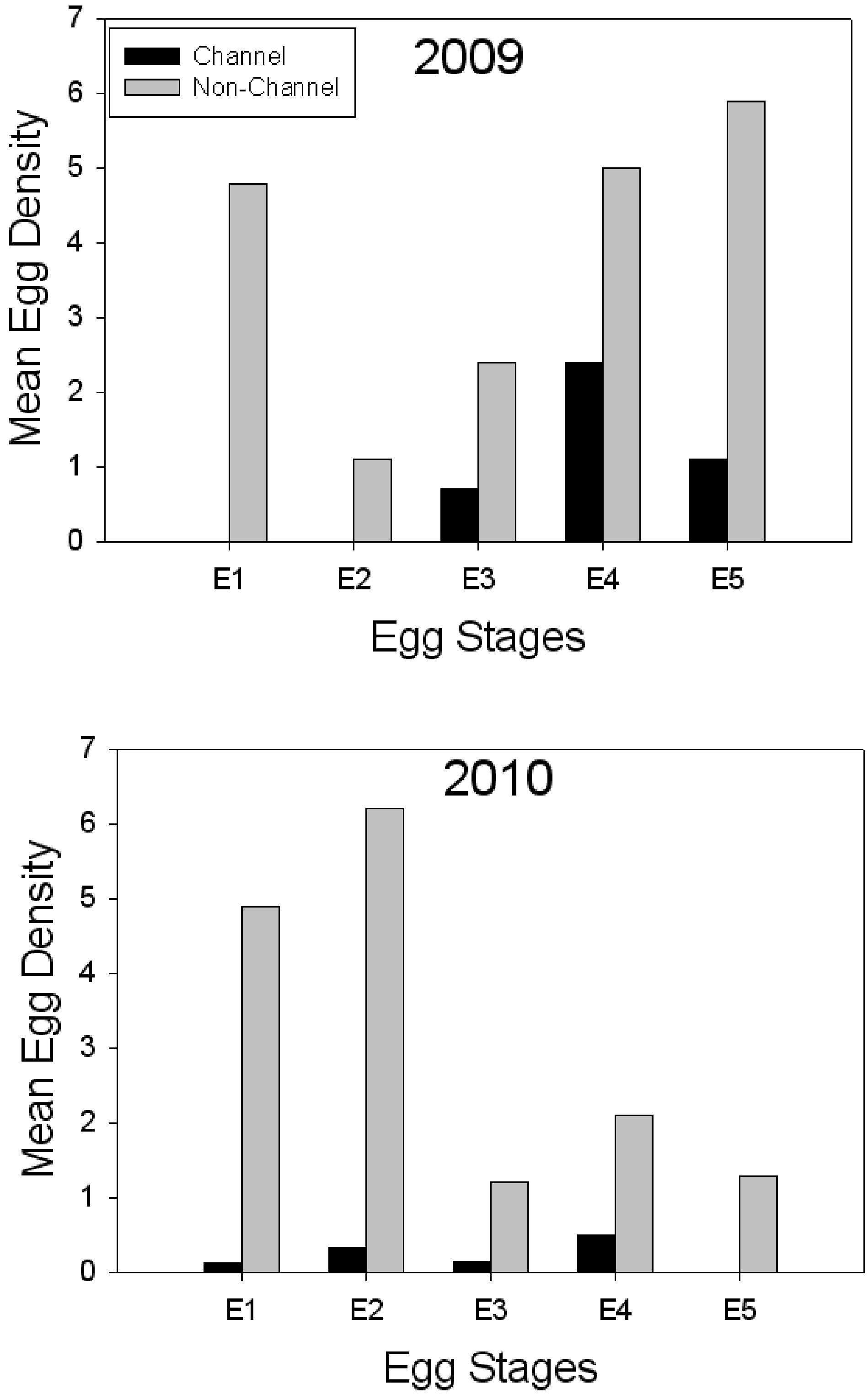



**Figure A-5.** Density (per 1000 $m^3$) of eggs by developmental stage.

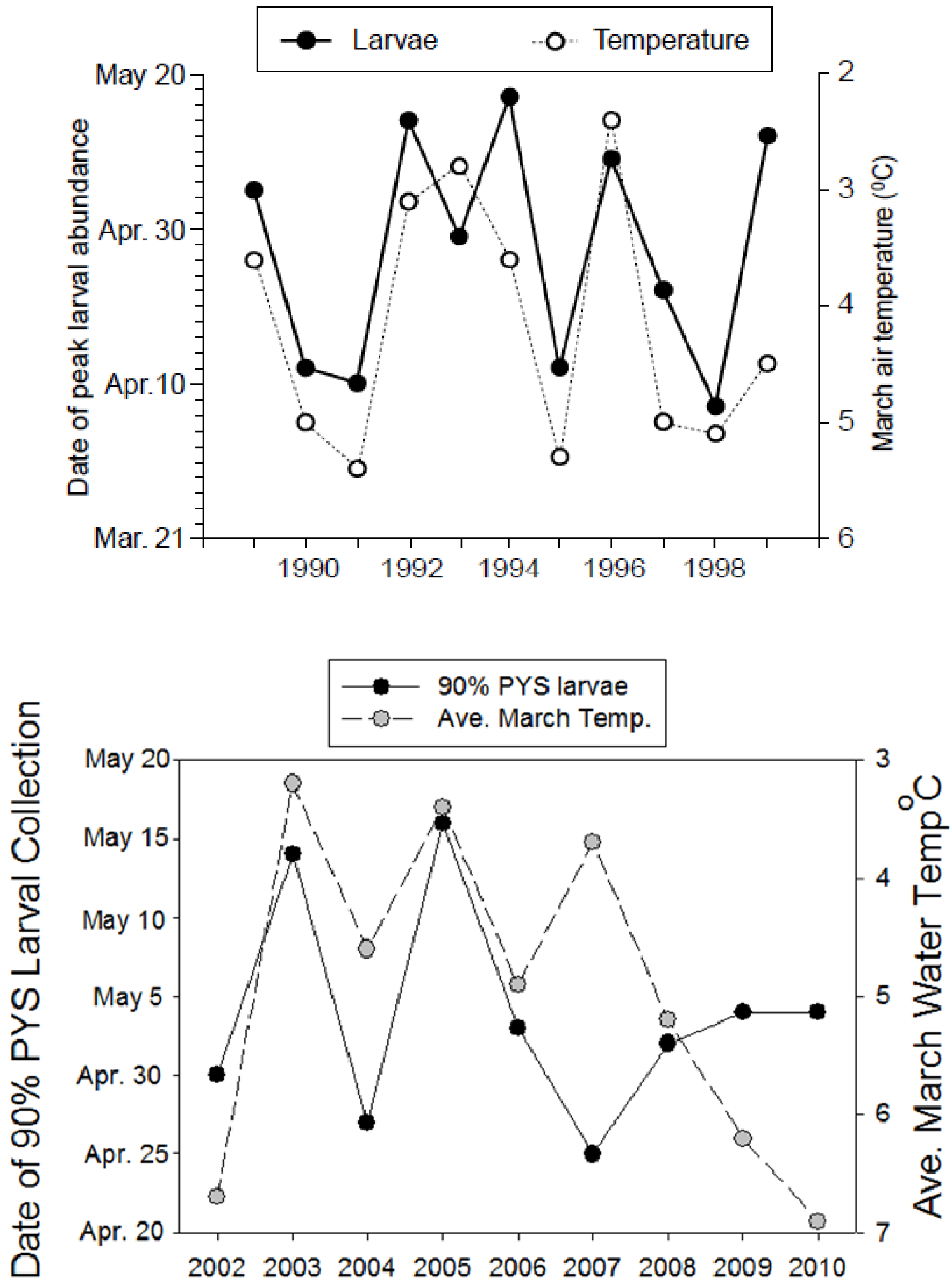



**Figure A-6.** Relationship between (a) peak larval collections in Great Bay, New Jersey and average March air temperatures (Sogard et al. 2001), and (b) the date at which 90% of post-yolk-sac larvae were collected in NY/NJ Harbor and average March water temperature (NOAA station 8518750). Note reverse scale on the temperature axes.

