US Army Corps
of Engineers®
New York District

NEW YORK AND NEW JERSEY HARBOR DEEPENING CHANNEL IMPROVEMENTS

NAVIGATION STUDY

DRAFT INTEGRATED FEASIBILITY REPORT & ENVIRONMENTAL ASSESSMENT

APPENDIX A1:

ENDANGERED SPECIES ACT

Biological Assessment

TABLE OF CONTENTS

1. Introduction

1.1. Purpose

This Biological Assessment (BA) is submitted to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) by the U.S. Army Corps of Engineers (USACE)-New York District (District) as part of the formal consultation process under Section 7 of the Endangered Species Act (ESA), as amended November 10, 1978. This BA assesses potential impacts to threatened and endangered species from proposed construction of channel improvements to the 50 Foot New York/New Jersey (NY/NJ) Harbor Deepening Project (HDP). The purpose of this document is to re-evaluate the potential effects to endangered species from the newly authorized Harbor Deepening Channels Improvement Study (HDCI). In March 2018, an Initial Appraisal Report, per compliance with Section 216 of WRDA 1970, was completed to determine if there is potential federal interest to undertake modifications to the existing 50-foot federal navigation project. The Initial Appraisal Report states that the accelerating expansion of the volume of trade that has taken place since the existing 50-foot federal navigation project was authorized has led to the existing project's dimensions, based on the design vessel the *Regina Maersk* as recommended in the 1999 Study, being superseded in use in the Port of New York and New Jersey much sooner than anticipated in the 1999 Study. This fact has a material effect on the economics and engineering design of the 50-foot federal navigation project. The Initial Appraisal Report found "a comparison of these facts with the requirements §216 indicates that all of the requirements of §216 have been meet." The Initial Appraisal Report made the recommendation to "investigate and determine if there is a Federal interest in continuing the project with the preparation of cost-shared feasibility report for analyzing alternatives to address the identified problems though possible modifications of the project." As an outcome of the Initial Appraisal Report, the resulting study is called the New York and New Jersey Harbor Deepening Channel Improvements, Navigation Feasibility Study (HDCI Study). Water Resources Development Act 1970 Section 216 limits the analysis of the NYNJHDCI Study to the constructed 50-foot federal navigation project.

Section 7 of the ESA requires that a BA be prepared for all major Federal actions when a federally listed or proposed endangered or threatened species may be affected. A BA was completed for the HDP by the District in 1999. Another BA was prepared to include the newly listed Atlantic Sturgeon for the same project in 2012. The purpose of this latest submittal is to address potential impacts to protected species under your jurisdiction that may result from the proposed channel improvements, as recommended under the HDCI authorization, to the HDP. This BA relies heavily on and directly incorporates, references and cites all relevant information and analyses from the 2012 Harbor Deepening BA and BO (USACE- 2012.).

1.2. Endangered Species Act

This BA is submitted as part of the process provided under Section 7 of the ESA. Section 7(a)(4) of the Act to provide NMFS and other Federal agencies a mechanism for identifying and resolving potential conflicts between a proposed action and proposed species at an early planning stage. Detailed procedures for the consultation process required under the ESA are defined in 50 CFR 402.

2. Project Background & General Description of the Proposed Project

The HDP is a Federal dredging project that deepened several navigation channels in the Port of NY & NJ to a depth of -50 feet below mean low low water (MLLW). It was authorized for construction under the Water Resources and Development Act of 2000 (Public Law No. 106-541, Dec 11, 2009). The HDP (a.k.a., NY& NJ Harbor Navigation Study) was described in detail in the USACE 1999 and 2012 BAs.

The NYNJ Harbor is a major shipping port and center of commerce, and key channels have to be dredged to meet the growing demands of the Port, which is the nation's third largest container port. The primary goal of the HDP is to provide access to and accommodate the demand for international cargo through the New York and New Jersey Region. The project improved navigational safety and allowed the Port to accommodate larger, deeper-draft vessels. Construction of the HDP was completed in 2014.

The purpose of this document is to re-evaluate the potential effects to threatened and endangered species resulting from the implementation of the newly authorized Harbor Deepening Channel Improvements Study (HDCI). In March 2018, an Initial Appraisal Report, per compliance with Section 216 of WRDA 1970, was completed to determine if there is potential federal interest to undertake modifications to the existing 50-foot federal navigation project. The Initial Appraisal Report states that the accelerating expansion of the volume of trade that has taken place since the existing 50-foot federal navigation project was authorized has led to the existing project's dimensions, which was based on the design vessel the *Regina Maersk* as recommended in the 1999 Study, and has being superseded in use in the Port of New York and New Jersey much sooner than anticipated in the 1999 Study. This fact has a material effect on the economics and engineering design of the 50-foot federal navigation project. The Initial Appraisal Report found "a comparison of these facts with the requirements §216 indicates that all of the requirements of §216 have been meet." The Initial Appraisal Report made the recommendation to "investigate and determine if there is a Federal interest in continuing the project with the preparation of a cost-shared Feasibility Report for analyzing alternatives to address the identified problems though possible modifications of the project."

2.1 Tentatively Selected Plan

The national economic development (NED) plan is the Tentatively Selected Plan (TSP) identified for this study (see Figure 1 for TSP Overview). The TSP involves deepening Ambrose Channel, Anchorage Channel and Port Jersey Channel, the Kill Van Kull, Newark Bay Channel, South Elizabeth Channel and Elizabeth Channel, by up to 5 feet. This includes the additional width required for structural stability and for the navigation of a *Triple E Class* vessel to transit from sea to Port Elizabeth and Port Jersey. Channel configurations were designed to avoid and minimize environmental and cultural resource impacts while still meeting navigation safety requirements.

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure 1. Tentatively Selected Plan Overview for HDCI.

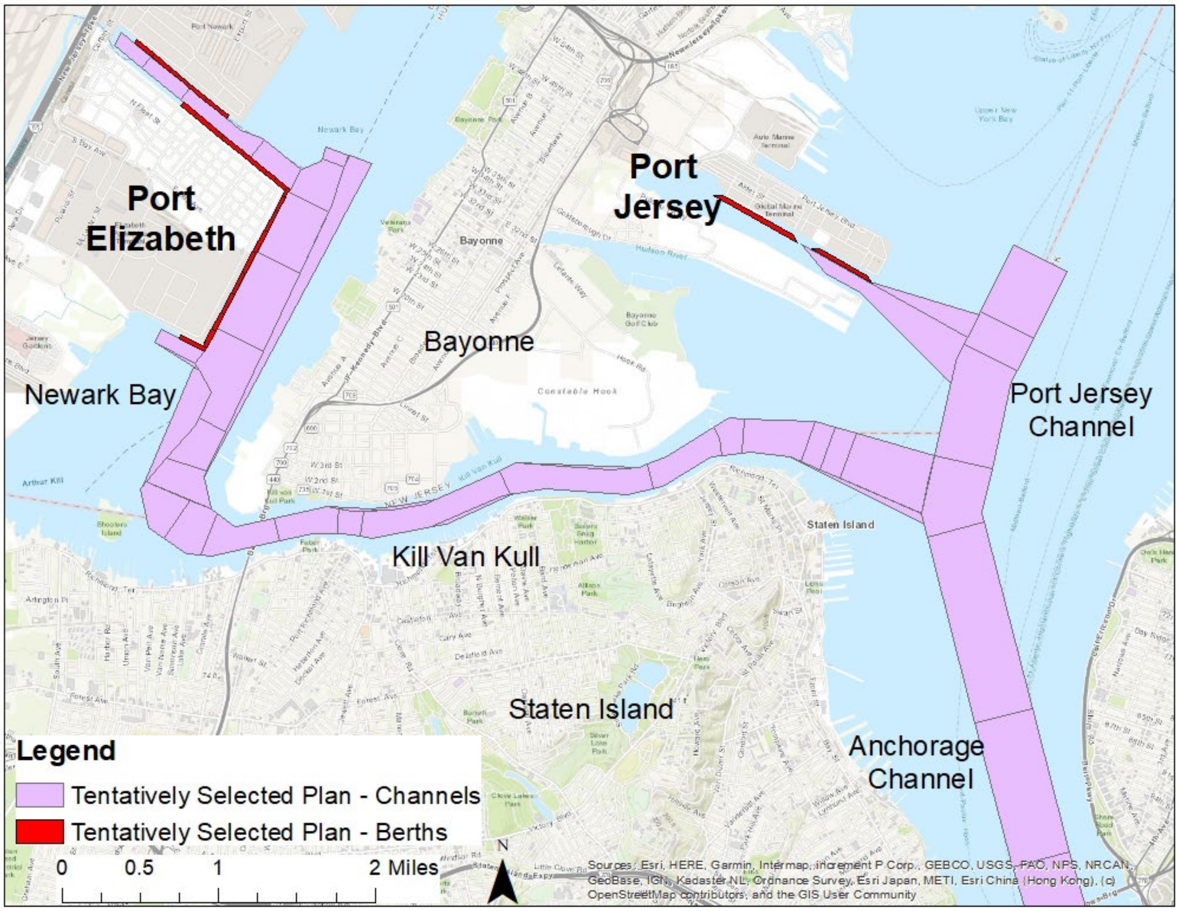

Figure 2. TSP Channel Configurations. Note: Berth Deepening is included in the TSP as an Associated Cost, only, per USACE regulations. Berths will not be deepened under the HDCI Project.

The following table (Table 1) describes the TSP Dimensions and Characteristics.

Table 1: TSP Channel Dimensions and Characteristics

	Proposed Authorized Channel Level[1] [ft MLLW]	Required Dredging Depth[2] [ft MLLW]	Length of Improvement [ft]	Quantity to be Dredged (cy)	Channel Bottom Width	Predominant Side Slope	Predominant Channel Bottom Material Type
Ambrose Channel	57	57	89,510	4,137,000	2,000	3:01	Sand
Anchorage Channel	54	54	31,262	3,800,000[9]	2,000	3:01	Sand
Port Jersey Channel	54	56[3]	5960[8]	2,744,000[4]	450 to 2,313[4]	3:1/1:1 against berths	Sand/sediment
Kill Van Kull	54	56[3]	28,047	3,237,000[5]	800 to 2,313[5]	3:1/1:1 through rock	Non-contaminated sediment & moderately hard rock and till
Newark Bay	54	56[3]	12,860	13,181,000[6]	1,740 to 2,008[6]	3:1/1:1 through rock & against berths	Contaminated sediment & moderately hard rock and till
South Elizabeth Channel	54	56[3]	1,586	423,000[7]	500 to 640[7]	3:1/1:1 through rock & against berths	Contaminated sediment & moderately hard rock and till
Port Elizabeth Channel	54	56[3]	7,689	855,000[3]	500 to 750	3:1/1:1 through rock & against berths	Contaminated sediment & moderately hard rock and till

[1] This includes the summer salt water draft, squat, salinity, wave motion, and safety clearance. The channels will be maintained at this depth.

[2] Required dredging depth / design depth is needed for initial construction and includes any additional safety clearance needed for hard bottom.

[3] Includes needed 2 feet for hard or rock bottom which must be blasted for initial deepening.

[4] Includes widening PJ-1

[5] Includes widenings KVK-1, KVK-3, KVK-4 and KVK-5

[6] Includes widenings NWK-1 and NWK-2

[7] Includes widening SE-1A

[8] Limit of disturbance ends approximately 400 ft from centerline of sewer crossing.

[9] Includes deepened area AN-1

The major channels under study in the HDCI will provide access to three main existing container terminals: The Port Newark Terminal and Elizabeth Marine Terminal in Newark Bay and the Global Marine Terminal on the Port Jersey Peninsula.

3. Federally Listed Species in the Project Area

3.1 The federally listed species that may occur in the action area are: the endangered Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus), the threatened Northwest Atlantic Ocean Distinct Population Segment (DPS) of the loggerhead turtle (Caretta caretta); the threatened North Atlantic DPS of green turtle (Chelonia mydas); the endangered Kemp's ridley turtle (Lepidochelys kempi); the endangered leatherback turtle (Dermochelys coriacea); the endangered North Atlantic right whale (Eubalaena glacialis); and the endangered fin whale (Balaenoptera physalus). Their NMFS listing and recovery plan citations follow:

- North Atlantic right whale (*Eubalaena glacialis*)(73 FR 12024; Recovery plan: NMFS 2005)
- Fin whale (*Balaenoptera physalus*)(35 FR 18319; Recovery plan: NMFS 2010)
- Loggerhead turtle (*Caretta caretta*)(76 FR 58868; Recovery plan: NMFS & USFWS 2008)
- Leatherback turtle (*Dermochelys coriacea*)(35 FR 8491; Recovery plan: NMFS & USFWS 1992)
- Green turtle (*Chelonia mydas*)(81 FR 20057; Recovery plan: NMFS & USFWS 1991) 2
- Kemp's ridley turtle (*Lepidochelys kempii*)(35 FR 18319; Recovery plan: NMFS et al. 2011)
- Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*)(77 FR 5880 and 77 FR 5914)

4. Primary Species of Concern: Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*)

As sea turtles and whales are determined not to be at greatest risk from dredging operations within the study area, this document will prioritize Atlantic sturgeon as the species of primary concern and focus analyses, accordingly.

