NATIONAL MARINE FISHERIES SERVICE

ENDANGERED SPECIES ACT

BIOLOGICAL OPINION

Agency: U.S. Army Corps of Engineers, Philadelphia District

Activity Considered: Reinitiation of the USACE Permit for the Development of the Paulsboro Marine Terminal Roll-on/Roll-off Berth (NAP-2007-1125-39)

GARFO-2023-00860

Conducted by: National Marine Fisheries Service

Greater Atlantic Regional Fisheries Office

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Approved by:

Michael Pentony
Regional Administrator

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1 INTRODUCTION

This constitutes the reinitiated biological opinion (Opinion) of NOAA's National Marine Fisheries Service (NMFS) issued pursuant to Section 7 of the Endangered Species Act (ESA) of 1973, as amended, on the effects of construction and operation of the Paulsboro Marine Terminal Roll-on/Roll-off (RoRo) Berth (Berth). We previously issued a biological opinion (GARFO-2023-00860) dated July 19, 2022, for the proposed construction and operation of the new RoRo Berth at the existing Paulsboro Marine Terminal deep-water import-export terminal along the Delaware River in Gloucester County, New Jersey. The purpose of the Berth is to support the shipment of monopiles, produced onsite, to offshore wind power generation projects. Consequently, on September 7, 2022, the U.S. Army Corps of Engineers (USACE), Philadelphia District, issued a permit to the South Jersey Port Corporation (SJPC or applicant) pursuant to Section 404 of the Clean Water Act (CWA) and Section 10 of the Rivers and Harbors Act of 1899, to discharge fill material and to conduct dredging and disposal activities within, and adjacent to, navigable waters of the United States at the proposed Port. The USACE informed us via email on June 1, 2023, that the applicant has completed all in-water work and that no take had occurred. The USACE expects the operation of the RoRo berth to support off-shore wind development over a 10-year (2023 through 2033) period.

Our previous biological opinion considered in-water activities at the existing Paulsboro Marine Terminal to construct additional structures and dredging to accommodate the class of vessel used to transport monopile foundations. Vessel traffic from the Berth to the mouth of the Delaware Bay associated with the operation of the Berth was also part of the consultation. The USACE has not indicated that any activities related to the proposed project have been subsequently modified in a manner that may cause an effect to the listed species or critical habitat that was not considered in the previous biological opinion. No new species have been listed nor critical habitat designated that may be affected by the action. However, subsequent to issuing the 2022 biological opinion, New Jersey Fish and Wildlife (NJFW) provided us with new information regarding vessel strike mortalities in the Delaware River and Bay that revealed effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered. Therefore, on June 9, 2023, we sent an email to the USACE with an attached letter where we recommended that the USACE reinitiate the consultation because this reinitiation trigger had been met per the ESA implementing regulations at 50 CFR 402.16. The USACE acknowledged the need to reinitiate the consultation in an email sent on June 26, 2023. Therefore, we consider the reinitiation date to be June 26, 2023. Since all construction and dredging have been completed and no take was reported, this Opinion is based on vessel activity during operation of the Berth and the effects on ESA-listed species and critical habitat as described in the Biological Assessment (BA) that USACE provided on January 5, 2022.

1.1 New Information

Subsequent to completing consultation in 2022, the Northeast Fisheries Science Center (NEFSC) completed review of a sturgeon carcass database maintained by NJFW. Their review concluded that the reported carcasses included in the NJFW database were additional mortalities beyond the observed mortalities reported in another database maintained by the Delaware Department of Natural Resources and Environmental Control (DNREC). For the previous biological opinion, we relied on the DNREC data to estimate the risk of vessel strike to sturgeon. In their review, the NEFSC also suggested that incorporating the additional NJFW reported mortalities into the DNREC reported mortalities would increase the calculated risk of a vessel striking and killing a sturgeon. Based on this, we concluded that the NJFW data constituted new information that reveals that the action may affect listed species in a manner and/or to an extent not previously considered in the current biological opinion and, therefore, the consultation needed to be reinitiated (50 CFR 402.16).

On July 5, 2022, the U.S. District Court for the Northern District of California issued an order vacating the 2019 regulations that were revised or added to 50 CFR part 402 in 2019 ("2019 Regulations," see 84 FR 44976, August 27, 2019) without making a finding on the merits. On September 21, 2022, the U.S. Court of Appeals for the Ninth Circuit granted a temporary stay of the district court's July 5 order. On November 14, 2022, the Northern District of California issued an order granting the government's request for voluntary remand without vacating the 2019 regulations. The District Court issued a slightly amended order two days later on November 16, 2022. As a result, the 2019 regulations remain in effect, and we are applying the 2019 regulations here. For purposes of this consultation and in an abundance of caution, we considered whether the substantive analysis and conclusions articulated in the biological opinion and incidental take statement would be any different under the pre-2019 regulations. We have determined that our analysis and conclusions would not be any different.

2 ESA CONSULTATION HISTORY

August 2010 through July 2011

On August 31, 2010, following the issuance of the initial Public Notice for the Paulsboro Marine Terminal Phase 1 of project construction, the USACE requested concurrence from us regarding their determination that the project "would not adversely affect shortnose sturgeon." and that "formal ESA consultation/conference was not warranted and requested concurrence with that determination." At that time, only the shortnose sturgeon was listed under the ESA. The Atlantic sturgeon was proposed for listing, and Atlantic sturgeon critical habitat had not yet been designated or proposed. We issued a letter of concurrence on July 25, 2011, stating that the proposed action was not likely to adversely affect shortnose sturgeon and that no further consultation was necessary.

April 2018 through August 2018

During the Paulsboro Marine Terminal Phase 2 permitting process, we received several letters dated April 2, June 4, and August 2, 2018 from the USACE requesting concurrence from us that the project construction "is not likely to adversely affect any federally listed threatened or endangered species under the responsibility of the National Marine Fisheries Service or adversely modify any designated critical habitat." No dredging was performed as part of the

Phase 2 improvements. In-water construction was limited to pile driving required to support the wharf. Prior to this consultation, Atlantic sturgeon were listed as endangered under the ESA and critical habitat was designated in the Delaware River for the New York Bight DPS. We issued a letter of concurrence on August 31, 2018, and stated that "no further consultation pursuant to Section 7 of the ESA is required."

<u>September 2021 through January 2022</u>

We reviewed and commented informally on draft BAs for this proposed action, offering guidance on how to provide a complete and adequate analysis in the final BA to be submitted to us.

<u>January 2022</u>

On January 5, 2022, we received an email from the USACE requesting consultation under the ESA on this proposed action. The USACE attached electronic copies of a signed letter requesting formal consultation and an associated BA to the BA.

On January 6, we sent an email to the USACE initiating formal consultation. The initiation date was set to January 5, 2022, when we received the request with adequate information to initiate formal consultation.

<u>May 2022</u>

On May 12, 2022, we requested that USACE extend the delivery date of our final signed Opinion to July 29, 2022. Subsequently, the applicant denied our request. On May 27, 2022, we sent USACE a letter providing our rationale for why we will be delivering the final, signed BO by July 29, 2022.

<u>July 2022</u>

We completed the biological opinion on July 19, 2022 (document number GARFO-2022-00012). The signed biological opinion and transmittal letter were sent via email to the USACE on July 20, 2022. A complete administrative record of this consultation is kept at our NMFS Greater Atlantic Regional Fisheries Office.

<u>September 2022</u>

The NEFSC conducted a review of a sturgeon carcass database maintained by NJFW and concluded that the data constituted best available information. They further recommended that the additional carcass data should be included in our analysis of baseline vessel strikes within the Delaware River and Bay.

<u>February 2023</u>

We received an email on February 15 from the USACE requesting on behalf of the applicant that the work window be extended from March 15, 2023, to March 31, 2023. On February 16, we sent an email to the USACE agreeing to the 15-day extension based on our review that the extension would not cause effects to listed species under our jurisdiction that were not considered in the 2022 biological opinion for the project.

June 2023

On June 6, we received an email from the USACE confirming that the applicant had completed all construction work on the RORO Berth on March 31, 2023, and that no take of listed species under our jurisdiction had occurred.

On June 9, we sent an electronic letter as an attachment in an email to the USACE informing them that based on the review of new NJFW data by the NEFSC; we have concluded that the data constituted new information that revealed that the action may affect listed species in a manner and/or to an extent not previously considered in the current biological opinion. Therefore, the consultation needed to be reinitiated per the ESA implementing regulations at 50 CFR 402.16. Our letter also informed the USACE that we understood, based on a prior inquiry that we had all the information needed to initiate consultation and that a reinitiation of the consultation would only consider the operation of the RORO Berth given that the applicant has completed all construction activities.

On June 26, we received an email from the USACE acknowledging the receipt of our email and letter informing them of the need to reinitiate the consultation. Accordingly, we consider the reinitiation date is June 26, 2023. We will keep a complete administrative record of this consultation at the NMFS Greater Atlantic Regional Fisheries Office.

3 PROJECT DESCRIPTION

The applicant applied for and received a permit from the USACE for construction activities to enhance the terminal facilities at the existing Paulsboro Marine Terminals. The applicant has now completed all construction activities. In a 2022 biological opinion for this project, we considered the following construction activities: (1) construction of mooring and berthing by pile driving steel pipe piles in-water, and constructing cast-in-place pile caps, fendering, and catwalks above the water line; (2) dredging of approximately 8.9 acres to a depth of -10 meters (m) (-33 feet (ft)) mean low water (MLW) for a access channel and mooring approach, and disposal of dredge materials; (3) the placement of stone revetment to stabilize shoreline sediment slopes, and (4) vessel activity associated with construction and dredging. Since construction activities and associated vessel traffic would not overlap with the presence of sea turtles and whales, none of these species would be affected and effects to these species from construction activities were not considered. We concluded that effects to listed sturgeon and critical habitat designated for Atlantic sturgeon from all activities related to construction of the Berth and dredging of the access channel would be insignificant or extremely unlikely to occur. In addition to the proposed construction activities, we also considered the consequences of operating the Berth. We concluded that the subsequent vessel traffic associated with the operation of the Berth is reasonably certain to cause consequences to listed species and that the vessel traffic and its consequences would not occur but for the proposed issuance of the permit by the USACE. In evaluating the consequences of the vessel traffic during operation of the Berth, we concluded that effects from habitat impacts caused by propeller scour from vessels traveling to and from the Berth will be insignificant but we did conclude that the vessel traffic, itself, is likely to adversely affect listed Atlantic sturgeon and shortnose sturgeon by direct vessel interaction. We concluded that vessel traffic associated with the operation of the Berth is not likely to adversely affect listed sea turtles, North Atlantic right whales, fin whales, or critical habitat designated for Atlantic sturgeon.

Given that the USACE has issued the permits for the proposed project and that all construction activities for the terminal enhancement have been completed, we will just briefly describe the construction and dredging activities below. However, we incorporate by reference the related effects analysis and determinations in our 2022 biological opinion as part of the environmental baseline for this opinion and, therefore, we will not discuss the consequences of construction activities and habitat effects any further but will rely on our analysis in the 2022 biological opinion. In this Opinion, we will analyze consequences to listed species from vessel traffic during operation of the Berth. In our June 9, 2023, letter to the USACE informing them about new information not previously considered, we also requested them to provide us with any information that would indicate that the proposed operation of the Berth had been modified from what was described in our 2022 biological opinion. In subsequent correspondence, the USACE has not provided us with any information that indicates that the anticipated operation of the Berth has changed from what we considered in the 2022 biological opinion; therefore, the description of Berth operations remain the same as in the 2022 biological opinion for this project and is included in section 3.4.

3.1 Site Location

The Paulsboro Marine Terminal is adjacent to the Delaware River and Mantua Creek in the Borough of Paulsboro, Gloucester County, New Jersey, along the east bank of the Delaware River. The proposed action is located within Block 1, Lots 2, 4, 5, 8, and 20 through 24; Block 1.07, Lot 26; Block 1.14, Lot 45; and Block 135, Lot 24.01. Latitude/Longitude: 39.852496 N, -75.238228 W (NAD 83) and approximately at River Kilometer (RKM) 145 (River Mile (RM) 90).

3.2 Existing Port Facilities and Structures

The Paulsboro Marine Terminal is a recently constructed, deep-water import-export terminal with an 869 m (2,850 ft) long, 46 m (150 ft) wide pile-supported wharf, with additional capabilities for processing, distribution, assembly, and intermodal operations. Developed as an omniport, it was designed to accommodate a wide variety of cargo types, including heavy lift components such as turbines, reactors, and boilers; lumber and forest products; metal products; and banana/fresh fruit and dry bulk commodities. The berth and marine-side infrastructure abut a large terminal backland, repurposed for the development of warehousing and production facilities directly tied to marine operations.

Development at the project site was conducted in phases. Both Phase 1 and Phase 2 of the project have been completed. At full buildout, the currently permitted terminal (Phases 1 and 2) includes three deep-water berths, one barge berth, and trestle connecting the wharf with the upland Terminal consistent with project planning from the outset.

3.3 Terminal Enhancements

To facilitate RoRo movements of offshore wind turbine monopile foundations for offshore wind turbines, the applicant proposed to enhance the Paulsboro Marine Terminal, which involved adding one additional berth at the downstream end of the existing wharf with mooring infrastructure (i.e., mooring and berthing dolphins). The new berth included dredging a new turning basin and adding mooring infrastructure at the downriver (west) end of the existing wharf. The USACE proposed several avoidance and minimization measures, including a March 15 to June 30 Time of Year Restriction (TOYR) period to protect diadromous fish migration and spawning, the use of a soft-start at the beginning of pile driving, and the use of a pile-driving caps to further reduce noise levels.

The project timeline included the following:

1. An initial two- to three-month construction period for mooring and berthing dolphins. The construction included the driving of 12 36-inch diameter piles and three 24-inch diameter piles as well as overwater work (pile cap forming/pouring, installation of fenders, and walkways/catwalks).
2. About 1.5 months of dredging to deepen the proposed berthing slip for RoRo vessels and creation of a turning basin to connect the Berth to the Federal Navigation Channel. Approximately 8.9 acres were dredged.
3. The final work was to place armored stone around the dolphin piles for a two-foot thick revetment, which together with the piles resulted in the loss of approximately 0.004 acres of freshwater soft substrate.

The applicant has now completed all construction activities for the Berth. On November 8, 2022, the USACE forwarded an email from the applicant stating that they had completed the construction of the dolphins. Dredging started on December 30, 2022, and was completed on February 24, 2023. On February 15, 2023, the USACE requested, on behalf of the applicant, that the in-water work window be extended from March 15 to March 31 to finish the installation of riprap revetment along the south edge of the berth pocket. After concluding that the extension would not result in effects not previously considered in the biological opinion, we agreed to extend the work window to March 31, 2023. Based on the information in subsequent email correspondence, all in-water work was completed by March 31, 2023. In our previous biological opinion, we concluded that we did not anticipate take of listed species during construction, and the USACE has confirmed that take did not occur during any construction activities.

3.4 Port Operation

The USACE expects that the proposed Berth will provide services for offshore wind developments for 10 years following start of operations in 2023. Its operation after that 10-year period cannot be reasonably determined and, therefore, it is not possible provide an estimate of vessel activity with reasonable certainty.

3.4.1 Vessel Activity during Operation

The new RoRo Berth will be primarily used to load fully assembled 91.4 m (300 ft) long monopiles from the Paulsboro Marine Terminal to a RoRo vessel for transport down the Delaware River and ultimately to wind turbine fields off the New Jersey coastline. Under the early phase of facility development, the RoRo Berth may also be used to import 27.4 m to 33.5 m (90 ft to 110 ft) long monopile foundation segments and steel components to the port where they will be assembled at existing or planned upland terminal manufacturing facilities. Vessel traffic or vessel calls to the Paulsboro Marine Terminal are expected to be fewer at startup, and increase annually as the manufacturing facility builds up to full capacity.

Vessels calling to the Paulsboro Marine Terminal RoRo Berth will arrive via the Federal Navigation Channel. At the Paulsboro Marine Terminal, the cargo vessel will approach the Berth from the north and rotate into position within the turning basin. Once the vessel is moored to the proposed dolphins, a stern loading ramp will be lowered to meet the wharf.

As mentioned above, initially, fewer vessels will make calls at the Paulsboro Marine Terminal as monopile segments are delivered for onsite assembly. Beginning in 2025, vessel calls will increase up to a maximum of 50 outbound calls annually to deliver fully assembled monopiles to offshore wind energy locations. Vessel traffic from the Paulsboro Marine Terminal to the offshore wind farms is anticipated to continue through 2032 when the construction phase of the wind energy facility is expected to be completed. Use of the RoRo Berth at the Paulsboro Marine Terminal beyond 2032 is dependent on the continued growth of the wind energy market and the development of other ports in the region equipped to supply construction materials for these types of projects.

Quantitatively estimating the usage of the RoRo Berth after completion is difficult; however, a reasonable estimate can be made based on the limits of the upland facility the RoRo Berth supports. The estimate of 50 vessel calls per year is based on the maximum throughput of piles that can be produced at the pile manufacturing facility as proposed. Expansion of this manufacturing facility is not planned, and may not be feasible because of space limitations at the Paulsboro Marine Terminal. Consequently, it is reasonable to assume that the maximum projected annual number of vessel calls beyond the 10-year projection planned at this stage would be the same or fewer as estimated for the first 10 years. Table 1 provides the range of vessel calls expected for each year of operation of the Paulsboro Marine Terminal RoRo Berth and the total number of vessel trips.

Table 1. Range of vessel calls for each year of operation

Year	Vessel Calls	Purpose	Trips
2023	5	Inbound receiving of monopile segments, November through end of year	10
2023	10	Inbound receiving of monopile segments throughout the year	20
2024	15 to 25	Outbound transport of fully assembled monopiles	30 to 50
2025	30 to 50	Outbound transport of fully assembled monopiles	60 to 100
2026	30 to 50	Outbound transport of fully assembled monopiles	60 to 100
2027	30 to 50	Outbound transport of fully assembled monopiles	60 to 100
2028	30 to 50	Outbound transport of fully assembled monopiles	60 to 100
2029	30 to 50	Outbound transport of fully assembled monopiles	60 to 100
2030	30 to 50	Outbound transport of fully assembled monopiles	60 to 100
2031	30 to 50	Outbound transport of fully assembled monopiles	60 to 100
2032	30 to 50	Outbound transport of fully assembled monopiles	60 to 100
		Total	**540 to 880**

Each vessel call corresponds to one unladen and one laden trip into the Berth. The variation in vessel calls arises from the uncertainty on vessel type and the differing capacity of either two or three full monopiles. Inbound vessel calls will be completed exclusively by a semi-submersible heavy lift vessel expected to have a length overall around 168 m (550 ft) and a breadth of 37 m (120 ft). This vessel is self-powered and expected to maneuver into the Berth without tug assistance using Azipods - a marine propulsion unit consisting of a fixed pitch propeller mounted on a steerable gondola ("pod") which also contains the electric motor driving the propeller. Outbound vessel calls may be completed either by the heavy lift vessel described above or by barges, measuring approximately 122 m (400 ft) long with a beam of approximately 30.5 m (100 ft). The barge will not have its own propulsion and will rely on tug assistance for berthing operations. It should be noted that the draft of the barges are anticipated to be approximately 2.4 m (8 ft), significantly less than the heavy lift vessel.

3.4.2 Ballast Water

Vessels traveling to and from the proposed Berth withdraw or discharge ballast water to ensure proper operation and stability of the vessels. Vessels arriving to load cargo will arrive partially ballasted, with ballast water taken on only locally from either the Federal Navigation Channel or near the mouth of the Delaware Bay. After mooring at the Berth, the vessel may discharge or intake ballast water as required to align the vessel cargo deck with the RoRo wharf deck (elevation 4.4 m (14.5 ft) MLLW) to load the monopile. During loading operations, ballast water will be rechambered (moved between ballast tanks in the vessel) and discharged to maintain the vessel cargo deck level with the RoRo wharf deck. After loading is completed, the vessel will either take on or discharge ballast water to obtain a safe draft based on the operational criteria of the vessel. The ship may fully ballast to the 7.3 m (24 ft) sailing draft at the Berth prior to casting off.

Literature review of vessel types indicates a wide range of flow rates for ballasting systems and specifics for the vessels likely to call at the Berth is not known. However, a flow rate of 2,000 m^3/h for barges and general cargo vessels is reasonable. Vessel ballast intakes are screened to minimize entrainment of aquatic organisms; typical screen openings are approximately 10 mm (0.4 in).

Ballast water discharges will be made in compliance with United States Coast Guard (USCG) ballast water exchange regulations (33 CFR 151.1510) and the United States Environmental Protection Agency's (EPA) Vessel General Permit program to avoid introduction of invasive species through discharged ballast water. During regular port operations, inbound and outbound vessels could potentially discharge or release oil, fuel, or waste. Such a discharge or release would be accidental and is considered unlikely. Vessels will need to implement measures in accordance with approved plans to avoid discharges and minimize effects should any discharges occur.

4 ACTION AREA

The action area is defined as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 CFR§402.02). For this project, the action area consists of the newly dredged access channel and berth, the permanent footprint of the dolphins, and the permanent footprint of the riprap revetment as described in the BA of January 2022 and in the 2022 biological opinion. Additionally, habitat impacts by vessels entering and leaving the Berth during operation of the Berth, and stressors associated with vessel impacts define the action area. The area directly affected by construction of the dolphins and riprap revetment is 0.0037 acres and the dredged access channel and berth area is 8.9 acres. In addition, the action area includes the areas transited by vessels calling at the Paulsboro Marine Terminal when the Berth is operating, which include the Delaware River Federal Navigation Channel from RKM 5 to 145 (RM 3.1 to 90) (RKM/RM designations based on DRBC, 1969), the federal precautionary area between the mouth of Delaware Bay and the beginning of the federal channel (~27,560 acres), the pilot area just outside of the bay (~2,600 acres), and the channel connecting the pilot and precautionary areas (~3,270 acres). Ships calling at Paulsboro are not expected to use anchorages and, after picking up a river pilot, will proceed directly up the navigation channel to the Berth.

4.1 Environmental Conditions and Habitat in the Action Area

The biological assessment reviewed the environmental conditions of the Delaware River at the project site. We have utilized most of the information provided in the BA, and have added information where necessary in order to support a complete and thorough effects analysis below.

The action area for the Proposed Action occurs entirely within the Delaware River and Bay, from the mouth of Delaware Bay at the pilot boarding location near Lewes, Delaware, along its eastern shoreline near the Borough of Paulsboro, Gloucester County, New Jersey at approximately RKM 145 (RM 90); directly across the river from the Philadelphia International Airport.

4.1.1 Access Channel and Berth Area

The access channel and berth area consists of 8.9 acres outside of the intertidal zone and below the subtidal zone (-1.8 m (-6 ft) MLLW) of the nearshore waterfront portion of the project where the proposed Berth and revetment was constructed. Aquatic habitat in the berth area and access channel is freshwater tidal, with existing water depths ranging from approximately -6 to -8.2 m (-20 to -27 ft). Bottom substrate consists primarily of sand and gravel. The shoreline in the construction area experiences high energy from wind, tide, and shipping traffic, and is armored in many areas with riprap, gabion baskets, and pilings. There are no vegetated wetlands or submerged aquatic vegetation (SAV) within the construction area.

Bottom substrate within the dredged area consists of fine-grained sediments (silt/clay/sand) and coarser-grained material (gravel) with consolidated virgin clay, based on Vibracore sampling results (May/June 2021) (biological assessment, 2021). There are no vegetated wetlands or SAV within the dredging area. This portion of the Delaware River is tidal freshwater. Mean tidal range in the Delaware River at Marcus Hook, PA, located approximately 15.8 km (9.8 mi) downriver of the Paulsboro site, is 1.70 m (5.59 ft).

4.1.2 Federal Navigation Channel, Precautionary Area, and Pilot Area

The Federal Navigation Channel is maintained at a controlling depth of -13.7 m (-45 ft) MLLW. Substrate types within the channel vary widely from silty clay to gravel (Sommerfield and Madsen 2003). The precautionary area and the pilot area consist of naturally deep areas at and near the mouth of Delaware Bay. Salinity ranges from tidal freshwater/oligohaline in the upper reaches of the federal channel to that of seawater at the mouth of Delaware Bay (Polis *et al.* 1973). The lower extent of the median hourly salt front (defined as 0.025 ppt) location in the Delaware River estuary is at RKM 107.8 (RM 67) and the upper extent of the median hourly salt front location is at RKM 122.3 (RM 76).

5 STATUS OF LISTED SPECIES[1]

5.1 Shortnose Sturgeon

Shortnose sturgeon are fish that occur in rivers and estuaries along the East Coast of the U.S. and Canada (SSSRT 2010). They have a head covered in bony plates, as well as protective armor called scutes extending from the base of the skull to the caudal peduncle. Other distinctive features include a subterminal, protractile tube-like mouth, and chemosensory barbels for benthic

[1] We have no new information since our 2022 biological opinion in which we considered effects to critical habitat from the proposed project. As such, our analysis in the 2022 biological opinion remains valid and, accordingly, here we incorporate by reference our analysis from the 2022 biological opinion.

foraging (SSSRT 2010). Sturgeon have been present in North America since the Upper Cretaceous period, more than 66 million years ago. The information below is a summary of available information on the species. Detailed information on the populations that occur in the action area is provided below while details on activities that impact individual shortnose sturgeon in the action area can be found in sections 6, 7, and 8.

5.1.1 Life History and General Habitat Use

There are differences in life history, behavior and habitat use across the range of the species. Current research indicates that these differences are adaptations to unique features of the rivers where these populations occur. For example, there are differences in larval dispersal patterns in the Connecticut River (MA) and Savannah River (GA) (Parker 2007). There are also morphological and behavioral differences. Growth and maturation occurs more quickly in southern rivers but fish in northern rivers grow larger and live longer. We provide general life history attributes in Table 2 below.

Table 2. General life history for shortnose sturgeon (range-wide)

Stage	Size (mm)	Duration	Behaviors/Habitat Used
Egg	3-4	13 days post spawn	stationary on bottom; Cobble and rock, fresh, fast flowing water
Yolk Sac Larvae	7-15	8-12 days post hatch	Photonegative; swim up and drift behavior; form aggregations with other YSL; Cobble and rock, stay at bottom near spawning site
Post Yolk Sac Larvae	15 – 57	12-40 days post hatch	Free swimming; feeding; Silt bottom, deep channel; fresh water
Young of Year	57 – 140 (north); 57-300 (south)	From 40 days post-hatch to one year	Deep, muddy areas upstream of the saltwedge
Juvenile	140 to 450-550 (north); 300 to 450-550 (south)	1 year to maturation	Increasing salinity tolerance with age; same habitat patterns as adults
Adult	450-1100 average; (max recorded1400)	Post-maturation	Freshwater to estuary with some individuals making nearshore coastal migrations

Shortnose sturgeon live on average for 30-40 years. Males mature at approximately 5-10 years and females mature between age 7 and 13, with later maturation occurring in more northern populations (Kynard *et al.* 2016). Females typically spawn for the first time 5 years post-maturation (age 12-18; Dadswell 1979, Dadswell *et al.* 1984) and then spawn every 3-5 years (Kynard *et al.* 2016). Males spawn for the first time approximately 1-2 years after maturity with spawning typically occurring every 1-2 years (Kynard *et al.* 2016). Shortnose sturgeon are iteroparous (spawning more than once during their life) and females release eggs in multiple "batches" during a 24 to 36-hour period (total of 30,000-200,000 eggs). Multiple males are likely to fertilize the eggs of a single female.

Cues for spawning are thought to include water temperature, day length and river flow (Brundage 2018, Kynard *et al.* 2016). In the Connecticut River, shortnose sturgeon spawn in freshwater reaches when mean daily water temperatures reach approximately 7–16°C in the spring (Kynard *et al.* 2016). Spawning occurs over gravel, rubble, and/or cobble substrate (Kynard *et al.* 2016) in areas with average bottom velocities between 0.4 and 0.8 m/s. Depths at spawning sites are variable, ranging from 1.2-27 m (4-89 ft) (multiple references in SSSRT 2010). Eggs are small and demersal and stick to the rocky substrate where spawning occurs.

Shortnose sturgeon occur in waters between 0 – 34°C (0 – 93.2°F) (Dadswell *et al.* 1984, Heidt and Gilbert 1978); with temperatures above 28°C (84.2°F) considered to be stressful. Depths used are highly variable, ranging from shallow mudflats while foraging to deep channels up to 30 m (98.4 ft) (Dadswell *et al.* 1984, Kynard *et al.* 2016). Salinity tolerance increases with age. Young-of-the-year must remain in freshwater; however, adults have been documented in the ocean with salinities of up 30 parts-per-thousand (ppt) (Kynard *et al.* 2016). Dissolved oxygen (DO) affects distribution, with preference for DO levels at or above 5mg/l and adverse effects anticipated for prolonged exposure to DO less than 3.2mg/L (Kynard *et al.* 2016).

Shortnose sturgeon feed on benthic insects, crustaceans, mollusks, and polychaetes (Kynard *et al.* 2016). Both juvenile and adult shortnose sturgeon primarily forage over sandy-mud bottoms, which support benthic invertebrates (Carlson and Simpson 1987, Kynard *et al.* 2016). Shortnose sturgeon have also been observed feeding off plant surfaces (Dadswell *et al.* 1984).

Following spawning, adult shortnose sturgeon disperse quickly down river to summer foraging grounds areas and remain in areas downstream of their spawning grounds throughout the remainder of the year (Kynard *et al.* 2016).

In northern rivers, shortnose aggregate during the winter months in discrete, deep (3-10m (9.8-32.8ft) freshwater areas with minimal movement and foraging (Brundage 2018, Buckley and Kynard 1985, Dadswell 1979, Dovel *et al.* 1992, Kynard *et al.* 2016). In the winter, adults in southern rivers spend much of their time in the slower moving waters downstream near the salt-wedge and forage widely throughout the estuary (Collins and Smith 1993, Weber *et al.* 1998). Pre-spawning sturgeon in some northern and southern systems migrate into an area in the upper tidal portion of the river in the fall and complete their migration in the spring (Kynard *et al.* 2016). Older juveniles typically occur in the same overwintering areas as adults while young of the year remain in freshwater (Jenkins *et al.* 1993).

5.1.2 Listing History

Shortnose sturgeon were listed as endangered in 1967 (32 FR 4001), and the species remained on the endangered species list with the enactment of the ESA in 1973. Shortnose sturgeon are thought to have been abundant in nearly every large East Coast river prior to the 1880s Kynard, 2016 #1586}. Pollution and overfishing, including bycatch in the shad fishery, were listed as principal reasons for the species' decline. The species remains listed as endangered throughout its range. While the 1998 Recovery Plan refers to Distinct Population Segments (DPS), the process to designate DPSs for this species has not been undertaken. The SSSRT published a Biological Assessment for shortnose sturgeon in 2010. The report summarized the status of shortnose sturgeon within each river and identified stressors that continue to affect the abundance and stability of these populations.

5.1.3 Current Status

There is no current total population estimate for shortnose sturgeon range wide. Information on populations and metapopulations is presented below. In general, populations in the Northeast are larger and more stable than those in the Southeast (SSSRT 2010). Population size throughout the species' range is considered to be stable; however, most riverine populations are below the historic population sizes and most likely are below the carrying capacity of the river (Kynard 1997, Kynard *et al.* 2016).

5.1.4 Population Structure

There are 19 documented populations of shortnose sturgeon ranging from the St. Johns River, Florida (possibly extirpated from this system) to the Saint John River in New Brunswick, Canada. There is a large gap in the middle of the species range with individuals present in the Chesapeake Bay separated from populations in the Carolinas by a distance of more than 400 km (248.5 mi). Currently, there are significantly more shortnose sturgeon in the northern portion of the range.

Recent developments in genetic research as well as differences in life history support the grouping of shortnose sturgeon into five genetically distinct groups, all of which have unique geographic adaptations (see (SSSRT 2010, Wirgin *et al.* 2005). These groups are: 1) Gulf of Maine; 2) Connecticut and Housatonic Rivers; 3) Hudson River; 4) Delaware River and Chesapeake Bay; and 5) Southeast. The Gulf of Maine, Delaware/Chesapeake Bay and Southeast groups function as metapopulations[2]. The other two groups (Connecticut/Housatonic and the Hudson River) function as independent populations.

While there is migration within each metapopulation (i.e., between rivers in the Gulf of Maine and between rivers in the Southeast) and occasional migration between populations (e.g., Connecticut and Hudson), interbreeding between river populations is limited to very few individuals per generation; this results in morphological and genetic variation between most river populations (Grunwald *et al.* 2002, SSSRT 2010, Wirgin *et al.* 2005). Indirect gene flow estimates from mtDNA indicate an effective migration rate of less than two individuals per generation. This means that while individual shortnose sturgeon may move between rivers, very few sturgeon are spawning outside their natal river; it is important to remember that the result of physical movement of individuals is rarely genetic exchange.

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[2] A metapopulation is a group of populations in which distinct populations occupy separate patches of habitat separated by unoccupied areas (Levins 1969). Low rates of connectivity through dispersal, with little to no effective movement, allow individual populations to remain distinct as the rate of migration between local populations is low enough not to have an impact on local dynamics or evolutionary lineages (Hastings and Harrison 1994). This interbreeding between populations, while limited, is consistent, and distinguishes metapopulations from other patchy populations.

5.1.5 Summary of Status of Northeast Rivers

In NMFS's Greater Atlantic Region, shortnose sturgeon are known to spawn in the Kennebec, Androscoggin, Merrimack, Connecticut, Hudson and Delaware Rivers. Shortnose sturgeon also occur in the Penobscot and Potomac Rivers; although it is unclear if spawning is currently occurring in those systems.

Gulf of Maine Metapopulation

Tagging and telemetry studies indicate that shortnose sturgeon are present in the Penobscot, Kennebec, Androscoggin, Sheepscot and Saco Rivers. Individuals have also been documented in smaller coastal rivers; however, the duration of presence has been limited to hours or days and the smaller coastal rivers are thought to be only used occasionally (Zydlewski *et al.* 2011).

Since the removal of the Veazie and Great Works Dams (2013 and 2012, respectively), in the Penobscot River, shortnose sturgeon range from the Bay to the Milford Dam. Shortnose sturgeon now have access to their full historical range. Adult and large juvenile sturgeon have been documented to use the river. While potential spawning sites have been identified, no spawning has been documented. Foraging and overwintering are known to occur in the river. Nearly all pre-spawn females and males have been documented to return to the Kennebec or Androscoggin Rivers. Estimated seasonal adult abundance ranging from 636-1285 (weighted mean), with a low estimate of 602 (95%CI: 409.6-910.8) and a high of 1306 (95% CI: 795.6-2176.4) (Fernandes 2008, Fernandes *et al.* 2010).

Kennebec/Androscoggin/Sheepscot

The estimated size of the adult population (>50cm [>19.7 in] TL) in this system, based on a tagging and recapture study conducted between 1977-1981, was 7,200 (95% CI = 5,000 - 10,800; Squiers *et al.* 1982). A population study conducted 1998-2000 estimated population size at 9,488 (95% CI = 6,942 -13,358; Squiers 2003). (Squiers 2003) suggested that the population exhibited significant growth between the late 1970s and late 1990s. Spawning is known to occur in the Androscoggin and Kennebec Rivers. In both rivers, there are hydroelectric facilities located at the base of natural falls thought to be the natural upstream limit of the species. The Sheepscot River is used for foraging during the summer months. Altenritter *et al.* (2017a) found that a large proportion of female shortnose sturgeon tagged in the Penobscot River migrated to the Kennebec River during probable spawning windows. They also found that shortnose sturgeon in the Penobscot River were larger and had a higher condition factor than shortnose sturgeon in the Kennebec River. Based on this, they speculated that, "increased abundance and resource limitation in the Kennebec River may be constraining growth and promoting migration to the Penobscot River by individuals with sufficient initial size and condition." These individuals then return to spawn in the Kennebec River at larger size that could potentially result in increased reproductive potential compared to nonmigratory females. Thus, migrants could experience an adaptive reproductive advantage relative to nonmigratory individuals. Further, Altenritter *et al.* (2017a) noted that although migrants to the Penobscot River may be a small proportion of the Kennebec River population, they could disproportionately contribute to regional recruitment and facilitate population resilience to disturbance.

Merrimack River

The historic range in the Merrimack extended to Amoskeag Falls (Manchester, NH, RKM 116 (RM 72)); currently shortnose sturgeon cannot move past the Essex Dam in Lawrence, MA (RKM 46 (RM28.6)). A current population estimate for the Merrimack River is not available. Based on a study conducted 1987-1991, the adult population was estimated at 32 adults (20–79; 95% confidence interval; B. Kynard and M. Kieffer unpublished information). However, recent gill-net sampling efforts conducted by Kieffer indicate a dramatic increase in the number of adults in the Merrimack River. Sampling conducted in the winter of 2009 resulted in the capture of 170 adults. Preliminary estimates suggest that there may be approximately 2,000 adults using the Merrimack River annually. Spawning, foraging and overwintering all occur in the Merrimack River.

Tagging and tracking studies demonstrate movement of shortnose sturgeon between rivers within the Gulf of Maine, with the longest distance traveled between the Penobscot and Merrimack Rivers. Genetic studies indicate that a small, but statistically insignificant amount of genetic exchange likely occurs between the Merrimack River and these rivers in Maine. The Merrimack River population is genetically distinct from the Kennebec-Androscoggin-Penobscot population (SSSRT 2010). In the fall of 2014, a shortnose sturgeon tagged in the Connecticut River in 2001 was captured in the Merrimack River.

Connecticut River Population

The Holyoke Dam divides the Connecticut River shortnose population; there is currently limited successful passage downstream of the Dam. No shortnose sturgeon have passed upstream of the dam since 1999 and passage between 1975-1999 was an average of four fish per year. The number of sturgeon passing downstream of the Dam is unknown. Despite this separation, the populations are not genetically distinct (Kynard 1997, Kynard *et al.* 2016, Wirgin *et al.* 2005). The most recent estimate of the number of shortnose sturgeon upstream of the dam, based on captures and tagging from 1990-2005 is approximately 328 adults (CI = 188–1,264 adults; B. Kynard, USGS, unpublished data in SSSRT 2010); this compares to a previous Peterson mark-recapture estimate of 370–714 adults (Taubert 1980). Using four mark-recapture methodologies, the long-term population estimate (1989-2002) for the lower Connecticut River ranges from 1,042-1,580 (Savoy 2004). Comparing 1989-1994 to 1996-2002, the population exhibits growth on the order of 65-138 percent. The population in the Connecticut River is thought to be stable, but at a small size.

The Turners Falls Dam is thought to represent the natural upstream limit of the species. While limited spawning is thought to occur below the Holyoke Dam, successful spawning has only been documented upstream of the Holyoke Dam. Abundance of pre-spawning adults was estimated each spring between 1994–2001 at a mean of 142.5 spawning adults (CI =14–360 spawning adults) (Kynard *et al.* 2012). Overwintering and foraging occur in both the upper and lower portions of the river. Occasionally, sturgeon have been captured in tributaries to the Connecticut River including the Deerfield River and Westfield River. Additionally, a sturgeon tagged in the Connecticut River was recaptured in the Housatonic River (T. Savoy, CT DEP, pers. comm.). Three individuals tagged in the Hudson River were captured in the Connecticut River, with one remaining in the River for at least one year (Savoy 2004).

Hudson River Population

The Hudson River population of shortnose sturgeon is the largest in the United States. Studies indicate an extensive increase in abundance from the late 1970s (13,844 adults (Dovel *et al.* 1992), to the late 1990s (56,708 adults (95% CI 50,862 to 64,072; Bain *et al.* 1998). This increase is thought to be the result of high recruitment (31,000 – 52,000 yearlings) from 1986-1992 (Woodland and Secor 2007). Woodland and Secor (2007) examined environmental conditions throughout this 20-year period and determined that years in which water temperatures drop quickly in the fall and flow increases rapidly in the fall (particularly October), are followed by high levels of recruitment in the spring. This suggests that these environmental factors may index a suite of environmental cues that initiate the final stages of gonadal development in spawning adults. The population in the Hudson River exhibits substantial recruitment and is considered to be stable at high levels.

Delaware River-Chesapeake Bay Metapopulation

Shortnose sturgeon range from Delaware Bay up to at least Scudders Falls (RKM 223); there are no dams within the species' range on this river. The population is considered stable (comparing 1981-1984 to 1999-2003) at around 12,000 adults (ERC 2006a, Hastings *et al.* 1987). Spawning occurs primarily between Scudders Falls and the Trenton rapids. Overwintering and foraging also occur in the river. Shortnose sturgeon have been documented to use the Chesapeake-Delaware Canal to move from the Chesapeake Bay to the Delaware River.

In Chesapeake Bay, shortnose sturgeon have most often been found in Maryland waters of the mainstem bay and tidal tributaries such as the Susquehanna, Potomac, and Rappahannock Rivers (Kynard *et al.* 2016, SSSRT 2010). Spells (1998), Skjeveland *et al.* (2000), and Welsh *et al.* (2002) all reported one capture each of adult shortnose sturgeon in the Rappahannock River. Recent documented use of Virginia waters of Chesapeake Bay is currently limited to two individual shortnose sturgeon: one captured in 2016 (Balazik 2017) and a second sturgeon (a confirmed gravid female) caught in 2018 in the James River (Balazik 2018).

Spawning has not been documented in any tributary to the Bay although suitable spawning habitat and two pre-spawning females with late stage eggs have been documented in the Potomac River. Current information indicates that shortnose sturgeon are present year round in the Potomac River with foraging and overwintering taking place there. Shortnose sturgeon captured in the Chesapeake Bay are not genetically distinct from the Delaware River population.

Southeast Metapopulation

There is no evidence of shortnose sturgeon between the mouth of Chesapeake Bay and the Carolinas. Shortnose sturgeon are only thought to occur in the Cape Fear River and Yadkin-Pee Dee River in North Carolina and are likely present in very small numbers.

The Altamaha River supports the largest known population in the Southeast with successful self-sustaining recruitment. The most recent population estimate for this river was 6,320 individuals (95% CI = 4,387-9,249; DeVries 2006). The population contains more juveniles than expected. Comparisons to previous population estimates suggest that the population is increasing; however, there is high mortality between the juvenile and adult stages in this river. This mortality likely results from incidental capture in the shad fishery, which occurs at the same time as the spawning period (DeVries 2006).

The only available estimate for the Cooper River is of 300 spawning adults at the Pinoplis Dam spawning site (based on 1996-1998 sampling; Cooke *et al.* 2004). This is likely an underestimate of the total number of adults as it would not include non-spawning adults. Estimates for the Ogeechee River were 266 (95% CI=236-300) in 1993 (Weber 1996, Weber *et al.* 1998); a more recent estimate (sampling from 1999-2004; (Fleming *et al.* 2003)) indicates a population size of 147 (95% CI = 104-249). While the more recent estimate is lower, it is not significantly different from the previous estimate. Available information indicates the Ogeechee River population may be experiencing juvenile mortality rates greater than other southeastern rivers.

Spawning is also occurring in the Savannah River, the Congaree River, and the Yadkin-Pee Dee River. There are no population estimates available for these rivers. Occurrence in other southern rivers is limited, with capture in most other rivers limited to fewer than five individuals. Shortnose sturgeon are extremely rare or possibly extirpated from the St. Johns River in Florida as only a single specimen was found by the Florida Fish and Wildlife Conservation Commission during extensive sampling of the river in 2002/2003. In these river systems, shortnose sturgeon occur in nearshore marine, estuarine, and riverine habitat.

5.1.6 Threats

Because sturgeon are long-lived and slow growing, stock productivity is relatively low; this can make the species vulnerable to rapid decline and slow recovery (Musick *et al.* 1994). In well studied rivers (e.g., Hudson, upper Connecticut), researchers have documented significant year to year recruitment variability (up to 10 fold over 20 years in the Hudson and years with no recruitment in the Connecticut). However, this pattern is not unexpected given the life history characteristics of the species and natural variability in hydrogeologic cues relied on for spawning.

The small amount of effective movement between populations means recolonization of currently extirpated river populations is expected to be very slow and any future recolonization of any rivers that experience significant losses of individuals would be expected to be very slow.

Despite the significant decline in population sizes over the last century, gene diversity in shortnose sturgeon is moderately high in both mtDNA (Quattro *et al.* 2002, Wirgin *et al.* 2005) and nDNA *(Kynard et al. 2016)* genomes.

A population of sturgeon can go extinct as a consequence of demographic stochasticity (fluctuations in population size due to random demographic events); the smaller the metapopulation (or population); the more prone it is to extinction. Anthropogenic impacts acting on top of demographic stochasticity further increase the risk of extinction.

All shortnose sturgeon populations are highly sensitive to increases in juvenile mortality that would result in chronic reductions in the number of sub-adults as this leads to reductions in the number of adult spawners (Gross *et al.* 2002, Secor *et al.* 2002). Populations of shortnose sturgeon that do not have reliable natural recruitment are at increased risk of experiencing population decline leading to extinction (Secor *et al.* 2002). Elasticity studies of shortnose sturgeon indicate that the highest potential for increased population size and stability comes from young-of-the-year and juveniles as compared to adults (Gross *et al.* 2002); that is, increasing the number of young-of-the-year and juveniles has a more significant long term impact to the population than does increasing the number of adults or the fecundity of adults.

The Shortnose Sturgeon Recovery Plan (NMFS 1998) and the Shortnose Sturgeon Status Review Team's Biological Assessment of shortnose sturgeon (2010) identify habitat degradation or loss and direct mortality as principal threats to the species' survival. Natural and anthropogenic factors continue to threaten the recovery of shortnose sturgeon and include: poaching, bycatch in riverine fisheries, habitat alteration resulting from the presence of dams, in-water and shoreline construction, including dredging; degraded water quality which can impact habitat suitability and result in physiological effects to individuals including impacts on reproductive success; direct mortality resulting from dredging as well as impingement and entrainment at water intakes; and, loss of historical range due to the presence of dams. Shortnose sturgeon are also occasionally killed as a result of research activities. The total number of sturgeon affected by these various threats is not known. Climate change, particularly shifts in seasonal temperature regimes and changes in the location of the salt wedge, may impact shortnose sturgeon in the future (more information on climate change is presented in section 7 of this Opinion. More information on threats experienced in the action area is presented in the *Environmental Baseline* (section 6) of this Opinion.