# APPENDIX B

# Existing Physical Conditions within NY/NJ Harbor

# Introduction

Essential fish habitat (EFH) as defined[2] under section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCA) and as amended by the Sustainable Fisheries Act (SFA) of 1996 includes "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." EFH embodies the physical, chemical, and biological growth properties of both the water column and the underlying substrate, including sediment, hard bottom, and other submerged structures.

USACE-NYD also reviewed available data collected as part of the Harbor Deepening Program that describes the existing physical conditions within New York/New Jersey Harbor (the Harbor) as it pertains to winter flounder EFH. The following datasets were reviewed and are summarized below:

- Annual water temperature, salinity and dissolved oxygen from USACE –NYD Aquatic Biological Survey;
- Freshwater discharge data obtained from USGS stations;
- MIKE3 modeling data summarized from USACE-NYD Harbor Navigation Study's Hydrodynamic & Water Quality Modeling Final Report (USACE 2004);
- Sediment profile imagery (SPI) surveys conducted by Iocco *et al.* 2000.

## Water Chemistry

Dissolved oxygen (DO), temperature, conductivity, and salinity were measured during each ABS survey at each station location using a calibrated YSI Model 85 Handheld Oxygen, Conductivity, Salinity and Temperature System meter. Measurements were

[2] Under the EFH definition, necessary habitat is that which is required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. EFH may be designated for the complete life cycle of a species, including spawning, feeding, and growth to maturity, or may be specific for each life stage (eggs, larvae, juvenile, adult, and spawning adult).

recorded from the bottom stratum of the water column at approximately one foot (0.3 m) above the substrate. Field instruments were calibrated each day both prior to and after 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.

To supplement the ABS data, water temperature data were also obtained from records for a NOAA gage (station ID 8518750) located at the Battery Station (40 42.0N, 74 0.8W). These data provide a continuous record of water temperature, allowing an examination of the duration and magnitude of extreme conditions, which is not possible using the biweekly water quality data collected during ABS sampling. During February through April, temperature data from the NOAA Battery station matched weekly mean temperatures from ABS sampling to within 0.5$^{o}$ C.

***Temperature***

Water temperature is an important environmental factor affecting the timing of winter flounder spawning and the development of eggs and larvae (Able and Fahay 1998; NMFS 1999). Figure B-1 shows the average monthly bottom water temperatures (January through June) in the Arthur Kill/Newark Bay, Lower Bay and Upper Bay areas of the Harbor for the sampling years 2002 through 2010. Low bottom water temperatures of generally less than 3°C were recorded in all three regions during January and February of 2003 and 2004. The warmest bottom water temperatures (generally above 5°C) during those months were recorded in 2002 and 2006. The lowest bottom water temperatures during the peak spawning months of March and April were recorded in 2003 and 2005 while 2002 and 2008 had the warmest bottom water temperature in March.

***Salinity***

Figure B-2 presents the average monthly bottom salinity (January through July) of the three Harbor regions for all data combined 2002 through 2010. All three harbor areas followed a predictable pattern of decreasing salinity from February into April followed by increasing values in May with peak salinity occurring in July. As expected, the Lower Bay had the highest salinity, followed by the Upper Bay and then the Arthur Kill/Newark Bay.

***Dissolved Oxygen***

Figure B-3 presents the average monthly bottom dissolved oxygen (January through July) of the three Harbor regions for all data combined 2002 through 2010. All three harbor areas followed a predictable pattern of peak dissolved oxygen in March (approximately 11.0 mg/l) followed by steadily decreasing dissolved oxygen to July in which all three regions averaged below 6.0 mg/l.

## Hydrodynamic Conditions

Hydrodynamic conditions within the Harbor were summarized using two primary data sources: from freshwater discharge data obtained from U.S. Geological Survey (USGS) gaging stations in closest proximity to the Harbor and from existing MIKE 3FM modeling data summarized from the Harbor Navigation Study's Hydrodynamic & Water Quality Modeling Final Report (USACE 2004).

Freshwater discharge to the New York/New Jersey Harbor is an environmental factor that is relevant to predicting the distribution of benthic and pelagic biological resources in the estuary. Knowledge of how tidal forces, river discharges and other influences on flow conditions (e.g., releases from sewage treatment plants and industry) interact to create overall hydrodynamic conditions is required to reliably estimate the potential transport of winter flounder eggs and larvae within the estuarine system.

***River Discharge Data***

River discharge to the New York/New Jersey Harbor is summarized for the January to June period from 2002 to 2009. Flow data were obtained from USGS stations in closest proximity to the Harbor with discharge data (Figure B-4). An additional source of discharge data was obtained from the USGS Salt Water Front Study in which estimates of monthly net discharge at the mouth of the Hudson River were available up through 2008. Flow data at the mouth of the Hudson River were available as monthly net discharge (cfs) and are estimated based on gaging stations that account for 76.3 percent of the drainage area. Although the Hudson River discharge data provides the best spatial proximity to flow conditions in the estuary, it is not possible to discern short term peaks in flows that might affect egg and larval distributions in the Harbor. Monthly net discharge values, however, can be compared across years to determine whether relative flow magnitudes correspond to egg and larval distribution patterns.

The relative discharge volumes and synchronicity of peak flow events for the three freshwater sources are illustrated for 2003 (Figure B-5). Net Hudson River discharge was significantly correlated with average monthly discharge from the Croton River (e.g., February discharges $r^2 = 0.83$, $p < 0.01$), and not significantly correlated with discharge from the gage stations on the Elizabeth and Hackensack Rivers. Croton River daily discharges, therefore, are plotted to depict the timing and magnitude of flow variation from 2003 through 2009 (Figure B-6). Because the gauging station at New Croton Dam is 1,000 feet below the dam, spikes in flow may include dam releases in addition to natural events upstream of the dam.

Because of the close proximity of the Battery location to winter flounder spawning habitat, data from this source are used to depict inter-annual variation in freshwater discharges to the Harbor. Hudson River discharge typically increases in March, peaks in April and declines from May to July (Figure B-7). February and March discharges were highest in 2008 and April discharge was highest in 2007 (Figure B-8).