General Atlantic Sturgeon Information

NMFS has determined that Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) is comprised of five distinct population segments (DPSs) that qualify as species under the ESA: Gulf of Maine (GOM), NY Bight (NYB), Chesapeake Bay (CB), Carolina, and South Atlantic. The Northeast Region of NMFS has listed the GOM DPS as threatened, and the NYB and CB DPSs as endangered. The HDP falls within the boundaries of the NYB population.

Since the 1970s, Atlantic sturgeon have been studied intensely but many important aspects of the species life history are still unknown (Murawski and Pacheco 1977, Van den Avyle 1983, Smith and Dingley 1984, Smith and Clugston 1997, Bain 1997, Bemis and Kynard 1997, and Kynard and Horgan 2002, as cited by ASSRT 2007 and USACE 2011; Gilbert 1989).

The historic geographic range of the Atlantic sturgeon extends from the coast of Labrador in Canada, south to the St. Johns River in Florida (Gruchy and Parker 1980b, and Wooley 1985, as cited by Gilbert 1989), and included estuarine and riverine systems (reviewed in Murawski and Pacheco 1997, and Smith and Clugston 1997, as cited by ASSRT 2007). The species was historically present in 38 rivers in the United States from St. Croix, ME to Saint Johns River, FL, most of which supported historical spawning populations. Currently, Atlantic sturgeon are known to be present in 35 rivers, and spawning occurs in at least 20 of these rivers (ASSRT, 2007, as cited by USACE 2011).

Atlantic sturgeon spawn in fresh water but move to coastal waters as subadults (ASSRT, 2007, as cited by USACE 2011). Coastal regions where migratory Atlantic sturgeon are commonly found include the Bay of Fundy, Massachusetts Bay, Rhode Island, NJ, Delaware, Delaware Bay, Chesapeake Bay and North Carolina (Dovel and Berggren 1983, Johnson et al. 1997, Rochard et al. 1997, Kynard et al. 2000, Eyler et al., 2004, Stein et al., 2004, and Dadswell 2006; as cited in ASSRT, 2007 and USACE 2011).

Atlantic sturgeon can attain lengths of up to 14 feet (425 cm) and weights of more than 800 pounds (363 kg). Atlantic sturgeon have been known to live up to 60 years (Mangin 1964, as cited by Grunwald et al. 2007 and USACE 2011), although age validation studies show a variation of ±5 years (Stevenson and Secor 1999, as cited by USACE 2011).

Sexual maturity occurs from 7-28 years, depending on geographic location and gender (Collins et al. 2000, as cited by USACE 2011). Atlantic sturgeon show latitudinal variation in growth and maturation (Vladykov and Greeley 1963; Huff 1975, as cited by Gilbert 1989), exhibiting faster growth and earlier age at maturation in more southern areas (Gilbert 1989). In the Hudson River, the age at first spawning for females has been recorded at age 18 (Dovel and Berggren 1983, as cited by Bain 1997), although Van Eenennaam et al. (1996, as cited by Bain 1997) reported age 15. Spawning males are 12 years or older (Van Eenennaam et al. 1996).

Atlantic sturgeon are anadromous, spending the majority of their adult phase in marine waters, migrating up rivers to spawn in fresh water and migrating to brackish waters in the juvenile growth phases (Bain 1997). Atlantic sturgeon undertake long-distance migrations along the Atlantic Coast (Bain 1997) and do not appear to spawn annually (Gilbert 1989); periods between spawning can range from 2-6 years (Vladykov and Greeley 1963, Van Eenennaam et al. 1996, and Stevenson and Secor 1999, as cited by USACE 2011). There is little information on the behavior of the species in marine waters (Bain 1997).

Adults return to their natal fresh water rivers to spawn (Dovel and Berggren 1983; Collins et al. 2000, and Grunwald et al. 2007, as cited by USACE 2011). They migrate prior to the spawning season, and the males arrive before the females by one week or longer (Smith 1985a, as cited by Gilbert, 1989). Southern populations typically spawn earlier (February-March) than mid-Atlantic region Atlantic sturgeon (April-May), and fish occupying the northernmost rivers spawn primarily from May-July (Murawski and Pacheco 1977, Smith 1985, Bain 1997, Smith and Clugston 1997, Caron et at. 2002, as cited by ASSRT 2007). In the Hudson River, movement by spawning adults into and out of the river appears to be related to temperature (Dovel and Berrgren 1983, and Smith 1985a, as cited by Gilbert 1989; Sweka et al. 2007).

Atlantic sturgeon eggs are highly adhesive and are deposited primarily on gravel, rocky hard-bottom substrates and fertilized externally (Borodin 1925, Smith et al. 1980, as cited by USACE 2011) and eggs, embryos and larvae are reported to have limited salt tolerance (Van Eenennaam et al. 1996, as cited by Bain 1997).

Spawning is believed to occur in water temperatures up to 24.3º C (Dovel and Berggren 1983, as cited by USACE 2011) and egg incubation periods vary with water temperature. Larval Atlantic sturgeon emerge from the egg in roughly 4-6 days (based on hatching temperatures of approximately 18º C-20º C). Newly hatched larvae exhibit negative phototactic behavior to avoid predation (Kynard and Horgan 2002, as cited by USACE 2011) and show a preference to migrate downstream towards more brackish waters (Smith et al. 1980, and Kynard and Horgan 2002, as cited by USACE 2011). Yolk sac absorption occurs within 8-12 days. At the end of their first summer, the majority of young-of-the-year (YOY) Atlantic sturgeon remain in their natal river while older subadults begin to migrate offshore (Dovel and Berggren 1983, as cited by USACE 2011).

The following spring returning subadults, as well as the overwintering river Young-of-Year (YOY), are thought to gradually move into summer foraging areas where they remain until the fall (Dovel and Berggren 1983, Kieffer and Kynard 1993, Shirey et al. 1997, and Savoy and Pacileo 2003, as cited in USACE 2011). In the Hudson River, juvenile males migrate to marine waters in year 2, whereas juvenile females remain in the river longer, until year 5 or 6 (Dovel and Berggren 1983, as cited by Bain 1997). Older subadult Atlantic sturgeon are known to undertake extensive marine migrations and occupy non-natal estuaries during the late spring, summer, and early fall months (Dovel and Berggren 1983, as cited by USACE 2011), presumably for feeding (Dadswell 1979, as cited by USACE 2011) or perhaps for thermal or salinity refuge (Savoy and Pacileo 2003, as cited by USACE 2011).

4.1. General Distribution within the New York Bight Distinct Population Segment

The NYB DPS includes all Atlantic sturgeon whose range occurs in watersheds that drain into coastal waters, including Long Island Sound, the NYB, and Delaware Bay, from Chatham, MA to the Delaware-Maryland border on Fenwick Island. Within this range, Atlantic sturgeon have been documented from the Hudson and Delaware Rivers as well as at the mouth of the

Connecticut and Taunton Rivers, and throughout Long Island Sound, with evidence to support that spawning occurs in the Hudson and Delaware Rivers (ASSRT 2007, as cited by USACE 2011).

More recently, attention is being focused on understanding how oceanic habitat is used by migrant Atlantic sturgeon (Dunton et al. 2010, Erickson et al. 2011). By examining five fishery-independent surveys of Atlantic sturgeon, Dunton et al. (2010) determined potential coastal migration pathways for northerly summer and southerly winter migrations. They also report that large aggregations of immature Atlantic sturgeon tend to congregate at the mouths of estuaries, including the Hudson River estuary in the spring and fall. The highest catches occurred in the NYB at depths of 10 to 15 m. Dovel and Berggren's (1983) tagging data revealed a southerly movement during the winter, which is consistent with a finding that 43.5% of the Atlantic sturgeon overwintering in North Carolina originated in the Hudson River (Laney et al. 2007). Dunton et al. (2010) concluded that depth was the primary environmental characteristic influencing Atlantic sturgeon distributions with juvenile migrants concentrated in coastal waters < 20 m deep in areas adjacent to the mouths of estuaries, such as the Hudson River. The authors suggest that depth restricts movements and that aggregations are related to food availability, and movement is triggered by temperature cues. Erickson et al. (2011) conducted a pop-up satellite tagging study to track the movements of adult Atlantic sturgeon after they left the Hudson River, which is the most significant spawning system within the NYB Distinct Population Segment (DPS). Of the 23 fish that were tagged, 15 returned to the ocean and 13 of those remained within the Mid-Atlantic Bight, one migrated as far north as Nova Scotia and one as far south as Georgia. These results are consistent with mitochondrial DNA analysis that showed that 97% of subadult Atlantic sturgeon caught in the Mid-Atlantic Bight were of Hudson River origin (Waldman et al. 1996). Atlantic sturgeon left the Hudson River and entered the ocean in the fall as water temperatures fell.

Habitat selection by subadult Atlantic sturgeon is likely driven by a combination of factors, including water temperature, salinity, dissolved oxygen, depth, substrate type, and available prey resources. Subadult Atlantic sturgeon are thought to occupy specific concentration zones within estuaries due to the presence of prey resources which, in part, are dependent on the aforementioned specific physiochemical characteristics (ECS 1993, as reported in Simpson 2008, and as cited by USACE 2011). A number of studies on subadult Atlantic sturgeon in different riverine systems identify preferred habitat as oligohaline (0.5-5.0 PPT). In the Hudson River low salinity areas serve as nursery habitat (Dovel and Berggren 1983, and Bain et al. 2000, as cited by USACE 2011). In the Chesapeake Estuary, hatchery-raised telemetered Atlantic sturgeon YOY, within one week after release, relocated (>90%) in oligohaline waters (Secor et al. 2000, as cited by USACE 2011). In the Merrimack River sub-adults occupied oligo-mesohaline habitats (Kiefer and Kynard 1993, Moser and Ross 1995, as cited by USACE 2011). Likewise within the Delaware River, concentration zones are typically found in the oligohaline and mesohaline reaches (Shirey et al. 1997, as cited by USACE 2011).

4.2. Distribution in Project Area

The first observations of sturgeon in the Hudson River date back to accounts of human settlement in the area. Fishery landings were recorded starting in 1880 and the large gear size in the fishery indicates that most of the harvest was Atlantic sturgeon (Bain et al. 2000). Scientific observations of the Hudson River population were first recorded in the 1930s and include documentation of sturgeon distributions by size and age (Bain 1997). Approximately 40 years elapsed before concern over potential impacts from electrical power plants initiated long-term monitoring programs in the 1970s that resulted in reports of sturgeon distributions and life history characteristics (Young et al. 1988). Due to a collapse in the fishery, the Atlantic sturgeon attracted little commercial interest in the Hudson River from 1900 through 1979 (Bain et al. 2000), however, the population exhibited a recovery in the 1980s and fishing for Atlantic sturgeon became a significant activity in the system in the 1990s, attracting the attention of fishery management agencies (Bain et al. 2000).

The Hudson River and estuary system is oriented in a north-south direction from NY/NJ Harbor (southern tip of Manhattan Island = km 0) with Atlantic sturgeon distributed within the tidal portion ranging as far north as the Troy Dam (km 246). Adult Atlantic sturgeon ($\geq$ 150 cm TL) marked in the Hudson River have been recaptured in coastal areas from North Carolina to Massachusetts (Bain 1997). Adult females migrate to spawning grounds, which are deep, channel or off-channel habitats within the Hudson River Estuary starting in mid-May (Dovel and Berggren 1983), spawn from May through July or possibly August, and return to marine habitat the following fall (Dovel and Berggren 1983, Van Eenennaam et al. 1996). Mature males are present in the Hudson River for a longer time period than mature females, extending from April to November (Dovel and Berggren 1983) and appear at spawning sites in association with females, suggesting they search for females while moving about in the river (Van Eenennaam et al. 1996). In the Hudson River, spawning occurs near the salt wedge (km 55) in late May, moving upstream to km 136 by early July (Dovel and Berggren 1983). Van Eenennaam et al. (1996) collected spawning Atlantic sturgeon near Hyde Park (km 130) and Catskill (km 182) and suggested that because sturgeon eggs, embryos and larvae are intolerant of brackish conditions, spawning occurs in freshwater habitat considerably upstream from brackish conditions. The Hyde Park site was also cited as a productive spawning area at river km 134, which was a major fishing location in the 1880s (Bain et al. 1998, Bain et al. 2000). In the Hudson River, Atlantic sturgeon embryos have been collected from km 60 through 148 (Dovel and Berggren 1983). Juvenile Atlantic sturgeon occur throughout the Hudson River from July through September (Bain 1997) and are most concentrated from km 63 to 140 moving between km 19 and 74 as water temperature drops below 20^{o} C in the fall (Dovel and Berggren 1983). It appears that juveniles stay in this portion of the river, moving little, between October and June (Bain 1997). Juvenile male Atlantic sturgeon migrate to marine habitat in year 2 and juvenile females in year 5 or 6. Juveniles grow rapidly, exceeding 70 cm TL by 3 years of age (Stevenson 1997). After about 10 years at sea, adult size (150 cm TL, Table 2 both sexes pooled) is reached (Bain 1997).