5.1.7 Survival and Recovery

The 1998 Recovery Plan outlines the steps necessary for recovery and indicates that each population may be a candidate for downlisting (i.e., to threatened) when it reaches a minimum population size that is large enough to prevent extinction and will make the loss of genetic diversity unlikely; the minimum population size for each population has not yet been determined. The Recovery Outline contains three major tasks: (1) establish delisting criteria; (2) protect shortnose sturgeon populations and habitats; and, (3) rehabilitate habitats and population segments. We know that in general, to recover, a listed species must have a sustained positive trend of increasing population over time. To allow that to happen for sturgeon, individuals must have access to enough habitat in suitable conditions for foraging, resting and spawning. In many rivers, particularly in the Southeast, habitat is compromised and continues to impact the ability of sturgeon populations to recover. Conditions must be suitable for the successful development of early life stages. Mortality rates must be low enough to allow for recruitment to all age classes so that successful spawning can continue over time and over generations. There must be enough suitable habitat for spawning, foraging, resting and migrations of all individuals. Habitat connectivity must also be maintained so that individuals can migrate between important habitats without delays that impact their fitness. The loss of any population or metapopulation would result in the loss of biodiversity and would create (or widen) a gap in the species' range.

5.1.8 Summary of Status

Shortnose sturgeon remain listed as endangered throughout their range, with populations in the Northeast being larger and generally more stable than populations in the Southeast. All populations are affected by mortality incidental to other activities, including dredging, power plant intakes and shad fisheries where those still occur, and impacts to habitat and water quality that affect the ability of sturgeon to use habitats and impacts to individuals that are present in those habitats. While the species is overall considered to be stable (i.e., its trend has not changed recently, and we are not aware of any new or emerging threats that would change the trend in the future), we lack information on abundance and population dynamics in many rivers. We also do not fully understand the extent of coastal movements and the importance of habitat in non-natal rivers to migrant fish. While the species has high levels of genetic diversity, the lack of effective movement between populations increases the vulnerability of the species should there be a significant reduction in the number of individuals in any one population or metapopulation as recolonization is expected to be very slow. All populations, regardless of size, are faced with threats that result in the mortality of individuals and/or affect the suitability of habitat and may restrict the further growth of the population. Additionally, there are several life history traits and factors that combine to make the species particularly sensitive to existing and future threats; these factors include: the small size of many populations, existing gaps in the range, late maturation, long residence time in rivers from egg to adulthood, the sensitivity of adults to very specific spawning cues that can result in years with no recruitment if conditions are not met, and the impact of losses of young of the year and juvenile cohorts prior to reaching spawning age on population persistence and stability.

5.2 Atlantic Sturgeon

The section below describes the Atlantic sturgeon listing, provides life history information that is relevant to all DPSs of Atlantic sturgeon and then provides information specific to the status of each DPS of Atlantic sturgeon. Below, we also provide a description of which Atlantic sturgeon DPSs are likely to occur in the action area and provide information on the use of the action area by Atlantic sturgeon.

The Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) is one of two subspecies of *A. oxyrinchus*, the other being the Gulf sturgeon, *A. o. desotoi*. It is distributed along the eastern coast of North America from Hamilton Inlet, Labrador, Canada to Cape Canaveral, Florida, USA (77 FR 5880; February 6, 2012). We have delineated U.S. populations of Atlantic sturgeon into five DPSs (77 FR 5880 and 77 FR 5914; February 6, 2012). These are: the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs (see Figure 1). The results of genetic studies suggest that natal origin influences the distribution of Atlantic sturgeon in the marine environment. However, genetic data as well as tracking and tagging data demonstrate sturgeon from each DPS and Canada occur throughout the full range of the subspecies (Kazyak *et al.* 2021, Wirgin *et al.* 2015b). Therefore, sturgeon originating from any of the five DPSs can be affected by threats in the marine, estuarine, and riverine environment that occur far from natal spawning rivers.

The New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs are listed as endangered, and the Gulf of Maine DPS is listed as threatened (77 FR 5880 and 77 FR 5914; February 6, 2012). The effective date of the listings was April 6, 2012. The DPSs do not include Atlantic sturgeon spawned in Canadian rivers. Therefore, Canadian spawned fish are not included in the listings.

The section below provides life history information that is relevant to all DPSs of Atlantic sturgeon. As described below, individuals originating from any of the five listed DPSs are likely to occur in the action area. Information specific to each of the relevant DPSs, is provided below.

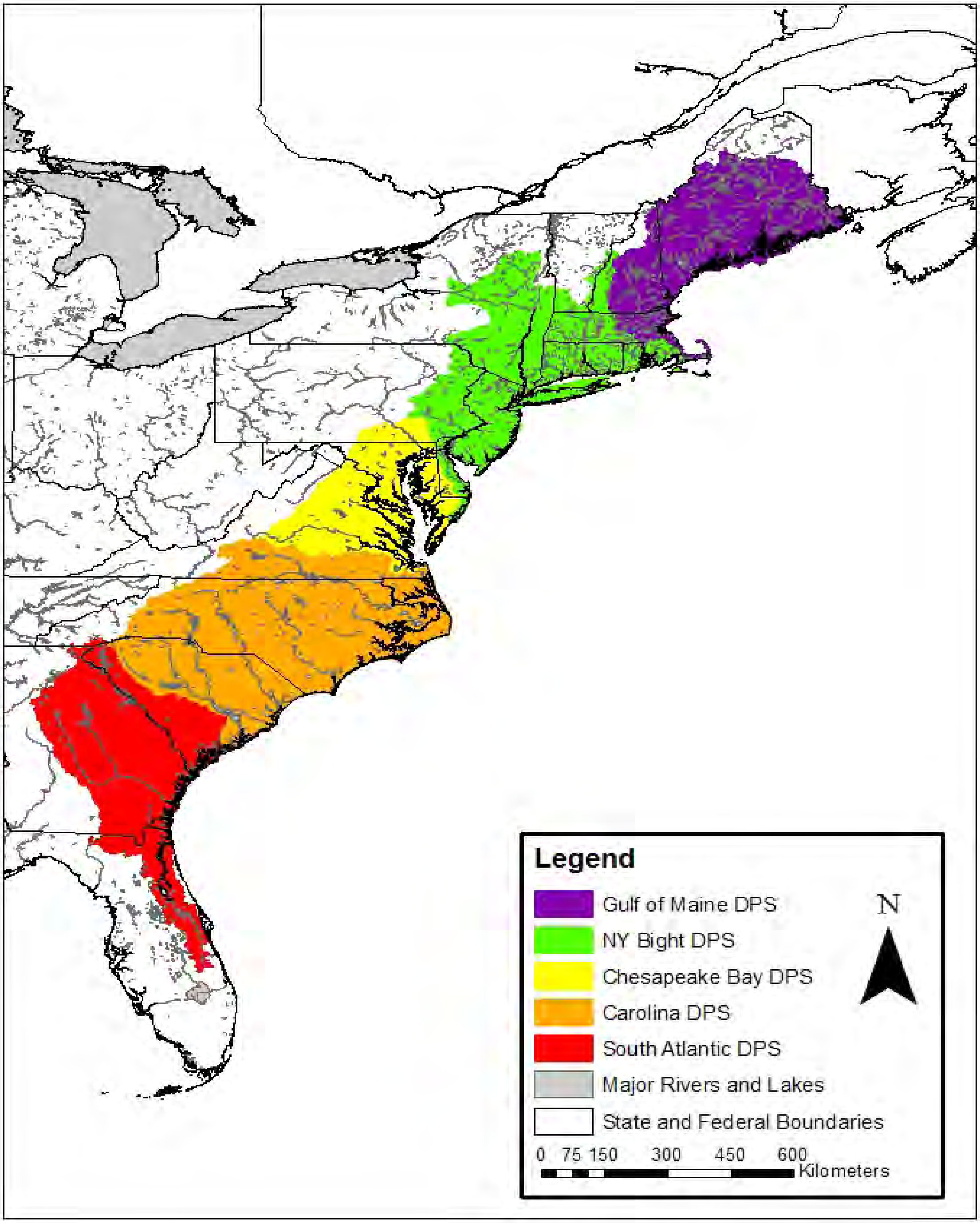

Figure 1. Map depicting the five Atlantic sturgeon DPSs to show the general northern and southern boundaries of each DPS at the coastline. The extent to which each DPS is depicted inland is for general illustration purposes only, since the regulatory definitions of each DPS do not include a western boundary.

5.2.1 Life History and Habitat Use

The Atlantic sturgeon is a long-lived (approximately 60 years), late maturing, and estuarine dependent, anadromous[3] fish (ASSRT 2007). They are a relatively large fish, even amongst sturgeon species (Pikitch *et al.* 2005). Once mature, they continue to grow, and the largest recorded Atlantic sturgeon was a female captured in 1924 that measured approximately 4.3 m (14 ft) (Vladykov and Greeley 1963). Males weigh up to 41 kg (90 pounds) and females weigh up to 73 kg (160 pounds).

In appearance, they are bluish-black or olive brown dorsally (on their back) with paler sides and a white belly. They have no scales, but five rows of scutes (bony plates) cover their head and body: one along the back, one on either side and two along the belly. Its long, hard snout has an upturned tip, with four sensory barbels on the underside of its snout. Its mouth is located on the underside (ventrally-located) of the head, is protruding (can be withdrawn and extended like an accordion), soft and toothless. Atlantic sturgeons are bottom feeders that use the protruding mouth to pick up food (Bigelow and Schroeder 1953b). The four chemosensory barbels in front of the mouth assist the sturgeon in locating prey.

The life stages of Atlantic sturgeon can be divided up into six general categories as described in the Table 3 below. Depending on life stage, sturgeon may be present in freshwater, marine and estuarine ecosystems.

[3] Anadromous refers to a fish that is born in freshwater, spends most of its life in the sea, and returns to freshwater to spawn.

Table 3. Descriptions of Atlantic sturgeon life history stages

Age Class		Size	Description
Egg		~2 to 3 mm diameter	Fertilized or unfertilized
Yolk Sac Larvae		~6 to 14 mm TL	Negative phototaxis, nourished by yolk sac (endogenous feeding)
Post Yolk Sac Larvae		~14 to 37 mm TL	Positive phototaxis, free swimming, actively feeding (exogenous feeding)
Young of the Year (YOY)		0.3 grams <41 cm TL	Fish that are > 3 months and < one year; capable of capturing and consuming live food
Juveniles		>41 cm and <76 cm TL	Fish that are at least age 1 and are not sexually mature and do not make coastal migrations.
Subadults		>76cm and <150cm TL	Fish that are not sexually mature but make coastal migrations
Adults		>150 cm TL	Sexually mature fish

Spawning

Atlantic sturgeon spawn in freshwater habitats (ASSRT 2007, NMFS 2017b) at sites with flowing water and hard bottom substrate (Bain *et al.* 2000, Balazik *et al.* 2012a, Gilbert 1989, Greene *et al.* 2009, Hatin *et al.* 2002, Mohler 2003, Smith and Clugston 1997, Vladykov and Greeley 1963). Water depths of spawning sites are highly variable, but may be up to 27 m (88.6 ft) (Bain *et al.* 2000, Crance 1987, Leland 1968, Scott and Crossman 1973). This is also supported by tagging records, which show that Atlantic sturgeon return to their natal rivers to spawn (ASSRT 2007). Spawning intervals ranging from one to five years in males (Caron *et al.* 2002, Collins *et al.* 2000, Smith 1985) and two to five years for females (Stevenson and Secor 1999, Van Eenennaam *et al.* 1996, Vladykov and Greeley 1963). Males spawn more frequently than females, and females can spawn in consecutive years, but female spawning periodicity is more variable than males (Breece *et al.* 2021). Given spawning periodicity and a female's relatively late age to maturity, the age at which 50 percent of the maximum lifetime egg production is achieved is estimated to be 29 years (Boreman 1997). While long-lived, Atlantic sturgeon are exposed to a multitude of threats prior to achieving maturation and have a limited number of spawning opportunities once they are mature.

The number of eggs produced by females range from 400,000 to approximately 4 million depending on body size (and age) (Hilton *et al.* 2016, Van Eenennaam and Doroshov 1998, Van Eenennaam *et al.* 1996). Therefore, observations of large-sized sturgeon are particularly important given that egg production correlates with age and body size (Dadswell 2006, Smith *et al.* 1982, Van Eenennaam and Doroshov 1998, Van Eenennaam *et al.* 1996).

Water temperature appears to play the primary role in triggering the timing of spawning migrations (Hilton *et al.* 2016). Spawning migrations generally occur during February-March in southern systems, April-May in Mid-Atlantic systems, and May-July in Canadian systems (Hilton *et al.* 2016). Male sturgeon begin upstream spawning migrations when waters reach approximately 6° C (43° F) (Hilton *et al.* 2016), and remain on the spawning grounds throughout the spawning season (Bain 1997). Females begin spawning migrations when temperatures are closer to 12° C to 13° C (54° to 55° F) (Dovel and Berggren 1983, Smith 1985), make rapid spawning migrations upstream, and quickly depart following spawning (Bain 1997). Females may leave the estuary and travel to other coastal estuaries until outmigration to marine waters in the fall (Bain 1997, Bain *et al.* 2000, Balazik *et al.* 2012c, Breece *et al.* 2013, Dovel and Berggren 1983, Greene *et al.* 2009, Hatin *et al.* 2002, NMFS 2017b, Smith 1985, Smith *et al.* 1982). Following spawning, males move downriver to the lower estuary and remain there until outmigration in the fall (Bain 1997, Bain *et al.* 2000, Balazik *et al.* 2012c, Breece *et al.* 2013, Dovel and Berggren 1983, Greene *et al.* 2009, Hatin *et al.* 2007b, Ingram *et al.* 2019, Smith 1985, Smith *et al.* 1982).

Eggs and Larvae

Sturgeon females deposit their eggs on the hard bottom substrate at the spawning site where they become adhesive shortly after fertilization (Hilton *et al.* 2016, Mohler 2003, Murawski and Pacheco 1977). Incubation time for the eggs increases as water temperature decreases (Mohler 2003). At temperatures of 20° and 18° C (68° and 64.4°F), hatching occurs approximately 94 and 140 hours, respectively, after egg deposition (ASSRT 2007).

Hatchlings (called free embryos) have a yolk sac that provides nourishment (endogenous feeding) during the first stage of larval development. Hatchlings are assumed to undertake a demersal existence, seek cover in the bottom substrate and yolk sac larvae (i.e., free embryos less than 4 weeks old, with total lengths (TL) less than 30 mm (1.2 in); Van Eenennaam *et al.* 1996) are assumed to inhabit the same riverine or estuarine areas where they were spawned (Bain *et al.* 2000, Kynard and Horgan 2002). The free embryo exhausts the yolk sac and becomes (post yolk sac) larvae after about eight days (Kynard and Horgan 2002). Post yolk sac larvae drift downstream where they eventually settle, become demersal, and start foraging in freshwater reaches above the salt front (Kynard and Horgan 2002).

Juveniles

Studies suggest that age-0 (i.e., young-of-the-year), age-1, and age-2 juvenile Atlantic sturgeon occur in low salinity waters of the natal estuary (Hilton *et al.* 2016) while older fish are more salt tolerant and occur in higher salinity waters as well as low salinity waters (Collins *et al.* 2000, Hilton *et al.* 2016). Atlantic sturgeon remain in the natal estuary for months to years before emigrating to open ocean as subadults[4] (ASSRT 2007, Dadswell 2006, Dovel and Berggren 1983, Hilton *et al.* 2016). Juvenile Atlantic sturgeon feed on aquatic insects, insect larvae, and other benthic invertebrates (ASSRT 2007, Bigelow and Schroeder 1953a, Bjorndal *et al.* 1994, Guilbard *et al.* 2007).

Subadults and Adults

Upon reaching the subadult phase, individuals enter the marine environment, mixing with adults and subadults from other river systems (Bain 1997, Dovel and Berggren 1983, Hatin *et al.* 2007a, McCord *et al.* 2007). Once subadult Atlantic sturgeon have reached maturity (i.e., adult stage), they will remain in marine or estuarine waters that are typically less than 50 m (164 ft.) deep, only returning far upstream to the spawning areas when they are ready to spawn (ASSRT 2007, Bain 1997, Breece *et al.* 2016, Dunton *et al.* 2012, 2015, Savoy and Pacileo 2003). Diets of adult and migrant subadult Atlantic sturgeon include gastropods, annelids (Polychaetes and Oligochaetes), crustaceans, and fish such as sand lance (ASSRT 2007, Bigelow and Schroeder 1953a, Guilbard *et al.* 2007, Savoy 2007).

Marine and Coastal Distribution

The marine range of U.S. Atlantic sturgeon extends from Labrador, Canada, to Cape Canaveral, Florida. As Atlantic sturgeon travel long distances in these waters, all five DPSs of Atlantic sturgeon have the potential to be anywhere in this marine range. Results from genetic studies show that, regardless of location, multiple DPSs can be found at any one location along the Northwest Atlantic coast. However, the New York Bight DPS was more prevalent relative to the other DPSs in Mid-Atlantic marine waters, bays, and sounds (Dunton *et al.* 2016, Waldman *et al.* 1996, Wirgin *et al.* 2015a, Wirgin *et al.* 2015b, Wirgin *et al.* 2018). A comprehensive analysis of Atlantic sturgeon stock composition coast wide provides further evidence that natal origin influences the distribution of Atlantic sturgeon in the marine environment. Atlantic sturgeon that originate from each of the five DPSs and from the Canadian rivers were represented in the 1,704 samples analyzed for the study. However, there were statistically significant differences in the spatial distribution of each DPS, and individuals were most likely to be assigned to a DPS in the same general region where they were collected (Kazyak *et al.* 2021). For the New York Bight DPS, the results support the findings of previous genetic analyses that Atlantic sturgeon belonging to the DPS occur in the Gulf of Maine and in the South Atlantic Bight but that they are most prevalent in the Mid-Atlantic Bight (ASMFC 2017b, 2019, ASSRT 2007, Chambers *et al.* 2012, Dadswell 2006, Dovel and Berggren 1983, Dunton *et al.* 2012, Dunton *et al.* 2015, Dunton

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[4] Some of the published literature for Atlantic sturgeon uses the term juvenile to refer to all sexually immature Atlantic sturgeon, including sexually immature fish that have emigrated from the natal river estuary. We use "juvenile" in reference to immature fish that have not emigrated from the natal river estuary, and we use the term "subadult" for immature Atlantic sturgeon that have emigrated from the natal river estuary.

et al. 2010, Erickson *et al.* 2011, Kynard *et al.* 2000, Laney *et al.* 2007, O'Leary *et al.* 2014, Stein *et al.* 2004b, Waldman *et al.* 2013, Wirgin *et al.* 2015a).

Based on fishery-independent, fishery dependent, tracking, and tagging data, Atlantic sturgeon appear to primarily occur inshore of the 50 m (164 ft) depth contour (Dunton *et al.* 2015, Dunton *et al.* 2010, Erickson *et al.* 2011, Laney *et al.* 2007, O'Leary *et al.* 2014, Stein *et al.* 2004a, b, Waldman *et al.* 2013, 2015a, Wirgin *et al.* 2015b). However, they are not restricted to these depths and excursions into deeper (e.g., 75 m (246 ft)) continental shelf waters have been documented (Colette and Klein-MacPhee 2002, Collins and Smith 1997, Dunton *et al.* 2010, Erickson *et al.* 2011, Stein *et al.* 2004a, Timoshkin 1968). Data from fishery-independent surveys and tagging and tracking studies also indicate that some Atlantic sturgeon may undertake seasonal movements along the coast (Dunton *et al.* 2010, Erickson *et al.* 2011, Hilton *et al.* 2016, Oliver *et al.* 2013, Post *et al.* 2014, Wippelhauser 2012). For instance, studies found that satellite-tagged adult sturgeon from the Hudson River concentrated in the southern part of the Mid-Atlantic Bight, at depths greater than 20 m (66 ft), during winter and spring; while, in the summer and fall, Atlantic sturgeon concentrations shifted to the northern portion of the Mid-Atlantic Bight at depths less than 20 m (66 ft) (Erickson *et al.* 2011).

In the marine range, several marine aggregation areas occur adjacent to estuaries and/or coastal features formed by bay mouths and inlets along the U.S. eastern seaboard (i.e., waters off North Carolina, Chesapeake Bay; Delaware Bay; New York Bight; Massachusetts Bay; Long Island Sound; and Connecticut and Kennebec River Estuaries). Depths in these areas are generally no greater than 25 m (82 ft) (Bain *et al.* 2000, Dunton *et al.* 2010, Erickson *et al.* 2011, Laney *et al.* 2007, O'Leary *et al.* 2014, Oliver *et al.* 2013, Savoy and Pacileo 2003, Stein *et al.* 2004b, Waldman *et al.* 2013, Wippelhauser 2012, Wippelhauser and Squiers 2015). Although additional studies are still needed to clarify why Atlantic sturgeon aggregate at these sites, there is some indication that they may serve as thermal refuge, wintering sites, or marine foraging areas (Dunton *et al.* 2010, Erickson *et al.* 2011, Stein *et al.* 2004b).

5.2.2 Abundance

The NEFSC suggested that cumulative annual estimates of surviving fishery discards could provide a minimum estimate of abundance. The objectives of producing the Atlantic Sturgeon Production Index (ASPI) were to characterize uncertainty in abundance estimates arising from multiple sources of observation and process error and to complement future efforts to conduct a more comprehensive stock assessment (Table 4). The ASPI provides a general abundance metric to assess risk for actions that may affect Atlantic sturgeon in the ocean; however, it is not a comprehensive stock assessment. In general, the model uses empirical estimates of post-capture survivors and natural survival, as well as probability estimates of recapture using tagging data from the USFWS sturgeon tagging database, and federal fishery discard estimates from 2006 to 2010 to produce a virtual population. The USFWS sturgeon tagging database is a repository for sturgeon tagging information on the Atlantic coast. The database contains tag, release, and recapture information from state and federal researchers. The database records recaptures by the fishing fleet, researchers, and researchers on fishery vessels.

Table 4. Description of the ASPI model and NEAMAP survey based area estimate method.

Model Name	Model Description
A. ASPI	Uses tag-based estimates of recapture probabilities from 1999 to 2009. Natural mortality based on Kahnle *et al.* (2007) rather than estimates derived from tagging models. Tag recaptures from commercial fisheries are adjusted for non reporting based on recaptures from observers and researchers. Tag loss assumed to be zero.
B. NEAMAP Swept Area	Uses NEAMAP survey-based swept area estimates of abundance and assumed estimates of gear efficiency. Estimates based on an average of ten surveys from fall 2007 to spring 2012.

In addition to the ASPI, a population estimate was derived from the Northeast Area Monitoring and Assessment Program (NEAMAP) trawl surveys (Kocik *et al.* 2013).[5] NEAMAP trawl surveys are conducted from Cape Cod, Massachusetts to Cape Hatteras, North Carolina in nearshore waters at depths up to 18.3 meters (60 feet) during the fall since 2007 and spring since 2008. Each survey employs a spatially stratified random design with a total of 35 strata and 150 stations.

As illustrated by Table 5 below, the ASPI model projects a mean population size of 417,934 Atlantic sturgeon and the NEAMAP Survey projects mean population sizes ranging from 33,888 to 338,882 depending on the assumption made regarding efficiency of that survey. As noted above, the ASPI model uses empirical estimates of post-capture survivors and natural survival, as well as probability estimates of recapture using tagging data from the USFWS sturgeon tagging database, and federal fishery discard estimates from 2006 to 2010 to produce a virtual population. The NEAMAP estimate, in contrast, is more empirically derived and does not depend on as many assumptions. For the purposes of this Opinion, while the ASPI model is considered as part of the 2017 ASMFC stock assessment, we consider the NEAMAP estimate as the best available information on population size.

Table 5. Model results

Model Run	Model Years	95% low	Mean	95% high
A. ASPI	1999-2009	165,381	417,934	744,597
B.1 NEAMAP Survey, swept area assuming 100% efficiency	2007-2012	8,921	33,888	58,856
B.2 NEAMAP Survey, swept area assuming 50% efficiency	2007-2012	13,962	67,776	105,984
B.3 NEAMAP Survey, swept area assuming 10% efficiency	2007-2012	89,206	338,882	588,558

[5] Since fall 2007, NEAMAP trawl surveys (spring and fall) have been conducted from Cape Cod, Massachusetts to Cape Hatteras, North Carolina in nearshore waters at depths up to 18.3 meters (60 feet). Each survey employs a spatially stratified random design with a total of 35 strata and 150 stations.

Available data do not support estimation of true catchability (i.e., net efficiency X availability) of the NEAMAP trawl survey for Atlantic sturgeon. Thus, the NEAMAP swept area biomass estimates were produced and presented in Kocik *et al.* (2013) for catchabilities from five to 100 percent. In estimating the efficiency of the sampling net, we consider the likelihood that an Atlantic sturgeon in the survey area is likely to be captured by the trawl. Assuming the NEAMAP surveys have been 100 percent efficient would require the unlikely assumption that the survey gear captures all Atlantic sturgeon within the path of the trawl and all sturgeon are within the sampling area of the NEAMAP survey. Thus, we have in previous biological opinions (e.g., NMFS 2018) and will, for this Opinion, rely on the population estimates derived from the NEAMAP swept area biomass assuming a 50 percent catchability (i.e., net efficiency x availability) rate. We consider that the NEAMAP surveys sample an area utilized by Atlantic sturgeon, but do not sample all the locations and times where Atlantic sturgeon are present. We also consider that the trawl net captures some, but likely not all, of the Atlantic sturgeon present in the sampling area. Therefore, we assume that net efficiency and the fraction of the population exposed to the NEAMAP surveys in combination result in a 50 percent catchability (NMFS 2013). The 50 percent catchability assumption reasonably accounts for the robust, yet not complete, sampling of the Atlantic sturgeon oceanic temporal and spatial ranges and the documented high rates of encounter with NEAMAP survey gear. As these estimates are derived directly from empirical data with fewer assumptions than have been required to model Atlantic sturgeon populations to date, we believe these estimates continue to serve as the best available information. Based on the above approach, the overall abundance of Atlantic sturgeon in U.S. Atlantic waters are estimated to be 67,776 fish (see Table 16 in Kocik *et al.* 2013). Based on genetic frequencies of occurrence in the sampled area, this overall population estimate was subsequently partitioned by DPS (Table 6). Given the proportion of adults to subadults in the NMFS NEFSC observer data (approximate ratio of 1:3), we have also estimated the number of adults and subadults originating from each DPS. However, this cannot be considered an estimate of the total number of subadults, because it only considers those subadults that are of a size that are present and vulnerable to capture in commercial trawl and gillnet gear in the marine environment.

The NEAMAP-based estimates do not include young-of-the-year fish and juveniles in the rivers. The NEAMAP surveys are conducted in waters that include the preferred depth ranges of subadult and adult Atlantic sturgeon and take place during seasons that coincide with known Atlantic sturgeon coastal migration patterns in the ocean. However, the estimated number of subadults in marine waters is a minimum count because it only considers those subadults that are captured in a portion of the survey area and are present in the marine environment, which is only a fraction of the total number of subadults. In regards to adult Atlantic sturgeon, the estimated population in marine waters is also a minimum count as the NEAMAP surveys sample only a portion of the area of the NEAMAP trawls, and therefore a portion of the Atlantic sturgeon's range.

Table 6. Calculated population estimates based on the NEAMAP survey swept area model, assuming 50 percent efficiency

DPS	Estimated Ocean Population Abundance	Estimated Ocean Population of Adults	Estimated Ocean Population of Subadults (of size vulnerable to capture in fisheries)
GOM	7,455	1,864	5,591
NYB	34,567	8,642	25,925
CB	8,811	2,203	6,608
Carolina	1,356	339	1,017
SA	14,911	3,728	11,183
Canada	679	170	509

Precise estimates of population growth rate (intrinsic rates) are unknown for the five listed Atlantic sturgeon DPSs due to a lack of long-term abundance data. The ASMFC (2017b) stock assessment referenced a population viability assessment (PVA) that was done to determine population growth rates for the five DPSs based on a few long-term survey programs, but most results were statistically insignificant or utilized a model that would not converge. In any event, the population growth rates reported from that PVA ranged from -1.8 percent to 4.9 percent (ASMFC 2017b).

The genetic diversity of Atlantic sturgeon throughout its range has been well-documented (ASSRT 2007, Bowen and Avise 1990, O'Leary *et al.* 2014, Ong *et al.* 1996, Waldman *et al.* 1996, Waldman and Wirgin 1998). Overall, these studies have consistently found populations to be genetically diverse, and the majority can be readily differentiated by using genetic data from individual fish. Relatively low rates of gene flow reported in population genetic studies (Fritts *et al.* 2016, Savoy *et al.* 2017, Wirgin *et al.* 2002) indicate that Atlantic sturgeon return to their natal river to spawn, despite extensive mixing in coastal waters.

5.2.3 Stock Assessments

Atlantic sturgeon were once present in 38 river systems and, of these, spawned in 35 (ASSRT 2007). There are currently 39 rivers and two creeks that are specifically occupied areas designated as critical habitat for Atlantic sturgeon (NMFS 2017b). The decline in abundance of Atlantic sturgeon has been attributed primarily to the large U.S. commercial fishery, which existed for the Atlantic sturgeon through the mid-1990s in some states. Based on management recommendations in the interstate fishery management plan (ISFMP), adopted by the Atlantic States Marine Fisheries Commission (the Commission) in 1990, commercial harvest in Atlantic coastal states was severely restricted and ultimately eliminated from all states (ASMFC 1998). In 1998, the Commission called for a coastwide moratorium on fishing for Atlantic sturgeon in state waters to allow 20 consecutive cohorts of females to reach sexual maturity and spawn, which will facilitate restoration of the age structure. The moratorium was expected to be in place for 20-40 years because they considered the median maturity of female Atlantic sturgeon to be about age 18 and, therefore, it was expected that it could take up to 38 years before 20 subsequent year classes of adult females is established (ASMFC 1998). In 1999, NMFS closed the Exclusive Economic Zone to Atlantic sturgeon retention, pursuant to the Atlantic Coastal Act

(64 FR 9449; February 26, 1999). However, all state fisheries for sturgeon were closed prior to this.

The most significant threats to Atlantic sturgeon are vessel strikes, bycatch in commercial fisheries, habitat changes, impeded access to historical habitat by dams and reservoirs in the south, degraded water quality, and reduced water quantity. Bycatch in fisheries together with vessel strike mortalities may exceed acceptable levels, reducing recovery rates for some DPSs (ASMFC 2017b). While bycatch in federal and state fisheries is one of the main causes of anthropogenic mortality of Atlantic sturgeon, our 2021 biological opinion on the authorization of federal fisheries concluded that the level of bycatch will not jeopardize the continued survival and recovery of any Atlantic sturgeon DPSs (NMFS 2021). New data indicates that bycatch in federal fisheries is, however, higher than what we considered in the 2021 biological opinion, and the batch consultation on the authorization of multiple federal fisheries is currently being reinitiated. Vessel strike has also been identified as a major cause of Atlantic sturgeon anthropogenic mortality and was a contributing factor in the 2012 ESA listing decision for Atlantic sturgeon in the New York Bight DPS. Several recent biological opinions considering the consequences to the Atlantic sturgeon NYB DPS of increased vessel activity from port developments concluded that these increases in vessel activity would not jeopardize the continued existence of any Atlantic sturgeon DPSs. Based on new information related to vessel strikes, consultation was reinitiated on one port, in addition to the Paulsboro Port considered herein, and we anticipate reinitiating consultation on another port.

The Commission completed an Atlantic sturgeon benchmark stock assessment in 2017 that considered the status of each DPS individually, as well as all five DPSs collectively as a single unit (ASMFC 2017b). The assessment concluded all five DPSs of Atlantic sturgeon, as well as each individual DPS remain depleted relative to historic abundance. The assessment also concluded that the population of all five DPSs together appears to be recovering slowly since implementation of a complete moratorium on directed fishing and retention in 1998. However, there were only two individual DPSs, the New York Bight DPS and Carolina DPS, for which there was a relatively high probability that abundance of the DPS has increased since the implementation of the 1998 fishing moratorium. There was considerable uncertainty expressed in the stock assessment and in its peer review report. For example, new information suggests that these conclusions about the New York Bight DPS primarily reflect the status and trend of only the DPS's Hudson River spawning population. In addition, there was a relatively high probability that mortality for animals of the Gulf of Maine DPS and the Carolina DPS exceeded the mortality threshold used for the assessment. Yet, the stock assessment notes that it was not clear if: (1) the percent probability for the trend in abundance for the Gulf of Maine DPS is a reflection of the actual trend in abundance or of the underlying data quality for the DPS; and, (2) the percent probability that the Gulf of Maine DPS exceeds the mortality threshold actually reflects lower survival or was due to increased tagging model uncertainty owing to low sample sizes and potential emigration. Therefore, while Atlantic sturgeon populations may be showing signs of slow recovery since the 1998 and 1999 moratoriums when all five DPSs are considered collectively, these trends are not necessarily reflected with individual DPSs and there is considerable uncertainty related to population trends (ASMFC 2017b). In summary, across all five DPSs, several life history traits and factors contribute to making Atlantic sturgeon particularly sensitive to existing and future threats. These factors include the small size of many river-specific populations, existing gaps in the range, late maturation, long residence time in rivers from egg to juvenile, the sensitivity of adults to very specific temperature spawning cues which can result in years with no recruitment if conditions are not met, and the impact of losses of young of the year and juvenile cohorts prior to reaching spawning age on population persistence and stability.

In 2022, pursuant to Section 4(c)(2)(A) of the ESA, we published the 5-year reviews for the New York Bight DPS, Chesapeake Bay DPS, and Gulf of Maine DPS of Atlantic sturgeon. As part of the 5-year reviews, we are required to consider new information that has become available since the New York Bight DPS of Atlantic sturgeon was listed as endangered in February 2012. In addition to previously available information, this Opinion includes new information that has become available since the ESA-listing and critical habitat designation for the New York Bight DPS, and is considered the best available scientific information. The findings of the 5-year reviews are included in our discussion below for each DPS. The complete 5-year reviews for the three DPSs, are available on our website at: https://www.fisheries.noaa.gov/action/5-year-review-new-york-bight-chesapeake-bay-and-gulf-maine-distinct-population-segments.

5.2.4 Critical Habitat

Critical habitat has been designated for the five DPSs of Atlantic sturgeon (82 FR 39160; August 17, 2017) in rivers of the eastern United States.

5.2.5 Recovery Goals

Recovery Plans for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs are currently at the draft stage, but have not been prepared for the South Atlantic and Carolina DPSs. A recovery outline (see https://www.fisheries.noaa.gov/resource/document/recovery-outline-atlantic-sturgeon-distinct-population-segments) has been developed as interim guidance to direct recovery efforts, including recovery planning, until a full recovery plan is approved.

5.2.6 Gulf of Maine DPS of Atlantic sturgeon

The Gulf of Maine DPS of Atlantic sturgeon includes Atlantic sturgeons spawned in the watersheds that drain into the Gulf of Maine from the Maine/Canadian border and extending southward to Chatham, MA. Within this range, Atlantic sturgeon historically spawned in the Penobscot, Kennebec, Androscoggin, Sheepscot, and Merrimack Rivers (ASSRT 2007). Spawning habitat is available and accessible in the Penobscot, Androscoggin, Kennebec, Merrimack, and Piscataqua (inclusive of Cocheco and Salmon Falls) Rivers. Spawning has been documented in the Kennebec River, and recent information from (Wippelhauser *et al.* 2017) confirms the location of occurrence (between RKM 70 and 75 (RM 43.5 and 46.6)). During this study, between 2009-2011, eight sturgeon, including one male in spawning condition, were also captured in the Androscoggin River estuary, which suggests that spawning may be occurring in the Androscoggin River as well (Wippelhauser *et al.* 2017). However, additional evidence, such as capture of a spawning female, sturgeon eggs or larvae, is not yet available to confirm that spawning for the Gulf of Maine DPS is occurring in that river. Studies are on-going to determine whether Atlantic sturgeon are spawning in the other rivers within the DPS, but as of now, nothing is confirmed.

Bigelow and Schroeder (2002 (revised)) surmised that Atlantic sturgeon likely spawned in Gulf of Maine Rivers in May-July. More recent captures of Atlantic sturgeon in spawning condition within the Kennebec River suggest that spawning more likely occurs in June-July (ASMFC 1998, NMFS (National Marine Fisheries Service) and U.S. FWS (U.S. Fish and Wildlife Service) 1998, Wippelhauser *et al.* 2017). Evidence for the timing and location of Atlantic sturgeon spawning in the Kennebec River includes: (1) the capture of five adult male Atlantic sturgeon in spawning condition (i.e., expressing milt) in July 1994 below the (former) Edwards Dam; (2) capture of 31 adult Atlantic sturgeon from June 15, 1980, through July 26, 1980, in a small commercial fishery directed at Atlantic sturgeon from the South Gardiner area (above Merrymeeting Bay) that included at least four ripe males and one ripe female captured on July 26, 1980; (3) capture of nine adults during a gillnet survey conducted from 1977-1981, the majority of which were captured in July in the area from Merrymeeting Bay and upriver as far as Gardiner, Maine (ASMFC 2007, NMFS (National Marine Fisheries Service) and U.S. FWS (U.S. Fish and Wildlife Service) 1998); and (4) as mentioned above, the capture of three Atlantic sturgeon larvae between RKM 72 and RKM 75 (RM 44.7 and RM 46.6) in July 2011 (Wippelhauser *et al.* 2017). The low salinity values for waters above Merrymeeting Bay are consistent with values found in rivers where successful Atlantic sturgeon spawning is known to occur. Additionally, limited new information regarding spawning periodicity indicates that over a four-year period from 2010-2014, one fish was detected in three consecutive years on the Kennebec River spawning grounds. The majority of fish (12 out of 21) were only detected during one season (Wippelhauser *et al.* 2017). The data confirms variability in spawning periodicity.

Atlantic sturgeons that spawn elsewhere continue to use habitats within all of these rivers as part of their overall marine range (ASSRT 2007). Additionally, Atlantic sturgeon that spawn in the Gulf of Maine DPS have been detected off of Delaware (Kazyak *et al.* 2021, Wirgin *et al.* 2015a) and as far south as Cape Hatteras. The movement of subadult and adult sturgeon between rivers, including to and from the Kennebec River and the Penobscot River, demonstrates that coastal and marine migrations are key elements of Atlantic sturgeon life history for the Gulf of Maine DPS as well as likely throughout the entire range (ASSRT 2007, Fernandes *et al.* 2010). The Saco River supports a large aggregation of Atlantic sturgeon that forage on sand lance in Saco Bay and within the first few kilometers of the Saco River, primarily from May through October. Some sturgeon also overwinter in Saco Bay (Beardsall *et al.* 2013, Hylton *et al.* 2018) which suggests that the river provides important wintering habitat as well, particularly for subadults. However, none of the new information indicates recolonization of the Saco River for spawning. It remains questionable whether sturgeon larvae could survive in the Saco River even if spawning were to occur because of the presence of the Cataract Dam at RKM 10 (RM 6.2) of the river (Little 2013a), which limits access to the freshwater reach. Some sturgeon that spawn in the Kennebec have subsequently been detected foraging in the Saco River and Bay (Novak *et al.* 2017, Wippelhauser *et al.* 2017).

Data collected from 11 dead adult Atlantic sturgeon in the Bay of Fundy (seven individuals with age ranges from 17 to 28 years) further informs the DPS mixing that occurs throughout the marine range and in Canadian waters (Stewart et al. 2017). Dadswell *et al.* (2016) describes seasonal aggregations and movement (generally May through September) of Gulf of Maine DPS sturgeon in the Bay of Fundy. This information supports the 2012 listing rule's finding that 35 percent of Atlantic sturgeon captured in Canadian fisheries are of Gulf of Maine DPS origin (Wirgin *et al.* 2012).

Multiple threats play a role in shaping the current status of Gulf of Maine DPS Atlantic sturgeon. Historical records provide evidence of commercial fisheries for Atlantic sturgeon in the Kennebec and Androscoggin Rivers dating back to the 17th century (Squiers *et al.* 1979). In 1849, 160 tons of sturgeon was caught in the Kennebec River by local fishermen (Squiers *et al.* 1979). Following the 1880s, the sturgeon fishery was almost non-existent due to a collapse of the sturgeon stocks. All directed Atlantic sturgeon fishing as well as retention of Atlantic sturgeon bycatch has been prohibited since 1998.

In the marine range, Gulf of Maine DPS Atlantic sturgeon are incidentally captured in federal and state-managed fisheries, reducing survivorship of subadult and adult Atlantic sturgeon (ASMFC 2007, Stein *et al.* 2004a). Incidentally caught Atlantic sturgeon in state-managed fisheries are reported to the ASMFC through voluntary reporting (ASMFC 2019), and in federally managed fisheries through the Northeast Fishery Management plans. There are strict regulations on the use of fishing gear in Maine state waters that incidentally catch sturgeon. In addition, there have been reductions in fishing effort in state and federal waters, which most likely would result in a reduction in bycatch mortality of Atlantic sturgeon. A significant amount of fishing in the Gulf of Maine is conducted using trawl gear, which is known to have a much lower mortality rate for Atlantic sturgeon caught in the gear compared to sink gillnet gear (ASMFC 2007). Atlantic sturgeon from the Gulf of Maine DPS are not commonly taken as bycatch in areas south of Chatham, Massachusetts, with only 8 percent (e.g., 7 of 84 fish) of interactions observed in the New York region being assigned to the Gulf of Maine DPS (Wirgin and King 2011). Tagging results also indicate that Gulf of Maine DPS fish tend to remain within the waters of the Gulf of Maine and only occasionally venture to points south. However, data on Atlantic sturgeon incidentally caught in trawls and intertidal fish weirs fished in the Minas Basin area of the Bay of Fundy (Canada) indicate that approximately 35 percent originated from the Gulf of Maine DPS (Wirgin *et al.* 2012), as stated above. Thus, a significant number of the Gulf of Maine DPS fish appear to migrate north into Canadian waters where they may be subjected to a variety of threats including bycatch. Dadswell *et al.* (2016) describes characteristics of the seasonal aggregation of sturgeon in the Bay of Fundy. Dadswell *et al*. does not identify the natal origin of each of the 1,453 Atlantic sturgeon captured and sampled for their study. However, based on Wirgin *et al.* (2012) and Stewart *et al.* (2017), NMFS considers the results of Dadswell *et al*. as representative of the movement of the Gulf of Maine DPS of Atlantic sturgeon. Dadswell *et al*. determined subadult and adult Atlantic sturgeon occur seasonally (approximately May to September) in the Bay of Fundy for foraging, and many return in consecutive years. Fork length (FL) of the 1,453 sampled sturgeon ranged from 45.8 to 267 cm (18 to 105 in), but the majority (72.5 percent) were less than 150 cm (59 in) FL. The age of the sturgeon (i.e., 4 to 54 years old) is also indicative of the two different life stages. Detailed seasonal movements of sturgeon to and from the Bay of Fundy are described in Beardsall *et al.* (2016).

Habitat disturbance and direct mortality from anthropogenic sources are significant concerns to Atlantic sturgeon. Riverine habitat may be impacted by dredging and other in-water activities, disturbing spawning habitat and also altering the benthic forage base. Many rivers in the Gulf of Maine DPS have navigation channels that are maintained by dredging. Dredging outside of Federal channels and in-water construction occurs throughout the Gulf of Maine DPS. While some dredging projects operate with observers present to document fish mortalities, many do not. To date, we have not received any reports of Atlantic sturgeon killed during dredging projects in the Gulf of Maine region; however, as noted above, not all projects are monitored for interactions with fish. At this time, we do not have any information to quantify the number of Atlantic sturgeon killed or disturbed during dredging or in-water construction projects. We are also not able to quantify any consequences to habitat. However, studies by Reine *et al.* (2014) and Balazik *et al.* (2020) indicate that sturgeon are not attracted to dredge activity and that dredging (i.e., associated noise and turbidity) was not a barrier to passage, even though fish can become impinged or entrained in the dredging gear, itself.

Connectivity is disrupted by the presence of dams on some rivers in the Gulf of Maine region, including the Merrimack River. While there are also dams on the Kennebec and Androscoggin Rivers, these dams are near the site of natural falls and likely represent the maximum upstream extent of sturgeon occurrence even if the dams were not present. Because no Atlantic sturgeon are known to occur upstream of any hydroelectric projects in the Gulf of Maine region, passage over hydroelectric dams or through hydroelectric turbines is not a source of injury or mortality in this area. While not expected to be killed or injured during passage at the dam, the extent that Atlantic sturgeon are affected by the existence of dams and their operations in the Gulf of Maine region is currently unknown. The tracking of spawning condition Atlantic sturgeon downstream of the Brunswick Dam in the Androscoggin River suggests however, that Atlantic sturgeon spawning may be occurring in the vicinity of at least that project and therefore, may be affected by project operations. Until it was breached in July 2013, the range of Atlantic sturgeon in the Penobscot River was limited by the presence of the Veazie Dam. Since the removal of the Veazie Dam and the Great Works Dam, sturgeon can now travel as far upstream as the Milford Dam. Atlantic sturgeon primarily occur within the mesohaline reach of the river, particularly in areas with high densities of sturgeon prey which means that the Penobscot River is likely an important foraging area for Atlantic sturgeon belonging to the Gulf of Maine DPS (Altenritter *et al.* 2017b). There is no current evidence that spawning is occurring in the Penobscot River. Acoustic tag detections suggest that the adults that forage in the Penobscot River travel to the Kennebec River to spawn (Altenritter *et al.* 2017b). The Essex Dam on the Merrimack River blocks access to approximately 58 percent of historically accessible habitat in this river. Atlantic sturgeon occur in the Merrimack River but spawning has not been documented. Like the Penobscot, it is unknown how the Essex Dam affects the likelihood of spawning occurring in this river.

Gulf of Maine DPS Atlantic sturgeon may also be affected by degraded water quality. In general, water quality has improved in the Gulf of Maine over the past decades (EPA 2008, Lichter *et al.* 2006). Many rivers in Maine, including the Androscoggin River, were heavily polluted in the past from industrial discharges from pulp and paper mills. While water quality has improved and most discharges are limited through regulations, many pollutants persist in the benthic environment. This can be particularly problematic if pollutants are present on spawning and nursery grounds, as developing eggs and larvae are particularly susceptible to exposure to contaminants.

The threat of vessel strike appears to be less for Atlantic sturgeon belonging to the Gulf of Maine DPS compared to the New York Bight or Chesapeake Bay DPSs based on the number of Atlantic sturgeon vessel struck carcasses that are found in Gulf of Maine rivers, and given the differences in vessel activity in the respective natal rivers. Nevertheless, some strikes do occur within the Gulf of Maine and sturgeon belonging to the Gulf of Maine can also be struck in other areas of their range including higher salinity waters of the Hudson River Estuary, Delaware River Estuary, and Chesapeake Bay.

We described in the listing rule that potential changes in water quality as a result of global climate change (temperature, salinity, dissolved oxygen, contaminants, etc.) in rivers and coastal waters inhabited by Atlantic sturgeon will likely affect riverine populations, and we expected these effects to be more severe for southern portions of the U.S. range. However, new information shows that the Gulf of Maine is one of the fastest warming areas of the world as a result of global climate change (Brickman *et al.* 2021, Pershing *et al.* 2015). Markin and Secor (2020) further demonstrate the consequences of temperature on the growth rate of juvenile Atlantic sturgeon, and informs how global climate change may impact growth and survival of Atlantic sturgeon across their range. Their study showed that all juvenile Atlantic sturgeon had increased growth rate with increased water temperature regardless of their genetic origins. However, based on modeling and water temperature data from 2008 to 2013, they also determined that there is an optimal water temperature range, above and below which juveniles experience a slower growth rate, and they further considered how changes in growth rate related to warming water temperatures associated with global climate change might affect juvenile survival given the season (e.g., spring or fall) in which spawning currently occurs.