***MIKE 3FM Modeling***

Existing MIKE 3FM modeling data summarized from the Harbor Navigation Study's Hydrodynamic & Water Quality Modeling Final Report (USACE 2004) was used to provide an overview of existing hydrodynamic conditions within the Harbor during typical ebb (Figure B-9) and flood conditions (Figure B-10). Within the Harbor, peak velocities of up to 0.6 m/s during both an ebb and flood tide can be expected in the area of Ambrose Channel between Sandy Hook and Rockaway Points in the Lower Bay and within the narrow channel of the Kill Van Kull. Peak velocities of less than 0.1 m/s can be expected within the inter-pier areas of Port Jersey and within the shallow areas of the Lower Bay and Newark Bay/Arthur Kill. Local hydrodynamics within the NY/NJ Harbor may play an important role in winter flounder spawning location preference and may transport eggs into the channels from shoals.

## Sediment Conditions

Iocco *et al.* (2000) surveyed benthic habitats in several sub-basins of the Lower Bay, including Newark Bay, the Upper Bay, Flushing Bay, Bowery Bay and Jamaica Bay. This study was unique in that it relied principally on data gathered using a Sediment Profile Image (SPI) camera system. Figure B-11 shows the surficial sediment grain size characterizations for the (a) Upper and (b) Lower Bay areas of NY/NJ Harbor. These characterizations, made by Dr. Robert Diaz (Virginia Institute of Marine Science), follow the Wentworth classification 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).

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National Marine Fisheries Service (NMFS). 1999. Essential Fish Habitat Source Document: Winter flounder, *Pseudopleuronectes americanus*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-138.

U.S. Army Corps of Engineers – New York District (USACE-NYD). 2004. New York and New Jersey Harbor Navigation Study: Hydrodynamic & Water Quality Modeling. Final Report. Model Calibration, Verification & Application. May 2004.

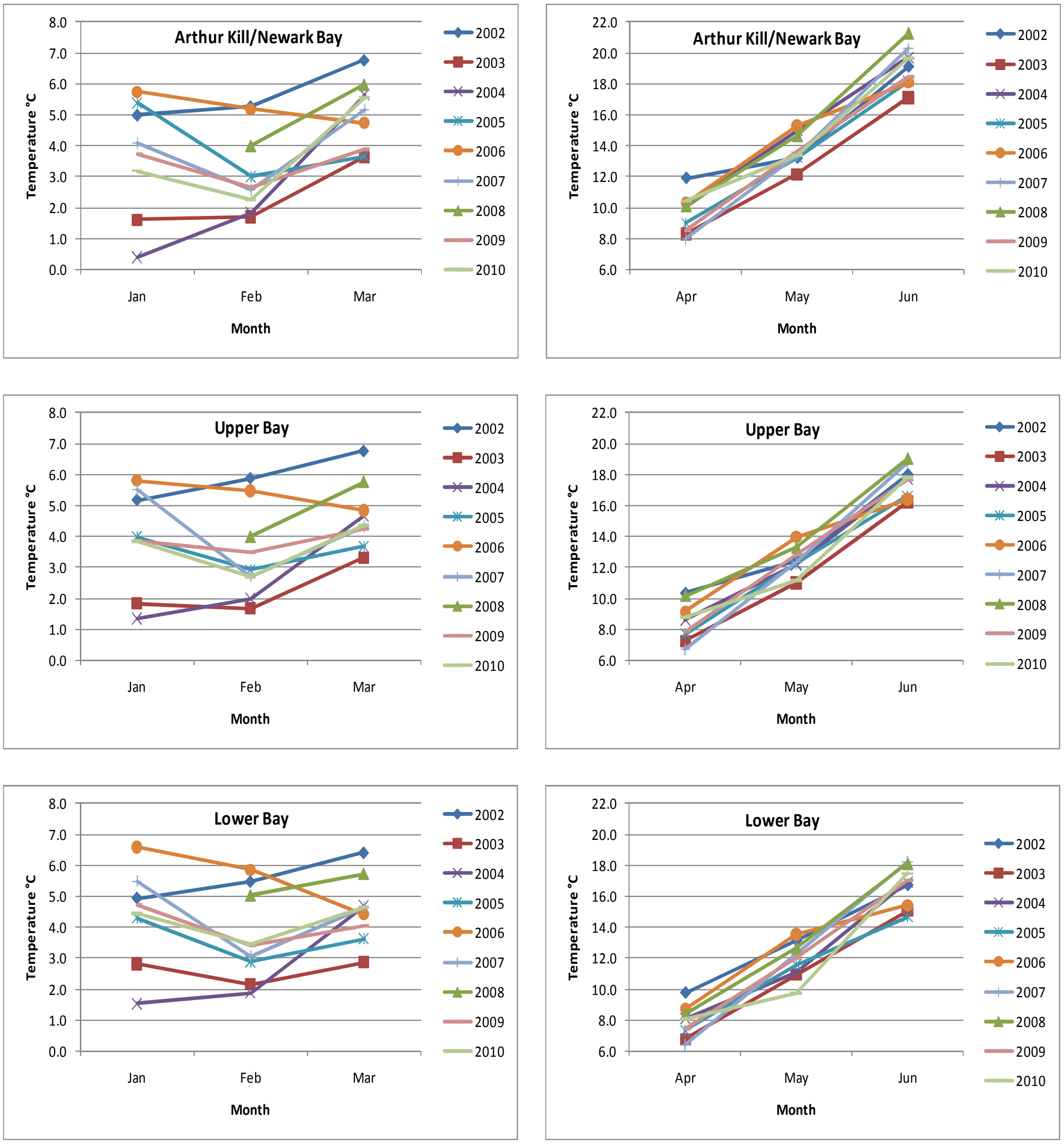



**Figure B-1.** Average monthly bottom water temperatures (January through June) from ABS sampling stations in the Arthur Kill/Newark Bay, Lower Bay and Upper Bay, 2002 through 2010.