Table 2: Ages and sizes of life history stages of Atlantic sturgeon in the Hudson River (from Bain 1997)

Life History Stage	**Age range (yr)**	**Fork length (cm)**	**Total length (cm)**
Larva	<0.08		≤3
Early juveniles	0.08-2	2-44	3-49
Intermediate juveniles	3-6	45-63	50-70
Late juveniles	6-11	>63-134	>70-149
Non-spawning adults	≥12	>135	≥150
Female spawners	≥15	>180	≥200
Male spawners	12-20	>135-190	≥150-210

Mitochondrial DNA analyses indicate that Hudson River Atlantic sturgeon are genetically distinct from other populations on the US Atlantic coast and this population overwhelmingly supports the fishery in the NYB (Waldman et al. 1996). The Newburgh and Haverstraw Bays in the Hudson River are areas where juvenile Atlantic sturgeon congregate, with highest catches occurring in deep (>9 m), soft-bottom areas of Haverstraw Bay in the spring (Sweka et al. 2007). In this study, hard substrate consisted of compacted sand, rock, gravel and oyster shell beds, whereas soft substrate was silt and mud. Seasonal movements occur down river when water temperatures drop below 20ºC (Dovel and Berggren 1983) and up river in the spring when temperatures rise above 4ºC (Sweka et al. 2007). Sweka et al. (2007) sampled from March through April and from October through November and report that these time periods bracketed the time periods when the sturgeon were moving up and down the river. The summer congregation of one-year-old Atlantic sturgeon in south Newburgh Bay provides a good opportunity to monitor population recovery because this group of fish is at the largest size observed before there is evidence of emigration from the Hudson River (Bain 2001). The distributions of juvenile Atlantic sturgeon collected in gill nets from June to mid-September 1995 (Haley et al. 1996) were higher than expected in the Highlands Gorge (km 68 -90) area and less than expected in the Narrow River (km 108-138) area. The Highland Gorge area is characterized as deep, mesohaline habitat dominated by silty substrate, whereas the Narrow River area is a freshwater zone. The distributions of stocked and wild juvenile sturgeon differed, with stocked sturgeon occurring more than expected in the Narrow River area. The stocked Atlantic sturgeon were significantly smaller than wild juveniles, which may account for the difference in their distributions. The Hudson River population of Atlantic sturgeon is one of two U.S. populations for which there is an abundance estimate (approximately 870 spawning adults/year, 600 males and 270 females; Kahnle et al. 2007) and it is considered one of the healthiest populations in the U.S. (ASSRT 2007).

The NY State Department of Environmental Conservation (DEC) conducted a tagging study in collaboration with the Hudson River Estuary Program, US Fish and Wildlife Service, Pew

Institute, Hudson River Foundation, and National Fish and Wildlife Foundation. In this study, Atlantic sturgeon are captured in the lower river and tagged with sonic tags. Preliminary results indicate that adults are attracted to muddy substrates, followed by sand, with lowest observances over gravel (*http://www.dec.ny.gov/animals/37121.html*).

As part of project specific biological monitoring conducted by the DISTRICT, there have been several sightings of sturgeon in Upper, Lower and Raritan Bays. From 1998 through 2010, bottom trawl surveys were conducted as part of the HDP. A primary goal of the Aquatic Biological Survey (ABS) was to collect data on finfish, shellfish, macroinvertebrates, and water quality, with a focus on fish community structure, distribution and seasonal patterns of habitat use in NY/NJ Harbor. ABS sampling occurred from December to June throughout the Harbor, with stations in Newark Bay, Arthur Kill, Upper Bay and Lower Bay. These station locations include channel stations and stations in close proximity to past and future dredging sites. Throughout the 12-year sampling period, two Atlantic sturgeon were captured in bottom trawls (Table 4). The first Atlantic sturgeon was captured in June 2005 at a non-channel station in the Upper Bay. It measured 790 mm total length and presumably was a late juvenile (Table 3). The other Atlantic sturgeon captured in the ABS surveys was 638 mm total length (an intermediate juvenile, Table 3) and was captured in December of 2009 at a channel station in the Lower Bay.

Bottom trawl surveys were also conducted in the fall of 2008 for a few days in Lower Bay as part of investigations of navigational hazards. Two Atlantic sturgeon were captured in October 2008 (Table 4). The first Atlantic sturgeon measured 1,220 mm and the second measured 1,180 mm.

Additional sightings and captures of sturgeon occurred during other monitoring activities by the District, and are summarized below in Table 3. Although the District conducted migratory finfish surveys in the HDP area in 2006 (USACE 2007), and reinitiated the study in 2011, no Atlantic or shortnose sturgeon observations were reported. The majority of the observations described in Table 4 were collected as part of long term and rigorous data collection efforts in the NY/NJ Harbor. Excluding the 1995 observation, only 13 sturgeon were observed over 14 years (1998-2011).

Table 3: Sturgeon observations in and around the HDP area

Species	***Date***	***Location***	***Length***	***Data Source/Comments***
Atlantic sturgeon	June 2005	Port Jersey (east of Liberty Golf Course)	790 mm	HDP ABS program
Atlantic sturgeon	October 2008	Lower Bay near approach to Ambrose Channel (between 40.457833, -73.89633 and 40.46117, -73.90267	1220 mm	Investigations near navigational obstructions

Species	***Date***	***Location***	***Length***	***Data Source/Comments***
Atlantic sturgeon	October 2008	Lower Bay near approach to Ambrose Channel (between 40.457833, -73.89633 and 40.46117, -73.90267	1180 mm	Investigations near navigational obstructions
Atlantic sturgeon	December 2009	Lower Bay(chapel hill south channel)	638 mm	HDP ABS program
Shortnose Sturgeon	June 2003	Upper Bay (near Statue of Liberty)	780 mm	HDP ABS program
Shortnose Sturgeon	June 2003	Upper Bay (near Statue of Liberty)	690 mm	HDP ABS program
Shortnose Sturgeon	June 2005	Port Jersey (east of Liberty Golf Course)	1250 mm	HDP ABS program
Shortnose Sturgeon	June 2005	Port Jersey (east of Liberty Golf Course)	840 mm	HDP ABS program
Shortnose Sturgeon	May 2008	Port Jersey (east of Liberty Golf Course)	900 mm	HDP ABS program
Shortnose Sturgeon	May 2009	Port Jersey (east of Liberty Golf Course)	910 mm	HDP ABS program
Sturgeon (species not identified)	October 1998	Port Jersey (adjacent and east of Global Marine Terminal)	not recorded	HDP ABS program
Sturgeon (species not identified)	October 2008	East of Sandy Hook between coordinates: 40.41087, -73.88474 to 40.41080, -73.88464	not recorded	Found in turtle cage during dredged material inspection. Noted on disposal log sheets from Dredged Material Inspectors, who accompany all vessels disposing dredged material at the HARS)
Sturgeon (species not identified)	September 2010	1 1/2 miles south of the Verrazano Bridge and 1/2 mile east of Hoffman Island near coordinate 40.57917, -74.04017	42"- 48" long (estimate)	Injured sturgeon (head injury) spotted by USACE vessel while conducting routine drift patrol
Atlantic sturgeon	1995	borrow area (BBA-5), between Belmar and Manasquan	Not recorded	Biological Monitoring program, Atlantic Coast of NJ: Asbury Park to Manasquan

4.3. Food Resources

Overall, sturgeon appear to feed indiscriminately throughout their lives (Bigelow and Schroeder 1953, Vladykov and Greeley 1963, Murawski and Pacheco 1977, van den Avyle 1984, as cited by Gilbert 1989) and are generally characterized as bottom feeding carnivores (Bain 1997). As sturgeon search for food, their protrusible mouth is used to "vacuum" along the bottom (Gilbert 1989). Adult Atlantic sturgeon feed on polychaetes, oligochaetes, amphipods, isopods, mollusks, shrimp, gastropods, and fish (Johnson et al. 1997, Haley 1998, Bigelow and Schroeder 1953, Vladykov and Greeley 1963, Smith 1985b, as cited in Gilbert 1989). Smith (1985b, as cited by Bain 1997) reported that: "Female sturgeon do not appear to feed on the spawning run in freshwater".

Although sturgeons generally occupy North American waters where temperatures range to 30° C, activity and growth are more optimal in cooler (<25° C) waters (Cech and Doroshov 2004, as cited by USACE 2011). Atlantic sturgeon are believed to seek thermal refuge in deepwater habitat and exhibit limited movement during periods of elevated temperatures (>25° C). As water temperatures peak during the summer months the ability of water to hold dissolved oxygen decreases, which may potentially drive subadult Atlantic sturgeon to cooler, deepwater habitat where dissolved oxygen levels are generally higher (Dovel and Berggren 1983, Moser and Ross 1995, Cech and Doroshov 2004, Niklitschek and Secor 2005, as cited by USACE 2011). These physiochemical parameters also determine the availability of prey resources, possibly driving subadult Atlantic sturgeon estuarine habitat occupation (Dadswell, 1979, as cited by USACE 2011).

Dadswell (1979) and Marchette and Smiley (1982) studied feeding habits of shortnose sturgeon. They reported that freshwater feeding occurs during portions of the year when water temperature is greater than 10° C. Feeding during colder months occurs at a depth of 15-25 m (49-82 feet). Feeding activity in saline water occurs year-round, although an analysis of stomach contents suggests that feeding is less frequent during the winter. Substrate types associated with important prey items for subadult Atlantic sturgeon include clay and silt in the Hudson River (Bain et al. 2000, as cited by USACE 2011), organic mud substrates in Albemarle Sound (Armstrong 1999, as cited by USACE 2011), and sandy mud and clay mud in the Savannah River (Hall et al. 1991, as cited by USACE 2011).

5. Factors Affecting the New York Bight Distinct Population Segment of Atlantic Sturgeon

Like all anadromous fish, Atlantic sturgeon are vulnerable to many habitat impacts because of their varied use of rivers, estuaries, bays, and the ocean throughout the phases of their life. Habitat alterations that may affect Atlantic sturgeon include: dam construction and operation; dredging and disposal; and water quality modifications such as changes in levels of DO, water temperature and contaminants (ASSRT, 2007, as cited by USACE 2011). Atlantic sturgeon also exhibit unique life history characteristics that make them particularly vulnerable to population collapse from overfishing (Boreman 1997, as cited by Bain 1997), including: "advanced age and large size at maturity, eggs that are numerous and small in relation to body size, and spawning that is episodic and seasonal" (Winemiller and Rose 1992, as cited by Bain 1997). Other threats to the species include vessel strikes.

Dredging in riverine, nearshore and offshore areas has the potential to impact aquatic ecosystems by removal/burial of benthic organisms, increased turbidity, alterations to the hydrodynamic regime and the loss of shallow water or riparian habitat. According to Smith and Clugston (1997, as cited by USACE 2011), dredging may impact important habitat features of Atlantic sturgeon if these actions disturb benthic fauna, or alter rock substrates. Indirect impacts to sturgeon from either mechanical or hydraulic dredging include the potential disturbance of benthic feeding areas, disruption of spawning migration, or detrimental physiological effects of resuspension of sediments in spawning areas. In addition, hydraulic dredges can directly impact sturgeon and other fish by entrainment in the dredge (ASSRT 2007, as cited by USACE 2011).

Atlantic sturgeon have been directly harvested for years. Many authors have cited commercial over-harvesting as the single greatest cause of the decline in abundance of Atlantic sturgeon (Ryder 1890, Vladykov and Greely 1963, Hoff 1980, ASMFC 1990, and Smith and Clugston 1997, as cited in ASSRT 2007 and USACE 2011). Harvest records indicate that sturgeon fisheries were established in every major coastal river along the Atlantic Coast at one time and were concentrated during the spawning migration (Smith 1985b, as cited by USACE 2011). Despite the fact that the fishery has been closed coast-wide since 1995, poaching of Atlantic sturgeon continues and is a potentially significant threat to the species, but the magnitude of the impact is unknown (ASSRT 2007, as cited by USACE 2011). Impacts to sturgeon through bycatch is also a significant concern, but one that is hard to quantify due to limited available data (USACE 2011).

According to ASSRT (2007, as cited by USACE 2011), "The recovery of Atlantic sturgeon along the Atlantic Coast, especially in areas where habitat and water quality is severely degraded, will require improvements in the following areas: 1) elimination of barriers to spawning habitat either through dam removal, breaching, or installation of successful fish passage options; 2) operation of water control structures to provide flows compatible with Atlantic sturgeon use in the lower portion of the river (especially during spawning season); 3) imposition of restrictions on dredging, including seasonal restrictions and avoidance of spawning/nursery habitat; and 4) mitigation of water quality parameters that are restricting sturgeon use of a river (*i.e.,* DO). Additional data regarding sturgeon use of riverine and estuarine environments is needed."