There are no abundance estimates for the Gulf of Maine DPS or for the Kennebec River spawning population. Wippelhauser and Squiers (2015) reviewed the results of studies conducted in the Kennebec River System from 1977-2001. In total, 371 Atlantic sturgeon were captured, but the abundance of adult Atlantic sturgeon in the Kennebec spawning population could not be estimated because too few tagged fish were recaptured (i.e., 9 of 249 sturgeon).

Another method for assessing the number of spawning adults is through determinations of effective population size[6], which measures how many adults contributed to producing the next generation based on genetic determinations of parentage from the offspring. Effective population size is always less than the total abundance of a population because it is only a measure of parentage, and it is expected to be less than the total number of adults in a population because not all adults successfully reproduce. Measures of effective population size are also used to inform whether a population is at risk for loss of genetic diversity and inbreeding. The effective population size of the Gulf of Maine DPS was assessed in two studies based on sampling of adult Atlantic sturgeon captured in the Kennebec River in multiple years. The studies yielded very similar results which were an effective population size of: 63.4 (95% CI=47.3-91.1) (ASMFC 2017b) and 67 (95% CI=52.0–89.1) (Waldman *et al.* 2019).

Summary of the Gulf of Maine DPS

Spawning for the Gulf of Maine DPS occurs in Kennebec and may occur Androscoggin and in other rivers, such as the Penobscot, but has not been confirmed. In the Stock Assessment, the Commission concluded that the abundance of the Gulf of Maine DPS is "depleted" relative to historical levels and there is a 51 percent probability that abundance of the Gulf of Maine DPS has increased since implementation of the 1998 fishing moratorium (ASMFC 2017b). The Commission also noted that the Gulf of Maine is particularly data poor among all five DPSs. Atlantic sturgeon continue to be present in the Kennebec River; in addition, they are captured in directed research projects in the Penobscot River, and are observed in rivers where they were unknown to occur or had not been observed to occur for many years (e.g., the Saco, Presumpscot, and Charles rivers). The Saco River supports a large aggregation of Atlantic sturgeon that forage on sand lance in Saco Bay and within the first few kilometers (km) of the Saco River, primarily from May through October with some overwintering as well (Hylton *et al.* 2018, Little 2013b). However, none of the new information indicates recolonization of the Saco River for spawning.

Some of the impacts from the threats that contributed to the decline of the Gulf of Maine DPS have been removed (e.g., directed fishing), or reduced because of improvements in water quality and removal of dams (e.g., the Edwards Dam on the Kennebec River in 1999). There are strict regulations on the use of fishing gear in Maine state waters that incidentally catch sturgeon. In addition, there have been reductions in fishing effort in state and federal waters, which most

[6] Effective Population Size is the number of individuals that effectively participates in producing the next generation. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/effective-population-size. It is less than the total number of individuals in the population.

likely would result in a reduction in bycatch mortality of Atlantic sturgeon. A significant amount of fishing in the Gulf of Maine is conducted using trawl gear, which is known to have a much lower mortality rate for Atlantic sturgeon caught in the gear compared to sink gillnet gear (ASMFC 2007). Atlantic sturgeon from the Gulf of Maine DPS are not commonly taken as bycatch in areas south of Chatham, Massachusetts, and tagging results indicate that Gulf of Maine DPS fish tend to remain within the waters of the Gulf of Maine and only occasionally venture to points south. However, data on Atlantic sturgeon incidentally caught in trawls and intertidal fish weirs fished in the Minas Basin area of the Bay of Fundy (Canada) indicate that approximately 35 percent originated from the Gulf of Maine DPS (Wirgin *et al.* 2012). Dadswell *et al.* (2016) describes characteristics of the seasonal aggregation of sturgeon in the Bay of Fundy and NMFS considers the results of Dadswell *et al.* (2016) as representative of the movement of the Gulf of Maine DPS of Atlantic sturgeon. Dadswell *et al*. (2016) determined subadult and adult Atlantic sturgeon occur seasonally (approximately May to September) in the Bay of Fundy for foraging, and many return in consecutive years.

As noted previously, studies have shown that in order to rebuild, Atlantic sturgeon can only sustain low levels of bycatch and other anthropogenic mortality (ASMFC 2007, Boreman 1997, Brown and Murphy 2010, Kahnle *et al.* 2007). We have determined that the Gulf of Maine DPS is at risk of becoming endangered in the foreseeable future throughout all of its range (i.e., is a threatened species) based on the following: (1) significant declines in population sizes and the protracted period during which sturgeon populations have been depressed; (2) the limited amount of current spawning; and, (3) the impacts and threats that have and will continue to affect recovery.

5.2.7 New York Bight DPS of Atlantic sturgeon

The New York Bight DPS includes the following: all anadromous Atlantic sturgeon spawned in the watersheds that drain into coastal waters (including bays and sounds) from Chatham, Massachusetts to the Delaware-Maryland border on Fenwick Island (Figure 1). Within this range, Atlantic sturgeon historically spawned in the Connecticut, Delaware, Hudson, and Taunton Rivers (ASSRT 2007, Murawski and Pacheco 1977, Secor 2002). Spawning still occurs in the Delaware and Hudson Rivers, but there is no recent evidence (within the last 15 years) of spawning in the Taunton River (ASSRT 2007). However, in 2014 new inconclusive information regarding potential Connecticut River spawning was received. Additionally, Atlantic sturgeon that are spawned elsewhere continue to use habitats within the Connecticut and Taunton Rivers as part of their overall marine range (ASSRT 2007, Savoy 2007, Wirgin and King 2011).

There is uncertainty related to trends in abundance for the New York Bight DPS (ASMFC 2017b). The Commission concluded for their 2017 Atlantic Sturgeon Stock Assessment that abundance of the New York Bight DPS is "depleted" relative to historical levels but, there is a relatively high probability (75 percent) that the New York Bight DPS abundance has increased since the implementation of the 1998 fishing moratorium, and a 31 percent probability that mortality for the New York Bight DPS exceeds the mortality threshold used for the assessment (ASMFC 2017b). Moreover, new information suggests that the Commission's conclusions primarily reflect the status and trend of only the DPS's Hudson River spawning population. The ASMFC did not estimate the abundance of the New York Bight DPS or otherwise quantify the trend in abundance because of the limited available information.

At this time, there are no overall abundance estimates for the entire New York Bight DPS. There are, however, some abundance estimates for specific life stages (e.g., natal juvenile abundance, spawning run abundance, and effective population size). In 1995, sampling crews on the Hudson River estimated that there were 9,500 juvenile Atlantic sturgeon in the estuary. Because 4,900 of these were stocked hatchery-raised fish, about 4,600 fish were of wild origin. Based on the juvenile assessments from Bain *et al.* (2000), the Hudson River suffered a series of recruitment failures, which triggered the ASMFC fishing moratorium in 1998 to allow the populations to recover. Based on commercial fishery landings from the mid-1980s to the mid-1990s, the total abundance of adult Hudson River Atlantic sturgeon was estimated to be 870 individuals (Kahnle *et al.* 2007). Using side scan sonar technology in conjunction with detections of previously tagged Atlantic sturgeon, Kazyak *et al*. (2021) estimated the 2014 Hudson River spawning run size to be 466 sturgeon (95% CI = 310-745). While the spawning run estimate by Kazyak *et al.* (2021) cannot be directly compared with the estimated total abundance of adults in the early 1990s to determine if adult abundance has changed since the fishery was closed, it is clear that adult abundance is still several magnitudes lower than historical abundances. There is evidence to support the notion that the Hudson River spawning population is more robust than the Delaware River spawning population. This is further supported by the fact that Atlantic sturgeon originating from the Hudson River spawning population are more prevalent in mixed aggregations than sturgeon originating from the Delaware River spawning population.

At the time of listing, catch-per-unit-effort (CPUE) data suggested that recruitment remained depressed relative to catches of juvenile Atlantic sturgeon in the Hudson River estuary during the mid-late 1980s (Fisher 2011, Sweka *et al.* 2007). In examining the CPUE data from 1985-2007, there are significant fluctuations during this time. There appears to be a decline in the number of juveniles between the late 1980s and early 1990s while the CPUE is generally higher in the 2000s as compared to the 1990s. Given the significant annual fluctuation, it is difficult to discern any trend. Despite the CPUEs from 2000-2007 being generally higher than those from 1990-1999, they are low compared to the late 1980s. However, the New York State Department of Environmental Conservation (DEC) has conducted annual surveys for Atlantic sturgeon juveniles in the Hudson River since 2004. Annual surveys for Atlantic sturgeon juveniles in the Hudson River conducted by the New York State Department of Environmental Conservation (NYDEC) since 2004 suggests that the catch rate of juvenile Atlantic sturgeon increased significantly during the period from 2005 to 2015 (DuFour and Qian 2023). Further, Pendleton and Adams (2021) estimated that the average catch rate for the period from 2012-2019 doubled compared to the previous eight years, from 2004-2011. Thus, the fishing moratorium may have resulted in an increase in recruitment of female spawners (and consequently number of juveniles produced) or the increase may have been because survival of early life stages and/or juveniles has increased (for unknown reasons) in the Hudson River since 2004. Still, there is currently not enough information regarding any life stage to establish a trend for the entire Hudson River population.

White *et al.* (2022) recently estimated the number (Ns) of adults in the Delaware River that successfully reproduced in order to create a cohort of offspring by using genetic pedigrees constructed from progeny genotypes. Ns estimates the number of successful breeders and is not synonymous with effective population size (Ne) or effective number of breeders (Nb) as these metrics describe genetic processes (e.g., inbreeding and genetic drift; Jamieson and Allendorf 2012, Waldman *et al.* 2019, Wang *et al.* 2016). (White *et al.* 2022) estimated that Ns ranged from 42 (95% CI: 36-64) spawners in 2014 to 130 (95% CI: 116-138) spawners in 2017 during the years from 2013 to 2019. Because Ns only includes adults that generate at least one offspring during a single breeding season, it sets a lower bound on the size of the spawning run. Nevertheless, the genetics information indicates that at least 42 to 130 adults successfully contributed to the 2014- and 2017-year classes. White *et al.* (2022) concluded that bias in the data when sample size of offspring is small may result in the Ns being underestimated, as such, the Ns for Delaware River Atlantic sturgeon is likely between 125 and 250. Hale *et al.* (2016) estimated that 3,656 (95% CI = 1,935-33,041) early juveniles (age zero to one) utilized the Delaware River estuary as a nursery in 2014.

The effective population size (Ne) measures the genetic behavior (inbreeding and genetic drift) of a stable population with a 50/50 sex ratio, random mating, and equal reproductive success among individuals (i.e., an idealized population). Thus, the Ne is not a population estimate but is used in conservation biology as a measure of the population's short- or long-term viability. Since the Ne is based on an 'idealized' population, the actual population of reproductive individuals needed for a particular Ne will usually, but not always, be larger than Ne. However, there is a general relationship between the size of the census population and the size of Ne. (White *et al.* 2021) found that the differences in estimated Ne between Atlantic sturgeon populations roughly corresponded to the differences in total population size. As such, the Hudson River has one of the largest estimates of Ne while the Delaware River has one of the smallest estimates. Based on genetic analyses of two different life stages, subadults and natal juveniles, Ne for the Hudson River population has been estimated to be 198 (95% CI=171.7-230.7; (O'Leary *et al.* 2014)) and 156 (95% CI=138.3-176.1), respectively, (Waldman *et al.* 2019), while estimates for the Delaware River spawning population from the same studies are 108.7 (95% CI=74.7-186.1) (O'Leary *et al.* 2014) and 40 (95% CI=34.7-46.2) (Waldman *et al.* 2019), respectively. Genetic testing can differentiate between individuals originating from the Hudson or Delaware River and available information suggests that the straying rate is moderate between these rivers (Grunwald *et al.* 2008). However, the small sample size and the potential inclusion of non-natal fish in the samples may bias the calculations for the Delaware and Hudson Rivers (L. Lankshear, personal communication, April 2023).

While the White *et al.* (2021) study did not address the status of short and long term viability of either population, the differences in estimated population size for the Hudson and Delaware River spawning populations and in Ne support the notion that the Hudson River spawning population is the more robust of the two spawning groups. This trend is further supported by genetic analyses that demonstrates Atlantic sturgeon originating from the Hudson River spawning population were more prevalent in mixed aggregations than sturgeon originating from the Delaware River spawning population, even when sampling occurred in areas and at times that targeted adults belonging to the Delaware River spawning population (Wirgin *et al.* 2015a, Wirgin and King). The Waldman *et al.* (2019) calculations of maximum effective population size, and comparison of these to four other spawning populations outside of the New York Bight DPS further supports our previous conclusion that the Delaware River spawning population is less robust than the Hudson River, which is likely the most robust of all of the U.S. Atlantic sturgeon spawning populations.

New information from Breece *et al.* (2021) supports evidence of males having shorter spawning periodicity than females, but that females have more variability in the timing and number of spawning runs they make in the Hudson River. Salvage data from 2016 of a female Atlantic sturgeon in the Delaware River provided further support for the timing of spring spawning. Although the most recent Stock Assessment noted that movement of tagged fish and anecdotal reports suggest a fall spawning in the Delaware River; no further information is available to confirm whether it is occurring at this time.

In 2014, the Connecticut Department of Energy and Environmental Protection (CT DEEP) captured Atlantic sturgeon in the river that, based on their size, had to be less than one year old. Therefore, given the established life history patterns for Atlantic sturgeon which include remaining in lower salinity water of their natal river estuary for more than one year, the sturgeon were likely spawned in the Connecticut River. However, genetic analysis for 45 of the smallest fish (ranging from 22.5 to 64.0 cm (9 to 25 in) TL) indicated that the sturgeon were most closely related to Atlantic sturgeon belonging to the South Atlantic DPS (Savoy *et al.* 2017). The conventional thinking is that the Connecticut River was most likely to be recolonized by Atlantic sturgeon from the Hudson River spawning population because: (1) it is the closest of the known spawning rivers to the Connecticut; the most robust of all of the spawning populations; and, (2) it occurs within the same, unique, ecological setting. Furthermore, the majority of the Atlantic sturgeon that aggregate in the Lower Connecticut River and Long Island Sound originate from the New York Bight DPS (primarily the Hudson River spawning population) whereas less than 10 percent originate from the South Atlantic DPS (Waldman *et al.* 2013). The genetic results for the juvenile sturgeon are, therefore, counter to prevailing information regarding straying and the affinity of Atlantic sturgeon for natal homing. The genetic analyses of the juvenile sturgeon also showed that many (i.e., 82 percent) were full siblings which means that relatively few adults contributed to this cohort. Based on the genetic analysis of the captured juveniles using the calculations utilized for the Hudson and Delaware Rivers, the effective population (Ne) size for the Connecticut River was estimated to be 2.4 sturgeon (Savoy *et al.* 2017). The CT DEEP is conducting a multiyear investigation to further inform the status and origin of Atlantic sturgeon spawning in the river. At this time, we are not able to conclude whether the juvenile sturgeon detected are indicative of sustained spawning in the river or whether they were the result of a single spawning event due to unique straying of the adults from the South Atlantic DPS's spawning rivers.

As previously mentioned, there is no abundance estimate for the New York Bight DPS. As such, for the purposes of ESA Section 7 consultations, we estimated adult and subadult abundance of the New York Bight DPS based on available information for the genetic composition and the estimated abundance of Atlantic sturgeon in marine waters (Damon-Randall *et al.* 2013, Kocik *et al.* 2013). We use the mixed stock marine analysis as a proxy for in river composition because we do not have a subadult and adult mixed stock analysis for in-river usage. Therefore, we define the subadult and adult abundance of the New York Bight DPS as 34,567 sturgeon (NMFS 2014). This number encompasses many age classes since subadults can be as young as one year old when they first enter the marine environment, and adults can live as long as 64 years (Balazik *et al.* 2012c, Hilton *et al.* 2016). For example, in their study of Atlantic sturgeon captured in the geographic New York Bight, Dunton *et al.* (2016) determined that 742 of the Atlantic sturgeon captured represented 21 estimated age classes and that, individually, the sturgeon ranged in age from 2 to 35 years old.

A number of threats to Atlantic sturgeon exist in marine waters including bycatch in fishing gear. In 2016, the NEFSC prepared Atlantic sturgeon bycatch estimates for the Northeast sink gillnet and otter trawl fisheries for the years 2011-2015. Using this information, the authors of the latest Atlantic Sturgeon Benchmark Stock Assessment (ASMFC 2017b) estimated that 1,139 fish (295 lethal; 25 percent) were caught in gillnet fisheries and 1,062 fish (41 lethal; 4 percent) were caught in otter trawl fisheries each year from 2000-2015. As presented in the mixed stock analysis results by Wirgin and King (2011), over 40 percent of the Atlantic sturgeon bycatch interactions in the Mid-Atlantic Bight region were sturgeon from the New York Bight DPS. In addition to capture in fisheries operating in federal waters, bycatch and mortality also occur in state fisheries; however, the primary fishery that impacted juvenile sturgeon (shad) in the Hudson River, has now been closed and there is no indication that it will reopen soon. Commercial shad fishery continues in the Delaware Bay but is closed in the Delaware River. In the Hudson River, sources of potential mortality include vessel strikes and entrainment in dredges. Impingement at water intakes, including the Danskammer, Roseton, Indian Point, Salem, and Hope Creek (on the Delaware river) power plants also occurs.

Several additional threats play a role in shaping the current status and trends observed in the Delaware River and Estuary. In-river threats include habitat disturbance from dredging, and impacts from historical pollution and impaired water quality, and climate change (EPA 2008, Lichter *et al.* 2006). Both the Hudson and Delaware rivers, as well as other rivers in the New York Bight region, were heavily polluted in the past from industrial and sanitary sewer discharges. While water quality has improved and most discharges are limited through regulations, many pollutants persist in the benthic environment. This can be particularly problematic if pollutants are present on spawning and nursery grounds, as developing eggs and larvae are particularly susceptible to contaminant exposure. Annual differences in the capture rates of age 0-1 Atlantic sturgeon in the fall and comparisons to annual dissolved oxygen levels during the preceding summer months provide additional evidence that low dissolved oxygen levels are causing or contributing to the death of the young sturgeon in the Delaware River in some years (Moberg and DeLucia 2016, Stetzar *et al.* 2015). On December 1, 2022, the EPA issued a determination that revised Water Quality Standards are necessary for the Delaware River Estuary to meet the requirements of the Clean Water Act. Specifically, the EPA determined that the aquatic life designated uses and corresponding dissolved oxygen criterion in Zones 3, 4, and RKM 126.8 to 112.7 (RM 78.8 to 70.0) of Zone 5 of the Delaware River Estuary must be revised to protect the propagation of resident and migratory fish species, including Atlantic and shortnose sturgeon, which are likely experiencing adverse effects under the currently applicable Water Quality Standards that were established in 1967.

On the Delaware River, a dredged navigation channel extends from Trenton seaward through the tidal river (Brundage and O'Herron 2009), and the river receives significant shipping traffic. A dredged navigation channel is present in the Hudson River as well. Although dredging occurs regularly, some projects have observers and some do not. At this time, we have reports of one Atlantic sturgeon entrained during hopper dredging operations in Ambrose Channel, New Jersey, and four fish were entrained in the Delaware River during maintenance and deepening activities in 2017 and 2018. Modeling by Breece *et al.* (2013) demonstrates that the Delaware River salt front is likely to advance even further upriver with climate change, which would reduce the amount of transitional salinity habitat available to natal juveniles, and individuals using the aforementioned habitat for specific behaviors. Coupled with other climate and anthropogenic changes, such as drought and channel deepening, the already limited amount of tidal freshwater habitat available for spawning could be reduced and the occurrence of low dissolved oxygen within early juvenile rearing habitat could increase.

Vessel strikes have been identified as a major threat in the Hudson and Delaware Rivers for migrating sturgeon and individuals aggregating on limited spawning or overwintering grounds. Vessel strikes occur in the Delaware River and Bay. One-hundred and three (103) Atlantic sturgeon mortalities believed to be the result of vessel strikes were documented in the Delaware River from 2005 to 2019, and at least 65 of these fish were large adults and subadults (data provided by DNREC, 2020). Fox *et al.* (2020) conducted a study of sturgeon carcass reporting rates in the Delaware River and Bay that found that the overall reporting rate of Atlantic Sturgeon carcasses was low (4.76%). Based on the study results coupled with sightings of sturgeon carcasses, Fox *et al.* (2020) estimated that a 199 and 213 carcasses were present along the Delaware Estuary shoreline in 2018 and 2019, respectively. Based on evidence of Atlantic sturgeon vessel strikes since the listing, it is now apparent that vessel strikes are also occurring in the Hudson River. For example, the New York DEC reported that at least 17 dead Atlantic sturgeon with vessel strike injuries were found in the river in 2019 of which at least 10 were adults. Additionally, 108 Atlantic sturgeon carcasses were observed on the Hudson River and reported to the NYSDEC between 2013 and 2017. Of these, 71 were suspected of having been killed by vessel strike (NMFS 2017c). Genetic analysis has not been completed on any of these individuals to date, given that the majority of Atlantic sturgeon in the Hudson River belong to the New York Bight DPS, we assume that the majority of the dead sturgeon reported to NYSDEC belonged to the New York Bight DPS. Given the time of year in which the fish were observed (predominantly May through July), it is likely that many of the adults were migrating through the river to the spawning grounds.

Based on genetic analyses, Atlantic sturgeon belonging to the New York Bight DPS have been identified among those captured in the Bay of Fundy, Canada as well as in U.S. waters that include Long Island Sound, the lower Connecticut River, and in marine waters off of western Long Island, New Jersey, Delaware, Virginia, and North Carolina. However, the New York Bight DPS was more prevalent relative to the other DPSs in Mid-Atlantic marine waters, bays, and sounds (Dunton *et al.* 2012, 2019, Waldman *et al.* 2013, Wirgin *et al.* 2015a, 2018). These findings support the conclusion of Wirgin *et al.* (2015b) that natal origin influences the distribution of Atlantic sturgeon in the marine environment, and suggest that some parts of its marine range are more useful to and perhaps essential to the New York Bight DPS.

Further evidence was presented by Erickson *et al.* (2011). Thirteen of the fifteen adult Atlantic sturgeon, that they captured and tagged in the tidal freshwater reach of the Hudson River (i.e., belonging to the Hudson River spawning population), remained in the Mid-Atlantic Bight during the 6 months to one year time period of data collection. Of the remaining two fish, one traveled as far north as Canadian waters where its tag popped up in June, nearly one year after being tagged. The second fish traveled south beyond Cape Hatteras[7] before its tag popped up, about 7 months after being tagged. Collectively, all of the tagged sturgeon occurred in marine and estuarine Mid-Atlantic Bight aggregation areas that have been the subject of sampling used for the genetic analyses, including in waters off Long Island, the coasts of New Jersey and Delaware, the Delaware Bay and the Chesapeake Bay.

Breece *et al.* (2016) further investigated the distribution and occurrence of Atlantic sturgeon in the Mid-Atlantic Bight based on associated habitat features, as well as the habitat features associated with presence of adults in the Delaware River, and their distribution and movements within Delaware Bay. The research provides evidence of specific, dynamic habitat features that Atlantic sturgeon are sensitive to in their aquatic environments such as substrate composition and distance from the salt front in the river estuary, water depth and water temperature in Delaware Bay, and depth, day-of-year, sea surface temperature, and light absorption by seawater in marine waters (2017, 2018, Breece *et al.* 2013). Their model, based on the features identified for the marine environment, was highly predictive of Atlantic sturgeon distribution in the Mid-Atlantic Bight from mid-April through October. Since the majority of Atlantic sturgeon occurring in the Mid-Atlantic Bight belong to the New York Bight DPS, these studies provide: (1) new information describing the environmental factors that influence the presence and movements of New York Bight DPS Atlantic sturgeon in the Mid-Atlantic Bight, the Delaware Bay and the Delaware River; (2) a modeling approach for predicting occurrence and distribution of New

[7] As explained in Erickson *et al.* (2011), relocation data for both of these fish were more limited for different reasons. Therefore, more exact locations could not be determined.

York Bight DPS Atlantic sturgeon, particularly in the spring through early fall; and, (3) information to better assess consequences to the New York Bight DPS given known, expected, or predicted changes to their habitat.

Summary of the New York Bight DPS

Atlantic sturgeon originating from the New York Bight DPS spawn in the Hudson and Delaware rivers. While genetic testing can differentiate between individuals originating from the Hudson or Delaware River, White *et al.* (2023) found that their genetic analysis could not distinguish Delaware River Atlantic sturgeon from Hudson River Atlantic sturgeon as clearly as they could distinguish Atlantic sturgeon from other rivers included in the study. This more recent study reinforces the findings of Grunwald *et al.* (2008) that there is moderate straying between river systems, which further supports the single DPS represented in the New York Bight.

There is uncertainty related to trends in abundance for the New York Bight DPS (ASMFC 2017b). The 2017 ASMFC Atlantic Sturgeon Stock Assessment states that the abundance of the New York Bight DPS is "depleted" relative to historical levels, but there is a relatively high probability (75 percent) that the New York Bight DPS abundance has increased since the implementation of the 1998 fishing moratorium. However, new information suggests that these conclusions primarily reflect the status and trend of only the Hudson River spawning population (NMFS 2022). Some of the impacts from the threats that contributed to the decline of the New York Bight DPS have been removed (e.g., directed fishing) or reduced as a result of improvements in water quality since passage of the CWA. In addition, there have been reductions in fishing effort in state and federal waters, which may result in a reduction in bycatch mortality of Atlantic sturgeon. Nevertheless, areas with persistent, degraded water quality, habitat impacts from dredging, global climate change, continued bycatch in state and federally-managed fisheries, and vessel strikes remain significant threats to the New York Bight DPS.

Additional information is available that informs the consequences of climate change on the New York Bight DPS. There is already evidence of habitat changes in the Delaware River from other anthropogenic activities. Modeling by Breece *et al.* (2013) demonstrates that the Delaware River salt front is likely to advance even further upriver with climate change, which would reduce the amount of transitional salinity habitat available to natal juveniles and would potentially restrict habitat for other necessary behaviors. With already limited tidal freshwater habitat available for spawning, habitat could be further reduced and the occurrence of low dissolved oxygen within early juvenile rearing habitat could increase. As evidenced by the studies of Hare *et al.* (2016) and Balazik *et al.* (2010), the Delaware spawning population is unlikely to redistribute to another river even if their habitat in the Delaware River is increasingly insufficient to support successful spawning and rearing for the New York Bight DPS due to climate change.

In the marine range, New York Bight DPS Atlantic sturgeon are incidentally captured in federal and state managed fisheries, reducing survivorship of subadult and adult Atlantic sturgeon (ASMFC 2007, Stein *et al.* 2004a). For Atlantic sturgeon, the model-based estimates of annual bycatch in gillnet and bottom trawl gear published in ASMFC (2017) represent the best available information for and analysis of bycatch. From 2011-2015, the average annual bycatch of Atlantic sturgeon in bottom otter trawl gear was 777.4 sturgeon under the best fit model. From 2011-2015, the average annual bycatch of Atlantic sturgeon in gillnet gear was 627.6 sturgeon under best fit model (ASMFC 2017b).

The best performing model for each gear type was applied to Vessel Trip Reports (VTRs) to predict Atlantic sturgeon bycatch across all trips. The total bycatch of Atlantic sturgeon from bottom otter trawls ranged between 624-1,518 fish over the 2000-2015 time series. The proportion of the encountered Atlantic sturgeon recorded as dead ranged from 0-18 percent (average 4 percent). This resulted in annual dead discards ranging from 0-209 fish. The total bycatch of Atlantic sturgeon from gillnets ranged from 253-2,715 fish. The proportion of Atlantic sturgeon recorded as dead ranged from 12-51 percent (average 30 percent), resulting in annual dead discards ranging from 110-690 fish. Otter trawls and gillnets caught similar sizes of Atlantic sturgeon, with most fish in the 3.3-6.6 ft (100-200 cm) total length range, although both larger and smaller individuals were captured. Wirgin and King (2011), indicates that over 40 percent of the Atlantic sturgeon bycatch interactions in the Mid-Atlantic Bight region were sturgeon from the New York Bight DPS. Individual-based assignment and mixed stock analysis of samples collected from sturgeon captured in Canadian fisheries in the Bay of Fundy indicated that approximately 1-2 percent were from the New York Bight DPS (Wirgin *et al.* 2012). At this time, we are not able to quantify the impacts from other threats or estimate the number of individuals killed as a result of other anthropogenic threats.

Riverine habitat may be impacted by dredging and other in-water activities, disturbing spawning habitat and altering the benthic forage base. Both the Hudson and Delaware rivers have navigation channels that are maintained by dredging. Dredging is also used to maintain channels in the nearshore marine environment. Dredging outside of Federal channels and in-water construction occurs throughout the New York Bight region. While some dredging projects operate with observers present to document fish mortalities, many do not. We have reports of one Atlantic sturgeon entrained during hopper dredging operations in Ambrose Channel, New Jersey, and four fish were entrained in the Delaware River during maintenance and deepening activities in 2017 and 2018. At this time, we do not have any additional information to quantify the number of Atlantic sturgeon killed or disturbed during dredging or in-water construction projects. We are also not able to quantify any consequences to habitat.

In the Hudson and Delaware Rivers, dams do not block access to historical habitat. The Holyoke Dam on the Connecticut River blocks further upstream passage; however, the extent that Atlantic sturgeon would historically have used habitat upstream of Holyoke is unknown. Connectivity may be disrupted by the presence of dams on several smaller rivers in the New York Bight region. Because no Atlantic sturgeon occur upstream of any hydroelectric projects in the New York Bight region, passage over hydroelectric dams or through hydroelectric turbines is not a source of injury or mortality in this area.

New York Bight DPS Atlantic sturgeon may also be affected by degraded water quality. In general, water quality has improved in the Hudson and Delaware over the past decades (EPA 2008, Lichter *et al.* 2006). With improved water quality and toxic discharges limited through regulations, reduced in-water pollutants may be less of a concern, but legacy pollutants may exist long term in the benthic environment. When pollutants are present on spawning and nursery grounds, where sensitive life stages occur, there is potential for long-term impacts to developing individuals.

Vessel strikes occur in the Delaware River and Bay, and many mortalities have been identified as large adults and subadults. The New York DEC has also reported that dead Atlantic sturgeon with vessel strike injuries in the river in 2019, confirming that vessel strikes are also an issue on the Hudson River. Given the time of year in which the fish were observed (predominantly May through July), it is likely that many of the adults were migrating through the river to the spawning grounds, and are assumed to be of New York Bight DPS origin.

Studies have shown that to rebuild, Atlantic sturgeon can only sustain low levels of anthropogenic mortality (ASMFC 2007, Boreman 1997, Brown and Murphy 2010, Kahnle *et al.* 2007). There are no empirical abundance estimates of the number of Atlantic sturgeon in the New York Bight DPS. For the listing of the New York Bight DPS, we determined that the DPS is currently at risk of extinction due to: (1) precipitous declines in population sizes and the protracted period in which sturgeon populations have been depressed; (2) the limited amount of current spawning; and (3) the impacts and threats that have, and will continue to affect population recovery (77 FR 5880, February 6, 2012). We reviewed new information for the 5-Year Review that became available since the listing and we concluded that the status of the DPS has likely neither improved nor declined from what it was when the DPS was listed in 2012. We, therefore, continued to recommend classification for the New York Bight DPS of Atlantic sturgeon as “endangered.” (NOAA 2022).

5.2.8 Chesapeake Bay DPS of Atlantic sturgeon

The Chesapeake Bay DPS of Atlantic sturgeon includes Atlantic sturgeon spawned in the watersheds that drain into the Chesapeake Bay and into coastal waters (including bays and sounds) from the Delaware-Maryland border at Fenwick Island to Cape Henry, Virginia. The marine range of Atlantic sturgeon from the Chesapeake Bay DPS extends from Hamilton Inlet, Labrador, Canada, to Cape Canaveral, Florida. Recent data confirms that Chesapeake Bay Atlantic sturgeon are most prevalent in the marine environment throughout the Mid-Atlantic Bight from Delaware to Cape Hatteras (Kazyak *et al.* 2021). The riverine range of the Chesapeake Bay DPS and the adjacent portion of the marine range are shown in Figure 1. Within this range, Atlantic sturgeon historically spawned in the Susquehanna, Potomac, James, York, Rappahannock, and Nottoway Rivers (ASSRT 2007). Based on the review by Oakley (2003), 100 percent of Atlantic sturgeon habitat is currently accessible in these rivers since most of the barriers to passage (i.e., dams) are located upriver of where spawning is expected to have historically occurred (ASSRT 2007). Spawning still occurs in the James River, amongst the additional spawning populations for the Chesapeake Bay DPS, and there is evidence that most of the Chesapeake Bay DPS spawning populations spawn in the late summer to fall (hereafter referred to as "fall spawning") rather than in the spring. Fall spawning activity has been documented in the newly discovered spawning populations in the Pamunkey River, a tributary of the York River, and in Marshyhope Creek, a tributary of the Nanticoke River (Hager *et al.* 2014, Kahn *et al.* 2014, Richardson and Secor 2016, Secor *et al.* 2021). The James River is currently the only river of the Chesapeake Bay DPS where evidence suggests there is both spring and fall spawning with separate spawning populations. The results of genetic analyses show that there is some limited gene flow between the populations but, overall, the spawning populations are genetically distinct (Balazik *et al.* 2017b, Balazik *et al.* 2012c, Balazik and Musick 2015). New detections of acoustically-tagged adult Atlantic sturgeon along with historical evidence suggests that Atlantic sturgeon belonging to the Chesapeake Bay DPS may be spawning in the Mattaponi and Rappahannock rivers as well (ASMFC 2017b, Hilton *et al.* 2016, Kahn 2019). However, information for these populations is limited and the research is ongoing.

Age to maturity for Chesapeake Bay DPS Atlantic sturgeon is unknown. However, Atlantic sturgeon riverine populations exhibit clinal variation with faster growth and earlier age to maturity for those that originate from southern waters, and slower growth and later age to maturity for those that originate from northern waters (75 FR 61872; October 6, 2010). Age at maturity is five to 19 years for Atlantic sturgeon originating from South Carolina rivers (Smith *et al.* 1982) and 11 to 21 years for Atlantic sturgeon originating from the Hudson River (Young *et al.* 1988). Recent data indicates that Chesapeake Bay DPS juvenile Atlantic sturgeon remain in the natal estuary between one and four years before emigrating to the marine environment (Balazik *et al*. 2012b), and that males mature at about age 10 and females at age 15 (Balazik *et al.* 2012b; Hilton *et al*. 2016). New information regarding spawning periodicity is supported by the fact that acoustically-tagged males have made annual returns to spawning locations. Tagged females have returned approximately every two to three years, with some returning annually (Balazik *et al*. 2017a; Kahn *et al*. 2019; Kahn *et al*. 2021; Secor *et al*. 2021). Additionally, Kahn *et al*. (2021) used detections of tagged male and female sturgeon to inform the sex ratio in the Pamunkey River spawning population (males make up approximately 51 percent (95% CI=0.43-0.58 of the adult population).

There is currently no total abundance estimate for the Chesapeake Bay DPS; however, we estimated subadult and adult abundance in marine waters and concluded that approximately 8,811 sturgeon comprise the DPS (NMFS 2013). There are also several estimates of effective population size for Atlantic sturgeon that are spawned in the James River although only one study examined the effective population size of both the spring and fall spawning populations. Nevertheless, the estimates of effective population size from separate studies and based on different age classes are similar. These are: 62.1 (95% CI=44.3-97.2) based on sampling of subadults captured off of Long Island across multiple years; 32 (95% CI=28.8-35.5) based on sampling of natal juveniles and adults in multiple years (Waldman *et al.* 2019); 40.9 (95% CI=35.6-46.9) based on samples from a combination of juveniles and adults, (ASMFC 2019); and, 44 (95% CI=26–79) and 46 (95% CI=32–71) for the spring and fall spawning populations, respectively, based on sampling of adults (Balazik *et al.* 2017b). There is a single estimate of 12.2 (95% CI = 6.7– 21.9) for the Nanticoke River system (Secor *et al.* 2021), and also a single estimate of 7.8 (95% CI=5.3-10.2) for the York River system based on samples from adults captured in the Pamunkey River (ASMFC 2017b).

Based on research captures of tagged adults, an estimated 75 Chesapeake Bay DPS Atlantic sturgeon spawned in the Pamunkey River in 2013 (Kahn *et al.* 2014). More recent information provided annual run estimates for the Pamunkey River from 2013 to 2018. The results suggest a spawning run of up to 222 adults but with yearly variability, likely due to spawning periodicity (Kahn 2019).

Research in the Nanticoke River system suggests a small adult population based on a small total number of captures (i.e., 26 sturgeon) and the high rate of recapture across several years of study (Secor *et al.* 2021). By comparison, 373 different adult-sized Atlantic sturgeon (i.e., total count does not include recaptures of the same fish) were captured in the James River from 2009 through spring 2014 (Balazik and Musick 2015). This is a minimum count of the number of adult Atlantic sturgeon in the James River during the time period because capture efforts did not occur in all areas and at all times when Atlantic sturgeon were present in the river.

New information regarding the importance of temperature on spawning and movement of sturgeon indicates that a relatively narrow temperature range (20°C to 25°C (68°F to 77°F)) triggers spawning, (Balazik *et al*. 2012a; Balazik *et al*. 2020; Hager *et al*. 2020; Secor *et al*. 2021), and new research has also demonstrated that limited hard-bottom habitat for Atlantic sturgeon spawning activities exist in Chesapeake Bay tributaries (Austin 2012; Bruce *et al*. 2016; Secor *et al*. 2021). Further informing potential spawning locations is research regarding the upriver range of the species based on detections of tagged adult Atlantic sturgeon (Balazik *et al*. 2021a; Hager *et al*. 2014; NMFS 2017; Secor *et al*. 2021), which supports the notion that available, suitable spawning habitat is sparse.

Several threats play a role in shaping the current status of Chesapeake Bay DPS Atlantic sturgeon. Historical records provide evidence of the large-scale commercial exploitation of Atlantic sturgeon from the James River and Chesapeake Bay in the 19th century (ASMFC 1998, ASSRT 2007, Bushnoe *et al.* 2005, Hildebrand and Schroeder 1928, Secor 2002, Vladykov and Greeley 1963) as well as subsistence fishing and attempts at commercial fisheries as early as the 17th century (ASSRT 2007, Balazik *et al.* 2010, Bushnoe *et al.* 2005, Secor 2002). Habitat disturbance caused by in-river work, such as dredging for navigational purposes, is thought to have reduced available spawning habitat in the James River (ASSRT 2007, Bushnoe *et al.* 2005, Holton and Walsh 1995). At this time, we do not have information to quantify this loss of spawning habitat.

Decreased water quality also threatens Atlantic sturgeon of the Chesapeake Bay DPS, especially since the Chesapeake Bay system is vulnerable to the consequences of nutrient enrichment due to a relatively low tidal exchange and flushing rate, large surface-to-volume ratio, and strong stratification during the spring and summer months (ASMFC 1998, ASSRT 2007, EPA 2008, Pyzik *et al.* 2004). These conditions contribute to reductions in dissolved oxygen levels throughout the Bay. The availability of nursery habitat, in particular, may be limited given the recurrent hypoxia (low dissolved oxygen) conditions within the Bay (Niklitschek and Secor 2005, 2010). Heavy industrial development during the 20th century in rivers inhabited by sturgeon impaired water quality and impeded these species' recovery.

Although there have been improvements in some areas of the Bay's health, the ecosystem remains in poor condition. In 2022, the Chesapeake Bay Foundation gave the overall health index of the Bay a grade of 32 percent (D+) based on the best available information about the Chesapeake Bay for indicators representing three major categories: pollution, habitat, and fisheries (Chesapeake Bay Foundation 2020). The score remained unchanged from 2020; however, of the 13 indicators assessed, three improved, three declined, and seven stayed the same. While 32 percent is one percent lower than the state of the Bay score in 2018, this was an 18.5 percent increase from the first State of the Bay report in 1998, which gave the Bay a score of 27 percent (D). According to the Chesapeake Bay Foundation, the unchanged score is largely a result of failures to make needed changes on farmland to reduce pollution, but noted improvements due to the promising results from oyster reef restoration, regulations allowing the striped bass population to rebuild by 2029, less phosphorous in the water and a smaller dead zone. Highlights from the 2022 report are summarized below:

- Monitoring data indicated that the 2022 dead zone was the tenth smallest in the past 38 years;
- Water clarity dropped one point in the report due to average water clarity in the Bay decreasing slightly in 2022 compared to 2020;
- In the pollution category nitrogen, toxics, and dissolved oxygen indicators were unchanged, the phosphorus indicator improved, and overall water clarity declined. Recent farm conservation funding at the federal and state levels should help reduce nitrogen and phosphorus pollution, which fuels harmful algal blooms that remove dissolved oxygen from the water;
- In the fisheries category, the rockfish (striped bass) and oyster indicators rose, while the blue crab indicator declined(Chesapeake Bay Foundation 2020); and
- In the habitat category, scores for underwater grasses, forest buffers, and wetlands remained unchanged, but resource lands fell slightly by a point. Resource lands refer to forests, natural open areas, and well-managed farmland. The drop in score was largely due to approximately 95,000 acres of farms and forests transitioning to development across the Bay watershed during the most recent reporting period, from 2013/14 to 2017/18.

At this time, we do not have sufficient information to quantify the extent that degraded water quality affects habitat or individuals in the James River or throughout the Chesapeake Bay.

Vessel strikes have been observed in the James River (ASSRT 2007). Eleven Atlantic sturgeon were reported to have been struck by vessels from 2005-2007. More than 100 Atlantic sturgeon carcasses have been salvaged in the James River since 2007 and additional carcasses were reported but could not be salvaged (Greenlee *et al.* 2019). Many of the salvaged carcasses had evidence of a fatal vessel strike. In addition, vessel struck Atlantic sturgeon have been found in other parts of the Chesapeake Bay DPS's range including in the York and Nanticoke river estuaries, within Chesapeake Bay, and in marine waters near the mouth of the Bay since the DPS was listed as endangered (NMFS Sturgeon Salvage Permit Reporting; Secor *et al.* 2021). The best available information supports the conclusion that sturgeon are struck by small (e.g., recreational) as well as large vessels. NMFS has only minimum counts of the number of Atlantic sturgeon that are struck and killed by vessels because only the sturgeon that are found dead with evidence of a vessel strike are counted. New research, including a study conducted along the Delaware River that intentionally placed Atlantic sturgeon carcasses in areas used by the public, suggests that most Atlantic sturgeon carcasses are not found and, when found, many are not reported to NMFS or to our sturgeon salvage co-investigators (Balazik, pers. comm. in ASMFC 2017b, Balazik *et al.* 2012d, Fox *et al.* 2020). There has been an increased number of vessel struck sturgeon reported in the James River in recent years (ASMFC 2017b). However, it is unknown to what extent the numbers reflect increased carcass reporting.

In the marine and coastal range of the Chesapeake Bay DPS from Canada to Florida, fisheries bycatch in federally and state-managed fisheries poses a threat to the DPS, reducing survivorship of subadults and adults and potentially causing an overall reduction in the spawning population (ASMFC 2007, ASSRT 2007, Stein *et al.* 2004a).

Summary of the Chesapeake Bay DPS

There are no overall abundance estimates for the entire Chesapeake Bay DPS or for the spawning populations in the James River or the Nanticoke River system; however, estimates from the marine environment and effective population size are available. A study on effective population size for Atlantic sturgeon that are spawned in the James River examined the effective population size of both the spring and fall spawning populations, whereas in other rivers, only the fall pawning run was considered.

At this time, spawning for the Chesapeake Bay DPS is known to occur in only the James and Pamunkey Rivers and in the Nanticoke River system. Spawning may be occurring in other rivers, such as the Mattaponi, Rappahannock, and Potomac, but has not been confirmed for any of those. There are anecdotal reports of increased sightings and captures of Atlantic sturgeon in the James River. However, this information has not been comprehensive enough to develop a population estimate for the James River or to provide sufficient evidence to confirm increased abundance.

Based on research captures of tagged adults, an estimated 75 Chesapeake Bay DPS Atlantic sturgeon spawned in the Pamunkey River in 2013 (Kahn *et al.* 2014). The results suggest a spawning run of up to 222 adults but with yearly variability, likely due to spawning periodicity (Kahn 2019). Research in the Nanticoke River system suggests a small adult population based on a small total number of captures (i.e., 26 sturgeon) and the high rate of recapture across several years of study (Secor *et al.* 2021). By comparison, 373 different adult-sized Atlantic sturgeon (i.e., total count does not include recaptures of the same fish) were captured in the James River from 2009 through spring 2014 (Balazik and Musick 2015).

Some of the impacts from the threats that facilitated the decline of the Chesapeake Bay DPS have been removed (e.g., directed fishing) or reduced because of improvements in water quality since passage of the CWA. Areas with persistent, degraded water quality, habitat impacts from dredging, continued bycatch in U.S. state and federally-managed fisheries, Canadian fisheries, and vessel strikes remain significant threats to the Chesapeake Bay DPS of Atlantic sturgeon. Of the 35 percent of Atlantic sturgeon incidentally caught in the Bay of Fundy, about one percent were Chesapeake Bay DPS fish (Wirgin *et al.* 2012). Studies have shown that Atlantic sturgeon can only sustain low levels of bycatch mortality (ASMFC 2007, Boreman 1997, Kahnle *et al.* 2007). The Chesapeake Bay DPS is currently at risk of extinction given (1) precipitous declines in population sizes and the protracted period in which sturgeon populations have been depressed; (2) the limited amount of current spawning; and, (3) the impacts and threats that have and will continue to affect the potential for population recovery.

5.2.9 Carolina DPS of Atlantic sturgeon

The Carolina DPS includes all Atlantic sturgeon that spawn or are spawned in the watersheds (including all rivers and tributaries) from Albemarle Sound southward along the southern Virginia, North Carolina, and South Carolina coastal areas to Charleston Harbor. The marine range of Atlantic sturgeon from the Carolina DPS extends from the Hamilton Inlet, Labrador, Canada, to Cape Canaveral, Florida. The riverine range of the Carolina DPS and the adjacent portion of the marine range are shown in Figure 1. Sturgeon are commonly captured 64.4 km (40 mi) offshore (D. Fox, Delaware State University, pers. comm.). Records providing fishery bycatch data by depth show the vast majority of Atlantic sturgeon bycatch via gillnets is observed in waters less than 50 m (164 ft) deep (ASMFC 2007, Stein *et al.* 2004a), but Atlantic sturgeon are recorded as bycatch out to 500 fathoms.