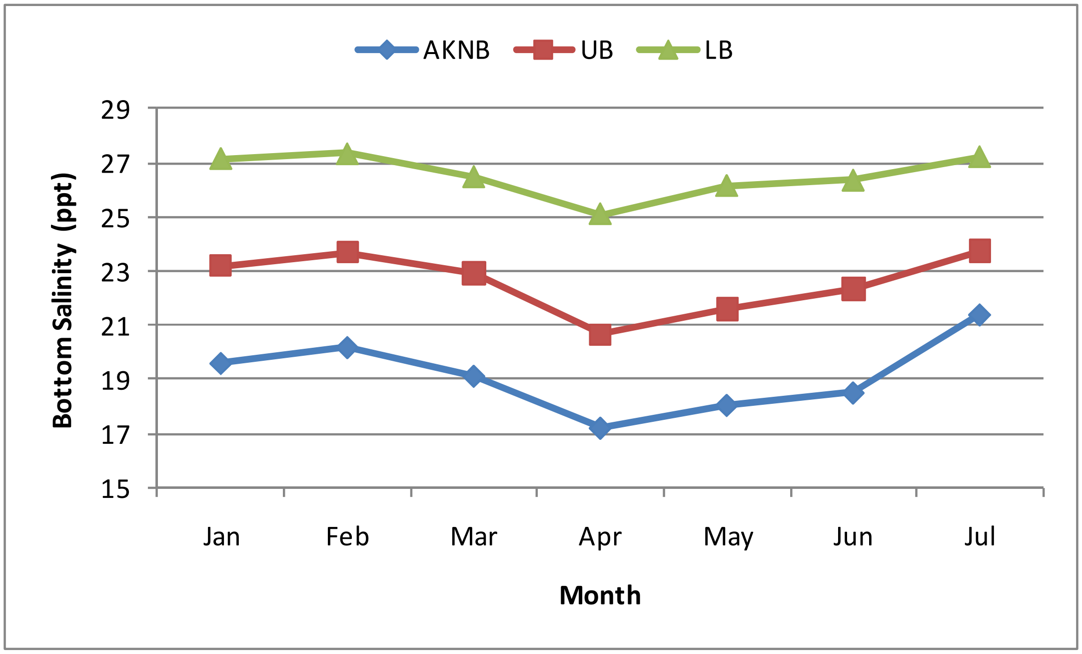



**Figure B-2.** Average monthly bottom salinity (January through July) from ABS sampling stations in the Arthur Kill/Newark Bay (AK/NB), Lower Bay (LB) and Upper Bay (UB), 2002 through 2010.

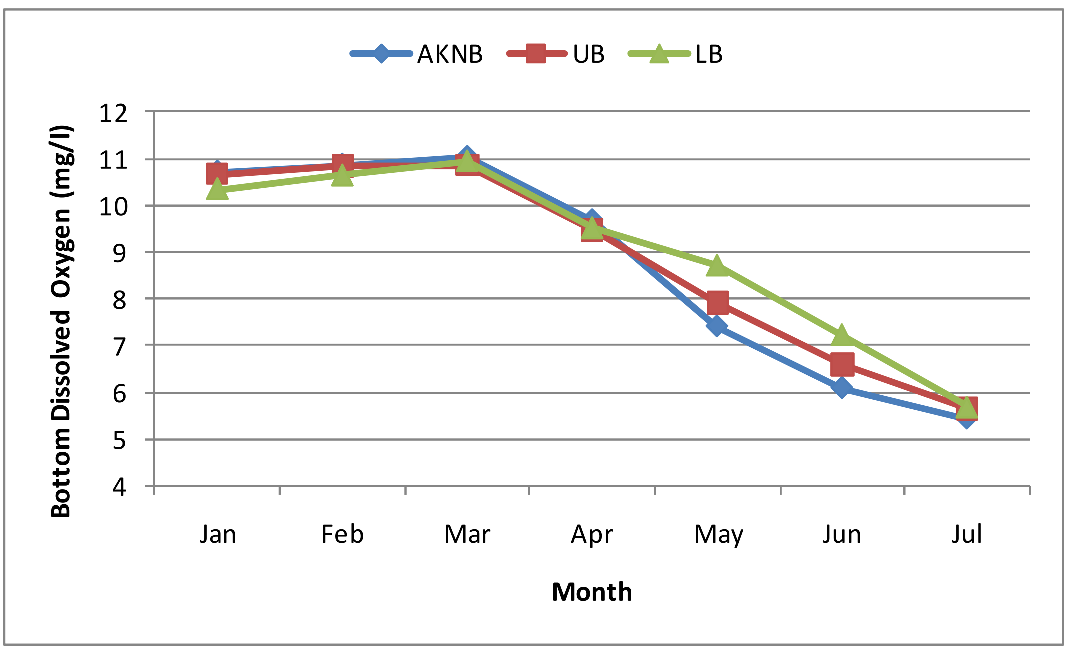



**Figure B-3.** Average monthly bottom dissolved oxygen (January through July) from ABS sampling stations in the Arthur Kill/Newark Bay (AK/NB), Lower Bay (LB) and Upper Bay (UB), 2002 through 2010.

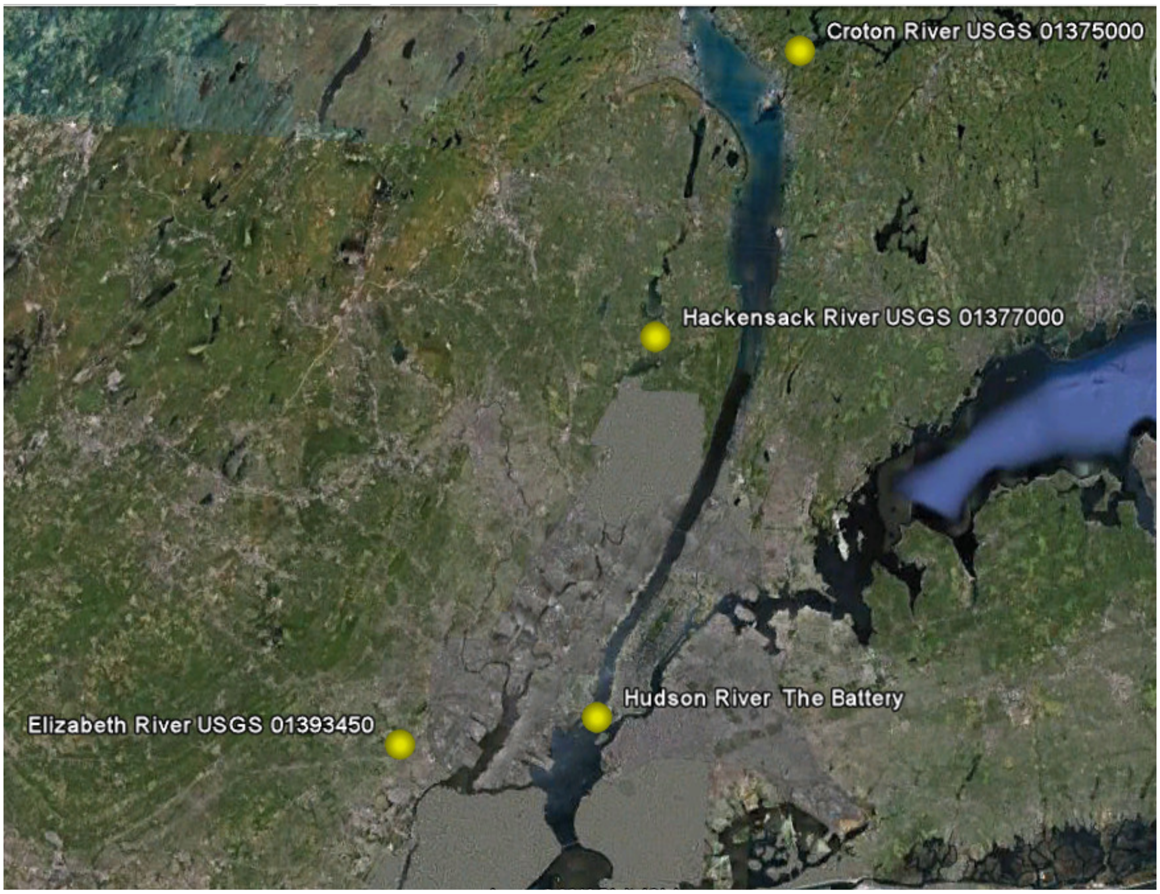



**Figure B-4.** Station locations of freshwater discharge (cubic feet per second) gages for stations near the New York/New Jersey Harbor along with location of estimated Hudson River net discharge at the Battery.