Although little is known about natural predators of Atlantic sturgeon, there are several documented fish and mammal predators, such as sea lampreys, gar, striped bass, common carp, northern pike, minnow, channel catfish, smallmouth bass, walleye, grey seal, fallfish and sea lion (ASSRT 2007). There are some concerns that predation may adversely affect sturgeon recovery efforts in fish conservation and restoration programs, and by fishery management agencies (Brown et al. 2005, and Gadomski and Parsley 2005, as cited by ASSRT 2007; ASSRT 2007). However, further research is needed.

Atlantic sturgeon may compete with other bottom feeding species for food, although there is "no evidence of abnormally elevated interspecific competition" (ASSRT 2007), and it has been suggested by van den Avyle (1984, as cited by Gilbert 1989) that "non-selective feeding of juvenile and adult sturgeons may reduce the potential for competition with other fish species". Also, since both shortnose and Atlantic sturgeon occur in many rivers along the Atlantic Coast, and have many shared life history attributes, they are suspected of competing for food and space during certain life stages (Pottle and Dadswell 1979, and Bain 1997, as cited in ASSRT 2007), and the species may be spatially segregated in connection with salinity (Dadswell et al., Dovel et al. 1992, Kieffer & Kynard 1993, as cited in Bain 1997). However, this is not the case in the Hudson River. Bain (1997) reports that: "Juvenile shortnose sturgeon and early juvenile Atlantic sturgeon have almost the same distributions in the Hudson River estuary during all seasons. During this period of co-occurence, both species are very similar in size, grow at about the same rate, feed on similar foods, and share deep channel habitats. Adult shortnose sturgeon distribution overlaps with the distribution of juvenile Atlantic sturgeon, and the latter commence river emigration at a size comparable to co-occurring adult shortnose sturgeon". However, no evidence has been published that either sturgeon species is food limited.

5.1. Factors Affecting the Hudson River Population of the Atlantic Sturgeon

In the Hudson River estuary, spawning, rearing, and overwintering habitats were reported to be intact by Bain (1997), supporting the largest remaining Atlantic sturgeon stock in the U.S., however, a population decline from overfishing has also been observed for this area (Bain 1997, Bain 2001, Peterson et al. 2000). Several life history characteristics make Atlantic sturgeon susceptible to overfishing, including their delayed age at maturity, vulnerability to capture, and long periods of non-spawning (Boreman 1997). Commercial landings of Atlantic sturgeon are available for NY State from 1880 through 1995. Until about 1980, most of the landings came from the Hudson River and highest annual landings occurred in 1898. Landings dropped through the early 1980's and in 1990, when the Atlantic States Marine Fisheries Commission (ASMFC) adopted an interstate fishery management plan for Atlantic sturgeon. States with open fisheries began to monitor harvest and population modeling was conducted to determine acceptable levels of harvest from the Hudson River stock. In 1993 through 1995, NY regulated the Atlantic sturgeon fishery with size limits, seasons, and area closures, determining that the Hudson River stock was being overfished. A harvest moratorium was implemented in 1996 and NJ followed with a zero quota in the same year.

Conservation of the Atlantic sturgeon population in the Hudson River has benefitted from an intensive research program in the mid-1990s funded by the Hudson River Foundation for Science and Environmental Research, which covered reproductive physiology, genetics, age structure, habitat use, behavior, and fishery attributes (Bain et al. 2000). Peterson et al. (2000) conducted a mark-recapture study to estimate the age-1 juvenile cohort size in the Hudson River and found an 80% decline in cohort size had occurred since a similarly conducted population estimate was made in 1976. Dovel and Berggren (1983) marked immature fish from 1976-1978 and calculated a year class age-1 cohort as approximately 25,000 fish, whereas the estimate by Peterson et al. (2000) from their 1994 study indicated 4,314 fish were in the age-1 cohort for that year.

Although the Hudson River subpopulation is believed to be the largest remaining Atlantic sturgeon subpopulation (NRDC 2009), bycatch mortality exceeds those levels needed to provide for a stable population (ASMFC 1990). Haley et al. (1996) cites Hoff et al. (1988) and Geoghegan et al. (1992) as reporting collections of Atlantic sturgeon as bycatch in trawl surveys conducted in the Hudson River by utility companies (April through December) between the Tappan Zee Bridge and Coxsackie.

Sediment contamination in NY/NJ Harbor includes synthetic compounds used in herbicide and pesticide production, metals, and petroleum hydrocarbons. Sources of contamination include combined sewer discharges, urban runoff, stormwater runoff, industrial discharges, and maritime and industrial accidents. Sediment contamination and silt/clay content are negatively correlated with the density and diversity of benthic organisms throughout the Harbor (Cerrato and Bokuniewicz 1986), which may in turn affect prey availability for Atlantic sturgeon.

Atlantic sturgeon are exposed to variations in dissolved oxygen because of their life history characteristics of benthic feeding and bottom dwelling and because they occur in areas with industrial pollution and temperature changes. Kieffer et al. (2011) found that Atlantic sturgeon were relatively tolerant of exposure to short-term severe hypoxia and that their biological responses may be influenced by temperature.

6. Potential Direct and Indirect Impacts from the HDCI Project

Examination of the potential direct and indirect impacts resulting from removal, modification or exclusion to Atlantic sturgeon habitat and on Atlantic sturgeon individuals is presented in this section. Different aspects of the HDCI have the potential to potentially impact Atlantic sturgeon. This section discusses the potential short term and long term impacts to Atlantic sturgeon resulting from implementation of the HDCI project including both physical effects on the fish and their food sources, as well as their spawning and overwintering habitat (USACE 2012).

6.1. Physical Injury During Construction

Potential direct and indirect impacts linked to physical injury of Atlantic sturgeon during dredging and blasting activities may include: direct removal (entrainment); noise disturbance; re-suspension of sediments in spawning areas, and disruption of spawning migrations (ASSRT 2007).

Although the ASSRT (2007) reports that dredging activities indirectly impact sturgeon by disrupting spawning migrations, it does not clearly state what the cause and rationale are for this threat. In the case of the Upper and Lower Bays, dredging and blasting activities have been ongoing for at least 100 years, and still the Hudson River population of Atlantic sturgeon is considered one of the healthiest populations in the U.S. (ASSRT 2007). Therefore, it would appear that despite regular dredging activities, Atlantic sturgeon are still finding and utilizing pathways through the NY/NJ Harbor to reach spawning grounds in the Hudson River. This is likely because the waterways available for migration extending from the mouth of the Hudson River to the marine environment are sufficiently deep enough and wide enough to permit Atlantic sturgeon to avoid potential dredging-related disturbances, including active dredges, and that long-term impacts to their habitat and food source are not typical.

It is possible for Atlantic sturgeon to be directly impacted by being entrained in a dredge. Dickerson (2006, as cited by USACE 2011) summarized sturgeon takes from Atlantic and Gulf Coast dredging activities conducted by the USACE between 1990 and 2005, which documented takes of 24 sturgeons (2 – Gulf, 11- Shortnose, and 11-Atlantic). The majority of the interactions were with a hopper dredge: sixteen takes with a Hopper dredge; five takes with a cutterhead dredge; and three takes with a mechanical dredge. Fifteen of the sturgeons were reported as mortalities, eight as alive, and one as unknown. These documented takes occurred during dredging operations in rivers and harbors, mainly in waterways along the Eastern coast that, from the map in the report, appear to be more narrow than the pathways available to Atlantic sturgeon in the NY/NJ Harbor (i.e., Delaware River, Savannah Harbor, etc). However, the risk still exists for Atlantic sturgeon to become entrained in dredges during HDCI construction. Physical contact with a hopper dredge's drag-arm and impeller pumps via entrainment may also pose a threat to sturgeon. A minimum of 0.6 sturgeon per year were estimated to be entrained by hopper dredges alone (ASSRT 2007).

Several studies have demonstrated that underwater blasting can cause fish mortality. Weight of the charge and distance from detonation are the most important factors affecting extent of injury and mortality, although depth of water, substrate type, and size and species of fish are also important (Keevin and Hempen 1997, Wiley et al 1981, Teleki and Chamberlain 1978, as cited by USACE 2004a). Teleki and Chamberlain (1978, as cited by USACE 2011) monitored fish mortality of 13 species in blasting experiments in Nanticoke, Lake Erie and found that fish were killed in radii ranging from 65.6 to 164 feet (20-50 m) for 50 lbs (22.7 kg) per charge and from 147.6 to 360.9 feet (45-110 m) for 600.5 lbs (272.4 kg) per charge. Mortality differed by species at identical pressure. No sturgeon were tested. Common blast-induced injuries included swimbladder rupturing and hemorrhaging in the coelomic and pericardial cavities.

In 2004, USACE conducted a blast monitoring study in KVK. The type of blasting activity for the 2004 study in KVK is similar to that anticipated for NB Complex contracts. A theoretical estimate of the pressure and impact of the "average" blast event monitored during the study would result in a pressure of about 90 psi with a kill radius of approximately 375 feet. The data also implies that the charges used in the KVK Blasting Program, which were confined, appeared to have less of an impact on fish than would equivalent open water charges. Using the results of the two referenced studies in this paragraph, it is reasonable to conclude that any potential blasting impacts in NB/KVK would not reach areas in which Atlantic sturgeon are known or expected to migrate through the NY/NJ Harbor to spawning grounds Recently, the District was informed by the New Jersey Department of Environmental Protection (NJDEP) that there are emerging raw data currently under analyses for report preparation (still unpublished) that is suggestive of sturgeon utilization of the upper NB channels. As a precaution, NJDEP has recently extended no dredge seasonal restrictions in the NB to the adjacent Port Elizabeth and South Elizabeth channels to be protective of sturgeon and other migratory finfish potentially utilizing the inner channel area.

6.2. Physical Injury Post Construction

Vessels traffic. Dredging provides safe passage for commercial shipping and recreational boat traffic. NY/NJ Harbor is historically one of the busiest ports in the United States. The long distance that vessels transit through the HDCI area through the narrowing upriver reaches allows for the possibility of ship encounters with migratory sturgeon. A study conducted in the Delaware estuary, which is narrower and shallower than the HDCI area, concluded that vessel strikes accounted for 50% of Atlantic sturgeon mortalities (Brown and Murphy 2010, as cited by USACE 2011). Although Atlantic sturgeon mortalities from encounters with commercial vessels could occur in the Harbor, the HDP will not increase the frequency of ship strikes since an increase in the number of ships traversing the Harbor is not anticipated and actually a reduction in transiting ships is likely due to their increased size (i.e. fewer ship calls due to increased efficiency) and deeper channels. Another potential benefit of the deeper (and wider) channels will result from a reduction in strikes due to increased clearance below/beside the keel of deep-draft vessels currently using the harbor.

There will be marine-based construction equipment vessels utilized to implement the HDCI project. While improvement of channels in ongoing, other vessel traffic will be

6.3. Habitat Impacts

The potential impacts of dredging to Atlantic sturgeon habitat may include loss of habitat and sedimentation.

Dredging may pose an adverse impact on egg survival through a temporary localized increase in suspended sediments in the water column, which may suffocate demersal sturgeon eggs

(Simpson 2008, as cited by USACE 2011). Additionally, contaminant loads have been known to alter development, growth and reproductive performance (Cooper 1989, and Sinderman 1994, as cited by ASSRT 2007 and USACE 2011). In the Hudson River, Atlantic sturgeon embryos have been collected from km 60 through 148 (Dovel and Berggren 1983). There is a substantial spatial buffer between the NY/NJ Harbor locations where dredging is currently scheduled to occur and the freshwater spawning sites located upriver, therefore, no adverse impacts to eggs and larvae will occur from the HDCI.

Suspended sediments may potentially affect adult and juveniles as well. Sediment plumes typically begin from the dredge site and decrease in concentration as sediment falls out of the water column as distance increases from the dredge. The size of the plume is influenced by the particular dredge used, the dredge operator, sediment type, strength of current and tidal stage. Construction activities at contract areas in the HDCI that could adversely affect migrating Atlantic sturgeon are those in which sturgeon are migrating through a narrow area, insufficiently wide to permit the safe passage of sturgeon, to and from their spawning grounds in the Hudson River.