Rivers known to have current spawning populations within the range of the Carolina DPS include the Roanoke, Tar-Pamlico, Cape Fear, Waccamaw, and Pee Dee Rivers. We determined spawning was occurring if young-of-the-year were observed or mature adults were present in freshwater portions of a system (Table 7). However, in some rivers, spawning by Atlantic sturgeon may not be contributing to population growth because of lack of suitable habitat and the presence of other stressors on juvenile survival and development. There may also be spawning populations in the Neuse, Santee, and Cooper Rivers, though it is uncertain. Historically, both the Sampit and Ashley Rivers were documented to have spawning populations at one time. However, the spawning population in the Sampit River is believed to be extirpated, and the current status of the spawning population in the Ashley River is unknown. Both rivers may be used as nursery habitat by young Atlantic sturgeon originating from other spawning populations.

Fish from the Carolina DPS likely use other river systems than those listed here for their specific life functions.

Table 7. Major rivers, tributaries, and sounds within the ranges of the Carolina DPS and currently available data on the presence of Atlantic sturgeon spawning population in each system.

River/Estuary	Spawning Population	Data
Roanoke River, VA/NC; Albemarle Sound, NC	Yes	collection of 15 YOY (1997-1998); single YOY (2005)
Tar-Pamlico River, NC; Pamlico Sound	Yes	one YOY (2005)
Neuse River, NC; Pamlico Sound	Unknown	
Cape Fear River, NC	Yes	upstream migration of adults in the fall, carcass of a ripe female upstream in mid-September (2006)
Waccamaw River, SC; Winyah Bay	Yes	age-1, potentially YOY (1980s)
Pee Dee River, SC; Winyah Bay	Yes	running ripe male in Great Pee Dee River (2003)
Sampit, SC; Winyah Bay	Extirpated	
Santee River, SC	Unknown	
Cooper River, SC	Unknown	
Ashley River, SC	Unknown	

Historical landings data indicate that between 7,000 and 10,500 adult female Atlantic sturgeon were present in North Carolina prior to 1890 (Armstrong and Hightower 2002, Secor 2002). Secor (2002) estimates that 8,000 adult females were present in South Carolina during that same time frame. Prior reductions from the commercial fishery and ongoing threats have drastically reduced the numbers of Atlantic sturgeon within the Carolina DPS. Currently, the Atlantic sturgeon spawning population in at least one river system within the Carolina DPS has been extirpated, with potential extirpation in an additional system. The abundances of the remaining river populations within the DPS, each estimated to have fewer than 300 spawning adults, are estimated to be less than 3 percent of what they were historically (ASSRT 2007). We have estimated that there are a minimum of 1,356 Carolina DPS adult and subadult Atlantic sturgeon of size vulnerable to capture in U.S. Atlantic waters.

Overutilization of Atlantic sturgeon from directed fishing caused initial severe declines in Atlantic sturgeon populations in the Southeast in the mid- to late 19th century, from which they have never rebounded. Continued bycatch of Atlantic sturgeon in commercial fisheries is an ongoing impact to the Carolina DPS. More robust fishery independent data on bycatch are available for the Northeast and Mid-Atlantic than in the Southeast where high levels of bycatch underreporting are suspected.

Although there are statutory and regulatory provisions that authorize reducing the impact of dams on riverine and anadromous species, these mechanisms have proven inadequate for preventing dams from blocking access to habitat upstream and degrading habitat downstream. Water quality continues to be a problem in the Carolina DPS, even with existing controls on some pollution sources. Current regulatory regimes are not effective in controlling water allocation issues (e.g., no restrictions on interbasin water transfers in South Carolina, the lack of ability to regulate non-point source pollution, etc.).

Summary of the Status of the Carolina DPS of Atlantic Sturgeon

Recovery of depleted populations is an inherently slow process for a late-maturing species such as Atlantic sturgeon. Their late age at maturity provides more opportunities for individuals to be removed from the population before reproducing. While a long life-span also allows multiple opportunities to contribute to future generations, this is hampered within the Carolina DPS by habitat alteration and bycatch. This DPS was severely depleted by past directed commercial fishing, and faces ongoing impacts and threats from habitat alteration or inaccessibility, bycatch, and the inadequacy of existing regulatory mechanisms to address and reduce habitat alterations and bycatch that have prevented river populations from rebounding and will prevent their recovery.

The presence of dams has resulted in the loss of more than 60 percent of the historical sturgeon habitat on the Cape Fear River and in the Santee-Cooper system. Dams are contributing to the status of the Carolina DPS by curtailing the extent of available spawning habitat and further modifying the remaining habitat downstream by affecting water quality parameters (such as depth, temperature, velocity, and dissolved oxygen) that are important to sturgeon. Dredging is also contributing to the status of the Carolina DPS by modifying Atlantic sturgeon spawning and nursery habitat. Habitat modifications through reductions in water quality are contributing to the status of the Carolina DPS due to nutrient-loading, seasonal anoxia, and contaminated sediments. Interbasin water transfers and climate change threaten to exacerbate existing water quality issues. Bycatch is also a current threat to the Carolina DPS that is contributing to its status. Fisheries known to incidentally catch Atlantic sturgeon occur throughout the marine range of the species and in some riverine waters as well. Because Atlantic sturgeon mix extensively in marine waters and may use multiple river systems for nursery and foraging habitat in addition to their natal spawning river, they are subject to being caught in multiple fisheries throughout their range. In addition to direct mortality, stress or injury to Atlantic sturgeon taken as bycatch but released alive may result in increased susceptibility to other threats, such as poor water quality (e.g., exposure to toxins). This may result in either reduced ability to perform major life functions, such as foraging and spawning, or even post-capture mortality. While many of the threats to the Carolina DPS have been ameliorated or reduced due to existing regulatory mechanisms, such as the moratorium on directed fisheries for Atlantic sturgeon, bycatch and habitat alterations are currently not being addressed through existing mechanisms. Further, despite NMFS's authority under the Federal Power Act to prescribe fish passage and existing controls on some pollution sources, access to habitat and improved water quality continues to be a problem. The inadequacy of regulatory mechanisms to control bycatch and habitat alterations is contributing to the status of the Carolina DPS.

5.2.10 South Atlantic DPS of Atlantic sturgeon

The South Atlantic DPS includes all Atlantic sturgeon that spawn or are spawned in the watersheds (including all rivers and tributaries) of the Ashepoo, Combahee, and Edisto Rivers (ACE) Basin southward along the South Carolina, Georgia, and Florida coastal areas to the St. Johns River, Florida. The marine range of Atlantic sturgeon from the South Atlantic DPS extends from the Hamilton Inlet, Labrador, Canada, to Cape Canaveral, Florida. The riverine range of the South Atlantic DPS and the adjacent portion of the marine range are shown in Figure 1.

Rivers known to have current spawning populations within the range of the South Atlantic DPS include the Combahee, Edisto, Savannah, Ogeechee, Altamaha, and Satilla Rivers. We determined spawning was occurring if young-of-the-year were observed, or mature adults were present, in freshwater portions of a system (Table 8). However, in some rivers, spawning by Atlantic sturgeon may not be contributing to population growth because of lack of suitable habitat and the presence of other stressors on juvenile survival and development. Historically, both the Broad-Coosawatchie and St. Mary's Rivers were documented to have spawning populations at one time; there is also evidence that spawning may have occurred in the St. Johns River or one of its tributaries. Recent evidence shows that a small number of fish have returned to the St. Mary's River, and may use the river for spawning. Both the St. Mary's and St. Johns Rivers are used as nursery habitat by young Atlantic sturgeon originating from other spawning populations. The use of the Broad-Coosawatchie by sturgeon from other spawning populations is unknown at this time. The presence of historical and current spawning populations in the Ashepoo River has not been documented; however, this river may currently be used for nursery habitat by young Atlantic sturgeon originating from other spawning populations. Fish from the South Atlantic DPS likely use other river systems than those listed here for their specific life functions.

Table 8. Major river, tributaries, and sounds within the range of the South Atlantic DPS and currently available data on the presence of an Atlantic sturgeon spawning population in each system.

River/Estuary	Spawning Population	Data
ACE (Ashepoo, Combahee, and Edisto Rivers) Basin, SC; St. Helena Sound	Yes	1,331 YOY (1994-2001); gravid female and running ripe male in the Edisto (1997); 39 spawning adults (1998)
Broad-Coosawhatchie Rivers, SC; Port Royal Sound	Unknown	
Savannah River, SC/GA	Yes	22 YOY (1999-2006); running ripe male (1997)
Ogeechee River, GA	Yes	age-1 captures, but high inter-annual variability (1991-1998); 17 YOY (2003); 9 YOY (2004)
Altamaha River, GA	Yes	74 captured/308 estimated spawning adults (2004); 139 captured/378 estimated spawning adults (2005)
Satilla River, GA	Yes	4 YOY and spawning adults (1995-1996)
St. Marys River, GA/FL	Unknown	
St. Johns River, FL	Extirpated	

Secor (2002) estimates that 8,000 adult females were present in South Carolina before the collapse of the fishery in 1890. However, because fish from South Carolina are included in both the Carolina and South Atlantic DPSs, it is likely that some of the historical 8,000 fish would be attributed to both the Carolina DPS and South Atlantic DPS. The sturgeon fishery had been the third largest fishery in Georgia. Reductions from the commercial fishery and ongoing threats have drastically reduced the numbers of Atlantic sturgeon within the South Atlantic DPS. We have estimated that there are a minimum of 14,911 South Atlantic DPS adult and subadult Atlantic sturgeon of size vulnerable to capture in U.S. Atlantic waters.

The directed Atlantic sturgeon fishery caused initial severe declines in southeast Atlantic sturgeon populations. Although the directed fishery is closed, bycatch in other commercial fisheries continues to impact the South Atlantic DPS. Statutory and regulatory mechanisms exist that authorize reducing the impact of dams on riverine and anadromous species such as Atlantic sturgeon, but these mechanisms have proven inadequate for preventing dams from blocking access to habitat upstream and degrading habitat downstream. Further, water quality continues to be a problem in the South Atlantic DPS, even with existing controls on some pollution sources. Current regulatory regimes are not effective in controlling water allocation issues (e.g., no permit requirements for water withdrawals under 100,000 gpd in Georgia, no restrictions on interbasin water transfers in South Carolina, the lack of ability to regulate non-point source pollution).

Summary of the Status of the South Atlantic DPS of Atlantic Sturgeon

Recovery of depleted populations is an inherently slow process for a late-maturing species such as Atlantic sturgeon. Their late age at maturity provides more opportunities for individuals to be removed from the population before reproducing. While a long lifespan also allows multiple opportunities to contribute to future generations, this is hampered within the South Atlantic DPS by habitat alteration, bycatch, and from the inadequacy of existing regulatory mechanisms to address and reduce habitat alterations and bycatch.

Dredging is contributing to the status of the South Atlantic DPS by modifying spawning, nursery, and foraging habitat. Habitat modifications through reductions in water quality and dissolved oxygen are also contributing to the status of the South Atlantic DPS, particularly during times of high water temperatures, which increase the detrimental consequences on Atlantic sturgeon habitat. Interbasin water transfers and climate change threaten to exacerbate existing water quality issues. Bycatch also contributes to the South Atlantic DPSs status. Fisheries known to incidentally catch Atlantic sturgeon occur throughout the marine range of the species and in some riverine waters as well. Because Atlantic sturgeon mix extensively in marine waters and may use multiple river systems for nursery and foraging habitat in addition to their natal spawning river, they are subject to being caught in multiple fisheries throughout their range. In addition to direct mortality, stress or injury to Atlantic sturgeon taken as bycatch but released alive may result in increased susceptibility to other threats, such as poor water quality (e.g., exposure to toxins). This may result in reduced ability to perform major life functions, such as foraging and spawning, or even post-capture mortality. While many of the threats to the South Atlantic DPS have been ameliorated or reduced due to the existing regulatory mechanisms, such as the moratorium on directed fisheries for Atlantic sturgeon, bycatch and habitat alteration are currently not being addressed through existing mechanisms. Further, access to habitat and good water quality continues to be a problem even with NMFS's authority under the Federal Power Act to prescribe fish passage and existing controls on some pollution sources. There is a lack of regulation for some large water withdrawals, which threatens sturgeon habitat. Existing water allocation issues will likely be compounded by population growth, drought, and, potentially, climate change. The inadequacy of regulatory mechanisms to control bycatch and habitat alterations is contributing to the status of the South Atlantic DPS.

6 ENVIRONMENTAL BASELINE

Environmental baselines for biological opinions include the past and present impacts of all state, federal or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions that are contemporaneous with the consultation in process (50 CFR 402.02). The environmental baseline for this Opinion includes the effects of several activities that may affect the survival and recovery of the listed species and critical habitat in the action area. The activities that shape the environmental baseline in the action area of this consultation generally include dredging operations, water quality, scientific research, shipping and other vessel traffic and fisheries, and recovery activities associated with reducing those impacts.

6.1 Environmental Setting

The Delaware River shoreline is generally heavily industrialized. Consequently, the shoreline has lost much of its connection with the floodplain from above Trenton, NJ to Wilmington, DE. However, larger stretches of the New Jersey shoreline below Little Tinicum Island (RKM 138 (RM 86)) consists of relatively undeveloped areas as well as municipal, state, and federal open land and protected tidal marshes. Connection to floodplains provides rivers with nutrients that are important for organic production in riverine ecosystems. Research in the Mississippi River indicates that shovelnose sturgeon and pallid sturgeon early life stages use habitat associated with channel borders such as side channels, areas behind dikes, and island side-channels (Phelps *et al.* 2010, Sechler *et al.* 2012). These areas may provide refuge from strong river flows and predators, as well as provide aquatic insect larva and other small invertebrates for foraging (Phelps *et al.* 2010, Sechler *et al.* 2012). Additionally, Atlantic sturgeon have been observed moving into mudflats during high tide to forage (McLean *et al.* 2013). Thus, the extensive shoreline development with associated hardening of the banks as well as the creation of navigation channels have reduced availability of diverse shoreline habitat. Further, the value of productive foraging areas may decline when natural sedimentation and nutrient processes from upland to deep-river habitat are interrupted by shoreline development. Additionally, hardened surfaces along the shoreline in developed areas increases both runoff and the concentration of pollutants in stormwater.

In contrast, the shorelines downstream of the Delaware to Chesapeake Canal (RKM 94/RM 58) have long undeveloped stretches, including tidal marshes, on both the Delaware and New Jersey side of the river. The Augustine State Wildlife Management Area (DE) and the Silver Run Wildlife Area (DE) are located approximately 54 km (33.5 mi) downstream from the Berth. The downstream shoreline also includes the Cedar Swamp Wildlife Area (DE) and Bombay Hook National Wildlife Refuge (DE). Additionally, the lower Delaware River on the New Jersey side downstream of Pennsville Township (downstream of RKM 105/RM 65) is less developed with large stretches of undeveloped shoreline. The Supawna Meadows National Wildlife Refuge is located approximately 38 km (23.6 mi) downstream of the proposed Berth site. The Abbotts Meadow Wildlife Management Area is located below Salem River and it includes the area upstream and inland of Artificial Island. The area and shoreline downstream of Artificial Island consists of the Made Horse Creek Wildlife Management Area. Therefore, the lower estuary is generally less polluted and more connected to the floodplain than the areas upstream of New Castle, DE (approximately RKM 104/RM 64.6).

6.1.1 Delaware River Flow Management

The Delaware River basin had no major diversions until 1927 when New York City (NYC) built three reservoirs to divert water from the Delaware River Basin to meet the needs of the growing city. A 1954 court order required NYC to release water to maintain a flow rate at Montague, NJ, to compensate for the diverted water and provide water for downstream uses. In 1983, the Delaware River Basin Commission adopted a drought management program and established the Trenton Flow Objective. The intent of the Trenton Flow Objective is to assure that enough freshwater flows into the estuary to "repel" salinity. Today, releases from several basin reservoirs are used to manage freshwater inflows to the estuary.

6.1.2 Salinity

Salinity affects the fitness and distribution of sturgeon age classes within the Delaware Bay and the tidal Delaware River. Early life stages such as eggs and larvae do not tolerate saline water and their presence is restricted to freshwater reaches upstream of the salt front.

The distribution of salinity in the Delaware estuary exhibits significant variability on both spatial and temporal scales (Figure 2). At any given time, the salinity levels reflect the opposing influences of freshwater inflow from upstream non-tidal portion of the Delaware River, tributaries, and precipitation events versus the saltwater tidal inflow from the Delaware Bay and the Atlantic Ocean, downstream. The estuary can be divided into four longitudinal salinity zones (PDE 2017). Starting at the downstream end, the mouth of the Bay to RKM 44 (RM 27) is considered polyhaline (18-30ppt) with a transition zone between RKM 44-50 (RM 27-31), RKM 50-92 (RM 31-57) is mesohaline (5-18ppt) with a transition zone between RKM 92-94 (RM 57-58), RKM 94-121 (RM 58-75) is oligohaline (0.5-5ppt), and upstream of RKM 121 (RM 75) is considered fresh (0.0-0.5ppt).

The salt front is considered the freshwater-saltwater interface in the estuary and the location is derived by calculating where the seven-day average chloride concentration equals 250 ppm (parts per million) in the River. Its location fluctuates in response to changing freshwater inflows and with each tidal cycle. Because of differences in precipitation during seasons, the salt front shifts seasonally with its locations usually being further downstream during spring months and farther upstream during fall months.

Today, flow and the location of the salt front is managed by the release of water from upstream reservoirs to augment flows and meet a daily flow target of 84.9 cubic meters per second (3,000 cubic feet per second) in the Delaware River at the Trenton, NJ gage. Consequently, seasonal and annual differences are less pronounced today than they were before 1969 when the salt front was further downstream during spring and farther upstream during fall. Since 1970, low-flow values that once occurred 10% of the time now occur only 1% of the time. Over the period from 1998 to 2013, the median monthly salt front locations occur between RKM 122 (RM 76) (September) and just below the Delaware Memorial Bridge at RKM 108 (RM 67) (April) (DRBC https://www.nj.gov/drbc/programs/flow/salt-front.html).

Median locations during the months of April, May, and June (1969 to 2019) are at or below RKM 112.7/RM 70) with the upper 50 percentiles a few miles below RKM 120.7 (RM 75) and the lower 50 percentiles being located at and upstream of RKM 104.6 (RM 65) (DRBC 2023). Median locations during the months of September, October, and November (1969 to 2019) are just upstream of RKM 112.7 (RM 70) with the upper 50 percentiles just below RKM 128.8 (RM 80) and the lower 50 percentiles just above RKM 112.7 (RM 70) (DRBC 2023).

Based on currently known salinity zones and the shifting location of the salt front, sturgeon spawning would have to occur upstream of RKM 120.50/ RM 75 with the downstream limit of larvae rearing fluctuating between RKM 104/RM 65 and RKM 129/RM 80. It appears likely that Atlantic sturgeon larvae in the Delaware River drift for only a short period of time, since long duration drift from the presumed spawning areas would transport the larvae into waters of higher salinity, where they would not survive. As with the larvae of other sturgeon species, Atlantic sturgeon have likely evolved river/population specific patterns of dispersal that result in their movement downriver from spawning areas to optimal rearing areas upriver of the salt front (Hilton *et al*., 2016). The presumed Atlantic sturgeon spawning reach in the lower tidal Delaware River (RKM 125-137) overlaps with the area of greatest abundance of young-of-year Atlantic sturgeon (RKM 123-129), which suggests that PYSL dispersal is minimal; however, it is assumed that spawning may occur as far up as Trenton, NJ. Thus, the action area does contain the substrate needed to support sturgeon spawning, and larval rearing may occur within the action area.

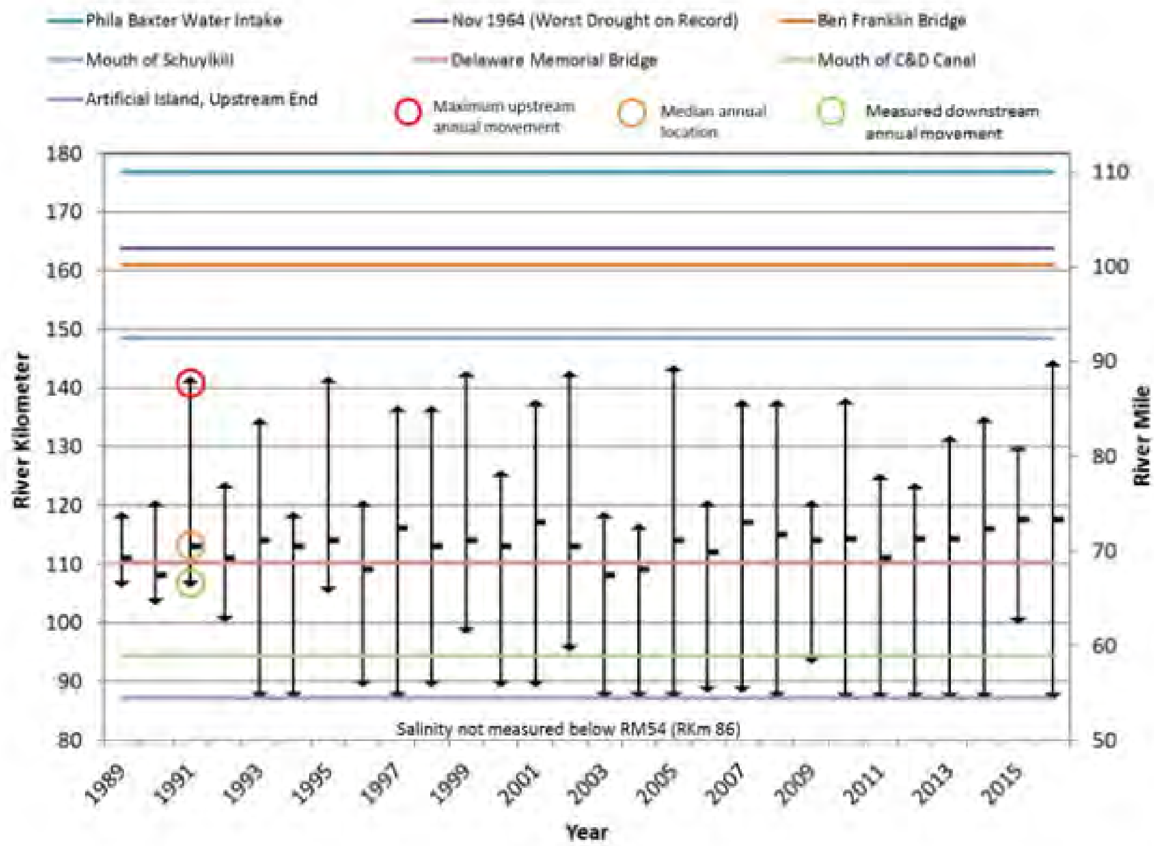

Figure 2. Range of annual salt front locations from 1989-2016. The salt front river mile is estimated by DRBC using data provided by USGS and the Kimberly Clark Corporation (Figure 2.5.1 in PDE 2017)

6.1.3 Dissolved Oxygen

Dissolved oxygen (DO) refers to the concentration of oxygen gas incorporated in water. Oxygen enters water both by direct absorption from the atmosphere, which is enhanced by turbulence, and as a by-product of photosynthesis from algae and aquatic plants. Sufficient DO is essential to growth and reproduction of aerobic aquatic life; however, low DO levels are connected to elevated nutrient levels (i.e., eutrophication). Historically in the Delaware River, discharge of raw and poorly treated wastewater resulted in the Delaware Estuary being plagued by hypoxic conditions (severe depression of DO) from Philadelphia and downstream to the river's mouth. However, in the past 20 to 30 years, the water quality has improved and anoxic conditions during summer months rarely occur (Kauffman 2010). Still, although the Estuary has seen a remarkable recovery since the 1960s, with fish such as striped bass and sturgeon now able to spawn more regularly within the Estuary, DO remains a critical issue for the Estuary because of continued depression of oxygen levels below saturation.

The U.S. Geological Survey (USGS) continuously measures DO at the Chester, PA gage in the Delaware River (USGS 01477050) at RKM 133.7 (RM 83.1) about 10 to 11 km (6.4 to 7 mi) downstream from the Berth. Dissolved oxygen levels at the gaging station near the proposed Berth vary greatly based on seasonality, with mean monthly average DO ranging between 12.23 to 10.87 mg/L in the winter months (i.e., December through January) to between 6.87 and 5.67 mg/L in the summer months (i.e., June through August) (see Table 9). DRBC's water quality standard for DO in the location of the proposed Berth is a 24-hour average concentration not less than between 4.5 mg/L and 6.0 mg/L in the lower Delaware Estuary. In the most recent Delaware River and Bay Water Quality Assessment (DRBC 2020 https://www.nj.gov/drbc/library/documents/WQAssessmentReport2020.pdf), 96.9% of observations near the Chester, PA gage in the lower Delaware River met daily mean water quality standards criteria and 98.7% of observations in the lower Delaware River and Delaware Bay met the instantaneous minimum criteria.

Table 9. Mean monthly dissolved oxygen in the Delaware River at Chester, PA (USGS 01477050) from January 2009 to December 2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly dissolved oxygen (mg/L)	12.23	-*	12.28	9.75	7.90	6.87	6.13	5.67	6.36	7.31	8.81	10.87

* No dissolved oxygen data was available at this location for the month of February

There are no available data on DO requirements for Atlantic sturgeon adults and little data for larvae, presenting a gap in the current scientific knowledge, but it is known that juvenile and larval life stage Atlantic sturgeon are sensitive to low DO at both the lethal and sub-lethal levels that occur in the Delaware Estuary. In the Atlantic sturgeon critical habitat designation, it was assumed that 6.0 mg/l DO or greater is needed for juvenile rearing habitat to support growth, development, and recruitment in the New York Bight DPS (82 FR 39160). There are no reported DO sensitivities for adult shortnose sturgeon, the life stage most likely to be present within the action area. In DO experiments conducted by Jenkins *et al*. (1993), shortnose sturgeon 22-77 days of age exposed to various DO levels in mostly freshwater at a mean temperature of 22.5°C experienced a significant decrease in percent survival between 3.5 and 3.0 mg/l DO. In addition, using various temperature, DO, and salinity combinations (2.0 to 4.5‰) in 24-hour exposures, Campbell and Goodman (2004) estimated the concentration that kills 50% (LC50) of 77 to 104 day old fish to be 2.7 mg/l (32% DO saturation, 22°C, 4‰), 2.2 mg/l (28% DO saturation, 26°C, 4.5‰), and 3.1 mg/l (42% DO saturation, 30°C, 2‰).

6.2 Listed Species and Critical Habitat in the Action Area

6.2.1 Shortnose Sturgeon in the Action Area

6.2.1.1 Overall Distribution in the Delaware River and Action Area

Shortnose sturgeon occur in the Delaware River from the lower bay upstream to at least Lambertville, New Jersey (RKM 238/RM 148). Based on documented habitat use by various life stages of shortnose sturgeon in the Delaware River, young-of-the-year, juveniles, and adults of this species are expected to occur near the proposed Berth (i.e., eggs and larvae of shortnose sturgeon are not likely to distribute downstream to the Berth area).

Although they have been documented in waters with salinities as high as 31 parts per thousand (ppt), shortnose sturgeon are typically concentrated in areas with salinity levels of less than 3 ppt (Altenritter *et al*. 2017, Wippelhauser *et al*. 2015). Jenkins *et al.* (1993) demonstrated in lab studies that 76-day old shortnose sturgeon experienced 100 percent mortality in salinity greater than 14 ppt. One-year-old shortnose sturgeon were able to tolerate salinity levels as high as 20 ppt for up to 18 hours but experienced 100 percent mortality at salinity levels of 30 ppt. A salinity of 9 ppt appeared to be a threshold at which significant mortalities began to occur, especially among the youngest fish (Jenkins *et al.* 1993). The Delaware River reach from approximately RKM 50 to 92 (RM 31 to 57.2) is considered mesohaline (5-18ppt). Thus, based on this information and the known salinity tolerances and preferences of shortnose sturgeon, this species is most likely to occur upstream of RKM 91/RM 57 where salinity is typically less than 5ppt. As tolerance to salinity increases with age and size, large juveniles and adults are likely to be present through the mesohaline area extending to RKM 50/RM 31. Due to the typical high salinities experienced in the polyhaline zone (below RKM 50/RM 31), shortnose sturgeon are likely to be rare in this reach of the river.

Historically, sturgeon were relatively rare below Philadelphia due to poor water quality. Since the 1990s, the water quality in the Philadelphia area has improved leading to an increased use of the lower river by shortnose sturgeon. Shirey *et al.* (1999) captured nine shortnose sturgeon at Cherry Island Flats and Artificial Island in 1998. During the June through September study period, Atlantic and shortnose sturgeon were found to use the area on the west side of the shipping channel between Deep Water Point, New Jersey, (RKM 102/RM 63.5 – below the Port site) and the Delaware-Pennsylvania line (RKM 126.8/RM 78.3). Shortnose sturgeon have also been documented at the trash racks of the Salem nuclear power plant in Salem, New Jersey at Artificial Island.

The discussion below will summarize the likely seasonal distribution in different reaches of the Delaware River for each shortnose sturgeon life stage. Based on the best available information on spawning locations and larval drift, eggs and larvae are not likely to be at the Berth site. Distribution of adult and juvenile shortnose sturgeon in the action area is influenced by seasonal water temperature, the distribution of forage items, and salinity.

Spawning

Movement to spawning areas is typically triggered in part by water temperature (Bowers-Altman and Brundage 2015). In the Delaware River, movement to the spawning grounds occurs in early spring, usually in late March, with spawning occurring through early May, and sturgeon typically leaving the spawning grounds by the end of May.

Spawning occurs in the upper tidal section and in the riverine reach of the Delaware River upstream of the action area. Studies conducted between 2007 and 2013 (Bowers-Altman and Brundage 2015, ERC 2008) indicate that shortnose sturgeon utilize at least a 22 km (13.7 mi) reach of the non-tidal river for spawning from Trenton rapids (about RKM 214/RM 133) to the Lambertville rapids.

During the spawning period, males remain on the spawning grounds for approximately a week while females only stay for a few days (O'Herron *et al.* 1993). Spawning typically ceases by the time water temperatures reach 15ºC (59°F), although sturgeon have been reported on the spawning grounds at water temperatures as high as 18ºC (64.4°F).

Eggs, larvae

Shortnose sturgeon eggs adhere to the substrate quickly after being deposited and will, therefore, remain in the spawning area. Studies of shortnose sturgeon in other rivers have generally found the yolk sac larva (also called free embryo) seek cover in-between coarse bottom substrate particles, and remain near the spawning site (Buckley and Kynard 1981, Kynard and Horgan 2002, Parker 2007). However, some swim up in the water column and drift behavior may occur immediately following hatching if the yolk sac larvae cannot find suitable cover or will undertake this behavior to initiate dispersal (Kynard and Horgan 2002). ERC (2008) sampled both shortnose sturgeon eggs and larvae in D-frame nets set approximately 50 m (164 ft) downstream of the I-95 bridge (approximately RKM 195/RM 121) in April and May of 2007 and 2008.

In general, we have very little information about shortnose sturgeon post yolk sac larvae distribution in the Delaware River. However, larvae do not tolerate saline water. Shortnose sturgeon eggs and larvae have been collected in the non-tidal Delaware River from immediately upriver of the Trenton rapids to the Lambertville rapids (ERC 2008). There are only two records of shortnose sturgeon larvae being collected in the upper tidal Delaware River, between RKM 204-212 (RM 126.8-131.7), during approximately the same time period. The SSSRT (2010) speculated that these may have been anomalous occurrences caused by a high river flow event that flushed the larvae out of the non-tidal river. Therefore, if post yolk sac larvae should migrate to the lower estuary, we expect the larvae to nurse above the salt front. The median monthly salt front location range is between RKM 108 and 122 (RM 67 and 76), which is within and slightly upstream of the action area. Based on the information above, shortnose sturgeon early life stages may be present within the upper portion of the action area if the salinity does not exceed their tolerance levels.

Juveniles

Young-of-the-year (YOY) shortnose sturgeon do not tolerate waters with high salinity but concentrate in freshwater upstream of the salt front. Over five winters (2015 to 2020), the USACE conducted blasting of rock outcrops in an effort to deepen the Federal Navigation Channel from 12 to 13.7 m (40 to 45 ft). Downstream of the action area, blasting of rock formations at Marcus Hook and Tinicum Ranges for the deepening of the Federal Navigation Channel required relocation trawls of sturgeon before blasting occurred (e.g., NMFS 2015, 2019a). The relocation trawls collected several YOY at the Marcus Hook Range based on their length from December and early January (ERC 2016, 2017, 2018, 2019, 2020b). We do not know when shortnose sturgeon young migrate downstream but the finding of YOY in December indicates that downstream migration from spawning site occur either as drifting post yolk sac larvae or in fall after they are fully developed into juveniles.

A total of 1,356 shortnose sturgeon were captured during the five seasons of relocation trawling. Juveniles (<500 mm (<20 in) Fork Length) represented from 9% of 539 total (2017-2018 relocation) to 92.3 percent of 259 (2019-2020 relocation). The results from the relocation trawls carried out each winter from 2015-2016 to 2019-2020, indicate that juvenile shortnose sturgeon are present in the Marcus Hook area during the winter in larger numbers than previously predicted.

In other river systems, older juveniles (3-10 years old) occur in the saltwater/freshwater interface and may move downstream into waters with moderate salinity (NMFS 1998). In these systems, juveniles moved back and forth in the low salinity portion of the salt wedge during summer. In years of high flow (for example, due to excessive rains or a significant spring runoff), the salt wedge will be pushed seaward and the low salinity reaches preferred by juveniles will extend further downriver. In these years, shortnose sturgeon juveniles are likely to be found further downstream in the summer months. In years of low flow, the salt wedge will be higher in the river and in these years juveniles are likely to be concentrated further upstream. In the Delaware River, the salt front location varies throughout the year, with the median monthly salt front ranging from RKM 107.8 to RKM 122.3 (RM 67 to 76) (DRBC 2023). The maximum recorded upstream occurred during the drought of 1960 with the salt front extending as far north as to Philadelphia, Pennsylvania (RKM 164/RM 102) and may retract as far south as Artificial Island at RKM 87 (RM 54).

Early telemetry studies found that large juvenile shortnose sturgeon (length ranged from 454-566 mm TL) use the lower estuary during early late fall with the largest sturgeon spending most of its time in the Baker Range during late fall to January (ERC 2007). Further, the BA for another consultation in this region (ERC 2020a) provided the results of tracking studies that indicate that during the winter months juvenile shortnose sturgeon are more widely distributed in the Delaware River and likely closer to the project site than previously thought. Juvenile (225 to 490 mm FL) and adult (502 to 905 mm FL) shortnose sturgeon were acoustically tagged as part of the sturgeon protection and monitoring program associated with USACE’s Delaware River deepening project (ERC 2020b). Based on telemetry data collected on acoustic receivers in the tidal Delaware River (Figure 3), juvenile shortnose sturgeon were detected throughout the year with fewer detections in August through September and January.

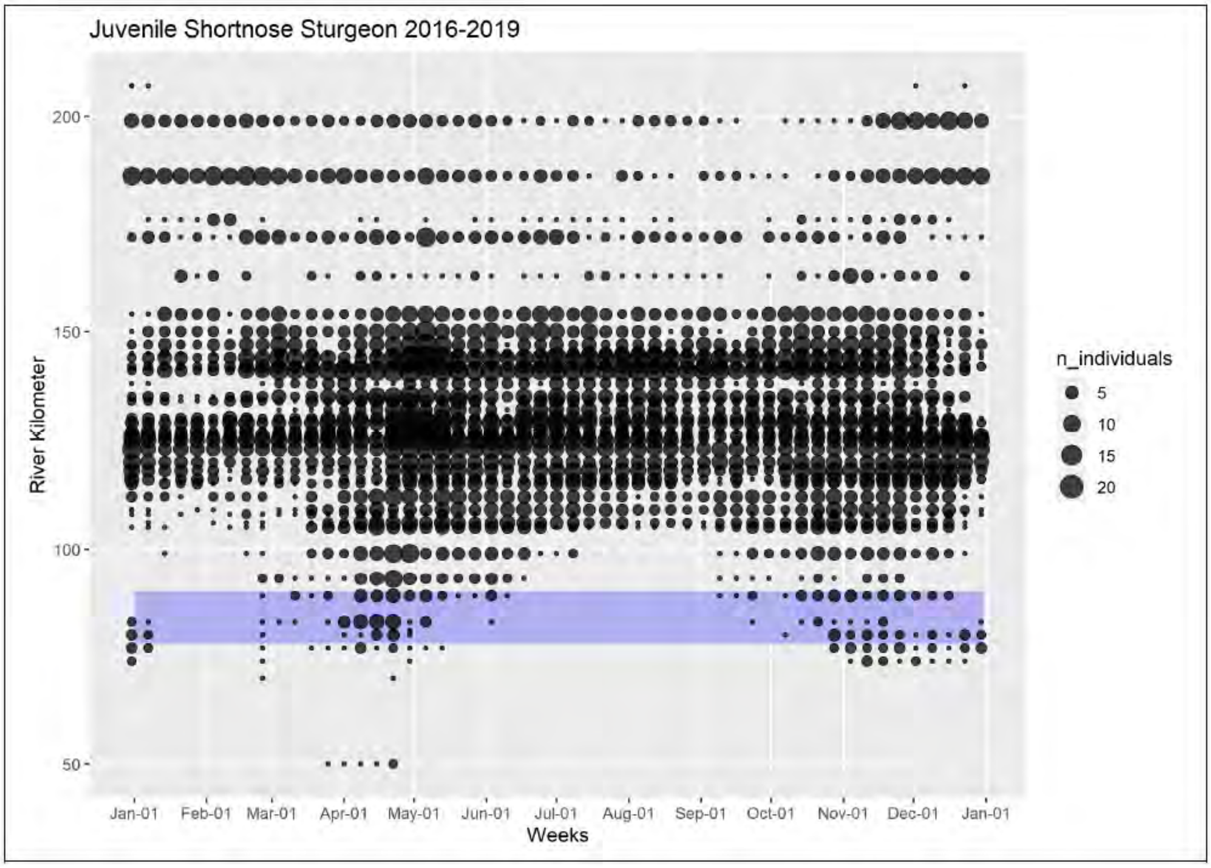

Figure 3. Distribution of Juvenile Shortnose Sturgeon in the tidal Delaware River, by week, all years combined

Adults

After spawning, which occurs during spring months and ceases by the time water temperatures reach 15ºC (although sturgeon have been reported on the spawning grounds with water temperatures as high as 18ºC), shortnose sturgeon move rapidly downstream to the Philadelphia area (~RKM 161/RM 100). After adult sturgeon migrate to the area around Philadelphia, many adults return upriver to between RKM 204 and 216 (RM 127 and 134) within a few weeks, while others gradually move to the same area over the course of the summer (O'Herron *et al.* 1993). However, the capture of multiple shortnose sturgeon at the Cherry Island Flats at RKM 119 (RM 74) during the summer months (Shirey *et al.* 1999) indicates that this area may serve as a summer aggregation and foraging site.

By the time water temperatures have reached 10°C, typically by mid-November[8], most adult sturgeon have returned to the overwintering grounds around Duck Island and Newbold Island. These patterns are generally supported by the movement of radio-tagged fish in the region

[8] Based on information from the USGS gage at Philadelphia (01467200) during the 2003-2008 time period, mean water temperatures reached 10°C between October 29 (2005 and 2006) and November 14 (2003). In the spring, mean water temperature reached 10°C between April 2 (2006) and April 21 (2009).

between RKM 201 and RKM 238 (RM 125 and RM 148) as presented by Brundage (1986). Based on water temperature data collected at the USGS gage at Philadelphia, in general, shortnose sturgeon are expected to be at the upstream overwintering grounds between RKM 190 and 211 (RM 118 and 131) between early November and mid-April.

Early studies of shortnose sturgeon adult movements found that some of the tagged adults moved rapidly between the upper tidal river (RKM 212/RM132) and the lower tidal river, moving as far downstream as RKM 93 (RM 58). These movements occurred in spring and early to mid-winter and were likely associated with sturgeon moving downstream to summer foraging and upstream to overwintering areas, respectively (ERC 2006a). However, three fish overwintered below Wilmington DE, but concluded that the majority of individuals overwinter in upstream areas below Trenton, NJ (RKM 212/RM 132).

Newer data indicates that adult shortnose sturgeon are present in the Marcus Hook area during the winter in larger numbers than previously predicted. The relocation trawls during deepening blasting within the Marcus Hook, Chester, Eddystone, and Tinicum ranges of the channel during the winters from 2015-2016 to 2019-2020 collected a large number of adult shortnose sturgeon. These data further demonstrate the use of the lower tidal river (below Little Tinicum Island) during the winter months; however, we do not expect them to occur in dense, sedentary aggregations as is seen in the upriver overwintering sites.

The results of tracking studies indicate that during the winter months, juvenile and adult shortnose sturgeon are more widely distributed in the Delaware River than previously thought. ERC (2007) tracked four shortnose sturgeon; three of the shortnose sturgeon were tracked through the winter (one shortnose was only tracked from May – August 2006). Shortnose sturgeon 171 was located in the Baker Range in early January (RKM 83/RM 51.6), and moved upriver to the Deepwater Point Range (RKM 105/RM 65) in mid-January where it remained until it moved rapidly to Marcus Hook (RKM 130/RM 81) on March 12. Shortnose sturgeon 2950 was tracked through February 2, 2007. In December the fish was located in the Bellevue Range (RKM 120/RM 74.6). Between January 29 and February 2, the fish moved between Marcus Hook (RKM 125) and Cherry Island (RKM 116/RM 72). Shortnose sturgeon 2953 also exhibited significant movement during the winter months, moving between RKM 123 and 163 (RM 76.4 and 101) from mid-December through mid-March. Tracking of adult and juvenile shortnose sturgeon captured near Marcus Hook (RKM 127-139/RM 79-86) and relocated to one of three areas (RKM 147, 176 and 193/RM 91, 109 and 120) demonstrated extensive movements during the winter period.

Telemetry data for adult shortnose sturgeon indicate that adults display similar seasonality as juveniles (ERC 2020a). Adults are detected in the Paulsboro region year round with a lower abundance December through February (Figure 4).

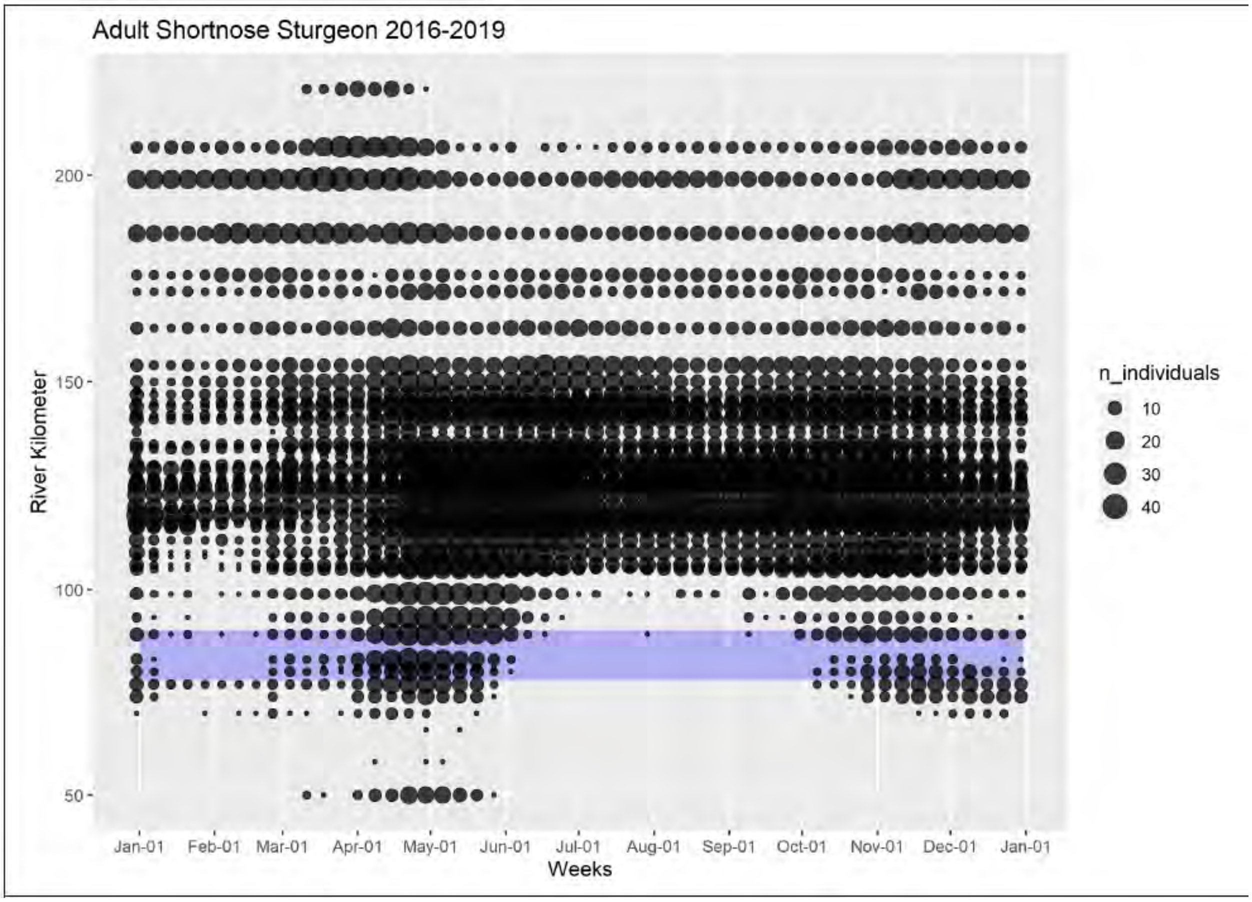

Figure 4. Distribution of Adult Shortnose Sturgeon in the tidal Delaware River, by week, all years combined

6.2.1.2 Summary of Shortnose Sturgeon Presence in the Action Area

The discussion below summarizes the likely seasonal distribution of shortnose sturgeon in river reaches within and upstream of the action area. Based on the best available information on spawning locations, eggs are not likely to be present within these reaches. The results of tracking studies and relocation trawling indicate that during the winter months, juvenile and adult shortnose sturgeon are more widely distributed in the lower Delaware River than previously thought. Distribution of adult and juvenile shortnose sturgeon in the action area is influenced by seasonal water temperature, the distribution of forage items, and salinity.