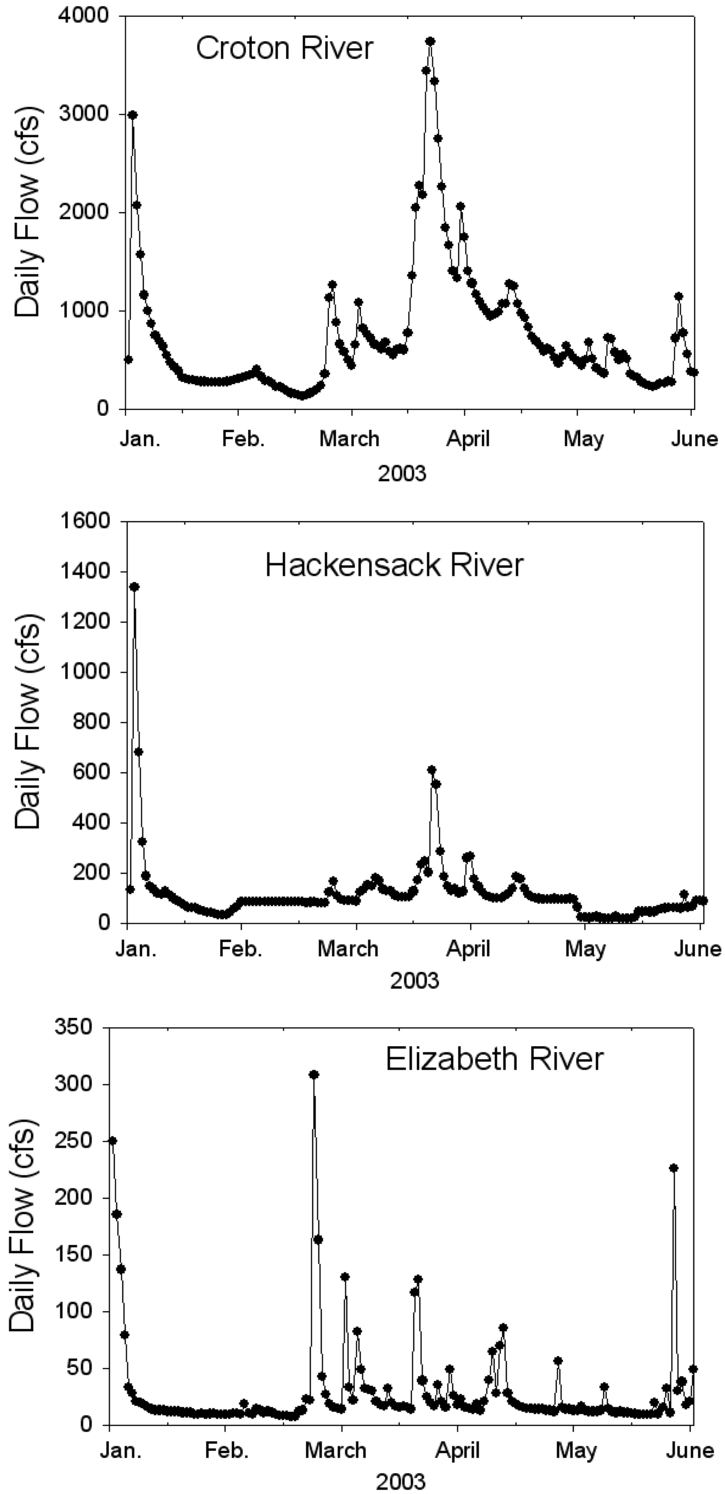



**Figure B-5.** Mean daily flow from three USGS stations on the Croton, Hackensack and Elizabeth Rivers from January to June, 2003.

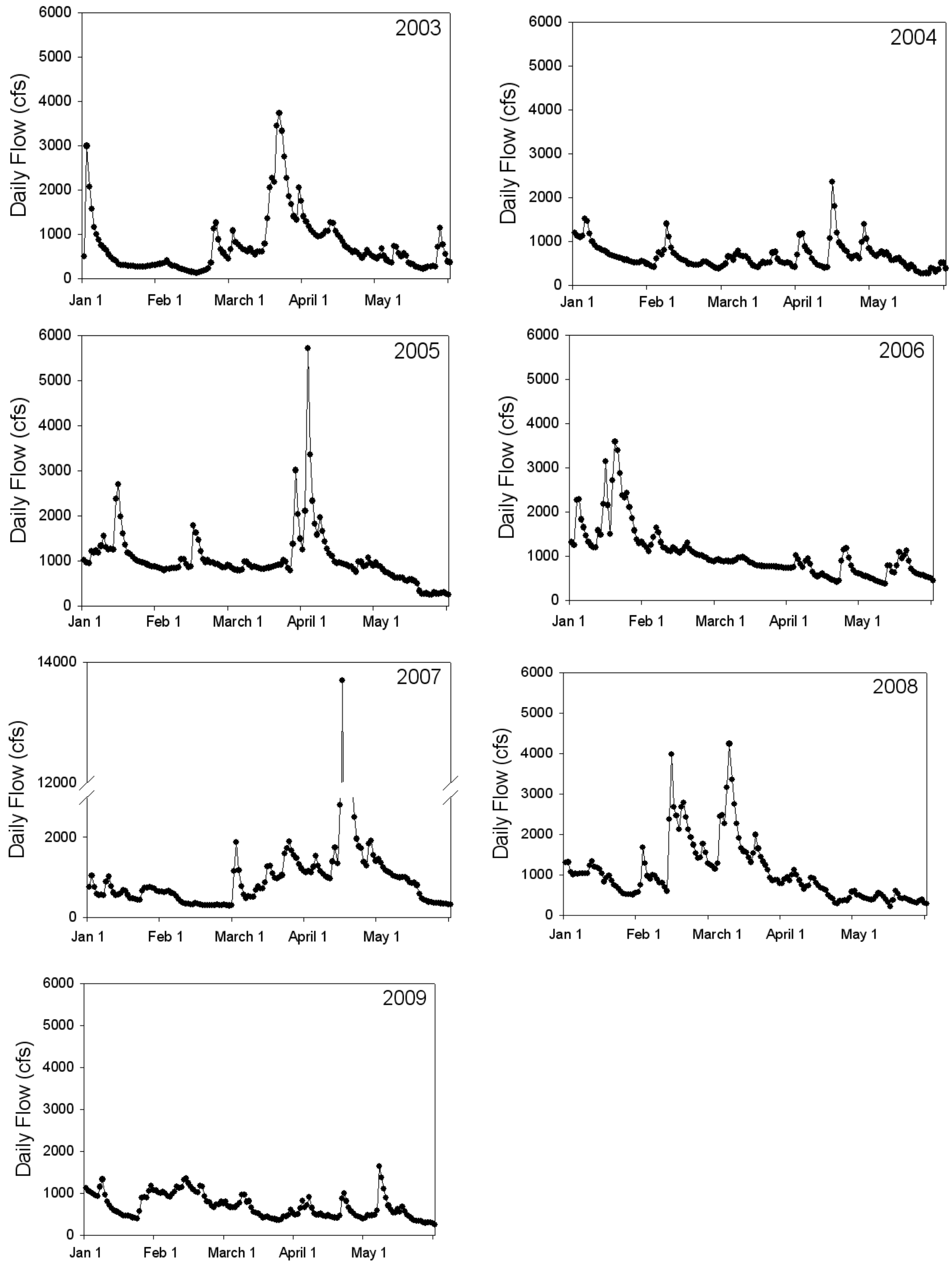



**Figure B-6.** Daily flows at the Croton River @ New Croton Dam USGS 01375000 gage from January through May of 2003 to 2009.