USACE has conducted several Total Suspended Solids (TSS) studies in NY/NJ Harbor; however, none were conducted in Ambrose Channel since there is no measurable resuspension associated with hydraulic dredging of sand. Given that Hopper dredges will be used in Ambrose, and that the sediment type is of a larger, coarser material (sand), this combination is expected to keep the plume negligible. A TSS event was completed for one of the HDP Anchorage contracts in January 2011 which consists mainly of sand and silt (USACE 2011a). In general, the suspended sediment plume was confined to the lower half of the water column and did not extend outside of the navigation channel. Suspended sediment concentrations were typically 200 mg/L or less within 500 meters of the dredge platform and dissipated to background conditions within 1,000 meters of the dredge. The suspended sediment concentrations found in the Anchorage Channel are below those shown to have an adverse effect on fish (Breitburg 1988, as cited by Burton 1993; Summerfelt and Moiser 1976, and Combs 1979, as cited in Burton 1993) and benthic communities at 390.0 mg/L (EPA 1986). Also, since Atlantic sturgeon are highly mobile, they are capable of avoiding a plume by moving outside the channel. Even if Atlantic sturgeon movement is altered, it is unlikely that this temporary and localized suspended sediment effect would have a long term and adverse impact on Atlantic sturgeon migration to/from spawning grounds, or in the ability to find other food resources outside of the small and localized sediment plume in comparison to the entire area available in the Upper Bay of NY/NJ Harbor. Also, since Atlantic sturgeon are indiscriminate feeders, turbidity would likely have little or no effect on feeding.

Dredging and blasting also has the potential to eliminate deep holes and alter rock substrates. Dovel and Berrgren (1983) reported that immature Atlantic sturgeon find and remain in channel holes or pockets during the winter between km 19 and 74 in the Hudson River Estuary. Dredging and blasting for the HDCI will occur at distances greater than 19 km from the juvenile overwintering sites, therefore, these activities are not expected to impact overwintering sites in the Hudson River. It is unclear from the literature whether Atlantic sturgeon utilize this type of habitat throughout their range and life history stages, including migrating juveniles and adults into or through the NY/NJ Harbor. If deep holes are used in the HDCI project area, and substrates are altered during dredging activities, it is unlikely that these changes would have a long term and adverse impact on Atlantic sturgeon given their transient behavior through the Harbor.

6.4. Impacts to Food Resources

Atlantic sturgeon are primarily benthic feeders and changes in bottom habitat that alter the benthic faunal community would result in a subsequent reduction in prey resources and thereby potentially impacting feeding adults and to a much greater extent, young and subadult Atlantic sturgeon. Sturgeon generally feed when the water temperature is greater than 10ºC (Dadswell 1979, and Marchette and Smiley 1982, as cited by USACE 2011) and in general, feeding is heavy immediately after spawning in the spring and during the summer and fall, and lighter in the winter. Subadult Atlantic sturgeon are thought to occupy specific salinity concentration zones within estuaries due to the presence of prey resources (ECS 1993 as reported in Simpson 2008, and as cited by USACE 2011). The diets of Atlantic and shortnose sturgeon in the Hudson River were found to be different. Using gastric lavage to sample stomach contents, Haley and Bain (1997, as cited in ASSRT 2007) retrieved primarily polychaetes and isopods from Atlantic sturgeon and amphipods from shortnose sturgeon.

The impacts of navigation channel dredging on benthic macro-invertebrates were determined by the District through pre- and post-dredging sampling at the areas within the Ambrose, Anchorage-PJ and NB complex channels. These surveys identified the benthic invertebrate community that is potentially available as a prey resource to Atlantic sturgeon within the NY/NJ Harbor and in areas where dredging projects will be conducted in the coming years. In the Ambrose Channel prior to HDP dredging, the benthos was dominated by annelids, arthropods, and mollusks, with a prevalence of blue mussels (*Mytilus edulis*). Benthic taxa deemed to be pollution tolerant were more common than pollution intolerant taxa. In 2009, following dredging, the benthic community was dominated by annelids *Magelona sp*. and no blue mussels were collected. The percentage of pollution tolerant taxa increased from 2% before dredging to 5% after dredging.

Baseline benthic sampling in Anchorage Channel revealed a similar community composition to that of Ambrose Channel prior to dredging with blue mussels also being dominant. Amphipods (Ampeliscidae), northern dwarf tellin (*Tellina agilis*), and the annelid species (*Spio setosa*) comprised dominant taxa in the benthic assemblage in this area. A much higher percentage of pollution tolerant taxa (29%) was present following dredging in 2009 compared to pre-dredging (10%) and blue mussels were absent post-dredging. The pre-dredging benthic community in the Kill Van Kull was dominated by nematodes, blue mussels, and polychaetes. Following dredging, annelids dominated the benthos, primarily due to high densities of *Sabellaria vulgaris*. The abundance of pollution tolerant species doubled between the pre- and post-dredging sampling events.

In general, the changes in the benthic community observed between pre- and post-dredging time periods in all three areas described above is typical of benthic responses to disturbance in which larger, longer-lived species are replaced by smaller, opportunistic taxa. In soft bottom communities, benthic recovery times from dredging disturbances tend to be limited to within two years of the dredging event (Wilber and Clarke 2007). The short-term loss of larger bivalves, such as blue mussels, may present the most significant impact on prey resources for foraging juvenile Atlantic sturgeon, although the presence of this particular species in their diet is not well documented.

Investigations at the entrance of Ambrose Channel (i.e., apex of NYB) were also conducted September 2009 (USACE 2010). Water depth at the obstruction is approximately 53 feet at MLW while nearby water depths range from 72 to 80 feet. Benthic prey resources in this area are similar to that described in previous investigations by Cerrato (2006) and are dominated by the annelid *Polygordius* sp. and *Polydora ligni* with nematodes, the arthropods *Unciola* sp. and *Ampelisca abdita,* the blue mussel (*Mytilus edulis*) and two gastropod species as well.

6.5. Cumulative Effects

In the 2012 HDP BO, NMFS outlined the cumulative effects associated with sources of human-induced mortality, injury, and/or harassment of Atlantic sturgeon. In the BO, the definition of cumulative effects was referenced in 50 CFR 402.02 to include "*the effects of future State or private activities, not involving Federal activities that are reasonably certain to occur within the action area. Future Federal actions are not considered in the definition of cumulative effects.*" The following provides an excerpt from the BO, as it is applicable to this document.

> *"Sources of human-induced mortality, injury, and/or harassment of Atlantic sturgeon... resulting from future State, tribal, local or private actions in the action area that are reasonably certain to occur in the future include incidental takes in state-regulated fishing activities, pollution, global climate change, and vessel collision. While the combination of these activities may affect Atlantic sturgeon,... preventing or slowing the species' recovery, the magnitude of these effects in the action area is currently unknown...*
>
> *Information on interactions with Atlantic sturgeon with state fisheries operating in the action area is not available, and it is not clear to what extent these future activities will affect listed species...*
> *Vessel Interactions-...private vessel activities in the action area may adversely affect listed species in a number of ways, including entanglement,*

> *boat strike, or harassment. As vessel activities will continue in the future, the potential for a ·vessel to interact with a listed species exists; however, the frequency in which these interactions will occur in the future is unknown and thus, the level of impact to ... Atlantic sturgeon populations cannot be projected… Pollution and Contaminants -Human activities in the action area causing pollution are reasonably certain to continue in the future, as are impacts from them on Atlantic sturgeon... However, the level of impacts cannot be projected. Sources of contamination in the action area include atmospheric loading of pollutants, stormwater runoff from coastal development, groundwater discharges, and industrial development. Chemical contamination may have an effect on listed species reproduction and survival…"*

7. Other Species of Concern

The biological information contained in the Districts HDP BAs on the impacts to protected species is still relevant and applicable. Although this BA is focused on updating the extensive analyses conducted for the previous BAs, we have also taken the opportunity to identify (in Section 2) the minor changes that will occur as a result of the implementation of the HDCI Recommended Plan. These changes include: deepening of those select channels from the authorized depth of -50’ to -54’, with associated widening. None of these measures will change the impacts assessment to sea turtles or whales from that described in the previous HDP BAs, and in the absence of this BA, would not have been seen as warranting any reinitiation of consultation pursuant to Section 7 of the ESA. However, in the interest of completeness, we have included the rationale for arriving at that conclusion.

7.1. Sea Turtles

It is unlikely that turtles are found in the majority of the Harbor Complex, especially in the Upper New York Bay and the highly congested and trafficked channels of the Newark Bay complex. Additionally, the physical habitat characteristics in the project area do not suggest that it would represent a concentration area of or for sea turtles. Therefore clamshell bucket/backhoe dredging and blasting in these channels are expected to have negligible impact on sea turtle foraging ability and survival.

7.1.1. Sea Turtle Distribution in the Project Area

An assessment of Lower Bay, only, is included, since this is the only part of the action area likely to see turtle utilization.

7.1.2. Potential Impacts to Sea Turtles in the Project Area

Historically, hopper dredging in Ambrose channel has been identified as the location and dredging type of concern for entraining sea turtles. The proposed action being considered for the Ambrose channel does include use of a hydraulic dredges.

If sea turtles are not directly harmed by dredging equipment, the main impact would most likely be the indirect effects of dredging activities on their food resources, namely crabs and mollusks (USACE 1999). The Ambrose channel proposed action would not be expected to significantly alter the food resources available to sea turtles for several reasons. The dredging footprint represents a very small area in throughout the Lower Bay, through which Ambrose Channel is deepened and maintained. The disturbed area of accumulated sand would be directly impacted by removal would retain the same sediment grain size characteristics post-construction, and be quickly colonized by nearby benthos, especially since scouring by vessels utilizing the channel would be eliminated. The proposed action temporary and short term modification of the physical substrate would allow for long term community stability to be re-established at the site since scouring by vessels would be significantly reduced or eliminated. The adverse effects in Ambrose channel are therefore determined to be negligible.

7.2. Whales

7.2.1. Whale Distribution in the Project Area

Federally endangered North Atlantic right and fin whales, are seasonally present in the waters off New York. These species use the nearshore, coastal waters of the Atlantic Ocean as they migrate to and from calving and foraging grounds.

Right whales in the NYB are primarily transiting the area on their way to more northerly feeding and concentration areas. During late winter and early spring, they begin moving north along the coast past Cape Hatteras and near the Long Island Coast. Individuals have been sighted along the south shore of Long Island, Block Island Sound, Gardiners Bay and south shore inlets and bays. They could be present in the action area year-round.

Finback whales occupy both deep and shallow waters and are probably the most abundant large cetacean in NY waters. They are most abundant in spring, summer, and fall, but do have some presence during the winter months. Therefore, fin whales could be present in the action area year-round.

7.2.2. Potential Impacts to Whales in the Action Area

ESA listed species of whales will not occur in the area north of the outer portions of the Ambrose Channel. Because whales forage upon pelagic prey items (e.g., krill, copepods), dredging at Ambrose and its secondary impacts on the benthic environment will not have any direct effects on whale prey/foraging items. As such, this section will only address vessel traffic and potential water quality impacts to whales at or near the Ambrose Channel.

Vessel Traffic.

Large whales, particularly right whales, are vulnerable to injury and mortality from ship strikes. Ship strike injuries to whales take two forms: (1) propeller wounds characterized by external gashes or severed tail stocks; and (2) blunt trauma injuries indicated by fractured skulls, jaws, and vertebrae, and massive bruises that sometimes lack external expression (Laist et al.2001). Collisions with smaller vessels may result in propeller wounds or no apparent injury, depending on the severity of the incident. Laist et al. (2001) reports that of 41 ship strike accounts that reported vessel speed, no lethal or severe injuries occurred at speeds below ten knots, and no collisions have been reported for vessels traveling less than six knots. Most ship strikes have occurred at vessel speeds of 13-15 knots or greater (Jensen and Silber 2003; Laist et al. 2001). An analysis by Vanderlaan and Taggart (2006) showed that at speeds greater than 15 knots, the probability of a ship strike resulting in death increases asymptotically to 100%. At speeds below11.8 knots, the probability decreases to less than 50%, and at ten knots or less, the probability is further reduced to approximately 30%.

An analysis by Vanderlaan and Taggart (2006, as referenced in HDP BO) showed that at speeds greater than 15 knots, the probability of a ship strike resulting in death of a whale increases asymptotically to 100%. At speeds below 11.8 knots, the probability decreases to less than 50%, and at ten knots or less, the probability is further reduced to approximately 30%. Impacts to listed species of whales during sand mining are unlikely because the hopper dredge would move very slowly at < 2.6 knots, a speed at which whales can avoid contact with the dredge.

Collisions with a slowly transiting hopper might occur, but the suggested reduced speed (10 knots) during transit lessens the probability of a ship strike resulting in death. Although vessel strikes are acknowledged as being one of the primary known sources of whale mortality in the northeast, ship strikes remain relatively rare events and a small increase in vessel traffic within the project area does not necessarily translate into an increase in ship strike events (NMFS Consultation Letter to USACE, DISTRICT, Daniel S. Morris 1/20/2012). Onboard lookouts would also reduce the risk of vessel-whale collisions. If the lookout on board the hopper dredge observes a whale in the vicinity of the vessel during transit throughout the project area, maximum vessel speeds would be limited to 10 knots. If a Right Whale is observed, the vessel would maintain a 500 yard buffer from the whale. For all other whale species, a 100 yard buffer would be maintained.