> **Berth Site Reach - Little Tinicum Island to Trenton, NJ – Tidal Freshwater:** Reach from RKM 138 to 214 (RM 86 to 133). Spawning occurs in riverine reaches upstream of Trenton, NJ, and potentially in the upper tidal river. Eggs and larvae are likely to occur in the upper tidal river. Post yolk sac larvae may occur as far downstream as Philadelphia, PA. Young shortnose sturgeon occur throughout the reach and use the channel for downstream migration to rearing areas at Marcus Hook. Adult shortnose sturgeon overwinter in dense aggregations in the upper tidal river between around Duck

Island and Newbold Island. Adults use the channel to migrate downstream after spawning to reside in areas at and downstream of Philadelphia.

Claymont, DE, to Little Tinicum Island – Tidal Freshwater: Reach from RKM 120.5 to 138 (RM 57 to 86). This reach includes the Marcus Hook Range where a large number of shortnose sturgeon juveniles, including YOY, are present indicating that this part of the river is an important year round rearing area. Adult shortnose sturgeon are present in this section of the river during winter.

Elsinboro Point, NJ, to Claymont, DE – Transition and Oligohaline: Reach from RKM 92-120.5 (RM 57-75). This reach includes the New Castle and Cherry Island Range where the 2003-2004 telemetry studies indicated was an area frequented by shortnose sturgeon. This area also includes the outlet of the Chesapeake-Delaware canal, where shortnose sturgeon have been documented moving between the upper Chesapeake Bay and the Delaware River. Based on the best available information, adult and juvenile shortnose may be present in this reach of the river year round in larger numbers than was previously considered. A review of available literature found only one record of a shortnose sturgeon in Brandywine Creek. Raasch (2007) reported that a 2-ft (adult) shortnose sturgeon was caught by a fisherman at the base of Dam 1 on July 5, 1955. No other documented occurrences have been noted since.

Lower Estuary - Mesohaline: RKM 78-92 (RM 48.5-57), includes the area near Artificial Island. Both juvenile and adult shortnose sturgeon are present from the upstream end of the Artificial Island to the mouth of the river with the Delaware Bay. However, the low number of juveniles documented occurrences in this reach combined with the higher salinity levels, make this reach less likely to be used by juveniles than other upstream reaches. Best available information indicates that the highest concentration of both adults and juveniles within this area occur from April to June and October to January. Shortnose sturgeon may be absent from this reach or occur in very low numbers during July through September.

Vessel Transit Route (Action Area): Downstream of RKM 78/RM 48.5, i.e. the Delaware Bay. As tolerance to salinity increases with age and size, occasional Adult and late-stage juvenile shortnose sturgeon may occur through the mesohaline area extending to RKM 50 (RM 31) between late April and mid-November. Due to the typical high salinities experienced in the polyhaline zone (below RKM 50/RM 31), shortnose sturgeon are likely to be rare in the Delaware Bay.

6.2.2 Atlantic Sturgeon in the Action Area

6.2.2.1 Overall distribution of Atlantic sturgeon within the Delaware River and Bay

In the Delaware River and Estuary, Atlantic sturgeon occur from the mouth of the Delaware Bay to the fall line near Trenton, New Jersey, a distance of almost 220 km (136.7 mi) (Hilton *et al.* 2016, Simpson 2008). An Atlantic sturgeon carcass was found at Easton, Pennsylvania (i.e., above the fall line of the Delaware River) in 2014 (NMFS 2017) suggesting that Atlantic sturgeon can move past the fall line. However, tracking and tagging information support that the fish typically occur downriver of the fall line (NMFS 2022). All historical Atlantic sturgeon habitats appear to be accessible in the Delaware (ASSRT 2007); however, given upstream shifts in the salt wedge over time, less river miles of freshwater habitat are available to Atlantic sturgeon compared to pre-industrial times.

Spawning

Spawning may occur from April to July. Atlantic sturgeon early life stages do not tolerate saline waters. Thus spawning must occur in freshwater upstream of saltwater intrusion. Based on this, spawning occurs within the section of the Delaware River that includes the action area.

Cobb (1899) and Borodin (1925) reported spawning between RKM 77 and 130 (RM 48 and 81) (Delaware City, DE to Chester City, Pennsylvania). However, based on tagging and tracking studies, current Atlantic sturgeon spawning may occur upstream of the salt front over hard bottom substrate between Claymont, Delaware/Marcus Hook, Pennsylvania (Marcus Hook Bar), approximately RKM 125 (RM 78), and the fall line at Trenton, NJ, approximately RKM 212 (RM 132) (Breece *et al.* 2013, Simpson 2008). The upstream shift from historical spawning sites is thought to be at least partially a result of dredging and climate change that shifted the location of the salt wedge over time and likely eliminated historic spawning habitats in the lower Delaware River (Breece *et al.* 2013). Though only one larva has been collected from the river, as noted below, the recent documented presence of YOY in the Delaware River provides confirmation that regular spawning is still occurring in this river.

The likely spawning area in the lower tidal river closest to the Berth site is located between the Marcus Hook Bar (RKM 125/RM 78) and the downstream end of Little Tinicum Island (RKM 138/RM 86). This area has hard bottom habitat believed to be appropriate for sturgeon spawning (gravel/coarse grain depositional material and cobble/boulder habitat) (Breece *et al.* 2013, Sommerfield and Madsen 2003). Tracking of adult male and female Atlantic sturgeon confirmed the use and affinity to this area by adults during April to July (Breece *et al.* 2013). The sturgeon selected areas with mixed gravel and mud substrate (Breece *et al.* 2013), DiJohnson *et al.* (2015). The entrainment of a yolk sac larva at the cooling intake of the Eddystone Generating Station in 2017 (NMFS 2020) confirms that spawning occurs in this reach of the river.

Breece *et al.* (2013) argues that sea level rise, in conjunction with channel deepening efforts, may shift the average location of the salt front upstream, compressing the available habitat for spawning. They also state that movement of the salt front may increase sedimentation rates over current spawning habitat and concentrate Atlantic sturgeon in areas of the river with the highest volume of vessel traffic.

Early Life Stages

All early life stages are intolerant of high salinity and only occur in the freshwater reach of the river. The Berth location is within the freshwater reach of the Delaware River but we do not expect it to contain hard substrate that would support Atlantic sturgeon spawning. However, drifting PYSL may occur at the Berth because they are free-swimming and hard bottom substrate that may support spawning is present upriver of the Berth location.

Atlantic sturgeon eggs are adhesive and stick to the substrate. Therefore, eggs will remain at or near the site where the female releases them in appropriate spawning habitat. Based on studies in artificial streams, hatchlings (yolk-sac larvae) will seek cover in the interstitial spaces of larger material such as gravel and cobble and are assumed to inhabit the same riverine or estuarine areas where they were spawned (Bain *et al.* 2000, Kynard and Horgan 2002). The larvae emerge from the gravel once the yolk sac is exhausted and drift with water currents that transport the larvae from spawning to downstream rearing areas just above the salt line without entering salt water (Kynard and Horgan 2002). We are not aware of any information about post yolk-sac larvae distribution and presence in the Delaware River. However, based on what is known about larval behavior, we expect post yolk-sac larvae to drift with currents downstream to the reach from Marcus Hook to Little Tinicum Island immediately above the salt front where they settle to feed and grow (Kynard and Horgan 2002). Thus, drifting post-yolk sac larvae may present in the river where the Berth will be located if Atlantic sturgeon spawn in reaches upstream of the Paulsboro Marine Terminal. Available information indicates that the Atlantic sturgeon spawn in the lower tidal Delaware River within the Chester and Eddystone Rangs (RKM 130-137 (RM 81-85)), which overlaps with the area of greatest abundance of young-of-the-year Atlantic sturgeon (RKM 123-129 (RM 76.4-80)).

Juveniles

All juvenile (non-migratory) Atlantic sturgeon are part of the New York Bight DPS. Juvenile Atlantic sturgeon are present from the mouth of the Delaware River and upstream to Trenton, New Jersey. Within the lower estuary, juveniles are present in the river off Paulsboro year round but with higher concentrations during spring/early summer and late fall (Figure 5). Older juveniles may move into the Delaware Bay and eventually make their way to marine waters at two-years or older.

YOY Atlantic sturgeon nurse in the Delaware River below Little Tinicum Island to just upstream of the salt front. Sampling in 2009 targeted YOY and resulted in the capture of more than 60 YOY in the Marcus Hook anchorage (RKM 127/RM 79) area during late October through late November 2009 (Calvo *et al.* 2010, Fisher 2009). Two telemetry studies of YOY with acoustic tags showed that YOY use several areas from Deepwater (RKM 105/RM 65) to Roebling (RKM 199/RM 124) during late fall to early spring. Some remained in the Marcus Hook area while others moved upstream, exhibiting migrations in and out of the area during winter months (Calvo *et al.* 2010, Fisher 2011). At least one YOY spent some time downstream of Marcus Hook

(Calvo *et al.* 2010, Fisher 2011). Downstream detections from May to August between Philadelphia (RKM 150/RM 93) and New Castle (RKM 100/RM 62) suggest non-use of the upriver locations during the summer months (Fisher 2011). Based on this, YOY occur within the action area. Similarly, Hale *et al.* (2016) captured age 0-1 year old sturgeon in the Delaware River in 2014, and passively tracked these for several months. During that time, the Marcus Hook area served as an important nursery ground but the sturgeon also used habitats as far upriver as RKM 152 (RM 94.4) and as far downriver as RKM 99 (RM 61.5) (Hale *et al.* 2016).

Salinity intrusion and water temperatures seems to influence summer distribution of late stage juveniles in the river with concentrations in the Marcus Hook occurring during years with high salinity and water temperatures and expanded distribution downstream to and below Artificial Island during years with below average salinity and water temperature (Fisher 2011). During the summer months, concentrations of Atlantic sturgeon have been located in the Marcus Hook (RKM 123-129/RM 76-80) and Cherry Island Flats (RKM 112-118/RM 70-73.3) regions of the river (Calvo *et al.* 2010, Simpson 2008) as well as near Artificial Island (Simpson 2008). ERC (2015), found that the juveniles shifted their center of distribution progressively down-estuary as they aged, until they migrated to the higher salinity waters of Delaware Bay and eventually the nearshore Atlantic Ocean during the fall of their second or third years. Brundage and O'Herron (in Calvo *et al.* (2010)) tagged 26 juvenile Atlantic sturgeon, including six YOY. For one-year old juveniles and older, most detections occurred in the lower tidal Delaware River from the middle Liston Range (RKM 70/RM 43.5) to Tinicum Island (RKM 141/RM 87.6). For non-YOY fish, these researchers also detected a relationship between the size of individuals and the movement pattern of the fish in the fall. The fork length of fish that made defined movements to the lower bay and ocean averaged 815 mm (range 651-970 mm) while those that moved towards the bay but were not detected below Liston Range averaged 716 mm (range 505-947 mm), and those that appear to have remained in the tidal river into the winter averaged 524 mm (range 485-566 mm) (Calvo *et al.* 2010).

Juvenile Atlantic sturgeon (254 to 750 mm fork length) were acoustically tagged from 2015 to 2019 as part of a sturgeon protection and monitoring program associated with the USACE Delaware River deepening project. Telemetry data from 2016 to 2019 indicate that acoustic-tagged juvenile Atlantic sturgeon occur in the Berth area throughout the year, based on acoustic detections at receivers in the tidal portion of the Delaware River (Figure 6). Overall, receivers located at and upstream of the Bulkhead Bar Range (~RKM 100/RM 63) detected acoustic-tagged juvenile Atlantic sturgeon year round (Figure 5). However, the telemetry data indicates that juvenile utilization of the area below RKM 100 (RM 62) varies seasonally with the number of detections being somewhat greater during the spring/early summer (April-June) months and fall (October and November). In general, within the Delaware River, the distribution of juvenile Atlantic sturgeon is centered on the Marcus Hook-Chester ranges (RKM 121-136/RM 75-84.5), consistent with earlier acoustic tracking studies (Brundage and O'Herron 2009, Hale *et al.* 2016).

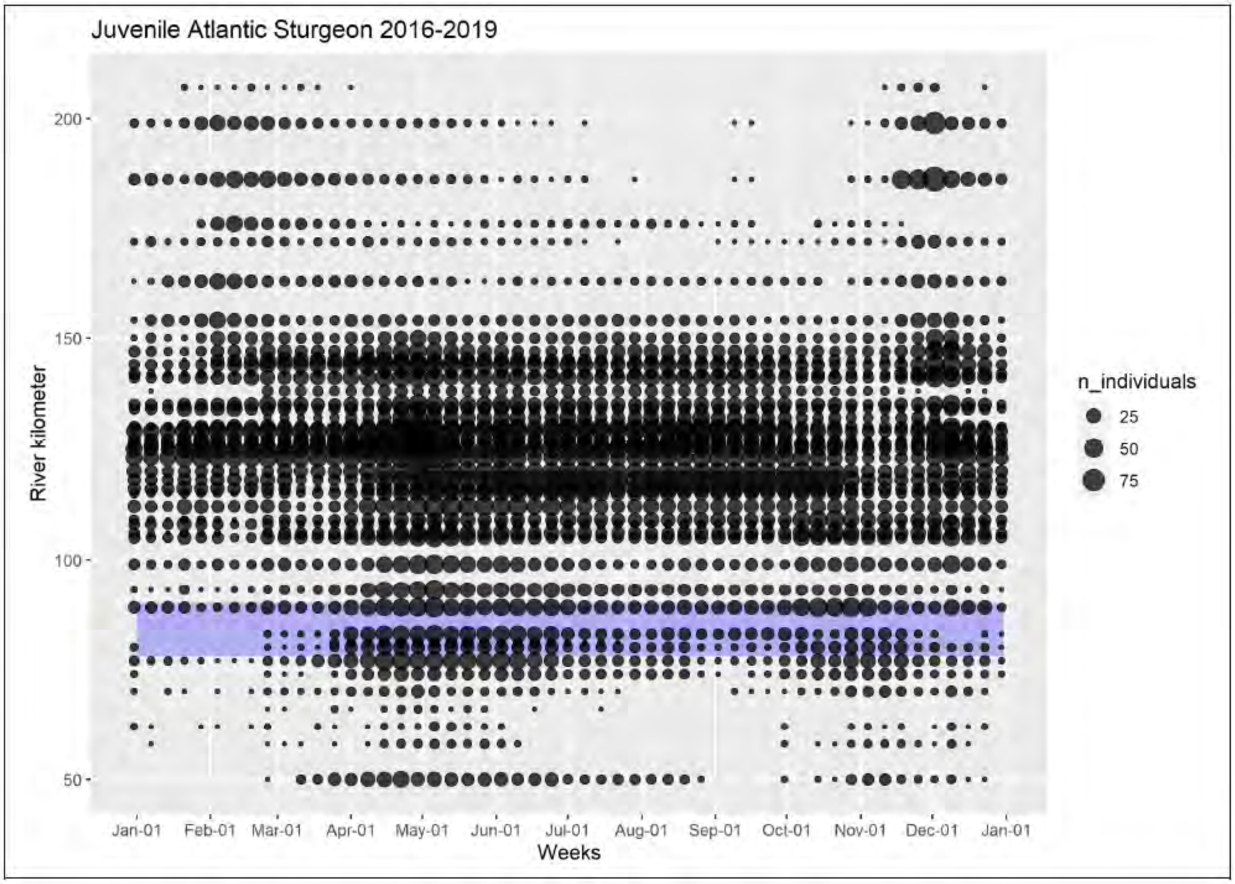

Figure 5. Distribution of Juvenile Atlantic Sturgeon in the tidal Delaware River, by week, all years combined.

Adults and Subadults

Adult and subadult Atlantic sturgeon both move through the action area during up and downstream migrations as well as for foraging and spawning staging (NYB adults only). Adults and, especially, subadults occur and reside in lower estuary while both life stages occur in dense aggregations throughout Delaware Bay and at the mouth of the Delaware Bay. The majority of adults entering the freshwater reaches of the river are of Delaware River origin while subadults may belong to any DPS. Adult and subadult Atlantic sturgeon in the Delaware Bay and at the mouth of the Bay consists of a mixture of several DPSs.

Spawning adults migrate upstream through the action area adjacent to the proposed Berth site during April and May. Spawning occurs through mid- to late-June (Simpson 2008). Females leave the spawning sites to move downstream soon after spawning but males may remain in the river until October. Some research indicates that there may be a fall spawning run of adult Atlantic sturgeon in the Delaware River, as seen further south in the James River (Balazik *et al.* 2012b, Fox *et al.* 2015); however, at this time, more research is needed to confirm whether or not an independent run of fall spawning Atlantic sturgeon is occurring in the Delaware River.

The Delaware River Estuary (the lower tidal river), Delaware Bay, and near coastal areas are used by sturgeon from multiple DPSs (Busch 2022, Damon-Randall *et al.* 2013, White *et al.* 2023, Wirgin *et al.* 2015a). For Atlantic sturgeon occurring in the Delaware River, there are no extensive genetic studies of non-Delaware River native fish relative to Delaware River natal fish. Damon-Randall *et al.* (2013)presented data for fish found in the spawning region of the Delaware River where approximately 38 percent (3 fish) was not of New York Bight DPS origin but they noted that the data was limited to only eight fish. Therefore, they suggested that the more data rich Hudson River studies of stock composition where approximately 92 percent of the Atlantic sturgeon were identified as being New York Bight fish should also be used for the Delaware River. This is because they assumed that because spawning Atlantic sturgeon have high fidelity to their natal river, the majority of adult and subadult Atlantic sturgeon would be from the Delaware River and, therefore, New York Bight DPS fish. However, contrary to this assumption, a recent study found that about ten times more tagged non-native Atlantic sturgeon entered the Delaware River than tagged fish genetically assigned as natal to the Delaware River. The proportion of natal Atlantic sturgeon entering the Delaware River (approximately at RKM 78 (RM 48.5)) was not significantly different from the proportion of Delaware River origin fish from aggregations in the Delaware Bay and nearshore areas off Delaware State (Busch 2022). However, telemetry showed that the genetically assigned Delaware River Atlantic sturgeon commonly traveled upstream to and above 68.8 km (42.8 mi) from the mouth of the river while the average furthest distance traveled by non-Delaware native fish was 18 km (11.2 mi). In other words, Atlantic sturgeon natal to the Delaware River commonly traveled past the Paulsboro Marine Terminal while non-native fish mostly remained in the lower saline estuary below Pea Patch Island (RKM 96/RM 60) downstream of the Port (Busch 2022).

Generally, subadults immigrate into the estuary in spring, establish home range in the summer months in the river, and emigrate from the estuary in the fall (Fisher 2011). Subadults tagged and tracked by Simpson (2008) entered the lower Delaware Estuary as early as mid-March but, more typically, from mid-April through May. Tracked sturgeon remained in the Delaware Estuary through the late fall departing in November (Simpson 2008). Previous studies have found a similar movement pattern of upstream movement in the spring-summer and downstream movement to overwintering areas in the lower estuary or nearshore coastal areas in the fall-winter (Brundage and Meadows 1982, Lazzari *et al.* 1986, Shirey *et al.* 1999, Shirey *et al.* 1997).

Fox *et al.* (2015) tracked (2009-2014) adult Atlantic sturgeon captured in marine waters off the Delaware Bay in the spring in an attempt to locate spawning areas in the Delaware River. Adults mostly used the area from New Castle, DE (RKM 100/RM 62) to Little Tinicum Island (RKM 138/RM 86) though adult Atlantic sturgeon were detected as far upstream as Roebling, NJ (RKM 201) (Fox *et al.* 2015). The earliest detection was in mid-April while the latest departure occurred in mid-June, which supports the assumption that adults are only present in the river during spawning. However, Fox *et al.* (2015) also observed several individuals of both sexes and unknowns that entered the river later in the spring and occupied suitable spawning habitats into the fall months. The sturgeon spent relatively little time in the river each year, generally about four weeks, though adult sturgeon of unknown sex remained in the area of likely spawning twice as long (67.1 days).

In general, Atlantic sturgeon from all rivers move south along the Atlantic coast during winter and north during summer (Erickson *et al.* 2011, Hilton *et al.* 2016, Smith 1985). Aggregations of sturgeon from Long Island to Virginia during winter months indicate the presence of important overwintering areas in coastal waters (Dunton et al. 2010). Aggregation areas are usually associated with bay mouths and inlets. The Delaware Bay mouth has been identified as an aggregation area (Dunton *et al.* 2010, Erickson *et al.* 2011, Fox *et al.* 2010, Stein *et al.* 2004a). Off the coast of New Jersey, Atlantic sturgeon generally use depths between 10 and 50 m (33 and 164 ft) and most captures occurs at depths of 20 m (65 ft) or less (Dunton *et al.* 2015, Dunton *et al.* 2010, Erickson *et al.* 2011). Savoy and Pacileo (2003)found that Atlantic sturgeon occur at depths as shallow as 2.5 m (8.2 ft).

A number of recent studies have provided us with an increasing understanding of Atlantic sturgeon utilization of the Delaware Bay and nearshore areas near its mouth (Breece *et al.* 2016, Breece *et al.* 2017, Breece *et al.* 2018, Haulsee *et al.* 2020, Kuntz 2021). These studies have identified important aggregations of Atlantic sturgeon subadults in the lower Delaware Bay and in the Atlantic Ocean off the Delaware Bay. Most of these aggregations occur adjacent to or within established shipping lanes (Breece *et al.* 2018, Haulsee *et al.* 2020). While Atlantic sturgeon may be present year round in these areas, both density and residency varies seasonally among sites. Depth distribution also shifts with season, as fish inhabit the deepest waters during winter and shallowest waters during summer and early fall. High occurrence rates at the mouth of the Delaware Bay occur in April and June and again in September and October corresponding with seasonal migration into and out of the Delaware Bay, respectively (Breece *et al.* 2017, Haulsee *et al.* 2020). The highest number of Atlantic sturgeon within the Delaware Bay occur during late spring through the fall while the highest number of Atlantic sturgeon in the deeper waters off the mouth occur during November and December. (Fox *et al.* 2010) detected a large aggregation of telemetered adult and subadult Atlantic sturgeon near the mouth of the Delaware Bay during summer months. During winter, Atlantic sturgeon movement level is high with small pockets of resident fish in deeper water near the mouth of the Delaware Bay occurring in early spring (Breece *et al.* 2018). As temperature increases, pockets of resident Atlantic sturgeon expand in an isolated region near the mouth of the Delaware Bay. Kuntz (2021) also found a large number of Atlantic sturgeon concentrated from late spring through the fall in two locations in the lower Delaware Bay. Telemetry studies and modeling identified Atlantic sturgeon areas of residency on the eastern side of the Delaware Bay and possibly in the shallow waters on the southwest side of the Delaware Bay (Breece *et al.* 2018). These areas are where many individuals remain from May to October. Breece *et al.* (2018) postulated that upwelling brings in cooler, nutrient-rich, highly oxygenated offshore waters that provide near-optimal metabolic temperatures along the bottom. Environmental conditions have also led to ideal foraging opportunities for Atlantic sturgeon and examination of gut content has confirmed that Atlantic sturgeon are feeding on benthic invertebrates in these areas (Fox *et al.* 2020).

6.2.2.1.1 Summary of Atlantic Sturgeon Presence in the Action Area

The discussion below summarizes the likely seasonal distribution of Atlantic sturgeon in river reaches within and just upstream of the action area. Atlantic sturgeon are well distributed throughout the Delaware River and Bay and could be present year round in the action area. Based the best available information on spawning locations, larvae may be present within the action area. Juvenile, subadult, and adult Atlantic sturgeon are also present throughout the action area. Adults and subadults may also be present in the navigation channel and pilot area off the Delaware Bay mouth. Distribution of adult and juvenile Atlantic sturgeon in the action area is influenced by seasonal water temperature, the distribution of forage items, and salinity.

Berth Site Reach - Little Tinicum Island to Trenton, NJ – Tidal Freshwater: Reach from RKM 138 to 214 (RM 86 to 133). Adult Atlantic sturgeon have been tracked as far upstream as the fall line by Trenton, NJ, during spring and into July. Spawning may occur throughout this reach where suitable spawning substrate is present. Thus, early life stages may be present from May through August. Juveniles occur in the river year round. This area includes the Berth site.

Claymont, DE, to Little Tinicum Island – Tidal Freshwater: Reach from RKM 120.5 to 138 (RM 57 to 86). This reach includes the Marcus Hook Range to the Little Tinicum Ranges and is an important nursing area for juveniles, with the Marcus Hook Range supporting high densities of YOY and young juveniles. The reach also includes likely Atlantic sturgeon spawning sites along the edge of the navigation channel. Post yolk sac larvae may occur throughout the reach above the salt front from late May to September depending on when spawning occurs.

Elsinboro Point, NJ, to Claymont, DE – Transition and Oligohaline: Reach from RKM 92-120.5 (RM 57-75). This includes the New Castle range where the outlet of the Chesapeake-Delaware canal is located, which Atlantic sturgeon may use to move between the upper Chesapeake Bay and the Delaware River. Early life stages are unlikely to be present because of their intolerance of higher salinity levels. Older Atlantic sturgeon juveniles expand their distribution into this reach as they become increasingly tolerant to saline waters with age but their center of distribution depends on salinity and water temperature

Lower Estuary - Mesohaline: RKM 78-92 (RM 48.5-57), includes the area near Artificial Island. Early life stages and young juveniles will not be present due to unsuitable salinity levels in this reach. Older (age-1+) juvenile, subadult, and adult Atlantic sturgeon are present from the upstream end of the Artificial Island to the mouth of the river with the Delaware Bay. Best available information indicates that the highest concentration of juveniles within the area occur from April to June and October to December. Adults start moving into the river in April to migrate to spawning sites. Adult and subadult summer and fall aggregation areas occur at the mouth or the river.

Delaware Bay: The Philadelphia to the Sea Federal Navigation Channel from RKM 78 to RKM 5 (RM 48.5 to RM 3.1), the pilot boarding area, and regulated Precautionary Area offshore of the mouth of the Bay. The Delaware Bay is polyhaline (> 18 ppt salinity). Adult and subadult Atlantic sturgeon move through the bay in April and June and again in October to December corresponding with spawning and coastal migration patterns, respectively. Adults and subadults aggregations at the mouth of the Delaware Bay occur from April to November. Though it is possible for subadults and adults to be present at the Bay mouth and in its near shore waters year round, it is unlikely that they are present during winter months. Mature adults migrating to spawn in the Delaware River belong to the New York Bight DPS, but subadults and non-mature adults may belong to multiple DPSs.

6.2.2.2 Determination of DPS Composition in the Action Area

The action area includes the Delaware River and Estuary. Until they are subadults, Atlantic sturgeon do not leave their natal river/estuary. Therefore, any early life stages (eggs, larvae), young of year, and juvenile Atlantic sturgeon in the Delaware River, also thereby, in the action area, will have originated from the Delaware River and belong to the New York Bight DPS. Subadult and adult Atlantic sturgeon can be found throughout the range of the species; therefore, subadult and adult Atlantic sturgeon in the action area would not be limited to only individuals originating from the New York Bight DPS. With respect to the river of origin, we have limited information from which to determine the percentage of New York Bight DPS adult and subadult fish within the action area that are likely to originate from the Delaware River versus the Hudson River.

The range of all five listed DPSs extends from Canada through Cape Canaveral, Florida. The most recently published mixed stock analysis (Kazyak *et al.* 2021) found that 37.5 percent of individuals sampled from the mid-Atlantic region (Cape Hatteras to Cape Cod) were assigned to populations in the New York Bight DPS. While the study by Kazyak *et al.* (2021) reflects an improvement in genetic approaches, we did not use the reported DPS frequencies because they were based on genetic sampling of Atlantic sturgeon that were encountered throughout the U.S. Atlantic coast. A recent (2022) master's thesis conducted a mixed stock analysis of tissue samples collected from adult and subadult Atlantic sturgeon caught in the Delaware River Estuary, Delaware Bay, and in coastal waters off Delaware (Busch 2022). The study found that 51 percent of adult and subadult Atlantic sturgeon sampled were of NYB DPS origin. This percentage as well as the percentages of the other DPSs were similar to what Damon-Randall *et al.* (2013) reported for their Marine Mixing Zone 2, which included Atlantic sturgeon sampled in marine areas from Chatham to Cape Hatteras. However, Damon-Randall *et al.* (2013) recognized that the mixed stock of Atlantic sturgeon found in the lower river/upper estuary area may differ from that reported in marine off-shore waters. Based on this, they also produced mixed stock assessment for estuarine/riverine zones (E/RMZ) that extended from the coastline up to the furthest extent of sturgeon migration in non-spawning rivers and up to the 0.5 parts per thousand (ppt) salinity threshold in spawning rivers. The NEFSC reviewed available mixed stock assessments, including Damon-Randall *et al.* (2013), and concluded that the E/RMZ 3 for the New York Bight and Chesapeake Bay should be used for consultations within the Delaware River Estuary and Delaware Bay.

The action area for this consultation includes the Delaware River from its mouth upstream to approximately RKM 145 (RM 90). The DPS composition of subadults and adults entering the river and traveling upstream may be different from that in estuarine, bay, and marine areas. Busch (2022) found that Atlantic sturgeon subadults and adults that do not originate from the Delaware River mostly do not travel upstream past RKM 96 (RM 60) and Damon-Randall *et al.* (2013)previously suggested using results from Hudson River as an estimate of in-river DPS proportions. Thus, E/RMZ3 from (Damon-Randall *et al.* 2013) may not precisely reflect the DPS composition of adults and subadults in the freshwater tidal reach of the Delaware River. Based on Busch (2022) and Damon-Randall *et al.* (2013), we expect that a large majority of Atlantic sturgeon in that portion of the river where the Berth is located would be of Delaware River origin. The remaining portion of the action area, consists of the Federal Navigation Channel through the lower and more saline estuary, the Delaware Bay, and the immediate coastal area off the bay's mouth where genetic and telemetry studies have identified aggregations of multiple DPSs. Only a relatively small portion of the tidal freshwater reach of the Delaware River is included in the action area and most Atlantic sturgeon carcasses that have been reported within the action area have been reported from downstream of Little Tinicum Island (DNREC and NJFW carcass data). Thus, we believe that the E/RMZ3 better reflects the stock composition in the areas where vessels calling at the Berth will travel during its operation and that it is the best available information to determine stock composition in this portion of the action area.

The genetic assignments in Damon-Randall *et al.* (2013) have a plus/minus 5 percent confidence interval; however, for purposes of the Section 7 consultation, we have selected the reported values below, which approximate the mid-point of the range, as a reasonable indication of the likely genetic makeup of Atlantic sturgeon in the action area. The Carolina DPS is the exception as its confidence interval for the E/RMZ 3 range from 0 to 6 percent. Thus, based on the E/RMZ 3 mixed-stock analysis by Damon-Randall *et al.* (2013), we have determined that subadult and adult Atlantic sturgeon in the action area likely originate from the five DPSs at the following frequencies: Gulf of Maine 13 percent; New York Bight 42 percent; Chesapeake Bay 24 percent; South Atlantic 20 percent; and Carolina 1 percent. We rely on Damon-Randall *et al.* (2013) because the DPS percentages are largely based on genetic sampling of individuals sampled in directed research targeting Atlantic sturgeon along the Delaware Coast, just south of Delaware Bay and the spawning zone in the Hudson and Delaware Rivers (described in detail in Damon-Randall *et al.* 2013). More recently, Busch (2022) and Wirgin *et al.* (2015a) found similar breakdowns of fish on the Delaware Coast, Bay, and River where fish were sampled.

Carolina DPS origin fish have rarely been detected in samples taken in the Northeast. Wirgin *et al.* (2015a) and Busch (2022) identified Carolina DPS sturgeon in the samples that were collected on the Delaware Coast or, in the case of Busch (2022), the Delaware Coast, Bay, and

River. Mixed stock analysis from one sampling effort (i.e., Long Island Sound, n=275), indicates that approximately 0.5 percent of the fish sampled were Carolina DPS origin. Additionally, two percent of Atlantic sturgeon captured incidentally in commercial fisheries along the U.S. Atlantic coast north of Cape Hatteras, and genetically analyzed, belong to the Carolina DPS (Damon-Randall *et al.* 2013). Because any Carolina origin sturgeon that were sampled in Long Island Sound could have swam through the action area on their way between Long Island Sound and their rivers of origin, it is reasonable to expect that one (1) percent of the Atlantic sturgeon captured in the action area could originate from the Carolina DPS. The assignments above and the data from which they are derived are described in detail in Damon-Randall *et al.* (2013).

6.2.2.3 Determination of New York Bight River Composition in the Action Area

We have reviewed mixed stock analyses available to us that included river distribution in their DPS determinations. These studies support the notion that the Hudson River spawning population is the more robust of the two spawning populations. This conclusion is further supported by genetic analyses that demonstrates Atlantic sturgeon originating from the Hudson River spawning population were more prevalent in mixed aggregations than sturgeon originating from the Delaware River spawning population, even when sampling occurred in areas and at times that targeted adults belonging to the Delaware River spawning population (Busch 2022, Kazyak *et al.* 2021, Wirgin *et al.* 2015a, Wirgin and King 2011). Wirgin *et al.* (2015a), which sampled migrating Atlantic sturgeon from an area 3 to 12 km (1.9 to 7.5 mi) from the Delaware coast, found that 10.6 percent of all the fish sampled were from the Delaware River and 44 percent were from the Hudson River. Kazyak *et al.* (2021) found that 37.5 percent of individuals sampled from the mid-Atlantic region (Cape Hatteras to Cape Cod) were assigned to populations in the New York Bight DPS. For the total sample, 11.4 percent were Delaware River fish and the remaining 26.2 percent were Hudson River fish. However, the sample seems to include juveniles (defined as <500mm TL) from the Delaware River and, therefore, may reflect an overrepresentation of Delaware River origin fish because juveniles do not leave their natal estuary, which is where some sampling must have occurred. A recent (2022) master's thesis conducted a mixed stock analysis of tissue samples collected from adult and subadult Atlantic sturgeon caught in the Delaware River estuary, Delaware Bay, and in coastal waters off Delaware (Busch 2022). The study found that 8.3 percent of all fish samples were Delaware River fish and 41.8 percent were Hudson River fish.

For this Opinion, we have calculated the average river distribution result from the studies described above and applied it to the New York Bight Atlantic sturgeon within the action area to estimate the rivers of origin. In the studies described above, New York Bight DPS fish represented 54.6 percent, 37.5 percent, and 51 percent of the individuals sampled. We then estimated the percentage of Delaware and Hudson River fish that comprise the fraction of all New York Bight DPS Atlantic sturgeon in the action area based on those studies' results. We calculated 23 percent as the average percentage of Delaware River fish and 77 percent as the average percentage of Hudson River fish occurring throughout the action area.

6.3 Private and Commercial Vessel Operations

Vessel traffic may affect ESA-listed sturgeon through generalized disturbance of essential life behaviors, injury/mortality due to collisions, and through the degradation of habitat (Brown and Murphy 2010, PIANC 2008, Stoschek *et al.* 2014). The Delaware River Basin port system is one of the largest in the US (Altiok *et al.* 2012). We have identified 11 major ports within the Delaware River, which together have over 39 terminals. Cargo and tanker vessels calling at these ports travel within the action area on the Philadelphia to the Sea Navigation Channel. In addition, substantial vessel activity by tugs that support vessels during docking and departure as well as other port activities (e.g., maintenance dredging of berths and constructions) occur on the river. This vessel traffic overlaps with Atlantic sturgeon distribution within the action area. A high volume of commercial traffic greatly increases the risk of vessel strikes (Fisher 2011, Simpson 2008).

6.3.1 Vessel Activity within the Action Area

We have reports of vessel interactions with sturgeon from several rivers, estuaries, and bays. Published studies in scientific journals, state sturgeon reporting programs, the NMFS salvage program and reports, personal communications, and news articles all provide information and data on sturgeon and vessel interactions. Vessels may impact listed species through generalized disturbance of essential life behaviors, injury/mortality due to collisions, and through the degradation of habitat (PIANC 2008, Stoschek *et al.* 2014). The following section describes vessel activity in the Delaware River and the Federal Navigation Channel and summarizes the best available information on the existing risk of vessel strike to shortnose and Atlantic sturgeon.

6.3.1.1 Project Area

The area between the proposed Berth and the Federal Navigation Channel did not have a maintained navigation channel prior to completing construction of the Berth, and very little, if any, vessel disturbance occurred within the dredged areas associated with construction. Thus, the river between the Federal Navigation Channel and the Berth provided a foraging area and a passageway for spawning migrations where movement was uninterrupted by maintained vessel infrastructure. However, the constructed Berth and the access channel are integrated with the existing deep-water berths at the Paulsboro Marine Terminal, which is present just upstream of and adjacent to the RORO Berth. The Paulsboro Marine Terminal currently provides berthing for large, deep draft, vessels. In addition, tugs regularly stop at the Paulsboro Marine Terminal because the terminal has berthing barges at the mouth of Mantua Creek, which is located at the upstream end of the terminal.

Cargo and tanker vessel movements are restricted to the maintained Navigation Channel and only cargo vessels approaching the existing marine terminal, tow or tug vessels, fishing vessels, large recreational vessels, and, likely, smaller recreational vessels operate within the project area (https://marinecadastre.gov/oceanreports and https://livingatlas.arcgis.com/vessel-traffic). The OceanReports website, a NOAA/BOEM partnership, provides an online accessible interactive website to explore vessel density in navigational rivers. The GIS based website shows annual vessel activity in different areas of the channel for different vessel types as well as for all vessel types combined. To calculate vessel density, the number of vessels that transect each cell in a grid of 100 m (328 ft) by 100 m (328 ft) cells is calculated using data from the automatic identification system (AIS). This data shows that vessel traffic in this reach of the river is concentrated to the Federal Navigation Channel with little traffic occurring within the Project Area (Figure 6). The recreational vessel traffic in this part of the river is relatively limited, but tugs traveling outside the Federal Navigation Channel or transecting to the existing berths at the Paulsboro Terminal regularly occur in the deeper portion of the project area and closer to the Navigation Channel (https://marinecadastre.gov/oceanreports and https://livingatlas.arcgis.com/vessel-traffic).

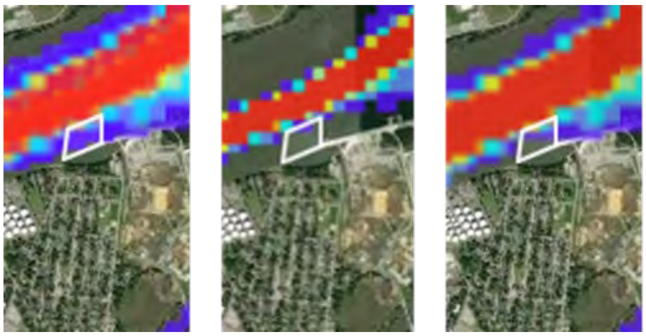

Figure 6. Vessel density of all vessels, cargo and tanker vessels, and tugboats, respectively, at the Berth site (outlined) where project vessels will operate during construction and operation of the proposed NJWP. Vessel activity is represented as number of vessels transecting each 100 x 100 meter square cell in a grid. Cooler colors (purple, blues) represent fewer vessels with number of vessels in a cell increasing with increasingly warmer (reds) cololors(colors are relative to overall vessel density for a vessel category and does not represent similar vessel density between layers of vessel types). The highest density of vessels occur in the navigation channel (not visible as the vessel activity cells cover the the navigatoin channel pollygone).

6.3.1.2 The Overall Action Area

The Delaware River is geographically and operationally one of the most significant waterways on the East Coast of the U.S. for port operations. Collectively, the Ports of Philadelphia, South Jersey, and Wilmington, DE represent one of the largest general cargo port complexes in the nation (Altiok *et al.* 2012).

The USACE Waterborne Commerce Statistics Center (WCSC) publishes data on waterborne traffic movements involving the transport of goods on navigable waters of the U.S. by both self-propelled and non-self-propelled vessels[9] (https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center-2/WCSC-Waterborne-Commerce/). The WCSC data does not include non-commercial vessels such as recreational vessels.

Vessel movements are reported as "trips." A trip is the movement of a vessel from a starting point to an end point. A vessel trip may be the loading of cargo on a vessel to the offloading site of the cargo or it may be the transport of the working crew to (or from) a work site (e.g.,

[9] With self-propelled vessel, it is meant a vessel that moves by its own power, e.g., a tugboat or container vessel. With non-self-propelled vessel, it is meant a vessel that is moved by the help of a self-propelled vessel, e.g., a barge that would need a tugboat to be moved.

dredging site). Thus, one vessel may have multiple trips during a day as it loads and unloads cargo or transports crew back and forth to a work site. The data includes ferry movements but movements of vessels exclusively engaged in construction (e.g., supporting a dredge) are not included, although movements of supplies and materials to and from a construction site must be reported. Movements of tugboats moving large ships in channels and harbors traveling less than one mile are not reported. Movements of towboats engaged in fleeting activities less than one mile are also not reported. In the spreadsheet, trips are reported as the annual number of trips by vessels of a given draft within a waterway or section of waterway. For this Opinion, the waterway of interest is the portion of the river that includes the Philadelphia to the Sea Federal Navigation Project (FNP) and the Philadelphia to Trenton FNP in the Delaware River. Because the action area includes the navigation channel of both FNPs, we will refer to the navigation channel as the Trenton to the Sea and use the WCSC consolidated report for the two FNPs[10].

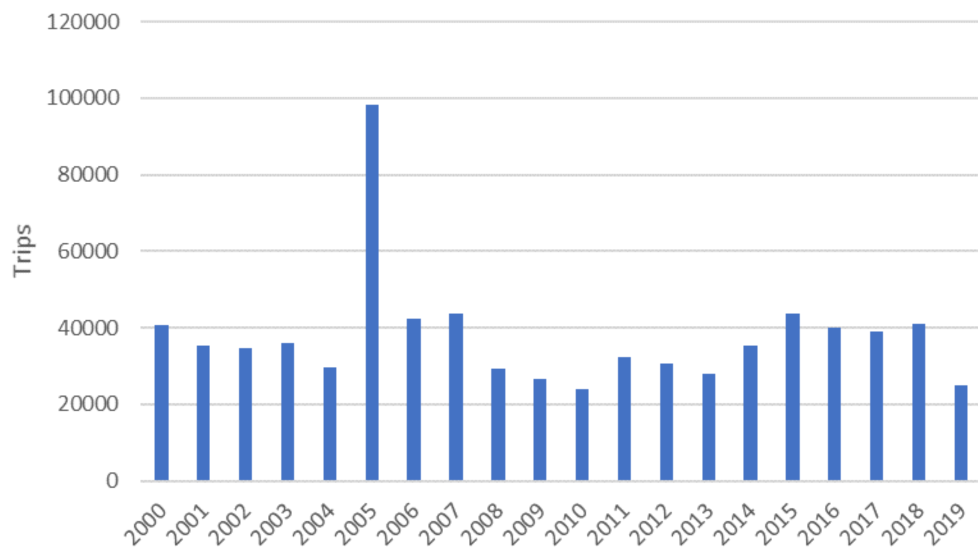

Figure 7. Annual number of trips by self-propelled vessels in the Trenton to the Sea Federal Navigation Channel.

The Waterborne Commerce data available to us includes data from 2000 to 2019. Vessel activity in the Trenton to the Sea Federal Navigation Channel during this period has varied with significant economic trends visible in the number of vessel trips (Figure 7). For this analysis, we used data from 2010 to 2019 to characterize the baseline annual vessel trips in the Trenton to the Sea Federal Navigation Channel (Figure 9). The annual number of trips for all vessels (self-propelled and non-self-propelled, all drafts) in the Federal Navigation Channel from Philadelphia to the Sea ranged from 30,853 to 52,032 (median = 41,795) during the period from 2010 through 2019 (Table 10). Based on the observations of vessel strikes and examination of carcasses,

[10] The WCSC reports waterborne commerce activities between Trenton and the mouth of the Delaware River (Trenton to the Sea) as well as separately for the Philadelphia to Trenton FNP and Philadelphia to the Sea. The vessel trips for Trenton to the Sea is not the same as the sum of trips for the Philadelphia to Trenton and Philadelphia to the Sea FNPs since trips overlap between the two FNPs.

entrainment through propellers and contact with the propeller blades appears to pose the greatest risk of injury or mortality (Balazik *et al.* 2012d, Brown and Murphy 2010). Therefore, non-self-propelled vessels likely pose minimal risk of a vessel strike that could injure or kill a sturgeon. Further, self-propelled vessels such as tugboats transport non-self-propelled vessels and, therefore, the self-propelled vessel and the barges they transport are considered one vessel trip and not two. The annual number of only self-propelled vessel trips ranged from 23,925 to 43,754 (median=33,799) with a total of 339,074 trips over the period from 2010 to 2019 (Table 11).

Large vessels with deep drafts providing little bottom clearance are likely to pose a greater risk of vessel strike than vessels with a draft that gives more bottom clearance because sturgeon tend to remain near the benthos for most of their time (Balazik *et al.* 2012d, Brown and Murphy 2010). Given that the navigation channel is -45 ft MLLW, that a propeller may draw water from five to six meters below the hull (Maynord 2000), and that a sturgeon may swim a couple of meters above the bottom while moving between foraging spots; we expect that a vessel traveling in the navigation channel would need less than 25 ft of draft (i.e., 6 m or 20 ft clearance) to avoid interacting with a foraging sturgeon. During the same 10-year period, a total of 38,115 up- and downbound trips (median of 3,848, min=3,380; max=4,268) occurred by self-propelled vessels with a draft of 25 ft or more (Table 12). Figure 8 shows number of vessel trips per year for different vessel types. However, during migration, sturgeon may occur in the water column at the same depth as the draft of a standard tugboat and, thereby, be exposed to the propeller of shallower draft vessels (Balazik *et al.* 2012d, Reine *et al.* 2014).

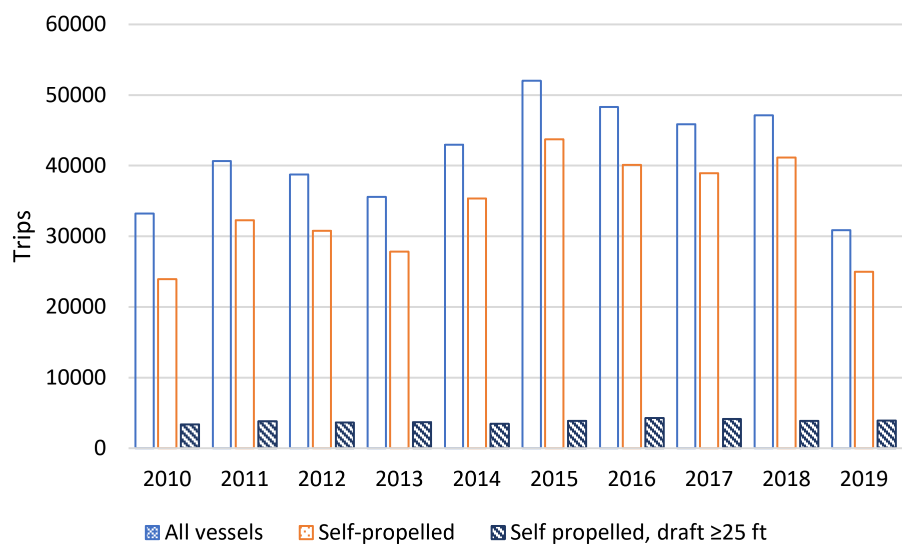

Figure 8. Annual number of Trenton to Sea vessel trips by vessel category (USACE Waterborne Commerce Data 2021).