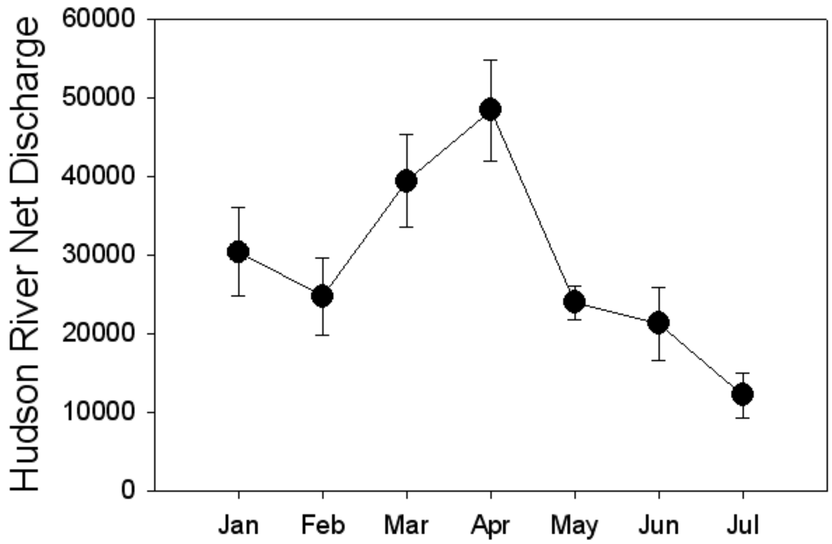



**Figure B-7.** Average (+ standard error) monthly Hudson River discharge into New York/New Jersey Harbor from January to July 2002-2008.