The potential for adding a minimal number of project vessels to the existing baseline could increase risk to whales to such a small extent that the effect of the action cannot be meaningfully measured or detected. The increase or change in traffic associated with the proposed project is small. Channel deepening dredging operations typically add approximately 6 vessels to the action area. Dredging operations, similarly, exclude other non-dredging vessels from the action area as a result of the functioning of the dredging operation vessels presence in the action area. It is the Districts conclusion that there is a net gain of zero vessels added to the action area due to the dredging operations established exclusionary zones implementation as well as the mandatory reduced speed of those vessels (as opposed to non-project-related vessels). To be conservative, the District will assume an addition of 6 vessels to the action area resulting from the Federal action. The addition of these project-related vessels will be intermittent (October through March of any year), temporary (7-8 trips per day during planned nourishment cycles, only, until 2050), and restricted to a small portion of the overall action area on any day dredging occurs. Once dredging is completed, the pre-project status quo of likely vessel numbers and vessel traffic patterns will likely decrease due to the deeper channels permitting greater efficiencies, such as fewer and larger and newer vessels accessing the terminals, and, thus, not permanently increase the risk of a vessel strike. Given that the action area associated with the greatest risk to whales is in a coastal environment where listed species are able to disperse widely, and due to the temporary and localized operation of the vessels associated with the Federal action, the risk of vessel strike is unlikely. As a result, the effect of the action on the risk of a vessel strike in the action area is discountable.

Water Quality.

Total Suspended Solids and turbidity are most likely to affect whales if a plume causes a barrier to normal behaviors. As whales breathe air and are highly mobile, they are likely to be able to avoid any sediment plume and any effect on their movements is likely to be insignificant. While the increase in suspended sediments, which is unlikely given the large grain size of the sand, may cause whales to alter their normal movements, any change in behavior is not able to be measured or detected, as it will only involve minor movements that alter their course out of any plume which will not disrupt any essential life behaviors. Based on this information, we believe the effects of suspended sediment on whales resulting from increased turbidity from dredging are too small to be meaningfully measured or detected and are insignificant.

8. Discussion/Conclusion

8.1. Atlantic Sturgeon

From reviewing the best available information on Atlantic sturgeon life history, and their behavior in and around the HDCI, it appears that Atlantic sturgeon are present in the vicinity of the HDCI contract areas primarily while migrating between spawning grounds in the Hudson River and their offshore oceanic environments, via the Ambrose and Anchorage channels. Several generic threats to Atlantic sturgeon from dredging and blasting activities have been identified. However, as summarized below, those most closely associated with and given the physical nature and actions associated with the HDCI contract areas are not deemed to impact the continued existence and recovery of the species.

Proposed construction for the HDCI will occur in the Ambrose, Anchorage- PJ, KVK and NB main channels, as well as into South Elizabeth and Elizabeth Channels. The potential impacts of dredging and blasting on benthic resources (e.g., Atlantic sturgeon prey) within the KVK-NB complex indicate a temporary and short-term loss and/or shift in benthic community within those localized contract areas. Given the nature of the impact, the availability of resources available to Atlantic sturgeon in those areas of the project where they are documented as primarily occurring and are ubiquitous, such as the Lower Bay and entire Raritan Bay, and that Atlantic sturgeon are indiscriminate feeders, the impacts associated with dredging on benthic resources is unlikely to have an adverse impact on the species.

Given the information described in this section, the greatest potential risk for indirect or direct impacts to Atlantic sturgeon from the HDCI is therefore limited to the Ambrose channel areas since this channel not only is situated as the major migratory spawning pathway for the NYB DPS, but, it is also the only channel at which a large hopper dredged will be deployed. The District is committed to minimizing impacts of hopper dredging activities on Atlantic sturgeon. To reiterate, because the area of impact from the contract areas in Ambrose channel is so small relative to the surrounding Lower and Raritan Bays, there are many opportunities available for Atlantic sturgeon to avoid active dredges. Additionally, as part of the conditions outlined in the NMFS 2012 BO, the District currently equips hopper dredges in the Ambrose channel with sea turtle deflectors (and UXO screens) on the draghead. This measure is meant to reduce the risk of interaction with protected species that may be present in the dredge area.

As part of the Terms and Conditions of the 2012 BO, USACE has been required to use NMFS-approved protected species observers (PSO) to monitor for takes onboard hopper dredges on deep draft navigation projects, as appropriate (ex. Ambrose Channel).

Additionally, a number of BMPs (in addition to observers) were reviewed and agreement between NMFS and the District was reached regarding the conduct of a pilot study, as an element of mitigation, to explore the feasibility of designing and deploying a tickler chain apparatus to attach to the draghead, which would serve to move bottom-dwelling individuals (turtles or Atlantic sturgeon) out ahead of and away from the area of effect of the draghead intake. This study has been deployed on one of the Districts' Coastal Storm Reduction projects (Fire Island to Moriches Inlet - FIMI), and was concluded 2020. The technical team comprised of ERDC subject matter experts (mechanical engineer and endangered species specialists) and District biologists have the report under preparation, currently, and the draft report will be coordinated with the NMFS team upon its completion this fall. The study is intended to identify the feasibility of deploying new BMPs, as well as identify any other BMPs for future feasibility investigations that could reduce the risk to protected species with the Districts' AOR.

Based on this BA, potential impacts to Atlantic sturgeon as part of the proposed improvements to the HDCI appears to be limited to a temporary and short-term loss and/or shift in benthic community and potential risk of entrainment by hopper dredges in the Ambrose channel, as well as possible adverse effects due to blasting activities in the Newark Bay-KVK Complex. These potential impacts are not likely to jeopardize the continued existence of Atlantic sturgeon due to the Districts use of BMPs during blasting activities that significantly reduce the adverse effects to finfish, and the implementation of seasonal restrictions (i.e. no dredging or blasting from

March 1 to June 30) protective of anadromous fish throughout the NB-KVK Complex. Construction activities at the Ambrose Channel are unlikely to increase risk to sturgeon due to the expansiveness of Lower Bay permitting ease of passage of sturgeon to and from their upriver spawning grounds, and to/from feeding, overwintering and offshore migratory pathways. The District will continue to actively work with NMFS to ensure that any potential impacts of the planned activities are minimized.

In addition to the limited effects of dredging activities there are a variety of other factors that may contribute to the vulnerability of Atlantic sturgeon to habitat impacts and potential further population collapse, many of which are more likely to impact the Atlantic sturgeon than a dredging project exercising prudent measures to avoid/minimize takes. These include: their unique life history characteristics, vessel strikes, overfishing, dam construction and operation, water quality modifications, bycatch and poaching. In order for recovery efforts to succeed, it is vital to practically address all potential threats to Atlantic sturgeon.

8.2. Sea Turtles

Sea turtles are not expected to occur in the Upper Bay-PJ or NB-KVK complex areas of the project because it is a highly congested and trafficked area, and the physical habitat characteristics in the area do not suggest that it would represent a concentration area for sea turtles.

If present at all in the New York Bight, sea turtles are more likely to be present as transients in the Lower Bay, well outside of the Ambrose Channel contracts footprint.

In the 2012 BO, hopper dredging, particularly utilizing large hopper dredges, was identified as a dredging type of concern for entraining sea turtles. Although a hopper dredge will be used to remove material from the Ambrose contract areas, the likelihood of adversely affecting a sea turtle will be rare.

Based on the many years of documented sea turtle observer data (1993-2010), there was only one observed Loggerhead turtle take out of 13 projects in New York, New Jersey and New England; the total dredged quantity during the turtle season was approximately 18.7 million cubic yards of material. The take was considered a freak incidence and occurred during a beach re-nourishment project along the Sandy Hook to Barnegat Inlet in 1997 (Long Branch borrow area), which is along the New Jersey shore and well away from the contract areas in the Ambrose Channel. Also, when compared to other dredging projects along the East Coast (see Sea Turtle Warehouse at: http://el.erdc.usace.army.mil/seaturtles), the overwhelming majority of turtle takes has been in the Gulf (200 takes) and South Atlantic Regions (446 takes) where sea turtles cluster to over winter, not in the North Atlantic (67) or New York District (1) where juveniles migrate to feed. Based on this information, observed take appears to be a rare occurrence within the District and should be an indication that sea turtle occurrence is rare in the contract areas for the HDCI, and new methods to monitor such an unlikely event are not warranted. Therefore, turtle deflectors will continue to be used, as appropriate, as well as an onboard lookout to determine the deflectors are deployed properly and to identify presence of turtles to vessel operators so they can be avoided.

Based on this BA, impacts to the leatherback, green, Kemp's ridley and Northwest Atlantic Ocean distinct population segment of loggerhead sea turtles as part of the proposed construction of the HDCI appears to be limited to a temporary and short-term loss and/or shift in benthic community and potential, low risk of entrainment by hopper dredges in the Ambrose channel. These impacts are not likely to jeopardize the continued existence of these sea turtle species. The District will continue to actively work with NMFS to ensure that any potential impacts of the planned activities are minimized, such as the continued use of sea turtle deflectors or, as applicable and permitted by NMFS, the use of the tickler chain apparatus on the dragheads of hopper dredges. The District concludes that potential impacts to turtles are negligible.

8.3. Whales

ESA listed species of whales will not occur in or utilize the Upper Bay or NB complex areas of the project. The Ambrose Channel element of the HDCI is the only area where whales would likely be found. Because whales forage upon pelagic prey items (e.g., krill, copepods), dredging and its impacts on the benthic environment will not have any direct effects on whale prey/foraging items. Additionally, as dredging operations will not be undertaken within the vicinity of ESA listed species of whales, migratory behaviors of ESA listed whales will also not be affected. As such, this section will only address vessel traffic, water quality, and aquatic biological monitoring impacts to whales at the NYOBA, while transiting from back and forth from NYOBA and the coastline.

Impacts to listed species of whales during deepening of the Ambrose Channel are unlikely because the hopper dredge would move very slowly at ≤ 2.6 knots, a speed at which whales can easily avoid contact with the dredge. Collisions with a transiting hopper dredge between the dredge site and the placement site could occur at offshore placement sites, such as the HARS. An analysis by Vanderlaan and Taggart (2006, as referenced in HDP BO) showed that at speeds greater than 15 knots, the probability of a ship strike resulting in death of a whale increases asymptotically to 100%. At speeds below 11.8 knots, the probability decreases to less than 50%, and at ten knots or less, the probability is further reduced to approximately 30%. The speed of the dredge in the proposed project is not expected to exceed 2.6 knots while dredging and 9.4 knots while transiting to/from the deepening /placement sites, thereby reducing the likelihood of vessel collision impacts.

Large whales, particularly right whales, are vulnerable to injury and mortality from ship strikes. Ship strike injuries to whales take two forms: (1) propeller wounds characterized by external gashes or severed tail stocks; and (2) blunt trauma injuries indicated by fractured skulls, jaws, and vertebrae, and massive bruises that sometimes lack external expression (Laist et al.2001). Collisions with smaller vessels may result in propeller wounds or no apparent injury, depending on the severity of the incident. Laist et al. (2001) reports that of 41 ship strike accounts that reported vessel speed, no lethal or severe injuries occurred at speeds below ten knots, and no collisions have been reported for vessels traveling less than six knots. Most ship strikes have occurred at vessel speeds of 13-15 knots or greater (Jensen and Silber 2003; Laist et al. 2001). An analysis by Vanderlaan and Taggart (2006) showed that at speeds greater than 15 knots, the probability of a ship strike resulting in death increases asymptotically to 100%. At speeds below 11.8 knots, the probability decreases to less than 50%, and at ten knots or less, the probability is further reduced to approximately 30%.

Collisions with a slowly transiting hopper might occur, but the suggested reduced speed (10 knots) during transit lessens the probability of a ship strike resulting in death. Although vessel strikes are acknowledged as being one of the primary known sources of whale mortality in the northeast, ship strikes remain relatively rare events and a small increase in vessel traffic within the project area does not necessarily translate into an increase in ship strike events (2012 BA). Onboard lookouts would also reduce the risk of vessel-whale collisions. If the lookout on board the hopper dredge observes a whale in the vicinity of the vessel during transit throughout the project area, maximum vessel speeds would be limited to 10 knots. If a Right Whale is observed, the vessel would maintain a 500 yard buffer from the whale. For all other whale species, a 100 yard buffer would be maintained. The District concludes that the potential impacts to whales is negligible.