These numbers represent the best available estimate of vessel traffic within the part of the action area that vessels will transit during operation of the Berth. The estimate excludes recreational vessels, vessels not engaged in movement of cargo, and Department of Defense (DoD) vessels (i.e., USN, USCG, etc.). Therefore, this number likely underestimates the total annual vessel traffic within the Delaware River. There is significant uncertainty in estimating the total amount of non-commercial vessel traffic in the action area. In general, recreational vessel traffic is expected to be seasonal with peak traffic occurring between the Memorial Day and Labor Day holidays.

Table 10. Annual number of vessel trips, Trenton to the Sea, for both self-propelled and non-self-propelled vessels. USACE Waterborne Commerce data.

Trip Direction	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	All years
Downbound	18,129	21,582	19,899	19,786	22,653	26,418	24,786	23,336	24,592	15,777	493,109
Upbound	15,099	19,053	18,855	15,806	20,301	25,614	23,536	22,534	22,521	15,076	481,298
Both	**33,228**	**40,635**	**38,754**	**35,592**	**42,954**	**52,032**	**48,322**	**45,870**	**47,113**	**30,853**	**974,407**

Table 11. Annual number of vessel trips, Trenton to the Sea, for self-propelled vessels of all drafts. USACE Waterborne Commerce Data.

Trip Direction	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	All years
Downbound	13,353	17,275	15,769	15,826	18,704	22,085	20,498	19,801	21,524	12,808	381,793
Upbound	10,572	14,983	15,031	12,017	16,636	21,669	19,591	19,124	19,624	12,184	374,304
Both	**23,925**	**32,258**	**30,800**	**27,843**	**35,340**	**43,754**	**40,089**	**38,925**	**41,148**	**24,992**	**756,097**

Table 12. Annual number of vessel trips, Trenton to the Sea, for self-propelled vessels with a draft at 25 feet or deeper. USACE Waterborne Commerce Data.

Trip Direction	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	All Years
Downbound	1,567	1,884	1,758	1,787	1,675	1,858	2,082	1,960	1,843	1,886	35,170
Upbound	1,813	1,944	1,905	1,895	1,798	2,009	2,187	2,194	2,042	2,028	41,220
Both	**3,380**	**3,828**	**3,663**	**3,682**	**3,473**	**3,867**	**4,269**	**4,154**	**3,885**	**3,914**	**76,390**

6.3.2 Information on Sturgeon Mortality Resulting from Vessel Strike

Published studies in scientific journals, state sturgeon reporting programs, the NMFS salvage program and reports, personal communications, and news articles all provide information and data on sturgeon and vessel interactions. The following section summarizes the best available information on the risk of vessel strike to shortnose and Atlantic sturgeon.

6.3.2.1 Available information and data

As detailed above, sturgeon vessel strike mortalities have been documented in the Delaware River and Bay and this is of concern as commercial traffic associated with the port system is high and may increase in the future. Brown and Murphy (2010) reported on 28 Atlantic sturgeon carcasses found in the Delaware River and Bay between 2005 and 2008 of which 14 mortalities were identified as the result of vessel strike. The remaining fish were too decomposed to determine cause of death but the authors believed that the majority most likely died after interaction with vessels. Brown and Murphy (2010) reported that a majority of mortalities in the river were adult Atlantic sturgeon greater than 150 cm (5 ft) total length with 39 percent of the mortalities reported being juveniles. The majority (71 percent) of sturgeon carcasses showed signs of interaction with large commercial vessels with large propellers and deep draft (Brown and Murphy 2010). This corresponds to conclusions drawn from other rivers (Balazik *et al.* 2012d). Brown and Murphy (2010) found that vessel strikes predominantly occur between May through July and likely affect adults migrating through the river to spawning grounds (Brown and Murphy 2010).

6.3.2.1.1 Delaware Department of Natural Resources and Environmental Control (DNREC)

The DNREC Division of Fish and Wildlife started a reporting program in 2005 where the public can report sturgeon carcasses they find in the Delaware River and Bay (https://dnrec.alpha.delaware.gov/fish-wildlife/fishing/sturgeon/). When possible, a biologist from the state or a sturgeon researcher will visit the site to retrieve the carcass, make a species identification, and collect data. DNREC enters, and maintains the sturgeon carcass data in a MS Excel spreadsheet. At the time of this consultation, we only had in our possession data from 2005 to 2019 (data provided by Ian Park, DNREC, 2020).

The data does not represent a scientific or dedicated survey. All of the sturgeon mortalities are reported by interested citizens or directly by agency biologists who encountered the carcasses while conducting surveys on other species (personal communication, Ian Park, DNREC, 2017). Thus, while it represents the best available data, we cannot use the data to compare mortality rates between years. A lack of a population index for the Delaware River further makes it impossible to evaluate the number of reported carcasses relative to, for instance, yearly differences in vessel activity. Over the period from 2005 through 2019[11], public and state employees reported 242 shortnose sturgeon and Atlantic sturgeon carcasses (excluding Atlantic sturgeon carcasses from an experimental study) as well as sturgeon carcasses not determined to species. Of these, 25 were reported from outside the Delaware River and Bay, leaving 217 carcasses observed within the Delaware River and Bay.

Of the 217 sturgeon carcasses reported within the Delaware River and Bay, 113 showed sign of interaction with boat propellers and 19 were identified as having died by other causes (some of these, e.g., entrapment in dredge, are included in discussions of mortalities caused by other stressors than vessel strike). Cause of death could not be determined for 85 of the carcasses, either because they were too decomposed when examined by state biologists or proper pictures were not provided (for carcasses not physically examined by state biologist) to identify injuries. However, many of the decomposed carcasses had missing heads or consisted of only body parts suggesting that a large propeller mutilated them. The DNREC spreadsheet includes 198 carcasses from the Delaware River and Bay when considering only mortalities where the cause of death was not determined and mortalities where the cause of death had been determined to be

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[11] The data provided are the same as used by Brown and Murphy (2010) for the years 2005 through 2008. However, the data provided us by DENRC includes an additional six reports of Atlantic sturgeon carcasses not included in Table 1 in Brown and Murphy (2010).

or were suspected to be vessel strike. Of these 198 reported carcasses, 180 were Atlantic sturgeon, 13 were shortnose sturgeon, and five (5) were not determined to species (Table 13).

6.3.2.1.2 New Jersey Fish and Wildlife (NJFW)

The NJFW also has a public reporting program for sturgeon carcasses (https://www.nj.gov/dep/fgw/news/2013/sturgeon_reporting.htm), and they provided us with a spreadsheet that includes data on all carcasses reported along the shores and in waters within the boundaries of the state of New Jersey (i.e., they do not track carcasses found outside of state boundaries) from 2013 to 2021. As with the DNREC data, the NJFW does not represent a scientific or dedicated survey. A 2022 review of the data by NOAA's Northeast Fisheries Science Center (NEFSC) found that none of the reported carcasses from NJFW were included in the DNREC data we previously considered. The review also indicates that the NJFW data constitutes the best available information in addition to the DNREC data, and that the carcasses reported to NJFW should be added to the total carcasses reported to DNREC when evaluating the risk of vessel strike in our analysis.

The NJFW spreadsheet contains 102 reported observations of sturgeon mortalities from New Jersey waters. In our review of the data, we determined that the location description for several reported carcasses reported in the Atlantic Ocean was likely wrong and subsequently corrected to the location to either Delaware River or Delaware Bay. After the correction, the NJFW spreadsheet includes data for 37 sturgeon mortalities reported from the Delaware River and Delaware Bay (only within New Jersey state boundaries) between the years of 2013-2021.

NJFW staff did not determine the likely cause of death for the sturgeon reported to them, and the spreadsheet only provides comments for 21 of the 37 sturgeon carcasses reported from the Delaware River and Bay. Two Atlantic sturgeon were reported as being entrained in a hopper dredge operated by the USACE and are excluded for the purpose of this vessel strike mortality analysis. Of the remaining 19, two comments mention interaction with a propeller as the likely cause of injury; eight had descriptions of severed bodies and/or cuts consistent with an interaction with propellers; and the remaining nine comments did not include a description of injury. In all, excluding the two dredge mortalities, the NJFW spreadsheet includes data on 35 sturgeon carcasses from within the Delaware River and Bay. Of these 35, 23 were identified as Atlantic sturgeon, four (4) as shortnose sturgeon, and eight (8) were not identified to species (Table 13).

Table 13. Sturgeon carcass reports by data source. DNREC 2005 to 2019 records and NJFW 2013 to 2022 records. The table shows the number of all sturgeon carcasses reported, number of all sturgeon carcasses reported within the Delaware River and Bay, and the number of carcasses reported within the Delaware River and Bay by species. ALL = all mortalities, VESSEL AND UNKNOWN = cause of mortality either unknown or likely vessel strike.

SOURCE	REPORTED - TOTAL	DELWARE RIVER & BAY (R & B): ALL	DELWARE R&B: VESSEL & UNKNOWN	ATLANTIC: R & B VESSEL & UNKOWN	SHORTNOSE: R & B VESSEL & UKNOWN	UNKOWN: R &B VESSEL & UNKNOWN
DNREC	242	217	198	180	13	5
NJFW	102	37	35	23	4	8
BOTH	**344**	**254**	**233**	**203**	**17**	**13**

When excluding known or likely causes of death other than vessel strike, the DNREC and NJFW spreadsheets include a total of 233 records of sturgeon carcasses in the Delaware River and Bay of which 220 were identified either as Atlantic sturgeon (203) or shortnose sturgeon (17) (Table 13).

6.3.2.2 Adjusting the number of vessel mortalities

Since it is unlikely that the public and other observers report all mortalities that occur in the Delaware River and Bay, we expect the actual number of sturgeon mortalities to be greater than the 233 reported above. For past biological opinions, we have used a study of sturgeon carcass observations on the James River (Virginia) by Balazik *et al.* (2012d) that found monitoring in the James River documented about one-third of all vessel strike mortalities.

However, the purpose of the study was to determine the likelihood of researchers finding carcasses during carcass surveys rather than opportunistic reporting rates. More recently, the Delaware State University in partnership with the USFWS and DNREC conducted a study to estimate opportunistic reporting rates of carcasses in the Delaware River and Bay (Fox *et al.* 2020). The estimated reporting rates varied from 2.0 (spring 2018) to 12.5 (summer and fall 2018) percent with a reporting rate of 4.76 percent when they combined the data for all seasons over the two years (2018 and 2019) of the study. A 2022 review of these two studies by the NEFSC concluded that the Fox *et al.* (2020) study is more appropriate for Delaware River biological opinions as it was specifically designed to estimate Atlantic sturgeon carcass reporting rates in the Delaware River. Therefore, in this Opinion, we will use the baseline vessel strike risk that the NEFSC calculated by using Fox *et al.* (2020) to adjust observed mortality. A more detailed discussion about the differences between these two studies and our reasoning for using Fox *et al.* (2020) was presented in the 2022 biological opinion for this project and in the 2023 biological opinion issued for the reinitiated consultation for the proposed development of a port at Edgemoor, Pennsylvania.

Based on the conclusion that (Fox *et al.* 2020) represents the best available information for carcass reporting rates on the Delaware River and Bay, we used the combined reporting rate of 4.76 percent and the number of observed (i.e., reported) carcasses to estimate the actual (reported and non-reported) number of mortalities. Table 14 and Table 15 show the number of observed Atlantic sturgeon and shortnose sturgeon, respectively, and the estimated number of mortalities when applying the reporting rate from Fox *et al.* (2020) to estimate the actual number of sturgeon mortalities.

Table 14. Number of reported and adjusted Atlantic sturgeon carcasses within the Delaware River and Bay. Shaded area shows years when data from DNREC and NJFW reports overlap. Adjusted numbers are calculated by dividing observed (reported) numbers by a 0.476 reporting rate.

YEAR	DNREC	NJFW	BOTH	BOTH ADJUSTED
2005	7	N/A	7	147
2006	11	N/A	11	231
2007	6	N/A	6	126
2008	10	N/A	10	210
2009	5	N/A	5	105
2010	13	N/A	13	273
2011	19	N/A	19	399
2012	16	N/A	16	336
2013	22	0	22	462
2014	12	0	12	252
2015	9	1	10	210
2016	19	2	21	441
2017	9	2	11	231
2018	9	10	19	399
2019	13	6	17	399
2020	N/A	2	2	42
2021	N/A	2	2	42
All Years	180	25	205	4,307
2013-2019	93	21	114	2,395

Table 15. Number of reported and adjusted shortnose sturgeon carcasses within the Delaware River and Bay. Shaded area shows years when data from DNREC and NJFW overlap. Adjusted numbers are calculated by dividing observed (reported) numbers by the reporting rate of 0.0476.

YEAR	DNREC	NJFW	BOTH	ADJUSTED
2005	0	N/A	0	-
2006	0	N/A	0	-
2007	0	N/A	0	-
2008	0	N/A	0	-
2009	0	N/A	0	-
2010	0	N/A	0	-
2011	3	N/A	3	63
2012	2	N/A	2	42
2013	1	1	2	42
2014	0	0	0	-
2015	3	2	5	105
2016	2	1	3	63
2017	0	0	0	-
2018	0	0	0	0
2019	2	0	2	42
2020	N/A	0	0	0
2021	N/A	0	0	0
All Years	13	4	17	357
2013-2019	8	4	12	252

6.3.2.3 Atlantic sturgeon vessel mortalities

For purposes of this Opinion, we assume that unknown mortalities were due to vessel strikes. This is reasonable since most reported sturgeon carcasses are adult, subadult, or larger juvenile Atlantic sturgeon, which have few natural predators, and most anthropogenic mortalities from other causes are reported as such (e.g., capture in dredge). However, some anthropogenic mortalities may not be reported (e.g., sturgeon caught in fishing nets). With the exception of one sturgeon noted as caught in gillnet and one as predated, none of the comments on individual records in the data indicate that something other than a vessel strike was the cause of death (e.g., presence of gillnet scars or entangled in fishing gear).

Combined, the two datasets include 203 reports of Atlantic sturgeon carcasses within the Delaware River and Bay for which the cause of death was unknown or identified as vessel strike. Using the 4.76 percent reporting rate from Fox *et al.* (2020), we estimate that the number observed mortalities represents 4,265 actual Atlantic sturgeon mortalities within the river and bay.

Since the DNREC and the NJFW data only overlap for the years 2013 to 2019, we used this period to calculate average annual mortality. Combined, for the years 2013-2019, the two data sets include 112 records from the Delaware River and Bay of Atlantic sturgeon with vessel strike or unknown as the cause of mortality. The number of Atlantic sturgeon mortalities considered as vessel strikes ranged from three (2015) to 14 (2013) with an average of 7.9 reported sturgeon mortalities per year. Using the 4.76 percent reporting rate gives an adjusted average of 165 vessel strikes per year. Assuming Atlantic sturgeon with unknown cause of death were in fact vessel strike mortalities, the adjusted number of Atlantic sturgeon carcasses reported each year ranged from 210 (2015) to 462 (2013) with a median of 357 and an average of 336 mortalities per year.

Seasonal and Life Stage Distribution of Mortalities

The majority of Atlantic sturgeon mortalities in the Delaware River and Delaware Bay were reported during spring and early summer (Table 19). Fifty-eight (58) percent of the Atlantic sturgeon vessel strike and unknown mortalities were reported during May and June. Ninety percent (90) were reported during the months from May through October. We expect more people to be on the river and bay during the warmer months, so it is possible that the low number of reports during winter is reflective of reduced public activity.

The NEFSC reviewed sturgeon length data in the DNREC spreadsheet to determine the life stage of Atlantic sturgeon based on reported length measurements (Table 16).

Table 16. Guidance for the assignment of life stage to Atlantic sturgeon carcasses.

Stage	**Minimum TL (cm)**	**Maximum TL (cm)**
Adult	≥150	
Subadult	≥76	<150
Juvenile		<76

The DNREC spreadsheet has life stages assigned to 132 of the carcasses found in the Delaware River and Bay between 2005 and 2019. Upon review, NEFSC deferred to the biologists that had examined the carcasses to determine life stage and assumed that all carcasses assigned as adult Atlantic sturgeon in the spreadsheet were correct. However, with the exception of three carcasses reported as subadults, the DNREC spreadsheet did not distinguish between juvenile (pre-migration to the ocean) and subadult Atlantic sturgeon. A closer review of reported total length or size of carcass segments suggest that many of those denoted as juvenile in the DNREC spreadsheet were likely subadult Atlantic sturgeon. Last, several records in the spreadsheet reported TL or other length measurements but did not assign life stage to them. Using the length guidance in Table 16, NEFSC used best professional judgment to assign each fish as a juvenile or subadult life stage based on reported measurements and descriptions of each carcass in the comment section. In all, NEFSC assigned life stages to 153 of the Atlantic sturgeon carcasses found in the river (Table 17). The DNREC spreadsheet did not include life stage or length measurements that NEFSC could evaluate for the remaining 26 Atlantic sturgeon reported from the Delaware River and Bay.

Table 17. Number and percentage of Atlantic sturgeon adult, subadult, juvenile, and unknown life stages.

Life Stage	Number	Percent
Adult	96	53.33%
Subadult	33	18.33%
Juvenile	24	13.33%
Unknown	26	15.00%
All	**179**	**100.00%**

Including only those reported as vessel mortalities, the majority (73 percent) of adult carcasses were reported during May and June (Table 18). The number of reported adult carcasses has the same distribution (70 percent reported in May and June) when both vessel strike mortalities and unknown mortalities are included (Table 18). Substantially fewer subadult than adult carcasses are reported from the Delaware River and Bay. However, while subadult carcass reports also peak in May, reports of carcasses continues to be relatively high through October (Table 19). The highest number (16) of reported carcasses (vessel strike and undetermined mortalities) of undetermined life stages was reported in May with three carcasses reported in each of June and July. These 22 carcasses constitute 85 percent of the Atlantic sturgeon carcasses of unknown life stage (Table 19). Most of the carcasses of unknown life stage were from May indicating that these individuals may be subadult or adult fish. In contrast to adults, juveniles were reported throughout the year though with somewhat higher numbers in June and July.

Since some carcasses were mutilated and size was estimated from remains, it is possible that some of the sturgeon reported as adults were sub-adults and vice versa. In addition, the relatively higher percentage of sturgeon reported between spring and fall may be a result of less public activity along the river during winter. Still, despite seasonal bias in reporting rates and possible mischaracterization of life stage, the results agree with findings by others that the majority of Atlantic sturgeon mortalities are adults and that they are at high risk of vessel strike in spring when they move into the river (Balazik *et al.* 2012d, Brown and Murphy 2010, Fisher 2011).

Table 18. Number of Atlantic sturgeon vessel strike mortalities within the Delaware River and Bay each month over the years 2005 to 2019. Based on data provided by DNREC. A = adult, SA = subadult, J = juvenile, Unk = unknown life stage.

Month	A#	A%	SA#	SA%	J#	J%	Unk#	Unk%	All#	All%
January	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
February	0	*0.00*	0	*0.00*	1	*7.69*	0	*0.00*	1	*0.97*
March	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
April	2	*2.99*	1	*5.26*	0	*0.00*	0	*0.00*	3	*2.91*
May	29	*43.28*	3	*15.79*	0	*0.00*	4	*100.00*	36	*34.95*
June	20	*29.85*	3	*15.79*	3	*23.08*	0	*0.00*	26	*25.24*
July	4	*5.97*	4	*21.05*	3	*23.08*	0	*0.00*	11	*10.68*
August	4	*5.97*	3	*15.79*	2	*15.38*	0	*0.00*	9	*8.74*
September	2	*2.99*	3	*15.79*	0	*0.00*	0	*0.00*	5	*4.85*
October	5	*7.46*	1	*5.26*	3	*23.08*	0	*0.00*	9	*8.74*
November	1	*1.49*	1	*5.26*	0	*0.00*	0	*0.00*	2	*1.94*
December	0	*0.00*	0	*0.00*	1	*7.69*	0	*0.00*	1	*0.97*
All Months	**67**	***100.00***	**19**	***100.00***	**13**	***100.00***	**4**	***100.00***	**103**	***100.00***

Table 19. Number of both Atlantic sturgeon vessel strike and unknown mortalities within the Delaware River and Bay each month over the years 2005 to 2019. Based on data provided by DNREC. A = adult, SA = subadult, J = juvenile, Unk = unknown life stage.

Month	A	A%	SA	SA%	J	J%	Unk	Unk%	All	All%
January	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
February	1	*1.04*	0	*0.00*	1	*3.45*	0	*0.00*	2	*1.11*
March	0	*0.00*	0	*0.00*	2	*6.90*	0	*0.00*	2	*1.11*
April	3	*3.13*	1	*3.45*	2	*6.90*	2	*7.69*	8	*4.44*
May	38	*39.58*	7	*24.14*	2	*6.90*	16	*61.54*	63	*35.00*
June	28	*29.17*	4	*13.79*	7	*24.14*	3	*11.54*	42	*23.33*
July	5	*5.21*	5	*17.24*	5	*17.24*	3	*11.54*	18	*10.00*
August	6	*6.25*	3	*10.34*	3	*10.34*	0	*0.00*	12	*6.67*
September	5	*5.21*	4	*13.79*	1	*3.45*	1	*3.85*	11	*6.11*
October	8	*8.33*	4	*13.79*	4	*13.79*	1	*3.85*	17	*9.44*
November	2	*2.08*	1	*3.45*	1	*3.45*	0	*0.00*	4	*2.22*
December	0	*0.00*		*0.00*	1	*3.45*	0	*0.00*	1	*0.56*
All Months	**96**	***100.00***	**29**	***100.00***	**29**	***100.00***	**26**	***100.00***	**180**	***100.00***

Baseline Vessel Strike Risk

The NEFSC calculate the risk of a vessel strike by dividing the number of suspected vessel mortalities during a given period by the number of vessel trips during the same period. This provides us with an estimate of vessel strike mortalities per vessel trip based on observed mortalities (M_o). However, since we expect that the number of observed mortalities is a fraction of actual mortalities within the Delaware River and Bay, the NEFSC used the estimated reporting rate (4.76 percent) by Fox *et al.* (2020) to adjust the risk of vessel strikes by dividing M_o by the 4.76 percent reporting rate to produce an adjusted vessel strike risk (M_a).

As described in section 6.3.2.1, DNREC (Division of Fish and Wildlife) maintains records of observed sturgeon mortalities within the Delaware River and Delaware Bay. Since 2012, public outreach and social media campaigns have improved public reporting of sturgeon carcasses (DNREC 2016) and 2019 is the most recent year of complete carcass data that we have in our possession. In addition, the NJFW provided us with data on reported sturgeon carcasses spanning the years from 2013 through 2021 (see section 6.3.2.1). These data represent the best available information for calculating sturgeon mortalities per vessel trip. The NEFSC use the combined DNREC and NJFW 2013 to 2019 data together with the WCSC vessel trip data (section 6.3.1.2) during the same years to calculate the risk of a vessel striking a sturgeon within the Delaware River and Bay.

For the years 2013-2019, the NEFSC calculated that DNREC and NJFW data sets include 109 records from the Delaware River and Bay of Atlantic sturgeon with vessel strike or unknown as the cause of mortality that they could use for risk calculations (NEFSC 2023 report). For purposes of this biological opinion, we assumed that unknown mortalities were due to vessel strikes. This is reasonable since most reported sturgeon carcasses are adult, subadult, or larger juvenile Atlantic sturgeon, which have few natural predators, and most anthropogenic mortalities from other causes are reported as such (e.g., capture in dredge). However, some anthropogenic mortalities may not be reported (e.g., sturgeon caught in fishing nets). Thus, assuming that all the reported mortalities with unknown cause of death were vessel strikes, then 109 reported Atlantic sturgeon mortalities in the Delaware River and Bay were caused by vessel strikes over the 7-year period (2013 through 2019) with an approximate average of 16 reported vessel strike mortalities per year (NEFSC report, 2023).

We obtained the number of vessel trips between Trenton and the mouth of the Delaware Bay from Waterborne Commerce data for the years 2013 through 2019. The WCSC data does not include recreational and fishing boats and is therefore an underestimate of all vessel traffic within the action area. However, recreational vessels typically have a draft of a couple of meters or less, and recreational and fishing vessels have small propeller blades that are unlikely to entrain sturgeon. Thus, the most likely interaction between smaller vessels and sturgeon would be through hull and propeller strike (the moving vessel and propeller hitting the fish), and not entrainment. In that case, the sturgeon would have to be in shallow waters or in the water column near the surface (because of the shallow draft of smaller vessels) and unable to escape as the vessel approached. Thus, the probability of a vessel striking a sturgeon is likely related to the speed of the vessel. Recreational vessels often operate at higher speeds, which may limit a sturgeon's opportunity to avoid being struck. There is evidence to suggest that small, fast vessels with shallow draft can strike and kill Atlantic sturgeon and shortnose sturgeon when moving at high speeds and/or over shallow areas. Brown and Murphy (2010) included information on a commercial crabber reporting that his outboard engine had hit an Atlantic sturgeon in a shallow area of the Delaware River. On November 5, 2008, in the Kennebec River in Maine, the Maine Department of Marine Resources (MEDMR) staff observed a small (<6 m (<20 ft)) boat transiting through a known shortnose sturgeon overwintering area at high speeds. When MEDMR approached the area after the vessel had passed, they discovered a fresh dead shortnose sturgeon. They collected the fish for necropsy, which later confirmed that the mortality was the result of a propeller wound to the right side of the mouth and gills. In another case, a 10.7 m (35-ft) recreational vessel traveling at 33 knots on the Hudson River was reported to have struck and killed a 1.7 m (5.5-ft) Atlantic sturgeon (NYSDEC sturgeon mortality database (9-15-14)).

Since sturgeon remain close to the bottom most of the time (Balazik *et al.* 2012d, Fisher 2011, Reine *et al.* 2014), interaction with a shallow draft vessel could mostly occur in shallow waters or when sturgeon surface. For the vessel to strike a sturgeon, the vessel and the surfacing sturgeon must be at the same spot at the exact same time. Since surfacing constitutes a very small portion of a sturgeon's daily activity (0 to 12 per day, Logan-Chesney *et al.* 2018), we expect that sturgeon exposure to shallow draft vessels are extremely rare and is most likely to occur where vessels travel over reaches with a substantially high number of sturgeon present (e.g., shortnose sturgeon overwintering holes). Conversely, cargo vessels and tugboats have large propellers that entrain large volumes of water and the observation of many severed sturgeon carcasses suggest that most vessel strike mortalities occur when sturgeon are entrained in the water going through the propellers of large vessels (Balazik *et al.* 2012d, Brown and Murphy 2010). Since the propellers on recreational and smaller fishing vessels are too small to entrain a sturgeon in the water going through the propeller, the interaction with sturgeon would only occur if the propeller blades directly strike the sturgeon while transiting over the fish. The probability of a propeller hitting a sturgeon when surfacing, even if the vessel is directly overhead, is small because the propeller's surface area is also small. Further, while we do not know the force that would be needed to injure or kill a sturgeon by direct impact, we do assume that a recreational vessel would have to travel at considerable speed for a direct impact by the hull to kill a sturgeon. Therefore, while vessel strike by recreational vessels and small fishing boats have occurred, we expect recreational vessel strike mortalities to be rare in the lower Delaware River estuary and in Delaware Bay. As such, they do not meaningfully contribute to our evaluation of baseline vessel strike risk.

Table 20. Vessel trip and carcass report statistics.

	Min	Max	Mean	Median	Total
Atlantic Sturgeon Mortalities	10	23	15.6	15	109
Vessel Trips	24,992	43,754	36,013	38,925	252,091

The number of vessel trips between Trenton and the mouth of the Delaware Bay during the period from 2013 to 2019 was 252,091 (Table 20). Given this scenario, we estimate the number of sturgeon killed per vessel trip by dividing the estimated number of Atlantic sturgeon vessel mortalities (109) by the number of vessel trips (252,091) over the same period. Thus, using the observed data, each vessel trip (M_o) killed 0.000432 sturgeon.

Given the known difficulties in observing deceased fish in a large, dynamic environment like the Delaware River and Estuary, it is necessary to account for unobserved mortalities. The NEFSC referred to this as the adjusted annual mortality rate, which is calculated by dividing the observed annual mortality rate (M_o) by an externally derived carcass reporting rate (Fox *et al.* 2020). This is represented by:

$$M_a = \frac{M_o}{R}$$

where M_o is the observed annual mortality rate and R is the Carcass Reporting Rate.

Using the carcass reporting rate calculated by Fox *et al.* (2020), the NEFSC calculated an actual or adjusted mortality rate by dividing M_o by 0.000432 to get a M_a of 0.0091. As such, we estimate that on average 0.0091 sturgeon are killed per vessel trip. This equates to one Atlantic sturgeon killed on average for every 110 vessel trips. The calculations show that the probability of a vessel strike is low for any one vessel traveling on the river or in the bay. However, as noted above, the Delaware River supports a number of major port complexes with many related vessel trips occurring per year. Therefore, the high level of vessel movements overlapping with the presence of Atlantic sturgeon aggregation sites, spawning migrations, and spawning areas, causes a high risk of vessel strikes within the action area.

6.3.2.4 Shortnose sturgeon vessel mortalities

Early reports of potential vessel strikes of shortnose sturgeon include one incident in 2007 and one in 2008. On June 8, 2008, a dead shortnose sturgeon was collected near Philadelphia. The fish was necropsied and found to have suffered blunt force trauma. Though the injury was considered to be caused by interaction with a vessel, this was never confirmed. On November 28, 2007, a shortnose sturgeon was collected on the trash racks of the Salem Nuclear Generating facility. The fish was not necropsied; however, the pattern of lacerations on the carcass suggested possible vessel interaction. It is unknown if those lacerations were caused pre- or post-mortem.

The DNREC data (2005 to 2019) includes 13 shortnose sturgeon mortalities in the Delaware River. The number or reported mortalities ranged from zero to three shortnose sturgeon per year over the ten-year period. Of the 13 shortnose sturgeon, eight were reported as likely vessel mortalities and five had no cause of death reported. Additionally, three (23 percent) were adults, three (23 percent) were juveniles, and no life stage was reported for seven (54 percent) of the carcasses.

The NJFW data (2013 to 2022) includes four shortnose sturgeon that were reported from the Delaware River and Bay. The information provided to us by NJFW did not include any description of injuries and the cause of death is unknown.

Of the 17 reported carcasses (DNREC and NJFW combined), 12 were reported between 2013 and 2019. If we assume that mortalities of unknown cause were vessel strike mortalities and that only 4.76 percent of carcasses are reported, then there were approximately 252 shortnose sturgeon vessel strike mortalities in the Delaware River during that seven-year period. Assuming that carcasses with an unknown cause of death likely are vessel strike mortalities is reasonable since most of the reported carcasses were larger fish that have few predators and most common anthropogenic mortalities such as dredging entrainment are reported as such to DNREC. Further, several of the carcasses with no decided cause of death had described injuries that are compatible with vessel strike (e.g., severed body). With 252,091 vessel trips during the same period, approximately 0.001 shortnose sturgeon are killed per vessel trip. This equates to one shortnose sturgeon vessel strike mortality occur for every 1,000 vessel trips.

The low number of shortnose sturgeon carcasses reported from the Delaware River basin may be related to several factors: little overlap between vessel activity and shortnose sturgeon distribution; low numbers of large fish present in areas with high vessel activity; fewer observed and reported remains due to their smaller size relative to Atlantic sturgeon; a combination of these factors; or other unknown factors. However, we do not have data to correct for these uncertainties.

6.3.3 Impacts to Bottom Substrate from Vessel Activity

The largest commercial vessels (e.g., oil tankers, container ships, etc.) pass throughout the navigation channel on a daily basis. Upon approaching the channel in the lower Delaware Bay from the Atlantic Ocean, many oil tankers have drafts exceeding 13.7 m (45 ft) because of their cargo. They are required to pay for lightering, where enough oil is pumped off the vessel so it may pass upstream during high tide with the required 0.6 m (2 ft) of draft clearance. Most of the largest tankers make their port calls before the Walt Whitman Bridge in Philadelphia. Given the size of the vessels and the proximity of the propeller to the bottom of the channel, there is a constant disturbance regime (increased turbidity and TSS) throughout the navigation channel. Vessels occasionally strike shoaled areas, but are still able to pass through. At least a couple of times per week, large tankers actually pass side by side as one travels upstream and the other downstream. In these instances, they may take up the majority of the navigation channel, likely causing sediment disturbance throughout the channel and beyond.

6.4 Contaminants and Water Quality

Non-point sources of contamination in the action area include atmospheric loading of pollutants, stormwater runoff from urban and residential development, groundwater discharges, and industrial activities. Vessel traffic also contributes pollutants to the ecosystem. The Delaware Bay and River hosts multiple commercial terminals and docks for recreational vessels. Consequently, the navigation channel supports a large number of commercial and private vessels. A high volume of vessel traffic increases the risk of oil spills and leakage of hydrocarbon-based pollutants into the waters of the Delaware River and Bay (Delaware River and Bay Oil Spill Advisory Committee 2010), which may detrimentally impact Atlantic sturgeon critical habitat as well as individual sturgeon.

Point source discharges (i.e., municipal wastewater, industrial or power plant cooling water or wastewater) and compounds associated with discharges (i.e., metals, dioxins, dissolved solids, phenols, and hydrocarbons) contribute to poor water quality and may affect the health of sturgeon populations. The compounds associated with discharges can alter the pH of receiving waters, which may lead to changes in fish behavior, deformations, reduced egg production and survival, as well as mortality.

Historically, shortnose sturgeon were rare in the area below Philadelphia, likely as a result of poor water quality (especially low DO concentrations), precluding migration further downstream. However, in the past 20 to 30 years, the water quality has improved, anoxic conditions during summer months no longer occur, and shortnose sturgeon are observed farther downstream (Kauffman 2010).

Though water quality in the Delaware River has improved over the last decades following the passage of the CWA, water-borne contaminants are still present in the action area, albeit at reduced levels (Kauffman 2010). Large portions of the Delaware River are bordered by highly industrialized waterfront development. Sewage treatment facilities, refineries, manufacturing plants and power generating facilities all intake and discharge water directly from the Delaware River. This results in large temperature variations and the presence of heavy metals, dioxin, dissolved solids, phenols and hydrocarbons, which alters the pH of the water and may eventually lead to fish mortality. Industrialized development, especially the presence of refineries, has also resulted in storage and leakage of hazardous material into the Delaware River. One superfund site is located approximately 17.7 km (11 mi) downstream from the Berth area at Pedricktown, NJ. Presently, 15 Superfund sites have been identified in Delaware and several have yet to be labeled as a Superfund site, but they do contain hazardous waste. Of the 15 sites, eight are in close proximity to the Delaware River or next to tributaries to the Delaware River. EPA has removed two sites at the Deepwater Point Range (RKM 102.2 and 109.4 (RM 63.5 and 68)) from the National Priority List (https://www.epa.gov/de/list-superfund-sites-delaware). Contaminants have been detected in Delaware River fish with elevated levels of PCBs in several species. Although difficult to evaluate the effects, it is possible that the presence of contaminants in the action area have adversely affected sturgeon abundance, reproductive success, and survival.

Several characteristics of sturgeon life history including long life span, extended residence in estuarine habitats, and being a benthic omnivore, predispose this species to experience bioaccumulation of toxins after long term, repeated exposure to environmental contaminants. (Dadswell 1979). Toxins introduced to the water column become associated with the benthos and can be particularly harmful to fish, such as sturgeon, that feed on benthic organisms. Heavy metals and organochlorine compounds are known to accumulate in fat tissues of sturgeon, but their long-term effects are not yet known (Ruelle and Henry 1992, Ruelle and Keenlyne 1993). Available data suggest that early life stages of fish are more susceptible to environmental and pollutant stress than older life stages (Rosenthal and Alderdice 1976). Although data on the impacts of contaminants on sturgeon are limited, elevated levels of environmental contaminants, including chlorinated hydrocarbons, in several other fish species have been associated with reproductive impairment (Cameron *et al.* 1992, Longwell *et al.* 1992), reduced egg viability (Hansen and Pethon 1985, Mac and Edsall 1991, Von Westernhagen *et al.* 1981), and reduced survival of larval fish (Berlin *et al.* 1981, Giesy *et al.* 1986). Some researchers have speculated that PCBs may reduce the shortnose sturgeon's resistance to fin rot (Dovel *et al.* 1992).

Although there is scant information available on levels of contaminants in Atlantic sturgeon and shortnose sturgeon tissues, some research on other, related species indicates that concern about effects of contaminants on the health of sturgeon populations is warranted. Detectable levels of chlordane, DDE, DDT, and dieldrin, and elevated levels of PCBs, cadmium, mercury, and selenium were found in pallid sturgeon tissue from the Missouri River (US Fish and Wildlife Service 1993). These compounds may affect physiological processes and impede a fish's ability to withstand stress. PCBs are believed to adversely affect reproduction in pallid sturgeon (Ruelle and Keenlyne 1993). Ruelle and Henry (1992) found a strong correlation between fish weight $r = 0.91$, $p < 0.01$), fish fork length $r = 0.91$, $p < 0.01$), and DDE concentration in pallid sturgeon livers, indicating that DDE concentration increases proportionally with fish size.

Contaminant analysis was conducted on two shortnose sturgeon from the Delaware River in the fall of 2002. Muscle, liver, and gonad tissue were analyzed for contaminants (ERC 2002). Sixteen metals, two semi-volatile compounds, three organochlorine pesticides, one PCB Aroclor, as well as polychlorinated dibenzo-p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) were detected in one or more of the tissue samples. Levels of aluminum, cadmium, PCDDs, PCDFs, PCBs and DDE (an organochlorine pesticide) were detected in the "adverse effect" range. It is of particular concern that of the above chemicals, PCDDs, DDE, PCBs and cadmium, were detected as these have been identified as endocrine disrupting chemicals. While no directed studies of chemical contamination in sturgeon in the Delaware River have been undertaken, it is evident that the heavy industrialization of the Delaware River is likely detrimentally impacting the Atlantic sturgeon and shortnose sturgeon populations.

6.5 Federal Actions that have Undergone Formal or Early Section 7 Consultation

We have undertaken several ESA Section 7 consultations to address the effects of actions authorized, funded or carried out by Federal agencies. Each of those consultations sought to develop ways of reducing the probability of adverse impacts of the action on listed species. Consultations are detailed below.

6.5.1 The Delaware River Federal Navigation Projects

The USACE have conducted annual maintenance dredging of the Delaware River for over 70 years. A batched consultation was completed in 1996 between us and the USACE on the effects on listed species and their habitat of the USACE's maintenance of the Philadelphia to Trenton

Federal Navigation Channel, maintenance of the Philadelphia to the Sea Federal Navigation Channel, and dredging projects conducted by private applicants and authorized by the USACE.

Since 2008, the USACE have been working with us to consider effects of the deepening of the Philadelphia to the Sea Federal Navigation Channel from -12 to -13.7 m (-40 to -45 ft) (with 0.6 m (2 ft) over-dredge) MLLW. A formal consultation was completed with issuance of a biological opinion dated July 17, 2009. The biological opinion concluded that dredging and rock blasting to deepen the channel from -12 to -13.7 m (-40 ft to -45 ft) may adversely affect, but is not likely to jeopardize the continued existence of shortnose sturgeon. In 2012, we listed the Atlantic sturgeon, and, consequently we reinitiated the consultation, and issued a biological opinion dated July 11, 2012. This consultation was again reinitiated in January 2014 and again in November 2015. The 2015 consultation included the use of a trawl to capture and relocate sturgeon from the blast site in the weeks before and during blasting. Both biological opinions concluded that the proposed project may adversely affect, but is not likely to jeopardize the continued existence of shortnose sturgeon and Atlantic sturgeon.

We published two proposed rules (81 FR 35701; 81 FR 36078) to designate critical habitat for the five distinct population segments of federally listed Atlantic sturgeon on June 3, 2016. Consequently, the USACE requested a conference to consider the effects of the remaining deepening project, Philadelphia to the Sea maintenance, and Philadelphia to Trenton maintenance. To streamline and consolidate these consultation processes, we (NMFS and the USACE) agreed to complete a new consolidated biological opinion to include the effects of the Delaware River channel deepening project, Philadelphia to the Sea maintenance dredging and Philadelphia to Trenton maintenance dredging. The USACE also requested that we include a new project, the Delaware River Dredged Material Utilization (DMU) study. On November 17, 2017, we issued a new, consolidated biological opinion that replaced the previous opinions covering these activities:

- 2015 Opinion: Deepening of the Delaware River Federal Navigation Channel
- 2013 Opinion: Maintenance of the 40-foot Philadelphia to the Sea navigation channel
- 1996 Opinion: Maintenance Dredging Operations within USACE's Philadelphia District

The 2017 Opinion included an analysis of the projects' effects on designated Atlantic sturgeon critical habitat, as we published the final rule in the Federal Register on August 17, 2017 (82 FR 39160; effective date: September 18, 2017). We reinitiated this consultation in 2018 and issued a new biological opinion on December 10, 2018. In 2019, USACE informed us that they needed a fifth season using explosives to remove additional rock pinnacles in the navigation channel that could not be removed with dredging equipment. We again reinitiated the consultation based on the USACE proposal to conduct additional blasting that was not considered in the 2018 biological opinion. On November 22, 2019, we issued the last biological opinion on the deepening and maintenance of the Philadelphia to the Sea Federal Navigation Project (FNP), the Philadelphia to Trenton FNP, and the DMU study. The biological opinion considered the deepening blasting, the associated sturgeon relocation trawling proposed to be conducted during the winter of 2019 and 2020, and 50 years of maintenance dredging (2020 to 2070) of the two FNPs.

The 2019 biological opinion concluded that the proposed action may adversely affect, but is not likely to jeopardize the continued existence of the shortnose sturgeon, the GOM, NYB, CB, and SA DPSs of Atlantic sturgeon, Kemp's ridley sea turtles, and loggerhead sea turtles. The biological opinion concluded that the proposed project was not likely to adversely affect Atlantic sturgeon from the Carolina DPS, green sea turtles, or leatherback sea turtles. We also determined that the proposed action is not likely to adversely affect critical habitat designated for the NYB DPS of Atlantic sturgeon

Although listed whales occur seasonally off the Atlantic coast of Delaware and right whales occasional transient near the mouth of the Delaware Bay, we determined that no listed whales are known to occur within the maintenance dredging action area. Therefore, the biological opinion did not discuss impacts to listed whale species.

6.5.1.1 Delaware River Philadelphia to Trenton Maintenance Dredging Program

The Philadelphia to Trenton FNP is upstream of the site of the proposed Port. The USACE maintains to -12 m (-40 ft) depth the Delaware River Navigation Channel from Allegheny Avenue in Philadelphia (RKM 176.9/RM 110) to Newbold Island in Bucks County (RKM 191.3/RM 119), north of Philadelphia. From there, the USACE maintains navigation channels of varying authorized depths to the upstream limit of the FNP (RKM 214.5/RM 133.3) just below the Penn-Central R.R. Bridge crossing over the Delaware River at Trenton, NJ. Dredging is completed by hydraulic dredging, bucket dredging, or hopper dredge and dredged material is transported to either Fort Mifflin or Palmyra Cove for containment.

Dredging of the Philadelphia to Trenton project has resulted in shortnose sturgeon mortality. In mid-March 1996, three fresh shortnose sturgeon were found in a dredge discharge pool on Money Island, near Newbold Island, Burlington County, New Jersey. The dead sturgeon were found on the side of the spill area into which the hydraulic pipeline dredge was pumping. In January 1998, three shortnose sturgeon were discovered in the hydraulic maintenance dredge spoil in the Florence to Trenton section of the upper Delaware River. These fish also appeared to have been alive and in good condition prior to entrainment (NMFS 2015). The entrainment of shortnose sturgeon in the cutterhead dredge occurred during dredging in or near aggregation areas during winter. Since 1998, the USACE has been avoiding dredging in the overwintering area during the time of year when shortnose sturgeon are present. The biological opinions for the Philadelphia to Trenton FNP as well as the subsequent consolidated biological opinions have required observation of the dredge spoils during hydraulic cutterhead dredging, and the USACE has not reported additional take of sturgeon from this project.

Since the 2015 biological opinion, maintenance dredging of the -12 m (-40 ft) Philadelphia to Trenton channel has resulted in three Atlantic sturgeon (dead) and one shortnose sturgeon (dead). All of the sturgeon takes occurred during hopper dredging.

6.5.1.2 Philadelphia to the Sea FNP Deepening and Maintenance

As reported in the 2015 Biological Opinion, the Delaware River Stem and Main Channel Deepening Project began in March 2010. The USACE completed the deepening of the channel from -12 m to -13.7 m (-40 ft to -45 ft) in 2020. Maintenance dredging of the -12 m (-40 ft) channel has occurred since the 1970s until completion of the deepening in 2020. The 2019 biological opinion for the Delaware River FNPs covers 50 years of maintenance dredging of the -13.7 m (-45 ft) channel.

River reaches from AA to E divide the Philadelphia to the Sea FNP. Reach E is the downstream end of the channel in the Delaware Bay that starts at RKM 5 (RM 3) and the uppermost reach, Reach AA, ends at Allegheny Avenue in Philadelphia (RKM 176.9/RM 110). The Berth access channel will connect with the Philadelphia to the Sea at Reach A (Figure 9).

Figure 9. Delaware River main channel deepening project

6.5.1.3 The Philadelphia to the Sea Deepening

Prior to completion of the deepening project, the USACE maintained the channel at a depth of 12m (40 ft) at MLLW. Only portions of the channel that were between 12 m and 13.7 m (40 ft and 45 ft) MLW were dredged for the deepening project. Explosives were used to deepen the channel in Reach B (Marcus Hook and Chester Ranges) where rock and hard substrate precluded dredging. Blasting occurred over five consecutive winters from 2015 to 2020. Relocation trawling for sturgeon occurred three weeks prior to blasting and during blasting. Relocation trawling consisted of trawling the blasting area and transport all sturgeon caught upriver near Trenton, NJ, where they were released.

The surface area of the Delaware estuary from the Ben Franklin Bridge to the capes (excluding tidal tributaries) is approximately 1,813 square kilometers (700 square miles). The Philadelphia to the Sea Federal Navigation Channel has a surface area of 39.6 square kilometers (15.3 square miles), or approximately 2.2 percent of the total estuary surface area, of which 22 square kilometers (8.5 square miles) has been dredged to 13.7 m (45 ft).