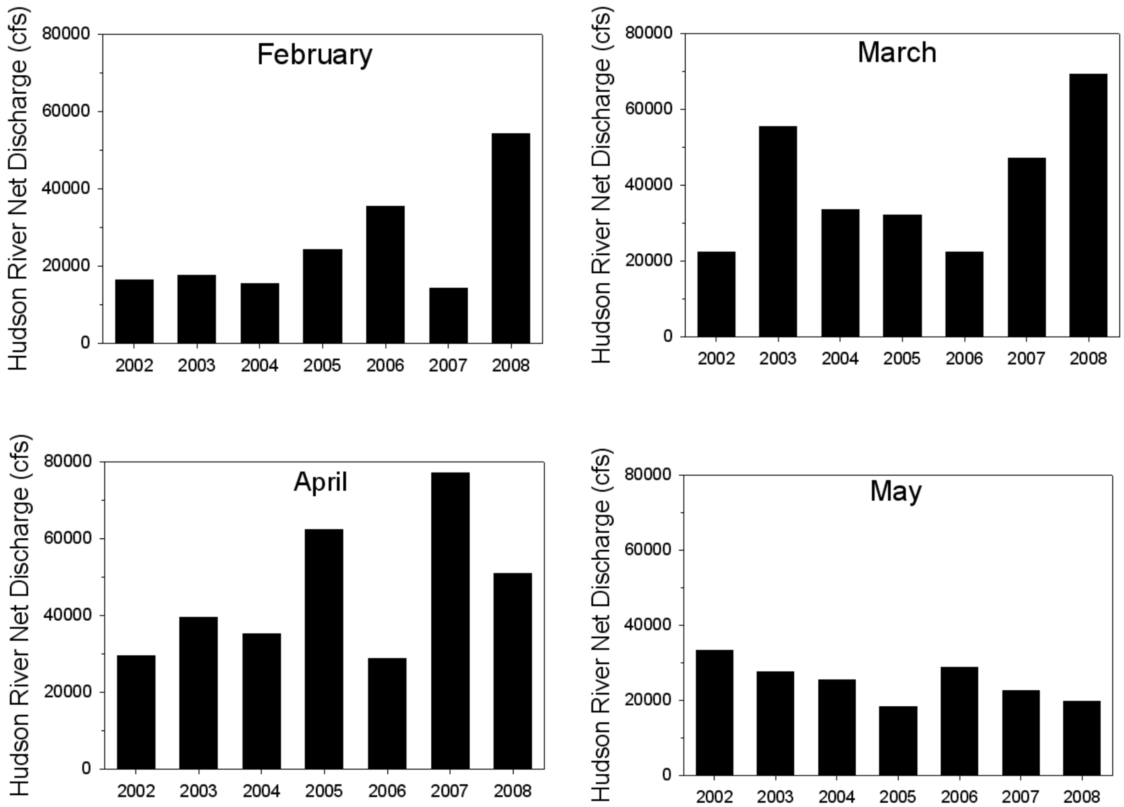



**Figure B-8.** Net monthly Hudson River discharge into New York/New Jersey Harbor (2002-2008) for February to May.

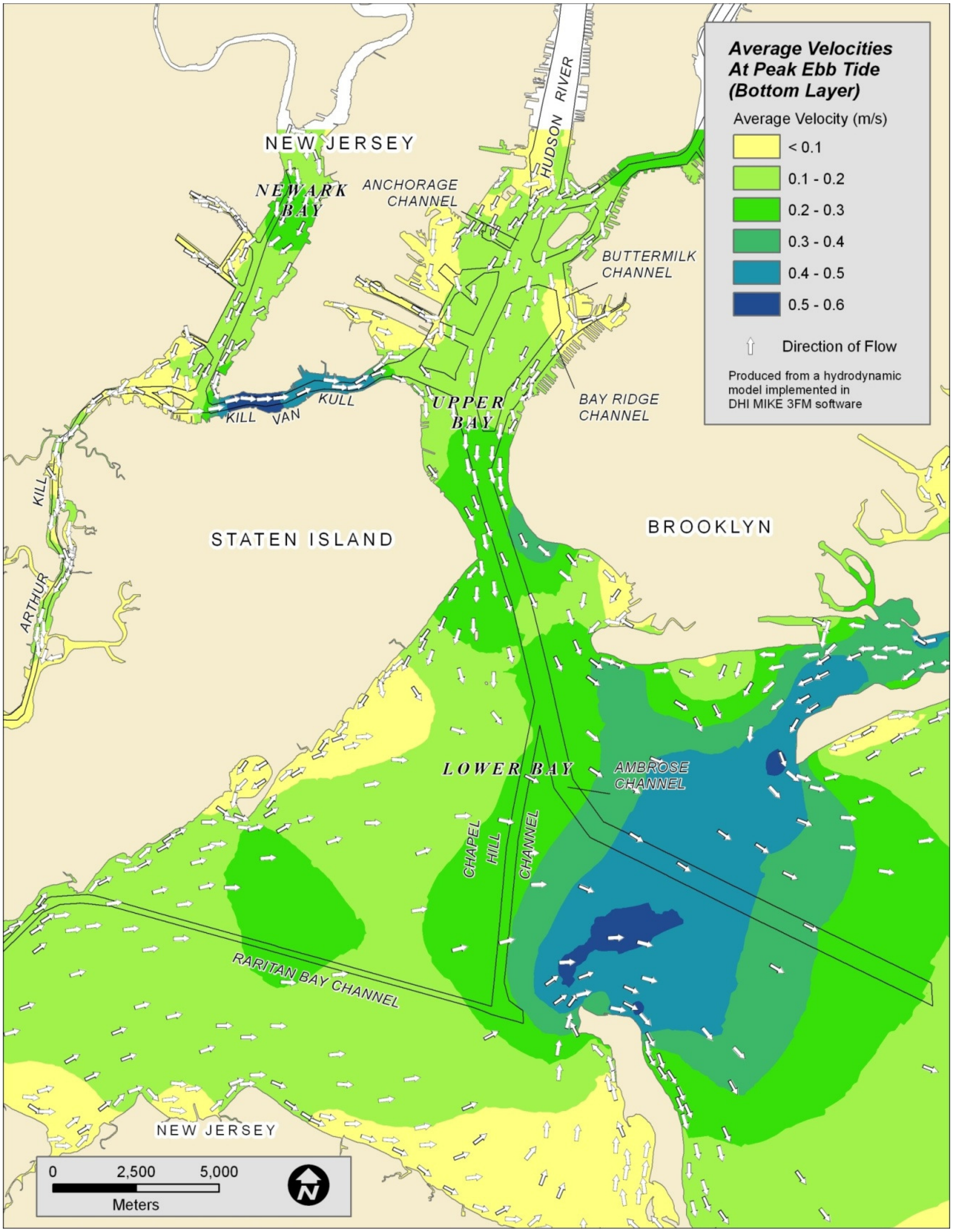



**Figure B-9.** Hydrodynamic conditions within NY/NJ Harbor during peak ebb conditions based on the MIKE 3FM modeling results.

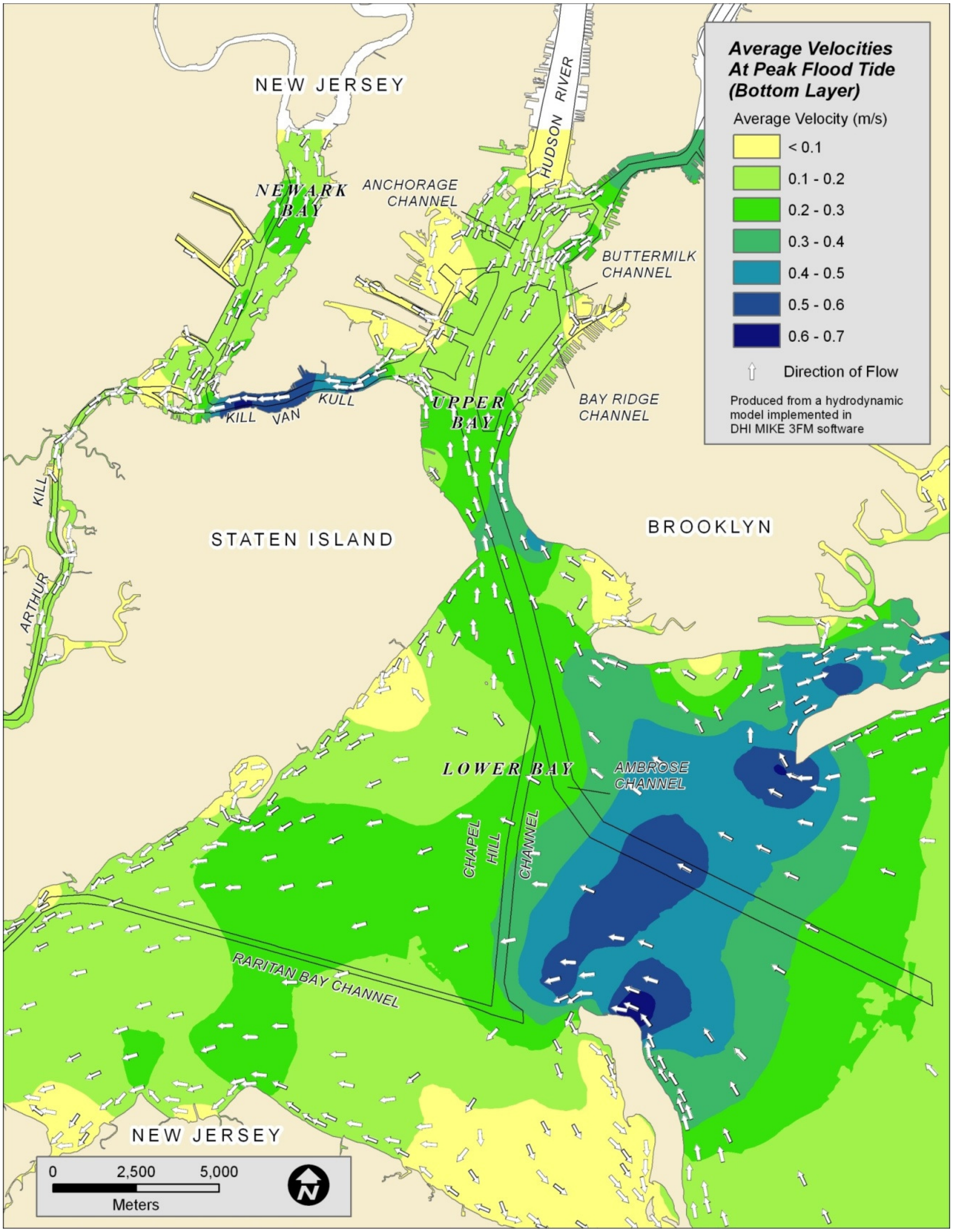
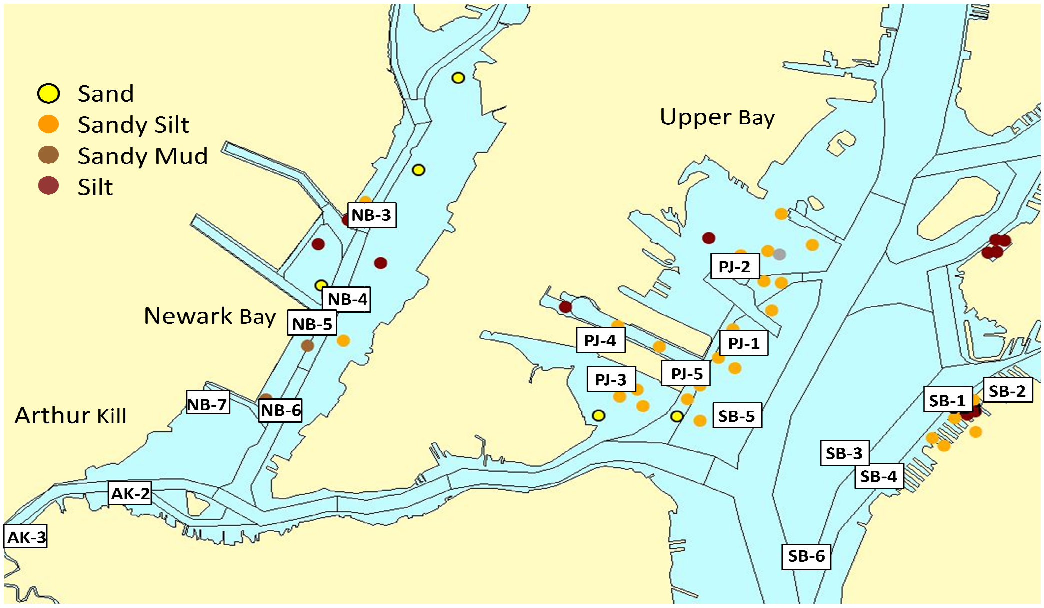
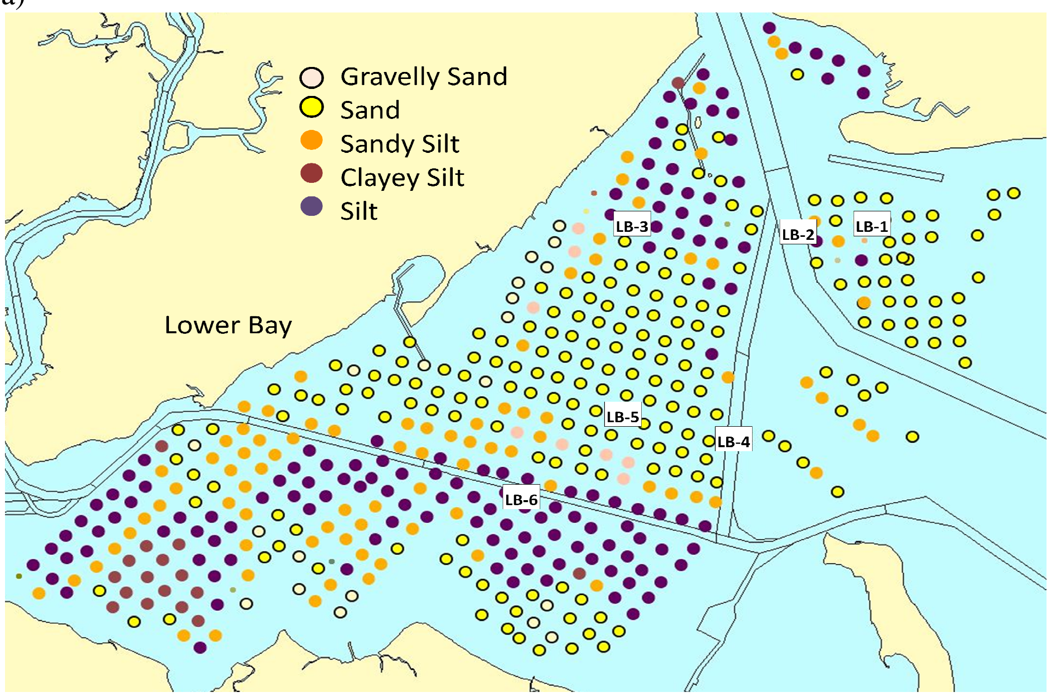