8.4. Recommendations

8.4.1 Best Managements Practices and Mitigation.

The District already abides by seasonal restrictions designed to be protective of Federal, state and locally regulated and protected aquatic resources. Currently, there are seasonal restrictions to be protective of aquatic species that prohibit dredging operations throughout the HDCI study footprint. Specifically, to protect migratory finfish a seasonal no dredge restriction is placed throughout the KVK channel (beginning at its junction with Anchorage Channel) and up through the Newark Bay Main Stem Channel (continuing up river to Hackensack and Passaic Rivers) from March 1- June 30. Another seasonal no dredge restriction is placed at the outer portion (intersect with Anchorage Channel) of the PJ channel from January 15 through May 31. Additionally, the District is requiring the use of a turtle exclusion devise (TED), in addition to UXO screens, and ESA Protected Species Observers (PSO) on Hopper dredges operating in the Ambrose channel. Finally, the District has concluded the pilot study coordinated with NMFS Protected Resources Division (PRD) to determine the feasibility of deploying a tickler chain apparatus designed to be protective of protected species that could be dwelling at/near the bottom during hopper dredge operations. The pilot study was undertaken at 100% Federal cost in response to PRDs per Section 7(a)(1) of the ESA places a responsibility on all federal agencies to "utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species." The HDP 2012 BO Conservation Recommendations included discretionary activities designed to minimize or avoid (mitigate) adverse effects of an action on listed species or critical habitat, to help implement recovery plans, or to develop information. Specifically, NMFS included the recommendation to USACE to coordinate with other districts and dredge operators regarding additional reasonable measures they may take to further reduce the likelihood of takes. The diamond-shaped pre-deflector, or other potentially promising pre-deflector designs such as tickler chains, water jets, sound generators, etc., should be developed and tested and used where conditions permit as a means of alerting sea turtles and sturgeon of approaching equipment. New technology or operational measures that would minimize the amount of time the dredge is spent off the bottom in conditions of uneven terrain should be explored. Pre-deflector use should be noted on observer daily log sheets, and annual reports to NMFS should note what progress has been made on deflector or pre-deflector technology and the benefits of, or problems associated with, their usage. The District has completed the field portion of the tickler chain pilot study and is now preparing the report for distribution, and eventually publication as an ERDC Technical Note.

A table (Table 4) is included below to summarize presumed hopper operations, only (due to increased risk to protected species), from 2025 through 2039 (approximate start and duration of 14 years for construction of the total (including mechanical dredging at KVK/NB/PJ channels) project.

Contract Area	Sediment Type	Volume (CY)	Equipment	# Vessels	Trips/Day (to ocean/offshore placement site)	Placement Site
Amb	Sand	8,320,000	Hydraulic	3	4	HARS
Anch	Sand/SIlt	4,030,000	Hydraulic	3	3	HARS/Non HARS
PJ	Sand/Silt	1,750,000	Hydraulic	3	3	HARS/Non HARS
KVK	Silt/Rock	1,620,000	Hydraulic	3	3	HARS/Non HARS
NB	Silt/Rock	1,200,000	Hydraulic	3	3	HARS/Non HARS
Total Hydraulic Volume		16,920,000				

Table 4. Summary of Hopper Dredge Operations

9. References

ASMFC (Atlantic States Marine Fisheries Commission). 1990. Interstate fishery 116 management plan for Atlantic sturgeon. Fisheries Management Report No. 17. Atlantic States Marine Fisheries Commission, Washington, D.C. 73 pp.

ASSRT (Atlantic Sturgeon Status Review Team). 2007. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Report to National Marine Fisheries Service, Northeast Regional Office. 174 pp.

Armstrong, J.L. 1999. Movement, habitat selection and growth of early-subadult Atlantic sturgeon in Albemarle Sound, North Carolina. Master's Thesis, Department of Zoology, North Carolina State University.

Bain, M.B. 1997. Atlantic and shortnose sturgeons of the Hudson River: common and divergent life history attributes. Environmental Biology of Fishes 48:347-358.

Bain, M. B. 2001. Sturgeon of the Hudson River ecology of juveniles. Final Report for The Hudson River Foundation , 40 West 20th St., 9th Floor, New York, NY 10011. 10pp.

Bain, M. B., Arend, K. Haley, N., Hayes, S., Knight, J., Nack, S. Peterson, D., and M. Walsh. 1998. Sturgeon of the Hudson River. Final Report for the Hudson River Foundation. 40 West 20th St., 9th Floor, New York, NY 10011. 83pp.

Bain, M., N. Haley, D. Peterson, J.R. Waldman, and K. Arend. 2000. Harvest and habitats of Atlantic sturgeon *Aciperser oxyrinchus* Mitchill, 1815 in the Hudson River estuary; lessons for sturgeon conservation. Boletin Instituto Espanol de Oceanografia 16(1-4) 2000:43-53.

Bemis, W.E. and B. Kynard. 1997. Sturgeon rivers: an introduction to *Acipenseriform* biology and life history. Environmental Biology of Fishes. 48: 167-183.

Bigelow, H. B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv. Fish. Bull. 74. 557 pp.

Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Env. Biol. Fish. 48.

Borodin, N.A. 1925. Biological observations on the Atlantic sturgeon *(Acipenser sturio).*Transactions of the American Fisheries Society 55:184-190.

Brown, J.J., J. Perillo, T.J. Kwak, and R.J. Horwitz. 2005. Implications of *Plyodictis olivaris* (Flathead Catfish) introduction into the Delaware and Susquehanna drainages. Northeastern Naturalist. 12: 473-484.

Brown, J. and G.W. Murphy, 2010. Atlantic sturgeon vessel-strike mortalities in the Delaware Estuary. Fisheries. Vol. 35, no. 2. 83 p.

Burton, W.H. 1994. Assessment of the Effects of Construction of a Natural Gas Pipeline on American Shad and Smallmouth Bass Juveniles in the Delaware River. Prepared by Versar, Inc. for Transcontinental Gas Pipe Line Corporation.

Caron, F., D. Hatin, and R. Fortin. 2002. Biological characteristics of adult Atlantic sturgeon (*Acipenser oxyrinchus)* in the Saint Lawrence River estuary and the effectiveness of management rules. Journal of Applied Ichthyology 18: 580-585.

Cech, J.J., and S.I. Doroshov. 2004. Environmental requirements, preferences, and tolerance limits of North American sturgeons. Pages 73-86 *in* LeBreton, G.T.O., F.W.H. Beamish and R.S. McKinley, (eds.). Sturgeons and Paddlefish of North America. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Cerrato, R.M. and H.J. Bokuniewicz. 1986. The Benthic Fauna at Four Potential Containment/Wetland Stabilization Areas in the New York Harbor Region. Marine Sciences Research Center, SUNY, Stony Brook, NY. Sponsored by NY Sea Grant Institute through a contract with the USACE. Special Report 73, Reference 86- 10.

Cerrato, R.M. 2006. Long-term and large-scale patterns in the benthic communities of New York Harbor. The Hudson River Estuary. Cambridge University Press. 242-265.

Collins, M.R., T.I.J. Smith, W.C. Post, and O. Pashuk. 2000. Habitat utilization and biological characteristics of adult Atlantic sturgeon in two South Carolina rivers. Transactions of the American Fisheries Society 129:982-988.

Cooper, K. 1989. Effects of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans on aquatic organisms. Reviews in: Aquatic Sciences 1(2): 227-242.

Dadswell, M.J. 1979. Biology and population characteristics of the shortnose sturgeon*, Acipenser brevirostrum* LeSueur, 1818 *(Osteichthyes: Acipenseridae),* in the Saint John River estuary, New Brunswick, Canada*.* Canadian Journal of Zoology 57:2186-2210.

Dadswell, M. 2006. A review of the status of Atlantic sturgeon in Canada, with comparisons to populations in the United States and Europe. Fisheries 31: 218-229.

Dickerson, D. 2006. Observed takes of sturgeon and turtles from dredging operations along the Atlantic Coast. Supplemental data provided by U.S. Army Engineer R&D Center Environmental Laboratory, Vicksburg, Mississippi.

Dovel, W.L. and T.J. Berggren. 1983. Atlantic sturgeon of the Hudson estuary*, New Y*ork. New York Fish and Game Journal 30(2):140-172.

Dovel, W.L., A.W. Pekovitch, and T.J. Berggren. 1992. Biology of the shortnose sturgeon (*Acipenser brevirostrum* Leseur, 1818) in the Hudson River estuary, New York. Pp 187-216. In: C.L. Smith (ed) Estuarine Research in the 1980s, State Univ. New York Press, Albany.

Dunton, K. J., A. Jordaan, K. A. McKown, D. O. Conover, and M. G. Frisk. 2010. Abundance and distribution of Atlantic sturgeon (*Acipenser oyxrinchus*) within the Northwest Atlantic Ocean, determined from five fishery-independent surveys. Fishery Bulletin 108:450-465.

ECS (Environmental Consulting Services, Inc.). 1993. Final report of survey of benthos: Delaware River Estuary: from the area of the C&D Canal through Philadelphia to Trenton, prepared for the Delaware River Estuary Program, Delaware River Basin Commission, Environmental Protection Agency, Middletown, Delaware.

Erickson, D. L., A. Kahnle, M. J. Millard, E. A. Mora, M. Bryja, A. Higgs, J. Mohler, M. DuFour, G. Kenney, J. Sweka, and E. K. Pikitch. 2011. Use of pop-up satellite archival tags to identify oceanic-migratory patterns for adult Atlantic Sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchell, 1815. Journal of Applied Ichthyology 27:356-365.

Eyler, S., M. Mangold, and S. Minkkinen. 2004. Atlantic Coast sturgeon tagging database. Summary Report prepared by US Fish and Wildlife Service, Maryland Fishery Resource Office, Annapolis, MD. 51 pp.

Federal Register. 2010. Endangered and threatened wildlife and plants: proposed listing determination for three distinct population segments of Atlantic sturgeon in the Northeast region. 75 Federal Register 193 (October 6, 2010), pp. 61872-61903.

Gadomski, D.M. and M.J. Parsley. 2005. Laboratory studies on the vulnerability of young white sturgeon to predation. North American Journal of Fisheries Management. 25: 667-674.

Geoghegan. P, M.T. Mattson, and R.G. Keppel. 1992. Distribution of the shortnose sturgeon in the Hudson River estuary. 1984-1988. Pages 217-227. In: C.L. Smith, editor. Estuarine Research in the 1980s. State University of New York Press. Albany, New York.

Gilbert, C.R. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic Bight)--Atlantic and shortnose sturgeons. U.S. Fish and Wildl. Serv. Biol. Rep. 82(11.122). U.S. Army Corps of Engineers, TR EL-82-4. 28 pp.

Gruchy, C. G., and B. Parker. 1980b. *Acipenser oxyrhynchus* Mitchill, Atlantic sturgeon. Page 41 in D.S. Lee et al. Atlas of North American freshwater fishes. North Carolina State Mu. Nat. Hist., Raleigh.

Grunwald, C., L.Maceda, J.Waldman, J. Stabile, and I. Wirgin. 2007. Conservation of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus:* delineation of stock structure and distinct population segments. Conservation Genetics 9:1111-1124.

Haley, N., J.Boreman, and M.Bain. 1996. Juvenile sturgeon habitat use in the Hudson River. Section VIII *in* J.R. Waldman, W.C. Nieder, and E.A. Blair (eds.) Final Report to the Tibor T. Polgar Fellowship Program, 1995. Hudson River Foundation, New York.

Haley, N., and M. Bain. 1997. Habitat and food partitioning between two co-occurring sturgeons in the Hudson River estuary. Paper presentation at the Estuarine Research Federation Meeting, Providence, Rhode Island, October 14, 1997.

Haley, N. 1998. A gastric lavage technique for characterizing diets of sturgeons. North American Journal of Fisheries Management 18:978-981.

Hall, J.W., T.I.J. Smith and S.D. Lamprecht. 1991. Movements and habitats of shortnose sturgeon, *Acipenser brevirostrum,* in the Savannah River. Copeia 1991:695-702.

Hoff, J. G. 1980. Review of the present status of the stocks of the Atlantic sturgeon *Acipenser oxyrhynchus,* Mitchill. Prepared for the National Marine Fisheries Service, Northeast Region, Gloucester, Massachusetts.

Hoff, T.B., R.J. Klauda, and J.R. Young. 1988. Contribution to the biology of shortnose sturgeon in the Hudson River estuary. Pages 171-189. In: C.L. Smith, editor, Fisheries Research in the Hudson River. State University of New York Press, Albany, New York.

Huff, J.A. 1975. Life History of Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi,* in Suwannee River, Florida. Fla. Mar. Res. Publ. 16:1-32.

Johnson, J.H., D.S. Dropkin, B.E. Warkentine, J.W. Rachlin, and W.D. Andrews. 1997. Food habits of Atlantic sturgeon off the central New Jersey coast. Transactions of the American Fisheries Society 126:166-170.

Kahnle, A. W., K.A. Hattala, K.A. McKown. 2007. Status of Atlantic Sturgeon of the Hudson River estuary, New York, USA. Pages 347-363 in J. Munro, D. Hatin, J.E. Hightower, K.A. McKown, K.J. Sulak, A.W. Kahnle, and F. Caron, editors. Anadromous sturgeons: habitats, threats and management. American Fisheries Society, Symposium 56, Bethesda, Maryland.

Keevin, Thomas M. and Hempen, G. L. 1997. The Environmental Effects of Underwater Explosions with Methods to Mitigate Impacts. U. S. Army Corps of Engineers, St. Louis District.