6.5.1.4 The Philadelphia to the Sea Maintenance Dredging

The USACE has maintained the Philadelphia to the Sea Channel at 13.7 m (45 ft) since the completion of the deepening in 2020. Maintenance dredging in the river typically occurs between August and December using a hydraulic cutterhead dredge. A federally owned hopper dredge, other large hopper dredges, and hydraulic cutterhead dredges are also used. Material excavated from the river is placed in existing upland CDFs located along the Delaware River or in the open water disposal site Buoy 10 in the Delaware Bay (NMFS 2019b). Table 21 and Table 22 show the frequency of maintenance dredging, expected volume dredged, and the periods when dredging can occur for each reach of the Philadelphia to the Sea FNP.

Table 21. Philadelphia to the Sea proposed maintenance activities, methods, and dates (NMFS 2019).

Activity	Channel Reach/ Location	River miles & (RKM)	Duration (mo.)	Dredge Frequency	Dredge Depth/ Width	Vol. (CY)	Type of Dredge/ Equipment	Disposal location (if applic-able)	Scheduled Dates
Maintenance dredging	A-B (Allegheny Ave., Philly to Burlington Island)	109.93-118.87 (176.9-191.3)	1-3	Annual	40' deep; 400' wide	100,000-200,000	Hopper, Cutter-head, or Mech-anical	Palmyra Cove, Burlington Island, Money Island, Biles Island, Ft. Mifflin	June 1 – March 15
Maintenance dredging	A-B (Burlington Island to Newbold Island, Bucks County)	118.87-126.88 (191.3-204.2)	1-3	2-3 year cycle	40' deep; 400' wide	700,000	Cutterhead or Mechanical	Money Island, Biles Island	July 1 – March 15 (Mechanical); July 1 – December 31 (Cutterhead)
Maintenance dredging	B-C (Newbold Island to Trenton	128.66-132.06 (207.1-212.5)	10-20 days	3-5 years	25' deep; 300' wide	150,000	Cutterhead or Mechanical	Money Island, Biles Island	July 1 – March 15 (Mechanical); July 1 –

Activity	Channel Reach/ Location	River miles & (RKM)	Duration (mo.)	Dredge Frequency	Dredge Depth/ Width	Vol. (CY)	Type of Dredge/ Equipment	Disposal location (if applic-able)	Scheduled Dates
	Marine Terminal)								December 31 (Cutterhead)
Maintenance dredging	C-D	132.07-133.29 (212.5-214.5)	1-3	Not routinely maintained	12' deep; 20' wide	<100,000	Cutterhead or Mechanical	Money Island, Biles Island	Oct. 1 – March 15
Maintenance dredging	Fairless Turning Basin	126.88 (204.2)	1	2 year cycle	40'	200,000	Cutterhead	Money Island	July 1 – March 15

Table 22. Philadelphia to the Sea proposed maintenance activities, methods, and dates (NMFS 2019). Shaded row indicates the reach where the Project Area of this consultation is located.

Activity	Channel Reach/ Location	River miles & (RKM)	Duration (mo.)	Dredge Frequency	Dredge Depth/ Width	Vol. (CY)	Type of Dredge/ Equipment	Disposal location (if applic-able)	Scheduled Dates
Maintenance dredging	E	5-41 (8-66)	2-3	Annual	45'	400,000	Hopper	Buoy 10	All Year
Maintenance dredging	D	41.1-55 (66.1-88.5)	2-3	3-Year Cycle	45'	1,000,000	Hopper & Cutterhead	Artificial Island CDF	All Year
Maintenance dredging	C	55.1-67 (88.7-107.8)	2-3	Annual	45'	2,000,000	Cutterhead & Hopper	Killcohook and Pedrick-town CDFs	All Year
Maintenance dredging	B	67.1-85 (108-136.8)	2-3	Annual	45'	2,700,000	Hopper & Cutterhead Suction & Mechanical	Oldmans and Pedrick-town CDFs	July 1 – March 15
Maintenance dredging	A	85.1-97 (137-156.1)	2-3	5-Year Cycle	45'	200,000	Mechanical & Hopper & Cutterhead	National Park & Fort Mifflin CDFs	July 1 - March 15
Maintenance dredging	AA	97.1-102 (156.3-164.2)	2-3	5-Year Cycle	45'	450,000	Mechanical & Hopper	National Park & Fort Mifflin CDFs	July 1 – March 15

6.5.1.5 2019 Biological Opinion ITS

The 2019 biological opinion concludes that the proposed action has the potential to result in the mortality of shortnose sturgeon and individuals from the New York Bight, Gulf of Maine, Chesapeake Bay and South Atlantic DPSs of Atlantic sturgeon due to entrainment in hopper or cutterhead dredges, entrapment in mechanical dredges, relocation trawling, and blasting activities. In the biological opinion, we concluded that the proposed project may affect but is not likely to adversely affect critical habitat designated for Atlantic sturgeon. We estimated that, on average, one sturgeon of either species will interact with a hopper dredge for every 2,496,000 cy of material dredged. In the 2019 biological opinion, we determined that the anticipated take is not likely to jeopardize the continued existence of listed species. The biological opinion exempts take incidental to the implementation of the proposed project as follows:

- The lethal take of eight adult or juvenile sturgeon during blasting and relocation trawling in 2019 and 2020. Of the eight, an undetermined fraction will be shortnose sturgeon and an undetermined fraction will be Atlantic sturgeon NYB DPS.
- The lethal take of up to 13 sturgeon takes as a consequence of handling stress and relocation of sturgeon, any combination of adult and/or juvenile shortnose and juvenile Atlantic sturgeon (NYB DPS).
- The lethal take by dredging entrainment/entrapment of up to 116 juvenile and/or adult sturgeon of which all or a fraction will be shortnose sturgeon or Atlantic sturgeon (i.e., an undetermined fraction will be shortnose sturgeon and an undetermined fraction will be Atlantic sturgeon). This take will occur during maintenance dredging from Trenton to the Sea over the next 50 years or until 2070.
- Of the 116 sturgeon killed, incidental take of up to 67 Atlantic sturgeon New York Bight DPS.
- Of the 116 sturgeon killed, incidental take of up to 21 Atlantic sturgeon Chesapeake Bay DPS.
- Of the 166 sturgeon killed, incidental take of up to 20 Atlantic sturgeon South Atlantic DPS.
- Of the 116 sturgeon killed, incidental take of up to 8 Atlantic sturgeon Gulf of Maine DPS.
- Lethal take of an unquantified number of post yolk-sac Atlantic sturgeon New York Bight DPS larvae.

The incidental take statement (ITS) also exempts the capture/collection of up to 1,663 sturgeon (any combination of NYB DPS Atlantic sturgeon and shortnose sturgeon) during relocation trawling project carried out over the blasting season (December 1, 2019-March 15, 2020). Of the 1,663, 100 sturgeon may be injured from surgery to install acoustic tags (any combination of NYB DPS Atlantic sturgeon and shortnose sturgeon).

6.5.2 Salem and Hope Creek Generating Stations (CENAP-OP-2006-6232)

PSEG Nuclear operates two nuclear power plants pursuant to licenses issued by the U.S. Nuclear Regulatory Commission (NRC). These facilities are the Salem and Hope Creek Generating Stations (Salem and HCGS), which are located on adjacent sites within a 740-acre parcel of property at the southern end of Artificial Island in Lower Alloways Creek Township, Salem County, New Jersey. Salem Unit 1 is authorized to operate until 2036 and Salem Unit 2 until 2040. Hope Creek is authorized to operate until 2046.

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property at the southern end of Artificial Island in Lower Alloways Creek Township, Salem County, New Jersey. Salem Unit 1 is authorized to operate until 2036 and Salem Unit 2 until 2040. Hope Creek is authorized to operate until 2046.

Consultation pursuant to Section 7 of the ESA between NRC and NMFS on the effects of the operation of these facilities has been ongoing since 1979. NMFS completed consultation with NRC in 2014 and issued a biological opinion considering the effects of operations under the renewed operating licenses (issued in 2011). In that biological opinion (NMFS 2014), we concluded that the continued operation of the Salem 1, Salem 2 and Hope Creek Nuclear Generating Stations through the duration of extended operating licenses may adversely affect, but is not likely to jeopardize, the continued existence of any listed species. In 2020, we reinitiated consultation between NRC and NMFS on the effects of the operation of these facilities. The consultation was completed in 2023 and a new biological opinion was issued on March 24, 2023. We concluded that the continued operation of the Salem 1, Salem 2 and Hope Creek Nuclear Generating Stations through the duration of extended operating licenses may adversely affect, but is not likely to jeopardize, the continued existence of any listed species.

As described in Table 23 through Table 25 below, the ITS of the Salem and Hope Creek Generation Stations 2023 biological opinion exempts take (injured, killed, capture or collected) of 32 shortnose sturgeon, 640 Atlantic sturgeon, and 4 loggerhead, 1 green, and 32 Kemp's ridley sea turtles resulting from the operation of the cooling water system. The ITS also exempts the capture of one live shortnose sturgeon and one live Atlantic sturgeon (originating from any of the five DPSs) during gillnet sampling associated with the Radiological Environmental Monitoring Program for either Salem 1, Salem 2, or Hope Creek. We did not identify any ESA-listed whale species within the Salem and HCGS action area.

As explained in the 2023 biological opinion, we also determined that the UBMWP and REMP, required by the NJPDES permit issued to PSEG for the operation of Salem 1 and 2, including the bay-wide trawl survey, beach seine sampling, and gillnet sampling are a activitye caused by the proposed action. Thus, in the Effects of the Action section, we considered the effects of the UBMWP and REMP. We estimated that the continuation of the bottom trawl survey will result in the non-lethal capture of 13 shortnose sturgeon and 17 Atlantic sturgeon (13 NYB, 3 CB, and and 1 of either SA, GOM, or Carolina DPS). We also expect the beach seine survey to result in the non-lethal capture of one Atlantic sturgeon (likely NYB DPS origin) or one shortnose sturgeon. We also anticipated the capture of one shortnose sturgeon and one Atlantic sturgeon (originating from any of the 5 DPSs) during gillnet sampling associated with the REMP programs for either Salem 1, Salem 2, or Hope Creek. The ITS exempts this amount of take ("capture" or "collect") of live shortnose sturgeon, Atlantic sturgeon and sea turtles incidentally captured during these surveys.

Table 23. Salem and HCGS - Impingement or Collection of Shortnose Sturgeon at the Trash Bars.

Salem Unit 1	Salem Unit 2	Total Unit 1 and 2
14 (10 dead, 5 dead due to impingement)	18 (13 dead, 6 dead due to impingement)	32 (23 dead, 11 due to impingement)

Table 24. Salem and HCGS - Impingement or Collection of Atlantic Sturgeon at the Trash Bars.

	Salem Unit 1	Salem Unit 2	Total Unit 1 and 2
All age classes and DPSs combined	112 (67 dead, 43 due to impingement)	144 (85 dead, 55 due to impingement)	256 (152 dead, 98 due to impingement)
Non-migrant subadults or juveniles (i.e., TL 760 mm or less) (NYB DPS)	61 (36 dead, 24 due to impingement)	78 (47 dead, 31 due to impingement)	139 (83 dead, 55 due to impingement)
Subadult or adult TOTAL:	51 (31 dead, 20 dead due to impingement)	66 (39 dead, 25 dead due to impingement)	117 (70 dead, 45 dead due to impingement)
Sub adult or adult NYB DPS	37 (22 dead, 15 dead due to impingement)	47 (28 dead, 18 dead due to impingement)	84 (50 dead, 32 dead due to impingement)
Sub adult or adult CB DPS	9 dead or alive	11 dead or alive	20 dead or alive
Subadult or adult SA DPS	4 dead or alive	5 dead or alive	9 dead or alive
Subadult or adult Carolina DPS	3 dead or alive	4 dead or alive	7 dead or alive
Subadult or adult GOM DPS	1 dead or alive	1 dead or alive	2 dead or alive

Table 25. Salem and HCGS - Impingement/Collection of Atlantic Sturgeon at the Traveling Screens.

	Salem Unit 1	Salem Unit 2	Total Units 1 and 2
NYB DPS	168 (14 injury or mortality)	216 (18 injury or mortality)	384 (32 injury or mortality)

6.5.3 Delaware River Partners (DRP) Marine Terminal

On December 8, 2017, we issued a biological opinion to the USACE for the development by the Delaware River Partners, LLC (DRP) of a multiuse deep-water seaport and international logistics center (DRP Port) on a portion of the former Dupont Repauno Property in Gibbstown, New Jersey at RKM 139/RM86.5 (NMFS 2017a). Thus, the port is located outside of the action area for this consultation. However, the biological opinion considered the consequences of vessel traffic that would travel between the Pilot Area at the mouth of the Delaware River and the DRP

Port. Therefore, the action area for the DRP Port overlaps with the action area for this consultation.

The proposed multiuse terminal will support automobile import and processing, perishables and bulk cargo handling, and bulk energy liquid products storage and handling. The development included dredging of an approach channel for vessels up to 265 m (870 ft) and 9 to 12 m (30 to 40 ft) deep draft, two berths with mooring dolphins, an auto terminal, a cargo area, facilities for bulk liquid energy storage, and warehouses. Estimated vessel traffic is 133 vessel calls per year. Of these, the USACE considered 91 vessel calls as new vessels to the Delaware River and the remaining 41 Roll On/Roll Off (RoRo) vessel calls to be vessels diverted and redistributed from existing terminals. Since vessel strikes are a stressor associated with vessel traffic, we determined that vessel traffic between the Pilot Boarding area at the mouth of the Delaware Bay and the proposed terminal was an activity interrelated to the proposed action. Thus, the action area for the proposed Port consultation overlaps with the action area for the DRP port from RKM 86/RM 53.5 to the end of the Federal Navigation Channel, the precautionary area, the connecting channel, and the pilot area.

In the biological opinion, we concluded that construction activities were not likely to adversely affect listed species or result in the destruction or adverse modification of critical habitat. However, based on the best science available at the time, we did determine that the transit of RoRo vessels interrelated to operation of the terminal will entrain and kill up to six adult sturgeon during the 30 years of terminal operation (until 2047) [12]. Four of these are likely to belong to the NYB DPS, one to CB DPS, and one from either SA DPS or GOM DPS[13]. We also determined that it is likely that RoRo vessels transiting the Delaware River during 30 years of terminal operation would result in the vessel strike mortality of one adult shortnose sturgeon. However, we concluded that these effects would not jeopardize the continued existence of these species. We concurred that the effects of the construction and operations of the facility were not likely to adversely affect listed sea turtles and whales.

On September 26, 2019, USACE sent us a request for reinitiation of consultation and a biological assessment for the development of a second dock (Dock 2) that can handle two vessels

[12] In May 2022, we received guidance from the Northeast Fisheries Science Center that, although our general analytical approach for the vessel traffic analysis applied in prior consultations was sound, certain improvements should be made, including incorporating the findings of a recent study by Fox et al. (2020) into the vessel strike rate analysis used to inform the amount of anticipated take of Atlantic sturgeon. Fox et al. (2020) estimated Atlantic sturgeon carcass reporting rates for the Delaware River and Estuary. This study was specifically designed to estimate Atlantic sturgeon carcass reporting rates in the Delaware River while accounting for temporal and spatial differences. Applying the reporting rates from Fox et al. (2020) results in 43 takes of Atlantic sturgeon over 30 years or 1.4 per year. To ensure that this Opinion fully complies with the analytical requirements of the ESA, including the requirement to use the best available scientific information, we will apply the updated take estimates for Atlantic sturgeon derived from the study by Fox et al. (2020) to the Environmental Baseline.

[13] The Northeast Fisheries Science Center also provided updated guidance on the mixed stock analysis rates. The updated rates are as follows: NYB 42%; CB 24%; SA 20%; and GOM 13%. Based on this new guidance, the updated rates for DRP are as follows: NYB 18; CB 10 (rounded down from 10.3); SA 9 (rounded up from 8.6); and GOM 6 (rounded up from 5.6).

simultaneously. The applicant proposed to change operations of Dock 1 from RoRo cargo to on/off loading of liquid energy products and to construct an additional dock specifically to be used to trans-load liquid energy products to two vessels simultaneously (allowing three vessels to be in port at any given time). Based on these changes, USACE informed us that they had determined that the proposed modifications would not change the number of vessels using the terminal (the existing dock and proposed dock combined) because handling of liquefied energy products requires a substantially longer docking time per vessel. However, because the construction of the additional dock included dredging of 45 acres of river bottom and the placement of numerous steel piles in the river, the USACE determined that the modifications would result in effects that were not considered in the previous biological opinion.

Combined, the dredging and use of the former and proposed access channels and berths will affect approximately 72 acres of benthic habitat and fauna. The proposed construction of the new wharf included pile driving of 280 24-inch to 48-inch steel piles and added another season of driving of piles. The proposed new dock will have an over-water footprint of 3.2 acres that added to the footprint of the wharf considered in the previous consultation. However, since the number of new vessel calls would not change, the USACE determined that the proposed modification to the project would not result in additional adverse effects to what were considered previously and that the proposed project was not likely to adversely affect (NLAA) listed species. On November 19, 2019, we issued a letter where we concurred with the USACE NLAA determination.

6.5.4 New Jersey Wind Port

On February 28, 2022, we issued a biological opinion to the USACE for the development by the Public Service Enterprise Group (PSEG) of a marshalling facility in support of offshore wind projects in New Jersey and other U.S. East Coast states. The Port will serve as a location where major offshore wind components are delivered (from manufacturing centers), partially assembled prior to loading onto an installation vessel/barge, and shipped (vertically) to an offshore wind site. The proposed Port is located on the east bank of the Delaware River within the greater estuary at approximately RKM 84 (RM 52), 24 km (15 mi) south of the Delaware Memorial Bridge. The Port will be constructed at the northwestern edge of the existing 734-acre PSEG property, which is the site of two power generation facilities, Salem Generating Station and Hope Creek Generating Station.[14] The proposed Port will occupy approximately 30 acres of the PSEG property, immediately to the south of USACE CDF Cell No. 3. The project site lies between the New Jersey shoreline and the Philadelphia to the Sea Federal Navigation Channel, located

[14] PSEG's Salem and Hope Creek Nuclear Generating Stations operate pursuant to licenses issued by the Nuclear Regulatory Commission. Incidental take of ESA-listed species as a result of these operations is exempted from Section 9 of the Endangered Species Act by an Incidental Take Statement (NER-2010-6581) issued by NMFS following the conclusion of formal ESA consultation on July 17, 2014. The Incidental Take Statement exempts take resulting from impingement or collection of sturgeon and sea turtles at the cooling water intake structure and from collection during routine biological monitoring. As a result of exceedances of the exempted take, formal consultation was reinitiated by the Nuclear Regulatory Commission on July 2, 2020 with the submission of a new BA for continued operation of Salem Generating Station (NRC 2020).

approximately 2,000 m (6,600 ft) west of the shoreline and maintained at approximately 13.7 m (45 ft) depth. The Artificial Island anchorage, General Anchorage No. 2, is located off the northern edge of Artificial Island, approximately 6 km (3.7 mi) upriver from the proposed Port.

In the biological opinion, we concluded that the proposed action may adversely affect, but is not likely to jeopardize the continued existence of the shortnose sturgeon, the GOM, NYB, CB, and SA DPSs of Atlantic sturgeon. We concurred that the effects of the construction and operations of the facility were not likely to adversely affect listed sea turtles and whales. In addition, we concluded that the proposed action may adversely affect, but is not likely to adversely modify or destroy critical habitat designated for the New York Bight DPS of Atlantic sturgeon. We determined that the proposed action has the potential to result in the mortality of shortnose sturgeon and NYB Atlantic sturgeon from entrainment in a cutterhead dredge and by vessel strike from construction vessels. We also anticipate that the long-term operation of the NJWP will cause vessel strikes of Atlantic sturgeon NYB, GOM, CB, and SA DPSs as well as shortnose sturgeon. We expect cutterhead dredging to kill up to two (2) sturgeon. These may be two juvenile shortnose sturgeon, two juvenile NYB DPS Atlantic sturgeon, or one of each. In addition, we expect that sturgeon interacting with construction vessels during construction of the NJWP will result in the mortality of one (1) shortnose sturgeon and one (1) Atlantic sturgeon. The shortnose sturgeon may be a juvenile or an adult. The Atlantic sturgeon will be either a juvenile or an adult of the NYB DPS. Finally, we expect up to 39 lethal vessel strikes over the operational life of the NJWP[15]. Of these:

- Up to 4 shortnose sturgeon juveniles, adults, or mix of the two
- Up to 7 juvenile Atlantic sturgeon from NYB DPS
- Up to 16 adult Atlantic sturgeon from NYB DPS
- Up to 5 adult Atlantic sturgeon from CB DPS
- Up to 5 adult Atlantic sturgeon from SA DPS
- Up to 2 adult Atlantic sturgeon from GOM DPS[16]

[15] In May 2022, we received guidance from the Northeast Fisheries Science Center that, although our general analytical approach for the vessel traffic analysis applied in prior consultations was sound, certain improvements should be made, including incorporating the findings of a recent study by Fox et al. (2020) into the vessel strike rate analysis used to inform the amount of anticipated take of Atlantic sturgeon. Fox et al. (2020) estimated Atlantic sturgeon carcass reporting rates for the Delaware River and Estuary. This study was specifically designed to estimate Atlantic sturgeon carcass reporting rates in the Delaware River while accounting for temporal and spatial differences. Applying the reporting rates from Fox et al. (2020) results in 250 takes of Atlantic sturgeon over 25 years or 10 takes per year. To ensure that this Opinion fully complies with the analytical requirements of the ESA, including the requirement to use the best available scientific information, we will apply the updated take estimates for Atlantic sturgeon derived from the study by Fox et al. (2020) to the Environmental Baseline.

[16] The Northeast Fisheries Science Center also provided updated guidance on the mixed stock analysis rates. The updated rates are as follows: NYB 42%; CB 24%; SA 20%; and GOM 13%. Based on this new guidance, the updated rates for NJWP are as follows: NYB 15 (rounded up from 14.7); CB 8 (rounded down from 8.4); SA 7; and GOM 5 (rounded up from 4.5).

However, subsequent to issuing the consultation, the NEFSC completed their review of reporting rates and new data on reported mortalities in the Delaware River and Bay received from NJFW (see section 6.3.2). Based on this review, we concluded that the data constituted new information that reveals that the action may affect listed species in a manner and/or to an extent not previously considered in the current biological opinion and, therefore, the consultation needed to be reinitiated per the ESA implementing regulations at 50 CFR 402.16. On July 20, 2023, the USACE requested that we reinitiate the consultation on the project. At the time of this Opinion, we have not yet received all the information necessary to initiate a new consultation on the NJWP project. For the purpose of this Opinion and its baseline, we have used the new information to recalculate estimated number of vessel strikes for the project as originally proposed. Based on this, we anticipate that the operation of the NJWP may result in 226 Atlantic sturgeon and 21 shortnose sturgeon vessel strike mortalities over 25 years of operation.

6.5.5 Edgemoor Container Port

On March 30, 2022, we issued a biological opinion to the USACE for the development by the Diamond State Port Corporation (DSPC) of a new shipping container port facility on a site formerly occupied by the Chemours (DuPont) Edge Moor Plant along the Delaware River in Edgemoor, New Castle County, Delaware. The re-development would convert the property into a multi-user containerized cargo port capable of accepting New Panamax cargo ships. The proposed Port will be located at 4600 Hay Road in the Edgemoor section of unincorporated New Castle County, Delaware, along the eastern shore of the Delaware River. Latitude/Longitude: 39.74825° N/75.496028° W (NAD 83) and approximately from RKM 117 to RKM 118 (RM 72.5 to RM 73.3).

However, subsequent to issuing the consultation, the NEFSC completed their review of reporting rates and new data on reported mortalities in the Delaware River and Bay received from NJFW (see section 6.3.2). Based on this review, we concluded that the data constituted new information that reveals that the action may affect listed species in a manner and/or to an extent not previously considered in the current biological opinion and, therefore, the consultation needed to be reinitiated per the ESA implementing regulations at 50 CFR 402.16. The consultation was reinitiated in September 2022 and we issued a new biological opinion on June 2, 2023.

In the biological opinion, we concluded that the proposed action may adversely affect, but is not likely to jeopardize the continued existence of the shortnose sturgeon, the GOM, NYB, CB, and SA DPSs of Atlantic sturgeon. We concurred that the effects of the construction and operation of the facility were not likely to adversely affect listed sea turtles and whales. In addition, we concluded that the proposed action may adversely affect, but is not likely to adversely modify or destroy critical habitat designated for the New York Bight DPS of Atlantic sturgeon. We determined that the proposed action has the potential to result in the mortality of shortnose sturgeon and NYB Atlantic sturgeon from entrainment in a cutterhead dredge and by vessel strike from construction vessels. We also anticipate that the long-term operation of the Port will cause vessel strikes of Atlantic sturgeon NYB, GOM, CB, and SA DPSs as well as shortnose sturgeon. We expect cutterhead dredging to kill up to three (3) sturgeon (no more than one per dredge cycle). These may be juvenile shortnose sturgeon or juvenile NYB DPS Atlantic sturgeon. In addition, we expect that sturgeon interacting with construction vessels during construction of the Port will result in the mortality of six (6) shortnose sturgeon and 14 Atlantic sturgeon. The shortnose sturgeon may be a juveniles or adults. The Atlantic sturgeon will be either juveniles or adults or both from the NYB DPS. Finally, we expect up to 373 lethal vessel strikes during 50 years of operation of the Port. Of these:

- Up to 50 shortnose sturgeon juveniles, adults, or mix of the two
- Up to 69 juvenile Atlantic sturgeon from NYB DPS
- Up to 76 adult Atlantic sturgeon from NYB DPS
- Up to 31 subadult Atlantic sturgeon from the NYB DPS
- Up to 61 adult/subadult Atlantic sturgeon from CB DPS
- Up to 51 adult/subadult Atlantic sturgeon from SA DPS
- Up to 33 adult/subadult Atlantic sturgeon from GOM DPS
- Up to 2 adult/subadult Atlantic sturgeon from the Carolina DPS[17]

6.6 Federal Actions that have Undergone Informal Consultations

Several federally authorized private projects in the Delaware River have undergone informal consultation. These projects includes dredging, construction (including pile driving), and vessel traffic associated with construction and operations of the new or modified port facilities discussed below. No interactions with ESA-listed sea turtles or sturgeon have been reported in association with any of these projects, nor has any take been authorized.

6.6.1 Consultations on Port and Terminal Constructions

Liberty Terminal (NAP-2016-00978-24)

In 2021, the USACE proposed to issue a Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403) and Section 404 of the Clean Water Act (33 U.S.C. 1344) to Liberty Terminal at Pennsauken Urban Renewal, LLC. The permit would allow the repair/rehabilitation of an existing dock facility to its intended purpose (i.e. loading of petroleum related product to land-based storage tanks) and bring the facility to modern working standards. In a letter dated September 2, 2021, we concurred with the USACE's determination that the proposed project may affect, but is not likely to adversely affect listed species under our jurisdiction or designated critical habitat.

The terminal is located in Pennsauken Township, Camden County, New Jersey at RKM 167 (RM 104). The proposed project included pile driving for construction of a new loading platform, mooring dolphins, and catwalks. The applicant did not propose dredging of the berth as the channel already is deep enough for vessels to dock at the landing platform. The proposed

[17] The Northeast Fisheries Science Center also provided updated guidance on the mixed stock analysis rates. The updated rates are as follows: NYB 42%; CB 24%; SA 20%; and GOM 13%. Based on this new guidance, the updated rates for Edgemoor are as follows: NYB 21; CB 12; SA 10; and GOM 7 (rounded up from 6.5).

project also included increasing the pipe diameter of two outfalls and placing protective riprap to protect the shoreline from scouring.

The applicant anticipated up to 120 tug-supported barges annually calling at the terminal during operation of the terminal. No more than one barge would be moored at any one time. According to the USACE, the applicant's marketing plan is based on attracting customers from other terminals in the area as the Liberty terminal will be a state of the art facility meeting or exceeding all terminal services provided by the existing old facilities and having the most up to date safety and emissions standards. The USACE concluded that the Liberty Terminal will be serving a portion of the refinery market that already uses the existing river traffic, and their operation would only replace a small fraction of this supply and demand. Therefore, the proposed project would not add vessels to the existing baseline as the need for transporting refinery products would occur irrespective of the proposed terminal.

Sunoco Marcus Hook Mariner East project (CENAP-OP-R-2013-0067-46)

The Sunoco Marcus Hook site is located in Marcus Hook, Delaware County, Pennsylvania at RKM 127 (RM 79), approximately 10 kilometers (6.3 mi) upstream of the proposed Port. The USACE issued a Public Notice on August 3, 2015 for the modification of the existing Dock IA to allow for the on-loading of ethane, butane, and propane to marine vessels in association with the Sunoco Partners Marketing & Terminals, L.P. - Marcus Hook Mariner East 1 project. The permit was issued on December 5, 2015, with work including the demolition of existing marine structures and construction of a new approach way, roadway and pipeline, pile-supported concrete deck platform, gangway/crane tower, six mooring dolphins, three breasting/mooring dolphins with fenders and concrete-filled pilings, and walkway, a concrete containment sump with associated sump pipes, re-ringing of existing breasting cells with new steel sheet piling, and installation of new piping systems on top of the pier, and the installation of structural and fender piles. No dredging would be required for this activity.

As stated in the Public Notice, a preliminary review of this application by USACE found that the proposed work may affect shortnose sturgeon and Atlantic sturgeon. No other ESA species were identified in the Mariner East action area. In communication to us (August 12 through September 3, 2015), USACE determined that the project may affect, but is not likely to adversely affect, the shortnose or Atlantic sturgeon.

By letter dated October 1, 2015, we agreed with USACE's determination that the project was not likely to adversely affect and listed species in NMFS jurisdiction. In this letter, NMFS did not identify any ESA-listed sea turtles or whales within the Mariner East action area. In this letter, NMFS discussed the potential effects to listed species associated with habitat modification, piling driving, and vessel traffic.

The potential increased risk of vessel strike to sturgeon was considered as it relates vessel traffic associated with construction. We found that, because the use of the dock would be the same as its previous use, there would not be an increase in vessel traffic (NMFS 2015a). Because no increase in vessel traffic was expected, NMFS concluded that there would be no increased risk of vessel strike in the future.

Southport Marine Terminal (CENAP-OP-R-2009-0933)

The Southport Marine Terminal project is located at the eastern end of the Philadelphia Naval Business Center, formerly known as the Philadelphia Naval Shipyard, in the city and county of Philadelphia, Pennsylvania. The applicant, Philadelphia Regional Port Authority, proposed to construct a new marine terminal on approximately 116 acres of currently vacant land. In a letter dated March 21, 2013, we concurred with the USACE's determination that the proposed action was not likely to adversely affect any ESA listed species under our jurisdiction and that all effects to protected species were insignificant and discountable. The consultation considered the effects from the dredging of approximately 35 acres within the Delaware River, construction of a pile supported wharf, installation of 731.5 m (2,400 ft) of riprap along the Delaware River shoreline, filling of approximately 11 acres of aquatic habitat within the Delaware River, and the maintenance dredging of the berths with the removal of approximately 20,000 cy of material every two years. In addition, the consultation also considered the effects of vessels traveling between the port and the mouth of the Delaware Bay during operation of the port. The USACE and applicant anticipated that the port would receive 260 cargo vessel calls per year. The Section 10/404 Permit was issued by the USACE on April 16, 2013. However, in November 2016, the Philadelphia Regional Port Authority suspended the bid process for the vacant 195-acre Southport Marine Terminal Complex (Loyd 2017). Instead of developing a new terminal facility, the Commonwealth of Pennsylvania invested $93 million into landside development of an auto terminal at the site, including development of 155 paved acres and conversion of a former seaplane hangar into an automobile processing and detailing facility (Loyd 2017). The development was completed in 2019. In late 2019, the USACE informed us that the applicant had requested an extension of the permit to allow for completion of the work as proposed in the original 2013 consultation. The USACE requested a reinitiation of the consultation to address effects to critical habitat designated for Atlantic sturgeon in 2017. Consequently, in a letter dated January 22, 2020, we concurred with the USACE's determination that the proposed project may affect but is not likely to adversely affect critical habitat designated for Atlantic sturgeon.

Paulsboro Marine Terminal (CENAP-OP-R-2007-1125)

The Paulsboro Marine Terminal (PMT) is located in Paulsboro, Gloucester County, New Jersey at RKM 144 (RM 89.5). USACE issued a permit for the construction of the project in January 2011. The New Jersey Department of Environmental Protection issued their permit, including water quality certification and coastal zone management approval, on October 15, 2010. The PMT wharf will accommodate four berths and is expected to handle a variety of general cargo. Berths 1, 2 and 3 are designed to accommodate Handymax[18] class cargo vessels, which are typically 198 m (650 ft) long and 29 m (95 ft) wide. The fourth berth will be designated as a

18 Handymax is a commonly occurring, general purpose bulk, oceangoing cargo ship at southern New Jersey ports. Typical Handymax ships are 650 feet long and 95 feet wide.

barge berth and is designed to accommodate a typical 122 m (400 ft) long by 30.5 m (100 ft) wide barge. A ship traffic modeling study was completed in September 2010 for the project. The model was used to assess the impact of the work load brought by PMT on the marine traffic in the Delaware River Main Channel. The results of the model show the expected increase in the daily number of vessels at seven locations within the Delaware River, once the Paulsboro terminal was operational. The predicted increase in daily counts at any location was consistently less than one and the 95 confidence interval was between 0.7 and 1. Using this model, USACE predicted that the construction and operation of the PMT would, on average, result in an increase of one additional ship in the Delaware River per day. In the 2010 consultation, the USACE determined that given the high volume of traffic on the river and the variability in traffic in any given day, the increase in traffic of one cargo vessel per day is negligible and that it is unlikely there would be any detectable increase in the risk of vessel strike to shortnose sturgeon, Atlantic sturgeon or sea turtles. Listed whales were not identified to be present within the PMT action area (which included the Philadelphia to the Sea Navigation Channel from the port to the mouth of the Delaware River) and therefore impacts to ESA-listed whale species were not discussed. In a letter dated July 25, 2011, we concurred with the USACE's determination that all effects to these species would be insignificant and discountable. Subsequently, Phase 1 of the project was completed. However, the permit expired and in 2018 the USACE requested reinitiation of the consultation to consider the effects of completing Phase 2 of the project on the listed Atlantic sturgeon and the designated critical habitat for Atlantic sturgeon. All dredging had been completed during Phase 1 and the consultation only considered the effects of pile driving for the construction of wharf structures. On August 31, 2021, we issued a letter concurring with the determination by the USACE that the proposed Phase 2 may affect but is not likely to adversely affect listed sturgeon or Atlantic sturgeon critical habitat.

Vessel Operations

Potential sources of adverse effects from federal vessel operations in the action area of this biological opinion include operations of the U.S. Navy (USN) and the U.S. Coast Guard (USCG) (which maintain the largest federal vessel fleets), the EPA, the National Oceanic and Atmospheric Administration (NOAA), and USACE. We have conducted formal consultations with the USCG, the USN, EPA, and NOAA on their vessel operations. In addition to operation of USACE vessels, we have consulted with the USACE to provide recommended permit restrictions for operations of contract or private vessels around whales. Through the Section 7 process, where applicable, we have and will continue to establish conservation measures for all these agency vessel operations to avoid adverse effects to listed species. Refer to the biological opinions for the USCG (September 15, 1995; July 22, 1996; and June 8, 1998) and the USN (May 15, 1997) for detail on the scope of vessel operations for these agencies and conservation measures being implemented as standard operating procedures. No interactions with sturgeon or sea turtles have been reported with any of the vessels considered in these biological opinions.

Other Projects

We have completed several other informal consultations on effects of in-water construction activities in the Delaware River permitted by the USACE. This includes several pier reconfiguration and maintenance dredging projects. No interactions with ESA-listed species have been reported in association with any of these projects.

We have also completed several informal consultations on effects of private dredging projects permitted by the USACE. All of the dredging was with a mechanical or cutterhead dredge. No interactions with ESA-listed species have been reported in association with any of these projects.

On April 12, 2017, we completed an informal, programmatic consultation pursuant to Section 7 of the ESA of 1973, as amended, for six categories of projects regularly permitted, funded, or otherwise carried out by the USACE (the NLAA program). Proposed projects within these activity categories will be covered by the programmatic consultation provided they meet the project design criteria (PDC) that are outlined in this programmatic consultation. For any project USACE considered covered under the program, they will provide us with a form verifying that each PDC is met or a justification for why they believe that the project fits under the program even if some PDC are not met. If we agree with their determination that a project fits under the program, we sign the form.

We have included several in-water construction activities in the Delaware River permitted by the USACE under the NLAA program. These include dock and pier repairs, bank stabilization projects, aquaculture projects, and routine maintenance dredging activities. No interactions with ESA-listed species have been reported in association with any of these projects, nor has any take been authorized.

6.7 Scientific Studies

NMFS has issued research permits under Section 10(a)(1)(A) of the ESA, which authorizes activities for scientific purposes or to enhance the propagation or survival of the affected species. The permitted activities do not operate to the disadvantage of the species and are consistent with the purposes of the ESA, as outlined in Section 2 of the Act. The following Section 10(a)(1)(A) permits are currently in effect for Atlantic sturgeon and shortnose sturgeon.

We searched for research permits on the NOAA Fisheries' online application system for Authorization and Permits for Protected Species (APPS) interactive website[19]. The search criteria used confined our search to active permits that include take of sturgeon within the Delaware River and Bay as well as research in coastal waters off Delaware and New Jersey.

There are currently five research permits pursuant to Section 10(a)(1)(A) of the ESA that authorize research of sturgeon in the Delaware River/Bay (Table 26 and Table 27). However, many research activities include a larger area of the Atlantic Ocean, and the requested take did

[19] APPS website URL: https://apps.nmfs.noaa.gov/index.cfm

not always specify the waters where take would occur. Thus, some of the take in the tables below include take for activities outside of the action area, i.e., mid-Atlantic coastal waters in general.

The requested take reported here only includes take authorized under section 10(a)(1)(A) of the ESA. In addition, research projects may include take authorized under other authority, e.g., under Section 7 of the ESA. These takes are presented elsewhere in this Opinion and, therefore, are not included here to avoid double counting of take provided under the ESA.

Table 26. Shortnose sturgeon Section 10(a)(1)(A) permits within the action area.

Permittee	File #	Project	Area	Shortnose Sturgeon Takes	Research Timeframe
School of Marine and Atmospheric Sciences, Stony Brook University	20351	Atlantic and Shortnose Sturgeon Population Dynamics and Life History in New York and Coastal Marine and Riverine Waters	Marine aggregation areas located in New York, New Jersey, Delaware, and Connecticut waters. Riverine and estuarine areas of the Hudson and Delaware Rivers.	<u>Lethal</u> Incidental mortality - 1 Adult/Sub-adult[20] - 1 Juvenile Direct mortality - 80 early life stages annually with no more than a total of 160 <u>Non-lethal</u> Gill net - 285 adults, 195 sub-adults, 195 juveniles, capture/handle/release, annually Trawl 285 adults, 195 sub-adults, 195 juveniles, capture/handle/release, annually	10 years, 02/27/2016 to 03/31/2027
Dewayne Fox, Assistant Professor, Delaware State University, Dept. of Agriculture and Natural Resources	20548	Reproduction, habitat use, and interbasin exchange of Atlantic and Shortnose Sturgeons in the mid-Atlantic	- Marine waters between Virginia and New York. - Delaware Bay and Delaware River and estuary. - Hudson River and estuary	<u>Lethal (annually)</u> Incidental mortality - 1 adult/sub-adult[21] <u>Non-lethal (annually)</u> - 150 adult, capture/handle/release, in each of Delaware and Hudson Rivers (Spawning Site Identification) - 100 adult, sub-adult from each of Delaware and Hudson Rivers (Hydroacoustic Assessment)	10 years, 03/31/2017 to 03/31/2027
Delaware Department of Natural Resources and Environmental Control	24020	Characterizing juvenile life stages of endangered Atlantic and Shortnose Sturgeon in the Delaware River and Estuary.		<u>Lethal</u> Incidental mortality - 1 adult (no more than 2 for 10 yr permit period) - 1 juvenile (no more than 2 for 10 yr permit period) <u>Non-lethal</u> - 10 adult - 65 juvenile	10 Years, 01/28/2021 to 01/31/2031

[20] Although GARFO does not include the term "sub-adult" as a lifestage for shortnose sturgeon, the term is often used by researchers and managers to indicate larger and older shortnose sturgeon individuals that have not yet reached maturity (i.e. adult phase). The application for permit 20351 states the sub-adult lifestage to range from 1000–1300 mm FL, while GARFO considers shortnose sturgeon ranging from 140 to 450 mm (in the northern part of their range) to be juveniles and sturgeon greater than 450 mm are considered to be adults.

[21] For permit 20548, the applicant describes the shortnose sturgeon sub-adult phase as ranging from 450– 600 mm FL.

Table 27. Atlantic sturgeon Section 10(a)(1)(A) permits within the action area.

Permittee	File #	Project	Area	Atlantic Sturgeon Takes	Research Timeframe
North East Fisheries Science Center	17225	Conservation engineering to reduce sea turtle and Atlantic sturgeon bycatch in fisheries in the Northeast Region	U.S. Atlantic waters managed under the Mid-Atlantic and New England Fishery Management Council's Fishery Management Plans. Part A: from and including MA south to the NC-SC border. Part B: U.S. Atlantic waters off NC, south to the border of GA and FL	Lethal: Incidental mortality - 6 adult/juvenile Non-lethal: - 223 adult/juvenile sturgeon (Part A: Northern Area) - 204 adult/juvenile sturgeon (Part B: Southern Area)	5 years, 01/01/2017 to 12/21/2022 Extension granted 11/09/21 for 1 year or less.
School of Marine and Atmospheric Sciences, Stony Brook University	20351	Atlantic and Shortnose Sturgeon Population Dynamics and Life History in New York and Coastal Marine an Riverine Waters	Marine aggregation areas located in NY, NJ, DE, and CT waters. Riverine and estuarine areas of the Hudson and Delaware Rivers.	Lethal Incidental mortality - 1 Adult/Sub-adult - 2 Juvenile Direct mortality - 80 early life stages annually with no more than a total of 160 Non-lethal Gill net - 71 adults, 352 sub-adults, 437 juveniles, 130 small juveniles, capture/handle/release, annually Trawl 71 adults, 352 sub-adults, 437 juveniles, 130 small juveniles, capture/handle/release, annually	10 years, 02/27/2016 to 03/31/2027
Dewayne Fox, Assistant Professor, Delaware State University, Dept. of Agriculture and Natural Resources	20548	Reproduction, habitat use, and interbasin exchange of Atlantic and Shortnose Sturgeons in the mid-Atlantic	- Marine waters between Virginia and New York. - Delaware Bay and Delaware River and estuary. - Hudson River and estuary	Lethal (annually) Direct mortality: - 150 early life stage from each of Delaware River and Hudson River Incidental mortality - 1 adult Non-lethal (annually) - 150 adult, capture/handle/release, in each of Delaware and Hudson Rivers (Spawning Site Identification) - 100 adult, sub-adult, and juvenile from each of Delaware and Hudson Rivers (Hydroacoustic Assessment) - 150 adults/sub-adults and/or juveniles, capture/handle/release, from Delaware River estuary, Bay, NJ near shore (Estuarine and Marine Foraging) - 300 adult and sub-adult and 150 juveniles, capture/handle/release (Coastal Sampling) - 300 early life stages from each of Delaware River and Hudson River, capture/handle/release (Spawning Site Identification)	10 years, 03/31/2017 to 03/31/2027
Delaware Department of Natural Resources and Environmental Control	24020	Characterizing juvenile life stages of Atlantic and Shortnose Sturgeon in the Delaware River and Estuary.	- In the tidal portion of the Delaware River, with a majority of the sampling being completed in the Marcus Hook area (may be adjusted using telemetry data)	Lethal Incidental mortality - 1 adult/subadult (no more than 2 for 10 yr permit period) - 1 juvenile (no more than 2 for 10 yr permit period) Non-lethal - 10 adult/subadult - 340 juvenile	10 Years, 01/28/2021 to 01/31/2031

6.7.1 Section 10(a)(1)(B) Permits

Section 10(a)(1)(B) of the ESA authorizes NMFS, under some circumstances, to permit non-federal parties to take otherwise prohibited fish and wildlife if such taking is "incidental to, and not the purpose of carrying out otherwise lawful activities" (50 CFR 217-222). As a condition for issuance of a permit, the permit applicant must develop a conservation plan that minimizes negative impacts to the species.

Active permits and permit applications are posted online for all species as they become available at https://www.fisheries.noaa.gov/national/endangered-species-conservation/incidental-take-permits. Most coastal Atlantic states are either in the process of applying for permits or considering applications for state fisheries. We are actively working with several states and other parties on Section 10(a)(1)(B) permits; however to date no Section 10(a)(1)(B) permits have been authorized for Delaware, Pennsylvania, or New Jersey states fisheries. We have issued a permit to the Exelon Generating Company, LLC., for the withdrawal of water through the cooling intake (Table 31). We issued a biological opinion for the permit on June 19, 2020 (NMFS 2020).

Table 28. Atlantic sturgeon and shortnose sturgeon Section 10(a)(1)(B) permits within the action area.

Permittee	Permit #	Project	Area	Atlantic Sturgeon Takes	Timeframe
Exelon Generating Company, LLC	23148	Operation of Eddystone Generating Station	Delaware River from 64 meters upriver from Eddystone (on the western shore of the Delaware River) downriver to the mouth, its tributary Crum Creek, and marine waters from the mouth of the Delaware River to New York Harbor.	New York Bight DPS Atlantic sturgeon Vessel Strike: 1 over 10 years (sub-adults/adults) Entrainment: 27,000 larvae (2 age-1 equivalents) per year Impingement: 5 per year (YOY/sub-adults) Total: 1 sub-adult/adult, 270,000 larvae, and 50 YOY/sub-adults over 10 years Shortnose sturgeon Impingement: 5 per year (YOY/sub-adults) Total: 50 YOY/sub-adults over 10 years.	10 Years, 07/06/2020 to 7/31/2030

6.8 State or Private Actions in the Action Area

6.8.1 State Authorized Fisheries

The action area includes portions of Pennsylvania, New Jersey and Delaware state waters within the Delaware River and Delaware Bay. Several fisheries for species not managed by a federal FMP occur in state waters. Atlantic and shortnose sturgeon may be vulnerable to capture, injury and mortality in a number of these fisheries. Atlantic sturgeon as well as shortnose sturgeon are also vulnerable to capture in state-water fisheries occurring in rivers, such as shad fisheries. Gear types used in these fisheries include hook-and-line, gillnet, trawl, pound net and weir, pot/trap, seines, and channel nets among others. The magnitude and extent of interaction, and the amount of gear contributed to the environment by all of these fisheries together is currently unknown.