**Figure B-10.** Hydrodynamic conditions within NY/NJ Harbor during peak flood conditions based on the MIKE 3FM modeling results.




a)




b)

**Figure B-11.** Sediment grain size characterizations for the (a) Upper and (b) Lower Bay areas.[3]

[3] 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).

# APPENDIX C

# Impacts to Construction of the Harbor Deepening Project: Economic, Safety and Management Implications of Seasonal Dredging Restrictions

## Construction Impacts of Seasonal Dredging Restrictions

Seasonal dredging restrictions placed on the HDP have had cost, schedule, navigation and equipment implications. Agency coordination can be of critical importance in project cost and time savings because seasonal dredging restrictions have the potential to impact construction in channels during an estimated 33% of a given calendar year (approximately 4 months) and may result in:

- Limited Work Areas: The impact to channel deepening construction durations in Newark Bay and the Arthur Kill has ranged from approximately 13% to as high as 63%. Because the restrictions do not affect the entire contract area, there has been no requirement to suspend all construction activity thereby allowing a contractor to work continuously. However, since channel configurations vary, the significance of the dredging restrictions may be defined best by its channel location.

- Extended Contract Durations/Increased Costs: Periods of no-dredging increase channel deepening contract durations and increase costs. It is estimated that construction durations in worst-case situations (such as Newark Bay) have been increased by at least one-third and construction costs have increased by approximately 25%.

- Coast Guard-Imposed Navigation Restrictions: Seasonal dredging restrictions require both the mariner and the contractor to focus resources more intensely to help ensure concurrent safe navigation and construction. The Coast Guard imposes a Restricted Navigation Area to help ensure a balance between navigation and construction safety.

- Contractor Equipment Limitations: Seasonal dredging restrictions can complicate a contractor's ability to allocate available resources most efficiently. For example, a contractor might wish to use larger, more powerful and thus more cost efficient equipment to cover larger areas of the contract not constrained by a dredging restriction.

- Restricted Vessel Transits: Seasonal dredging restrictions may indirectly affect the transit of large ships such as Panamax and post-Panamax vessels to the Elizabeth Port Authority Marine Terminal in Newark Bay and the New York Container Terminal in the Arthur Kill. Additionally, large petroleum tankers (Eagle-class) transit the Arthur Kill to points beyond the New York Container Terminal. Seasonal dredging restrictions may delay navigation improvements and thus compel these large ships to reduce speed, transit during limited slack water periods and/or utilize costly tug assistance despite the presence of Coast Guard restrictions intended to reduce the need for tugs.

- Terminal Impacts: Seasonal dredging restrictions can delay navigation improvements and thus compel stevedores to reschedule loading/unloading operations, requiring overtime or a delay in ship arrivals/departures. Additionally, the logistics of storing, positioning and delivering containers and other cargo to and from a terminal efficiently may be strained and/or compromised to accommodate the ship schedules as a result of these dredging restrictions.

- Increased costs due to dredging constraints are not limited to the costs of dredging activities; NYD has incurred substantial costs to the government associated with technical studies required to support and confirm the protective use of seasonal restrictions.

USACE-NYD is aware of the need to protect our nation's natural resources, and USACE's congressionally mandated mission requires equal consideration (as stated in our Environmental Operating Principles) of resource protection and environmental sustainability initiatives in analyses integral to the National Economic Development (NED) plan. However, Congress also requires that we execute our navigation program in both an efficient and cost-effective manner. Therefore, in addition to the scientific data presented in this memo, the USACE-NYD considers national, regional, and local economic costs of dredging constraints.