Kieffer, M.C. and B. Kynard. 1993. Annual movements of shortnose and Atlantic sturgeons in the Merrimack River, Massachusetts. Transactions of the American Fisheries Society 122:1088-1103.

Kieffer, J. D., D. W. Baker, A. M. Wood, and C. N. Papadopoulos. 2011. The effects of temperature on the physiological response to low oxygen in Atlantic sturgeon. Fish Physiology and Biochemistry DOI: 10.1007/s10695-011-9479-y.

Kynard, B., M. Horgan, M. Kieffer, and D. Seibel. 2000. Habitats used by shortnose sturgeon in two Massachusetts rivers, with notes on estuarine Atlantic sturgeon: a hierarchical approach. Transactions of the American Fisheries Society 129: 487-503.

Kynard, B., and M. Horgan. 2002. Ontogenetic behavior and migration of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus,* and shortnose sturgeon, *A.brevirostrum,* with notes on social behavior. Environmental Behavior of Fishes 63:137-150.

Laney, R. W., J. E. Hightower, B. R. Versak, M. F. Mangold, W. W. Cole Jr., and S. E. Winslow. 2007. Distribution, habitat use, and size of Atlantic sturgeon captured during cooperative winter tagging cruises, 1988–2006. *In* Anadromous sturgeons: habitats, threats, and management (J. Munro, D. Hatin, J.E. Hightower, K. McKown, K. J. Sulak, A. W. Kahnle, and F. Caron, eds.) p. 167–182. Am. Fish. Soc. Symp. 56, Bethesda, MD.

Mangin, E. 1964. Croissance en longuer de trois sturgeons d'amerique du nord: *Acipenser oxyrinchus,* Mitchell, *Acipenser fulvescens,* Rafinesque, et *Acipenser brevirostris* LeSuer. Verth. Int. Ver. Limnology 15: 968-974.

Marchette, D.E. and R. Smiley. 1982. Biology and life history of incidentally captured shortnose sturgeon, *Acipenser brevirostrum,* in South Carolina. South Carolina Wild. Mar. Res. Inst. 57 pp.

Moser, M.L. and S.W. Ross. 1995. Habitat use and movements of shortnose and Atlantic sturgeons in the lower Cape Fear River, North Carolina. Transactions of the American Fisheries Society 124:225-234.

Moser, Mary. 1999. Cape Fear River Blast Mitigation Tests: Results of Caged Fish Necropsies, Final Report to CZR, Inc. under Contract to US Army Corps of Engineers, Wilmington District.

Murawski, S. A. and A. L. Pacheco. 1977. Biological and fisheries data on Atlantic Sturgeon, *Acipenser oxyrhynchus* (Mitchill). National Marine Fisheries Service Technical Series Report 10: 1-69.

National Marine Fisheries Service. 2000. Biological opinion on the effects of the Army Corps of Engineers' (ACOE) proposed New York and New Jersey Harbor Navigation project on threatened and endangered species. Sea turtles (F/NER/2000/00596).

National Marine Fisheries Service. 2010. Species of Concern, Atlantic Sturgeon, *Acipenser oxyrinchus oxyrinchus.* www.nmfs.noaa.gov/pr/pdfs/species/atlanticsturgeon_detailed.pdf.

National Marine Fisheries Service. March 1, 2011. Letter to Jenine Gallo regarding the Ambrose Obstruction Removal Project; Threatened or Endangered Species Information Request.

National Marine Fisheries Service. 2012. Biological Opinion for the Harbor Deepening Project.

NRDC (National Resource Defense Council). 2009. Petition to List Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) as an Endangered Species, or to List Specified Atlantic Sturgeon DPSs as Threatened and Endangered Species, and to Designate Critical

Habitat. 77pp.

Niklitschek, E.J., and D.H. Secor. 2005. Modeling spatial and temporal variation of suitable nursery habitats for Atlantic sturgeon in the Chesapeake Bay. Estuarine, Coastal and Shelf Science 64:135-148.

Peterson, D. L., M. B. Bain, and N. Haley. 2000. Evidence of declining recruitment of Atlantic sturgeon in the Hudson River. North American Journal of Fisheries Management 20: 231-238.

Pottle, R. and M.J. Dadswell. 1979. Studies on larval and juvenile shortnose sturgeon. Report to Northeast Utilities. Hartfoed, Connecticut. (MS report available from M.J. Dadswell).

Rau, M., C. Smith, and N. Lombardero. Undated. Biological Assessment for the Use of Bed-Leveling Devices in Port Canaveral – Baseline Research and Data Compilation. Prepared for the USACE-Jacksonville District.

Rochard, E., M. Lepage, and L. Meauze. 1997. Identification and characterization of the marine distribution of the European sturgeon, *Acipenser sturio*. Aquatic Living Resources 10: 101-109.

USACE, H. J., and Morreale, S. J. 1999. Draft Biological Assessment for Sea Turtles New York New Jersey Harbor Complex. (Submitted to NMFS as part of consultation process).

Ryder, J.A. 1890. The sturgeon and sturgeon industries of the eastern coast of the United States, with an account of experiments bearing upon sturgeon culture. Bulletin of the U.S. Fish Commission (1888)8:231-328.

Savoy, T. and D. Pacileo. 2003. Movements and important habitats of subadult Atlantic sturgeon in Connecticut waters. Transactions of the American Fisheries Society 132:1-8.

Secor, D. H. 1995. Chesapeake Bay Atlantic sturgeon: current status and future recovery. Summary of Findings and Recommendations from a Workshop convened 8 November 1994 at Chesapeake Biological Laboratory. Chesapeake Biological Laboratory, Center for Estuarine and Environmental Studies, University of Maryland System, Solomons, Maryland.

Secor, D.H., E.J. Niklitschek, J.T. Stevenson, T.E. Gunderson, S.P. Minkkinen, B. Richardson, B. Florence, M. Mangold, J. Skjeveland, and A. Henderson-Arzapalo. 2000. Dispersal and growth of yearling Atlantic sturgeon*, Acipenser oxyrinchus,* released into Chesapeake Bay. Fishery Bulletin 98:800-810.

Shirey, C.A., C.C. Martin, and E.J. Stetzar. 1997. Abundance of subadult Atlantic sturgeon and areas of concentration within the lower Delaware River. Final Report. August 1, 1996-September 30, 1997. Delaware Division of Fish and Wildlife, Dover, DE. 21 pp.

Simpson, P.C. 2008. Movements and habitat use of Delaware River Atlantic sturgeon. Master

Thesis, Delaware State University, Dover, DE 128 p.

Sindermann, C. J. 1994. Quantitative effects of pollution on marine and anadromous fish populations. NOAA Technical Memorandum NMFS-F/NEC-104, National Marine Fisheries Service, Woods Hole, Massachusetts.

Smith, C. L. 1985a. The inland fishes of New York State. The New York State Dep. Of Environmental Conservation. Albany. Xi + 522 pp.

Smith, T.I.J. 1985b. The fishery, biology, and management of Atlantic sturgeon*, Acipenser oxyrhynchus,* in North America. Environmental Biology of Fishers 14(1):61-72.

Smith, T.I.J., and E.K. Dingley. 1984. Review of biology and culture of Atlantic (*Acipenser oxyrhynchus)* and shortnose sturgeon (*A. brevirostrum).* Journal of World Mariculture Society 15: 210-218.

Smith, T.I.J., E.K. Dingley, and E.E. Marchette. 1980. Induced spawning and culture of Atlantic sturgeon*.* Progressive Fish Culturist 42:147-151.

Smith, T.I.J., and J.P. Clugston. 1997*.* Status and management of Atlantic sturgeon*, Acipenser oxyrinchus,* in North America. Environmental Biology of Fishes 48:335-346.

Stein, A.B., K.D. Friedland, and M. Sutherland. 2004. Atlantic sturgeon marine distribution and habitat use along the northeastern coast of the United States. Transactions of the American Fisheries Society 133:527-537.

Stevenson, J. T. 1997. *Life history of Hudson River Atlantic sturgeon and a model for fishery management*. Masters Thesis, University of Maryland, College Park. Maryland, USA: 222 pp.

Stevenson, J.T., and D.H. Secor. 1999. Age determination and growth of Hudson River Atlantic sturgeon*, Acipenser oxyrinchus.* Fishery Bulletin 97:153-166.

Sweka, J.A., J. Mohler, M.J. Millard, T. Kahnle, K. Hattala, G. Kenny, and A. Higgs. 2007. Juvenile Atlantic sturgeon habitat use in Newburgh and Haverstraw Bays of the Hudson River: implications for population monitoring. Transactions of the American Fisheries Society 27:1058-1067.

Teleki, G.C. and A.J. Chamberlain. 1978. Acute Effects of Underwater Construction Blasting in Fishes in Long Point Bay, Lake Erie. J. Fish. Res. Board Can. 35: 1191-1198.

U.S. Army Corps of Engineers (USACE), New York District. 1999a. Interim Report for the Army Corps of Engineer Biological Monitoring Program: Atlantic Coast of New Jersey, Asbury Park to Manasquan Inlet Section Beach Erosion Project.

U.S. Army Corps of Engineers (USACE), New York District. 1999b. Draft Biological Assessment for Sea Turtles New York and New Jersey Harbor Complex.

U.S. Army Corps of Engineers (USACE) New York District. 2004. Environmental Assessment for the New York and New Jersey Harbor Deepening Project.

U.S. Army Corps of Engineers (USACE) New York District. 2004a. Blast Monitoring Program for the Kill Van Kull Deepening Project.

U.S. Army Corps of Engineers (USACE) New York District. Draft Report September 2007. New York/New Jersey Harbor Deepening Project 2006 Migratory Finfish Report.

U.S. Army Corps of Engineers (USACE) New York District. 2010. Ambrose Obstruction Biological Sampling Report.

U.S. Army Corps of Engineers (USACE), Philadelphia District. 2011. Supplemental BA for Potential Impacts to the New York Bight Distinct Population Segment of Atlantic Sturgeon (A*cipenser oxyrinchus oxyrinchus)* which is proposed for Federal endangered species listing resulting from the Delaware River Main Stem and Channel Deepening Project.

U.S. Army Corps of Engineers (USACE) New York District. 2011a. Technical memo: Far-Field Surveys of Suspended Sediment Plumes Associated with Harbor Dredging in Upper Bay, S-AN-2 contract area (Anchorage Channel).

U.S. Army Corps of Engineers (USACE) New York District. 2012. Biological Assessment for the Harbor Deepening Project.

Van Eenennaam, J.P., S.I. Doroshov, G.P. Moberg, J.G. Watson, D.S. Moore, and J. Linares. 1996. Reproductive Conditions of the Atlantic sturgeon *(Acipenser oxyrinchus)* in the Hudson River**.** Estuaries 19(4):769-777.

van den Avyle, M. J. 1983. Species profiles: life histories and environmental requirements (South Atlantic) - Atlantic sturgeon. U.S. Fish and Wildlife Service, Division of Biological Services FWS/OBS-82/11. U.S. Army Corps Eng. TREL-82-4. 38 pp.

van den Avyle, M. J. 1984. Species profile: life histories and environmental requirements of coastal fishes and invertebrates (south Atlantic)—Atlantic sturgeon. U.S. Fish Wildl. Serv. Biol. Rep. 81(11.25). U.S. Army Corps of Engineers, TR EL-82-4. 17 pp.

Vladykov, V.D., and J.R. Greely. 1963. Fishes of the Western North Atlantic 1:24-60.

Waldman, J. R., K. Nolan, J. Hart, and I.I. Wirgin. 1996. Genetic differentiation of three key anadromous fish populations of the Hudson River. Estuaries 19: 759-768.

Wilber, D. H. and D. G. Clarke. 2007. Defining and assessing benthic recovery following dredging and dredged material disposal. *Proceedings of the Eighteenth World Dredging Congress*. Pp. 603-618. Robert E. Randall, editor. Newman Printing Company, Bryan, Texas 77801.

Wiley, M.L., J.B. Gaspin, and J.F. Goertner. 1981. Effects of Underwater Explosions on Fish with a Dynamic Model to Predict Fishkill. Ocean Science and Engineering 6(2): 223-284.

Winemiller, K.O., and K.A. Rose. 1992. Patterns of life history diversification in North American fishes: implications for population regulation. Can. J. Fish Aquat. Sci. 49: 2196-2218.

Wooley, C. M. 1985. Evaluation of morphometric characters used in taxonomic separation of Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi.* Pages 97-103 in F.P. Binkowski and S.I. Doroshov, eds. North American sturgeons: biology and aquaculture potential. Developments in environmental biology of fishes 6. Dr W. Junk bv Publishers, Dordrecht, the Netherlands. 163 pp.

Young , J.R., T.B. Hoff, W.P. Dey, and J.G. Hoff. 1988. Management recommendations for a Hudson River Atlantic sturgeon fishery based on an age-structured population model. Fisheries Research in the Hudson River. State University of New York Press, Albany, New York. 353pp.