Captures of Atlantic sturgeon (ASMFC 2017b, ASSRT 2007) have been reported through state reporting requirements, research studies, vessel trip reports (VTRs), NEFSC observer programs, and anecdotal reports. In most cases however, there is limited observer coverage of these fisheries, and the extent of interactions with ESA-listed species is difficult to estimate. Information on the number of sturgeon interactions in state fisheries is extremely limited. The available bycatch data for FMP fisheries indicate that sink gillnets and bottom otter trawl gear pose the greatest risk to Atlantic sturgeon, although they are also caught by hook and line gear, fyke nets, pound nets, drift gillnets, and crab pots (ASMFC 2017a). It is likely that this vulnerability to these types of gear is similar to federal fisheries, although there is little data available to support this. An Atlantic sturgeon "reward program" provided commercial fishermen monetary rewards for reporting captures of Atlantic sturgeon in Maryland's Chesapeake Bay from 1996 to 2012 (Mangold *et al.* 2007). The data from this program show that Atlantic sturgeon have been caught in a wide variety of gear types, including hook and line, pound nets, gillnets, crab pots, eel pots, hoop nets, trawls, and fyke nets. Pound nets (58.9 percent) and gillnets (40.7 percent) accounted for the vast majority of captures. Of the more than 2,000 Atlantic sturgeon reported in the reward program over a 16-year period from 1996-2012, biologists counted ten individuals that died because of their capture. No information on post-release mortality is available (Mangold *et al.* 2007).

Efforts are currently underway by the Commission and the coastal states to assess the impacts of state authorized fisheries on sturgeon. Several states (including Delaware and New Jersey) are working on applications for ESA Section 10(a)(1)(B) incidental take permits to cover their fisheries; however, to date, no permit applications have been submitted to NMFS by states that authorize fisheries within the Delaware River/Bay[22]. Below, we discuss the different fisheries authorized by the states and any available information on interactions between these fisheries and sturgeon. Fisheries that use types of gear unlikely "to harass, harm…wound, kill, trap, capture, or collect" (ESA Section 2(a)(19)) sturgeon, or where there is no documented interactions of the fishery with sturgeon (e.g., American eel, American lobster, whelk) are not included.

Atlantic croaker fishery

Atlantic croaker (*Micropogonias undulates*) occur in coastal waters from the Gulf of Maine to Argentina, and are one of the most abundant inshore bottom-dwelling fish along the U.S. Atlantic coast. Recreational fisheries for Atlantic croaker are likely to use hook and line; commercial fisheries targeting croaker primarily use otter trawls. An Atlantic croaker fishery using trawl and gillnet gear also occurs within the action area and is managed under an ASMFC Interstate Fisheries Management Plan (ISFMP) (including Amendment 1 in 2005 and Addendum 1 in 2010), but no specific management measures are required. Atlantic croaker are seasonally present in Delaware Bay; fishing occurs for this species in the Bay but not in the river.

[22] A Section 10 (a)(1)(b) permit was issued to the State of Georgia (Permit No. 16645) on January 8, 2013, exempting the incidental take of shortnose sturgeon and Atlantic sturgeon (SA, Carolina and CB DPS) in the State shad fishery. A Section 10 (a)(1)(b) permit was issued to the State of North Carolina on July 9, 2014, to exempt incidental take of Atlantic sturgeon from all 5 DPSs in the North Carolina inshore gillnet fishery.

Atlantic sturgeon interactions have been observed in the Atlantic croaker fishery, but a quantitative assessment of the number of Atlantic sturgeon captured in the croaker fishery is not available. A mortality rate of Atlantic sturgeon in commercial trawls has been estimated at 5 percent. A review of the Northeast Fisheries Observer Program (NEFOP) database indicates that from 2006-2010, 60 Atlantic sturgeon (out of a total of 726 observed interactions) were captured during observed trips where the trip target was identified as croaker. This represents a minimum number of Atlantic sturgeon captured in the croaker fishery during this time period as it only considers trips that included a NEFOP observer onboard. Because the fishery occurs in the Bay, we do not anticipate any interactions with shortnose sturgeon.

Weakfish fishery

The weakfish fishery occurs in both state and Federal waters from Nova Scotia to southeastern Florida, but the majority of commercially and recreationally caught weakfish are caught in state waters (ASMFC 2002) from New York to North Carolina, including the Delaware Bay. The dominant commercial gears include gillnets, pound nets, haul seines, flynets, and trawls, with the majority of landings occurring in the fall and winter months (ASMFC 2002, Weakfish Plan Review Team 2019). Weakfish landings were dominated by the trawl fishery through the mid-1980s, after which gillnet landings began to account for most weakfish landed (ASMFC 2002). Other gears include pound nets, haul seines, and beach seines (ASMFC 2016). The recreational fishery catches weakfish using live or cut bait, jigging, trolling, and chumming, and the majority of fish are caught in state waters.

In our 2021 biological opinion for the authorization of multiple fisheries (Batch BO), we determined that it is extremely unlikely that the fisheries, including the weakfish fishery, considered in the biological opinion will interact with shortnose sturgeon. A quantitative assessment of the number of Atlantic sturgeon captured in the weakfish fishery is not available; however, a mortality rate of Atlantic sturgeon in commercial trawls has been estimated at 5 percent. Weakfish has also been identified as the top landed species on observed trips where sturgeon were incidentally captured (NEFSC observer/sea sampling database, unpublished data). In addition, the weakfish-striped bass fishery was identified as having higher bycatch rates using data from 1989-2000 (ASSRT 2007); however, there are a number of caveats associated with this data.

Crab fisheries

Crab fisheries use a variety of gears including hand, pot/trap, trawl, and dredge. These fisheries occur in federal and state waters and target species such as blue, Jonah, rock and horseshoe crab. While the blue crab fishery occurs throughout the Mid-Atlantic south to the Gulf of Mexico, Maryland, Virginia, and North Carolina harvesters execute the majority of the effort. The Chesapeake Bay Program's Blue Crab Management Strategy indicates that there are multiple commercial and recreational gear types, various season lengths and regulations in three management jurisdictions. Fishing practices and the resulting harvest vary because of the complex ways crabs migrate and disperse throughout Chesapeake Bay.

The Jonah and rock crab fisheries may be carried out in conjunction with the lobster fishery. In this case, lobster traps are likely to be used. Depending on state regulation, other style traps may be available for use. Jonah crabs are harvested from deeper waters than rock crabs, and presently, are more highly valued. The commercial Jonah crab fishery is centered around Massachusetts and Rhode Island, though landings occur throughout New England and Mid-Atlantic states. The majority of horseshoe crab harvest comes from the Delaware Bay region, followed by the New York, New England, and the Southeast regions. Trawls, hand harvests, and dredges make up the bulk of commercial horseshoe crab landings.

Horseshoe crab fisheries occur in saline and marine waters and are unlikely to interact with shortnose sturgeon. Atlantic sturgeon are known to be caught in state water horseshoe crab fisheries using trawl gear (Stein *et al.* 2004b). With the exception of New Jersey state waters, the horseshoe crab fishery operates in all state waters that occur in the action area. Along the U.S. East Coast, hand, bottom trawl, and dredge fisheries account for the majority (86 percent in the 2017 fishery) of commercial horseshoe crab landings in the bait fishery. Other methods used to land horseshoe crab are gillnets, fixed nets, rakes, hoes, and tongs (ASMFC (Atlantic States Marine Fisheries Commission) 2019, Horseshoe Crab Plan Review Team 2019). For most states, the bait fishery is open year round. However, the fishery operates at different times due to movement of the horseshoe crab. New Jersey has prohibited commercial harvest of horseshoe crabs in state waters (N.J.S.A. 23:2B-20-21) since 2006 (Horseshoe Crab Plan Review Team 2019). Other states also regulate various seasonal and area closures and other state horseshoe crab fisheries are regulated with various seasonal/area closures (Horseshoe Crab Plan Review Team 2019). The majority of horseshoe crab landings from the bait fishery from 2014-2018 came from Maryland, Delaware, New York, Virginia, and Massachusetts (Horseshoe Crab Plan Review Team 2019). There is also a smaller fishery for biomedical uses.

An evaluation of bycatch of Atlantic sturgeon using the NEFSC observer/sea sampling database (1989-2000) found that the bycatch rate for horseshoe crabs was low, at 0.05 percent (Stein *et al.* 2004a). An Atlantic sturgeon "reward program," where commercial fishermen were provided monetary rewards for reporting captures of Atlantic sturgeon in the Maryland waters of Chesapeake Bay operated from 1996 to 2012.[23] From 1996-2006, the data showed that one of 1,395 wild Atlantic sturgeon was found caught in a crab pot (Mangold *et al.* 2007).

American shad fishery

An American shad fishery occurs in state waters of New England and the Mid-Atlantic and is managed under the Commission's ISFMP. Amendment 3 to the ISFMP requires states and jurisdictions to develop sustainable FMPs, which are reviewed and approved by the Commission's Technical Committee, in order to maintain recreational and commercial shad fisheries (ASMFC 2010). In 2005, the directed at-sea fishery was closed and subsequent landings from the ocean are only from the bycatch fishery. In 2012, only one commercial fishing

[23] The program was terminated in February 2012, with the listing of Atlantic sturgeon under the ESA.

license was granted for shad in New Jersey. The fishery occurs in rivers and coastal ocean waters and uses five-inch mesh gillnets left overnight to soak. Based on the available information, there is little bycatch mortality.

Recreational shad fishing is currently allowed within the Delaware River with hook and line only; commercial fishing for shad occurs with gill nets, but only in Delaware Bay. Recreational hook and line shad fisheries are known to capture shortnose sturgeon and Atlantic sturgeon. Data from the Atlantic Coast Sturgeon Tagging Database (2000-2004) shows that the shad fishery accounted for 8 of Atlantic sturgeon recaptures. In the past, it was estimated that over 100 shortnose sturgeon were captured annually in shad fisheries in the Delaware River, with an unknown mortality rate (O'Herron and Able 1985). Nearly all captures occurred in the upper Delaware River, upstream of the action area. No recent estimates of captures or mortality of shortnose or Atlantic sturgeon are available. Shortnose and Atlantic sturgeon continue be exposed to the risk of interactions with this fishery; however, because increased controls have been placed on the shad fishery, impacts to shortnose and Atlantic sturgeon are likely less than they were in the past.

Striped Bass Fishery

Since 1981, the Commission has managed striped bass, from Maine to North Carolina through an ISFMP. The striped bass fishery occurs only in state waters. With the exception of a defined area around Block Island, Rhode Island, federal waters have been closed to the harvest and possession of striped bass since 1990. All states are required to have recreational and commercial size limits, recreational creel limits, and commercial quotas. The commercial striped bass fishery is closed in Maine, New Hampshire, and Connecticut, but open in Massachusetts (hook and line only), Rhode Island, New Jersey (hook and line only), Delaware, Maryland, and Virginia. Recreational striped bass fishing occurs all along the U.S. East Coast.

Several states have reported incidental catch of shortnose sturgeon and Atlantic sturgeon during striped bass fishing activities (NMFS (National Marine Fisheries Service) 2011). There are numerous reports of Atlantic sturgeon bycatch in recreational striped bass fishery along the south shore of Long Island, NY. Shortnose sturgeon and Atlantic sturgeon bycatch is occurring in the Delaware Bay and River, but little bycatch mortality has been reported. Unreported mortality may occur.

Data from the Atlantic Coast Sturgeon Tagging Database showed that from 2000-2004, the striped bass fishery accounted for 43 percent of Atlantic sturgeon recaptures (ASSRT 2007). The striped bass-weakfish fishery also had one of the highest bycatch rates of 30 directed fisheries according to NMFS Observer Program data from 1989-2000 (ASSRT 2007).

Fish trap, seine, and channel net fisheries

No information on interactions between sturgeon and fish traps, long haul seines, or channel nets is currently available; however, depending on where this gear is set and the mesh size, the potential exists for shortnose sturgeon and Atlantic sturgeon to be entangled or captured in net gear.

State gillnet fisheries

State gillnet fisheries might occur in the action area. However, limited information is available on interactions between these fisheries and protected species. Large and small mesh gillnet fisheries occur in state waters. Based on gear type (i.e., gillnets), it is likely that shortnose sturgeon and Atlantic sturgeon would be vulnerable to capture in these fisheries. Bycatch of a few shortnose sturgeon in the commercial gillnet fishery for shad (fixed and drift gillnets) in the Delaware River has been reported (SSSRT 2010). The majority of reports of Atlantic sturgeon captures during the Atlantic sturgeon reward program have been in drift gillnets and pound nets.

State Trawl Fisheries

Trawl fisheries also occur in state waters. Bottom otter trawls in the Northern shrimp fishery are known to interact with Atlantic sturgeon, but exact numbers are not available (NMFS (National Marine Fisheries Service) 2011). A majority (84 percent) of Atlantic sturgeon bycatch in otter trawls occurs at depths <20 m (<65.6 ft), with 90 percent occurring at depths of <30 m (<98.4 ft) (ASMFC 2007). During the NEFSC's spring and fall inshore northern shrimp trawl surveys, northern shrimp are most commonly found in tows with depths of >64 m (>210 ft) (ASMFC (Atlantic States Marine Fisheries Commission) 2011), which is well below the depths at which most Atlantic sturgeon bycatch occurs. Since these fisheries occur in saline waters, it is highly unlikely that they will capture shortnose sturgeon.

Other trawl fisheries occur in state waters, but information is limited. In these fisheries, the gear may operate along or off the bottom. Atlantic sturgeon have been observed captured on state trawl fisheries from 2009-2018. Top landed species on these trips included, among others, summer flounder, little skate, scup, butterfish, longfin squid, spiny dogfish, smooth dogfish, and bluefish. Information available on interactions between ESA-listed species and these fisheries is incomplete.

State recreational fisheries

Atlantic sturgeon and shortnose sturgeon have been observed captured in state recreational fisheries, yet the total number of interactions that occur annually is unknown. There have been no post-release survival studies for this species. However, we anticipate that sturgeon will likely be released alive, due to the overall hardiness of the species. In addition, almost every year in spring during the American shad fishing season in the Delaware River, the NJ Department of Fish and Wildlife receives reports from hook and line anglers of foul hooked and released shortnose sturgeon in the vicinity of spawning grounds (SSSRT 2010). NMFS also engages in educational outreach efforts on disentanglement, release, and handling and resuscitation of sturgeon.

7 CLIMATE CHANGE

The discussion below presents background information on global climate change and information on past and predicted future consequences of global climate change throughout the range of the listed species considered here. Additionally, we present the available information about predicted consequences of climate change in the action area and how those predicted environmental changes may affect listed species and critical habitat. Climate change is relevant to the *Status of the Species*, *Environmental Baseline*, *Consequences of the Action*, and *Cumulative Effects* sections of this biological opinion. Therefore, rather than include partial discussions in several sections of this Opinion, we are synthesizing this information into one discussion.

7.1 Background Information on Global Climate Change

In its Sixth Assessment Report (AR6) from 2021, the Intergovernmental Panel on Climate Change (IPCC) found that human activities are estimated to have caused approximately a 1.07°C (likely range 0.8°C to 1.3°C) global surface temperature increase over pre-industrial (1850-1900) levels. For the first time in an IPCC report, assessed future changes in global surface temperature, ocean warming, and sea level were constructed by combining multi-model projections with observational constraints based on past simulated warming, as well as the AR6 assessment of climate sensitivity. Even under a very low greenhouse gas (GHG) emissions scenario, the IPCC predicts that the 1.5°C global warming level is more likely than not going to be exceeded in the near term (2021-2040) (IPCC 2021). Since the 1860s, the Northeast U.S. shelf sea surface temperature (SST) has exhibited an overall warming trend, with the past decade measuring well above the long-term average (and the trend line). Changes in the Gulf Stream, increases in the number of warm core ring formations, and anomalous onshore intrusions of warm salty water are affecting the coastal ocean dynamics with important implications for commercial fisheries and protected species. Annual surface and bottom temperatures in the Gulf of Maine and Georges Bank have trended warmer since the early 1980s. The 2020 seasonal surface temperatures have trended warmer in summer and fall and just slightly warmer than average in the winter and spring throughout New England. The 2020 summer SST was the highest on record in Georges Bank with a heatwave of 4.3°C above the heatwave threshold. Annual surface and bottom temperatures in the Mid-Atlantic Bight have also trended warmer since the early 1980s, and seasonal temperatures have similarly trended warmer (NEFSC (Northeast Fisheries Science Center) 2020).

Model projections of global mean sea level rise (relative to 1995-2014) suggest that the likely global mean sea level rise by 2100 is 0.28-0.55 m under the very low GHG emissions scenario, 0.32-0.62 m (1.05-2.03 ft) under the low GHG emissions scenario, 0.44-0.76 m (1.4-2.5 ft) under the intermediate GHG emissions scenario, and 0.63-1.01 m (2.07-3.3 ft) under the very high GHG emissions scenario (IPCC 2021). It is virtually certain that global mean sea level will continue to rise over the 21st century. The magnitude and rate of rise depends on future emission pathways (IPCC 2021). Temperature increases will very likely be associated with more extreme precipitation and faster evaporation of water, leading to greater frequency of both very wet and very dry conditions. Climate warming has also resulted in increased river discharge and glacial and sea-ice melting (Greene *et al*. 2008).

Ocean temperatures in the U.S. Northeast Shelf and surrounding Northwest Atlantic waters have warmed faster than the global average over the last decade (Pershing *et al.* 2015). New projections for these waters suggest that this region will warm two to three times faster than the global average; given this, existing projections from the IPCC may be too conservative (Saba *et al.* 2015).

The past few decades have also witnessed major changes in ocean circulation patterns in the Arctic, and these were accompanied by climate associated changes as well (Greene *et al.* 2008). Shifts in atmospheric conditions have altered Arctic Ocean circulation patterns and increased the export of freshwater to the North Atlantic. Large discharges of freshwater into the North Atlantic subarctic seas can lead to intense stratification of the upper water column and a disruption of North Atlantic Deepwater (NADW) formation (IPCC Greene *et al.* 2008, 2007). There is evidence that the NADW has already freshened significantly (IPCC 2007). This in turn can lead to a slowing down of the global ocean thermohaline (large-scale circulation in the ocean that transforms low-density upper ocean waters to higher density intermediate and deep waters and returns those waters back to the upper ocean). This in turn, can have climatic ramifications for the entire world (Greene *et al.* 2008). Changes in salinity and temperature may be the result of changes in the Earth's atmosphere caused by anthropogenic forces (IPCC 2021). Specifically, recent research on the North Atlantic Oscillation (NAO), which impacts climate variability throughout the Northern Hemisphere, has found potential changes in NAO characteristics under future climate change until 2100 (Hanna and Cropper 2017).

Global warming of 1.5°C is projected to shift the ranges of many marine species to higher latitudes and drive the loss of coastal resources. The risk of irreversible loss of many marine and coastal ecosystems increases with global warming, especially at 2°C or higher (high confidence) (IPCC 2018). There is a high confidence, based on substantial new evidence, that observed changes in marine systems are associated with rising water temperatures, as well as changes in ice cover, salinity, oxygen levels, and circulation. Changes to the marine ecosystem due to climate change may also result in changes in the distribution and abundance of the prey for protected species.

While predictions are available regarding potential consequences of climate change globally, it is more difficult to assess the potential consequences of climate change on smaller geographic scales, such as in the action area. The consequences of future change will vary greatly in diverse coastal regions in the United States. For example, sea level rise is projected to be worse in low-lying coastal areas where land is sinking (e.g., the Gulf of Mexico) than in areas with higher, rising coastlines (e.g., Alaska) (Jay *et al.* 2018). Climate change can cause or exacerbate direct stress on ecosystems through high temperatures, a reduction in water availability, and altered frequency of extreme events and severe storms. As climate warms, water temperatures in streams and rivers are likely to increase; this will likely result in wide-ranging consequences to aquatic ecosystems. Changes in temperature will be most evident during low flow periods when the water column in waterways is more likely to warm beyond the physiological tolerance of resident species (NAST 2000). Low flow can also impede fish entry into waterways and combined with high temperatures can reduce survival and recruitment in anadromous fish (Jonsson and Jonsson 2009).

Expected consequences of climate change for river systems are wide ranging. Rivers are already under a great deal of stress due to excessive water withdrawal or land development, and this stress may be exacerbated by changes in climate (Hulme 2005). Rivers could experience a decrease in the amount of dissolved oxygen in surface waters and an increase in the concentration of nutrients and toxic chemicals due to reduced flushing rate (Murdoch *et al.* 2000). Increased water volume in a warmer-wetter climate could ameliorate poor water quality conditions in places where human-caused concentrations of nutrients and pollutants currently degrade water quality (Murdoch *et al.* 2000). Increases in water temperature and changes in seasonal patterns of runoff will very likely disturb fish habitat and affect recreational uses of lakes, streams, and wetlands. Surface water resources along the U.S. Atlantic coast are intensively managed with dams and channels and almost all are affected by human activities; in some systems water quality is either below recommended levels or nearly so. Within 50 years, river basins that are impacted by dams or by extensive development will experience greater changes in discharge and water stress than non-impacted, free-flowing rivers (Palmer *et al.* 2008). Given this, a global analysis of the potential consequences of climate change on river basins indicates that large river basins impacted by dams will need a higher level of reactive or proactive management interventions in response to climate change than basins with free-flowing rivers (Palmer *et al.* 2008). Human-induced disturbances also influence coastal and marine systems, often reducing the ability of the systems to respond and/or adapt to change. Given the above, under a continually changing environment, maintaining healthy riverine ecosystems will likely require adaptive management strategies (Hulme 2005).

Recent changes in climate conditions are well documented and are predicted to continue (IPCC 2021), increasing the likelihood for consequences to marine and anadromous protected species and their habitats. In marine systems, climate change impacts extend beyond changes in temperature and precipitation to include changes in pH, ocean currents, loss of sea ice, and sea level rise. The increased frequency and intensity of floods, droughts, summer low-flows, and stressful water temperatures already occurring in freshwater rivers and streams used by anadromous species are expected to continue or worsen in many locations. Estuaries may experience changes in habitat quality/quantity and productivity because of changes in freshwater flows, nutrient cycling, sediment delivery, sea level rise, and storm surge.

7.2 Species Specific Information on Climate Change Effects

7.2.1 Shortnose and Atlantic Sturgeon

Shortnose and Atlantic sturgeon have persisted for millions of years and have experienced wide variations in global climate conditions, to which they have successfully adapted. Climate change at historical rates (thousands of years) is not thought to have been a problem for sturgeon species. However, at the current rate of global climate change, future consequences to sturgeon are possible. Shortnose and Atlantic sturgeon spawning occurs in freshwater reaches of rivers because early life stages have little to no tolerance for salinity. However, rising sea level may result in the salt wedge moving upstream in affected rivers, reducing the available spawning habitat. For foraging and physical development, juvenile sturgeon need aquatic habitat with a gradual downstream gradient of 0.5 up to as high as 30 ppt (NMFS 2017b). If the salt wedge moves further upstream, sturgeon rearing habitat could also be restricted. In river systems with dams or natural falls that are impassable by sturgeon, the extent that spawning or rearing habitat could shift upstream to compensate for the movement of the salt wedge would be limited. While data indicates that an increase in sea level rise would shift the location of the salt wedge, at this time there are no predictions on the timing or extent of any shifts that may occur; thus, it is not possible to predict any future loss in spawning or rearing habitat. However, in all river systems, spawning occurs miles upstream of the salt wedge. It is uncertain over the long term (which includes the foreseeable future) that shifts in the location of the salt wedge would reduce freshwater spawning or rearing habitat in any measurable way. Although if habitat was restricted or somehow eliminated, productivity or survivability would likely decrease.

The increased rainfall predicted by some models within given areas may increase runoff and scour spawning habitat. Additionally, flooding events could cause temporary water quality issues. Rising temperatures predicted for all of the U.S. could exacerbate existing water quality problems with dissolved oxygen (DO) and temperature. Shortnose and Atlantic sturgeon are tolerant to water temperatures up to approximately 28°C (82.4°F); these temperatures are experienced naturally in some rivers during the summer months. If river temperatures rise and temperatures above 28°C (82.4°F) are experienced over larger expanses, sturgeon may be excluded from some currently occupied habitats.

Increased droughts (and water withdrawal for human use) predicted by some models for certain areas may result in the loss of and access to spawning habitat. Drought conditions in the spring may also expose eggs and larvae in rearing habitats to unfavorable conditions. If a river becomes too shallow or flows become intermittent, all sturgeon life stages, including adults, may become susceptible to stranding or habitat restriction. Low flow and drought conditions are also expected to cause additional water quality issues, such as increased concentrations of pollutants, or insufficient flushing of toxins. Any of the conditions associated with climate change are likely to disrupt river ecology, causing shifts in ecological community structure and the type and abundance of available prey. Additionally, temporal shifts in the cues for spawning migration and spawning, itself, may occur and create scenarios where preferred prey are not sufficiently available for developing sturgeon in their rearing habitat.

Shortnose and Atlantic sturgeon are most likely to experience the effects of global climate change in warming water temperatures, which could change their range and migratory patterns. Warming temperatures predicted to occur over the next 100 years may result in a northward shift/extension of their range (i.e., into the St. Lawrence River, Canada) while truncating the southern distribution, thus affecting the recruitment and distribution of sturgeon range-wide. In the foreseeable future, gradual increases in SST are expected, but it is unlikely that this expanded range will be observed in the near-term future. If any shift does occur, it is likely to be minimal and thus, it seems unlikely that any increases in temperature will cause significant impacts to shortnose and Atlantic sturgeon or a significant modification to the number of sturgeon likely to be present in the action area over the life of the proposed action. However, even a small increase in temperature can affect DO concentrations. For instance, a 1°C change in temperature in the Chesapeake Bay could make parts of Chesapeake Bay inaccessible to sturgeon due to decreased levels of DO (Batiuk *et al.* 2009). Low DO was until recently a problem in the Delaware River, excluding sturgeon from the areas upstream and downstream of Philadelphia during summer months. While conditions have improved, areas with critical low DO still occur occasionally depending on flow and water temperatures. Thus, we expect similar consequences as in the Chesapeake Bay if summer water temperatures in the Delaware River should increase by 1°C.

Elevated temperatures could modify cues for spawning migration, resulting in an earlier spawning season, and thus, altering the time of year sturgeon may or may not be present within spawning rivers. This may cause an increase or decrease in the number of sturgeon spawners during spawing runs. However, because spawning is not triggered solely by water temperature, but also by day length (which would not be affected by climate change) and river flow (which could be affected), it is not possible to predict how any change in water temperature alone will affect the seasonal movements of sturgeon.

In addition, changes in water temperature may also alter the forage base and thus, foraging behavior of sturgeon. Any forage species that are temperature-dependent may also shift in distribution as water temperatures warm and cause a shift in the distribution of sturgeon. However, because we do not know the adaptive capacity of these species or how much of a change in temperature would be necessary to cause a shift in the species in distribution, it is not possible to predict how these changes may affect foraging sturgeon. If sturgeon distribution shifted along with prey distribution, it is likely that there would be minimal, if any, impact on the availability of food, and they would be able to continue to meet their foraging needs. Similarly, if sturgeon shifted to areas where different forage was available and sturgeon were able to obtain sufficient nutrition from that new source of forage, any effects would also be minimal. The greatest potential for effects to forage resources would be if sturgeon shifted spatially or temporally where insufficient forage was available; however, the likelihood of this happening seems low because sturgeon feed on a wide variety of species and in a wide variety of habitats.

Hare *et al.* (2016) provided a method for assessing the vulnerability of shortnose and Atlantic sturgeon to climate change using the best available information from climate models and what we know of the life history, biology, and habitat use of each species. Based on their assessment, Hare *et al.* (2016) determined that shortnose and Atlantic sturgeons (all DPSs) are highly vulnerable to climate change. Contributing factors include their low potential to alter their distribution in response to climate change (e.g., spawning locations are specific to a population or DPS within a specific geographic region), and their general exposure to the stressors caused by climate change throughout their range, including in estuarine and marine waters. The determinations are supported by the information of Balazik *et al.* (2010) that suggests individual spawning populations will respond to shifting climate conditions with physiological changes (e.g., variation in growth rate) rather than redistributing to a more southern or northern habitat to maintain their exposure to a consistent temperature regime. The low likelihood of shortnose and Atlantic sturgeon to shift distribution in response to current global climate change will also expose them to climatic consequences on estuarine habitat such as variation in the occurrence and abundance of prey species in currently identified key foraging areas.

Climate factors such as sea level rise, reduced DO, and increased temperatures have the potential to decrease productivity, but the magnitude and interaction of consequences is difficult to assess (Hare *et al.* 2016). Increasing hypoxia, in combination with increasing temperature, affects juvenile sturgeon metabolism and survival (Secor and Gunderson 1998). A multivariable bioenergetics and survival model predicted that within the Chesapeake Bay, a 1°C increase in Bay-wide temperature reduced suitable habitat for juvenile Atlantic sturgeon by 65 percent (Niklitschek and Secor 2005). These studies highlight the importance of the availability of water with suitable temperature, salinity and DO; climate conditions that reduce the amount of available habitat with these conditions could reduce the productivity of shortnose and Atlantic sturgeon.

Changes in water availability may also affect the productivity of populations of shortnose and Atlantic sturgeon. In rivers with dams or other barriers that limit access to upstream freshwater reaches, spawning and rearing habitat may be restricted by increased saltwater intrusion; however, no estimates of the impacts of such change are currently available.

7.2.2 Consequences of Climate Change in the Action Area on Shortnose and Atlantic Sturgeon and the Delaware River Critical Habitat Unit

As there is significant uncertainty in the rate and timing of climate change as well as the effects that may be experienced in the action area, predicting the impact of these changes on shortnose and Atlantic sturgeon is difficult. We have analyzed the best available information; however, to consider likely impacts to sturgeon and their habitat in the action area. The proposed action under consideration is the operation of the Port**.**

Water availability, either too much or too little, as a result of global climate change is expected to have an effect on the features essential to successful sturgeon spawning and recruitment of offspring to the marine environment (for Atlantic sturgeon). The increased rainfall for certain areas predicted by some models may increase runoff, scour spawning areas, and create flooding events that dislodge early life stages from the substrate where they refuge in the first weeks of life (PBF 1). High freshwater inputs during juvenile development can influence juveniles to move further downriver and, conversely, lower than normal freshwater inputs can influence juveniles to move further upriver potentially exposing the fish to threats they would not typically encounter (PBF 2). Increased number and/or duration of drought events (and water withdrawal for human use) predicted in certain areas by some models may cause loss of and access to spawning, rearing, and foraging habitat (PBFs 1-4). Drought conditions in the spawning season(s) may also expose eggs and larvae in rearing habitats. If a river becomes too shallow or flows become intermittent, all sturgeon life stages, including adults, may become susceptible to stranding or habitat restriction. Low flow and drought conditions are also expected to cause additional water quality issues including shifting (potentially worsening the resulting effects of) the combined interactions of DO, water temperature, and salinity (PBF 4). Elevated air temperatures can also impact DO levels in the water, particularly in areas of low water depth, low flow, and elevated water temperature. Rising temperatures predicted for all of the U.S. could exacerbate existing water quality problems affecting DO and temperature (PBF 4).

If sea level rise was great enough to consistently shift the salt wedge far enough upstream, it would likely restrict the range of juvenile sturgeon and may affect the development of these life stages (also affecting Atlantic sturgeon critical habitat PBFs 1, 2, and 4). Moberg and DeLucia (2016) noted that low flow conditions influence the salt front location and available freshwater habits that are suitable for early life stages. Dissolved oxygen concentrations between 2005 and 2014 were often in ranges identified as impaired or lethal for Atlantic sturgeon early life stages (Moberg and DeLucia 2016). However, an upstream shift in the salt wedge will have little effect on shortnose sturgeon spawning and egg development as they spawn in the riverine and upper tidal reaches (RKM 214-238/RM 133-148) of the Delaware River more than 90 river kilometers (>56 mi) upstream of the current median upper monthly location of the salt wedge.

Atlantic sturgeon spawning and rearing habitat (PBF 1) in the Delaware River are found in the tidal river upstream of the Delaware border (~RKM 125/RM 77.7) to Trenton, New Jersey, (~RKM 214/RM 133) and there are no impassable falls or manmade barriers that limits upstream access. Based on predicted upriver shifts in the salt wedge, areas specific to where Atlantic sturgeon currently spawn could, over time, become too saline to support spawning and rearing. Recent modeling by NRC indicates that this is unlikely to occur before 2070, but modeling conducted by Collier (2011) suggests that by 2100, some areas within the range where spawning is thought to occur (RKM 125-212/RM 77.7-132) may be too salty and spawning would need to shift further upstream. Breece *et al.* (2013) used habitat modeling to consider where adult Atlantic sturgeon would be located under various scenarios including any shifts in the location of the salt front’s current location between RKM 108 and 122 (RM 67-76) due to changes in sea level rise in 2100 (i.e., shift to RKM 122-137/RM 76-85 based on a 1986 EPA report for the Delaware Estuary) and under extreme historic drought (i.e., restricted to RKM 125, 130 and 153 (RM 77.7, 81 and 95) based on various drought conditions observed in the 1960s). Given the availability and location of spawning habitat in the river, it is unlikely that the salt front would shift far enough upstream to result in a significant restriction of spawning habitat. Freshwater rearing habitat for Atlantic sturgeon post yolk sac larvae and young juveniles (RKM 125 to 214/RM 77.7-133) is at greater risk from encroaching salt water as some of the best potential rearing habitat occur at the downstream end of that range (i.e., Marcus Hook Bar area below Little Tinicum Island). Above Little Tinicum Island (RKM 142/RM 88), the shorelines on both sides are characterized by industrial and urban development and the river becomes more channelized with little habitat complexity. Thus, the available habitat for juveniles of both sturgeon species could decrease over time and a shift of the salt front several miles upstream could have a significant effect on juvenile sturgeon production. The areas in the Delaware River critical habitat unit containing PBF 2 (aquatic habitat with soft substrate and a gradual downstream salinity gradient of 0.5-30 ppt for juvenile foraging and physiological development) may also shift upstream, but would not necessarily be diminished in size or quality.

Any forage species that are temperature dependent may also shift in distribution as water temperatures warm. However, because we do not know the adaptive capacity of these individuals or how much of a change in temperature would be necessary to cause a shift in distribution, it is not possible to predict how these changes may affect foraging sturgeon. If sturgeon distribution shifted along with prey distribution, it is likely that there would be minimal, if any, impact on the availability of food. Similarly, if sturgeon shifted to areas where different forage was available and sturgeon were able to obtain sufficient nutrition from that new source of forage, any effect would also be minimal. The greatest potential for effects to forage resources would be if sturgeon shifted spatially or temporally and insufficient forage was available; however, the likelihood of this happening is low because sturgeon feed on a wide variety of species and in a wide variety of habitats.

Limited information on the thermal tolerances of Atlantic and shortnose sturgeon is available. Atlantic sturgeon have been observed in water temperatures above 30°C (86°F) in the south (see Damon-Randall *et al.* 2010); in the wild, shortnose sturgeon are typically found in waters less than 28°C (82.4°F). In the laboratory, juvenile Atlantic sturgeon showed negative behavioral and bioenergetics responses (related to food consumption and metabolism) after prolonged exposure to temperatures greater than 28°C (82.4°F) (Niklitschek 2001). Tolerance to temperatures is thought to increase with age and body size (Jenkins *et al.* 1993, Ziegeweid *et al.* 2008), however, no information on the lethal thermal maximum or stressful temperatures for subadult or adult Atlantic sturgeon is available. Muhling *et al.* (2017) noted that the predicted increase in summer surface temperatures may increase to between 27-29°C (80.6-84.2°F) and >30°C (86°F) depending on the climate model, in the Chesapeake Bay which represents a moderate to potentially lethal change in conditions for species such as Atlantic sturgeon. It is possible that these values will be similar to the Delaware Bay (see above). Shortnose sturgeon have been documented in the lab to experience mortality at temperatures of 33.7°C (92.66°F) or greater and are thought to experience stress at temperatures above 28°C (82.4°F). For purposes of considering thermal tolerances, we consider shortnose sturgeon to be a reasonable surrogate for Atlantic sturgeon given similar geographic distribution and known biological similarities. Mean monthly ambient temperatures in the Delaware estuary range from 11-27°C (51.8-80.6°F) from April through November, with temperatures lower than 11°C (51.8°F) from December-March. As noted above, there are various studies looking at temperature in the Delaware Bay (Moberg and DeLucia 2016). Rising temperatures could meet or exceed the preferred temperature of shortnose and Atlantic sturgeon (28°C (82.4°F)) on more days and/or over larger areas. This could result in shifts in the distribution of sturgeon out of certain areas during the warmer months. Information from southern river systems suggests that during peak summer heat, sturgeon are most likely to be found in deep-water areas where temperatures are coolest. Thus, we could expect that over time, sturgeon would shift out of shallow habitats on the warmest days. This could result in reduced foraging opportunities if sturgeon were foraging in shallow waters.

As described above, over the long term, global climate change may affect shortnose and Atlantic sturgeon by affecting the location of the salt wedge, distribution of prey, water temperature and water quality. However, there is significant uncertainty, due to a lack of specific scientific data, on the degree to which these effects may be experienced and the degree to which shortnose or Atlantic sturgeon will be able to successfully adapt to any such changes. Any activities occurring within and outside the action area that contribute to global climate change are also expected to affect shortnose and Atlantic sturgeon in the action area. While we can make some predictions on the likely effects of climate change on these species and critical habitat, without modeling and additional scientific data, these predictions remain speculative. This is especially true for the 10-year period that this Opinion covers.

The overall vulnerability of Atlantic sturgeon to climate change has been found to be very high (Hare *et al.* 2016). Moberg and DeLucia (2016) recommended the following water quality standards to support successful recruitment of Atlantic sturgeon in the Delaware River: instantaneous DO ≥ 5.0 mg/L; temperature < 28°C (82.4°F); salinity < 0.5 ppt; and discharge > July Q85 (4,000 cfs @ Ben Franklin), when average daily dissolved oxygen < 5.5 mg/L. Our final rule for Atlantic sturgeon critical habitat (NMFS 2017b) states that DO levels of 6.0 mg/L or greater likely supports juvenile rearing habitat, whereas DO less than 5.0 mg/L for longer than 30 days is less likely to support rearing when water temperature is greater than 25°C (77°F). In temperatures greater than 26°C (78.8°F), DO levels greater than 4.3 mg/L are needed to protect survival and growth. Temperatures of 13 to 26°C (55.4-78.8°F) likely support spawning habitat.

More information for shortnose sturgeon in Delaware River and Bay, as well as additional information on Atlantic sturgeon are needed in order to better assess impacts from climate change.

8 CONSEQUENCES OF THE ACTION ON SPECIES

As described in section 3.3, the USACE issued its permits for construction in September 2022 and the applicant completed all construction work and dredging for the Berth by April 1, 2023. In our 2022 biological opinion, we determined that all effects to listed species and designated critical habitat from the proposed construction and dredging activities would be either insignificant or extremely unlikely to occur. This included analyses of effects from noise during pile driving, potential capture, or entrainment in mechanical and hydraulic dredges, and vessel strike by project construction vessels. In addition, the analysis evaluated effects to listed species and designated critical habitat from the dredging of approximately 8.9 acres of soft sediment bottom habitat and the permanent loss of less than 0.4 acre of soft sediment bottom substrate where three mooring dolphins are located. Since the applicant has completed all construction work associated with the Berth, we incorporate by reference our effects analysis in our previous biological opinion of July 19, 2022, which includes future effects caused by impacts from propeller scour on bottom habitat during operation of the Berth. At this time, the applicant and USACE have not proposed modifications to the number or type of vessels that will use the Berth once it is in operation. Thus, we will not analyze in this Opinion the effects to listed species or designated critical habitat caused by habitat modifications. The USACE has not issued a permit for future maintenance dredging and, therefore, we do not anticipate impacts from additional dredging of the Berth. If future maintenance dredging is proposed, reinitiation of consultation may be required.

Herein we analyze effects to listed sturgeon from interactions with vessels during operation of the Berth. It is necessary to conduct a new analysis of effects because the NJFW has provided us with new data regarding sturgeon mortalities in the Delaware River and Delaware Bay, indicating that the baseline risk of interactions is higher than what we determined previously. However, we have neither new information about vessels interacting with sea turtles or whales within the action area nor new information indicating that our understanding of the risk of such interactions has changed subsequent to issuing our previous biological opinion for this project. Thus, we do not include an analysis of the risk of sea turtle and whale vessel strikes here but incorporate by reference our analysis in our previous biological opinion. In our 2022 biological opinion for this project, we concluded that effects to whales and sea turtles from operation of the proposed Berth are insignificant.

8.1 Consequences of Vessel Activity during Port Operation

Operation of the Berth will cause an increase in vessels operating within the Delaware River and the Delaware Bay. As explained in the Project Description above, during its 10-year operational lifetime, vessels will travel to the proposed Berth using the Philadelphia to the Sea Navigation Channel. These vessel trips would not occur but for the proposed Berth. Further, these vessel trips are new, entirely associated with the operation of the proposed Paulsboro Marine Terminal RoRo Berth, and will not result from traffic redistributed from other ports.

An operating vessel can cause injury or death to a sturgeon when the hull or propeller strikes the sturgeon, or the sturgeon becomes entrained through the propeller. Examination of sturgeon carcasses in the Delaware River and the James River shows that the majority of carcasses found have damages consistent with vessel strike (Balazik *et al.* 2012d, Brown and Murphy 2010; also, see discussion in previous sections of this Opinion). Direct observations of vessel strikes killing sturgeon have also been reported (e.g., Park 2017, personal communication). Therefore, vessel traffic related to operation of the Port may increase the risk of lethal vessel strikes of sturgeon. In this section of the Opinion, we consider if the increase in vessel traffic, when added to the baseline, will increase the risk of interactions between sturgeon and vessels in the action area.

The timing and location of vessel traffic in the action area may influence the risk of a vessel striking a sturgeon. Sturgeon are migratory species that travel from marine waters to natal rivers to spawn. A significant increase in vessel traffic during the spawning period could potentially increase the risk of vessel strike for migrating adult sturgeon (Fisher 2011, Hondorp *et al.* 2017). Similarly, narrow channels or passageways with restricted clearance may increase the probability that sturgeon will be struck and killed by a vessel (Balazik *et al.* 2012d).

We expect the operation of the proposed Berth to increase vessel traffic at the site and within the Federal Navigational Channel. Shipping vessel activities could result in vessels colliding with or the propellers striking listed species. Here, we review what we know about vessel-species interactions and the factors contributing to them, and analyze the effects of the proposed Berth on ESA-listed sturgeon.

8.1.1 Factors Relevant to Vessel Strike

For sturgeon to interact with vessels and their propellers, they must overlap spatially and temporally. First, a vessel's activity has to occur in the same reach of the river where sturgeon are present. Second, a particular sturgeon life stage has to occupy the same portion (lateral location) of the river channel as the vessel (e.g., the maintained navigation channel versus the non-navigational portion of the channel or waterway). Lastly, the hull, propeller, and the hydrological forces around the vessel have to be at the same depth in the water column as the sturgeon. Factors relevant to determining the risk of vessel strikes include, but may not be limited to, the size and speed of the vessels, navigational clearance (i.e., depth of water and draft of the vessel) in the area where the vessel is operating, and the size and behavior of sturgeon in the area (e.g., foraging, migrating, etc.). Physical characteristics of the river (e.g., narrow channels, channel constrictions, etc.) may also be relevant risk factors.

For a vessel strike to occur, the sturgeon must either not respond to an approaching vessel (i.e., not moving away or trying to avoid interaction) or be unable to avoid the vessel. It is well documented that adult and juvenile sturgeon are specifically killed by interactions with vessel propellers of vessels (Balazik *et al.* 2012d, Brown and Murphy 2010, Demetras *et al.* 2020, Killgore *et al.* 2011). Therefore, it is clear that not all sturgeon respond to an approaching vessel by moving out of its way or are not able to evade the propeller(s) even if they do attempt to move out or the way of an approaching vessel. A few studies have used VEMCO Positioning System (VPS) receiver arrays to study Atlantic sturgeon response to approaching vessels. Preliminary tracking studies in the James River indicate that Atlantic sturgeon seem to be oblivious to the threat of vessel propellers. In other words, they do not make any effort to leave the navigation channel or avoid approaching and passing deep draft vessels (Balazik 2018, Balazik *et al.* 2017a), and, occasionally, the researchers observed sturgeon move into the path of an approaching vessel (Balazik *et al.* 2017a). DiJohnson (2019) studied Atlantic sturgeon responses to approaching vessels in the Delaware River similarly using a VEMCO Positioning System to monitor fine-scale movements of telemetered adults and subadults as large vessels approached. The recently completed study found no evidence that Atlantic sturgeon altered their behavior in the presence of approaching commercial vessel traffic in the Delaware River (DiJohnson 2019, DiJohnson *et al.* 2015). Both Balazik *et al.* (2017a) and DiJohnson (2019) concluded that their findings suggest that either Atlantic sturgeon do not consider vessels a threat or they cannot detect a vessel until it is too late.

The hull itself may hit sturgeon that fail to avoid a vessel and cause injury or mortality. It seems likely that the chance of injury and death by impact increases with the vessel's speed and mass but we do not know at what speed mortality would occur for different types of vessels or for different sizes of sturgeon. Fast vessels have been implicated in shortnose sturgeon vessel strikes but there is no information available to suggest a minimum speed necessary for a sturgeon to avoid an approaching vessel nor has a threshold speed at which a sturgeon is injured or killed by a vessel hull been defined. More often observed is evidence that vessel strike mortalities occur when a propeller hits a sturgeon. The propeller may hit a sturgeon that is directly in the path of a vessel or when the water being sucked through a propeller entrains a sturgeon. Entrainment of an organism occurs when a water current (in this case the current created by the propeller) carries the organism along at or near the velocity of the current without the organism being able to overcome or escape the current. Propeller engines work by creating a low-pressure area immediately in front of the propeller and a high pressure behind. In the process, the propeller moves water at high velocities (can exceed 6 m/s) through the propeller. Thus, as the boat propeller draws water through the propeller, it can also consequently entrain an organism in that water. Fish that cannot avoid a passing vessel, that are entrained by the propeller current, and who are unable to escape the low-pressure area in front of the propeller, will go through the propeller.

Entrainment can occur if a sturgeon is exposed to the water being sucked into the propeller and that individual is not able to escape the current velocity as water is drawn through the propeller. The zone of influence, the part of the water body being entrained through the propeller, is the depth, width, and length in front of the propeller at which water is drawn through. Models of water entrained during maneuvering of tow vessels in the Mississippi River found the volume of water to be about twice the propeller area times the distance travelled (Wilcox 1991). Larger propellers draw larger volumes of water, and we therefore expect the likelihood of a propeller entraining a fish to increase with propeller size. Recreational vessels rarely have propellers exceeding 0.5 m (1.6 ft) in diameter, towboats and tugs commonly have propellers between 2-3 m (6.5-9.8 ft) in diameter, and tankers and bulk carrier vessels with a 12 m (40 ft) draft may have propellers that are 7-8 m (23-26 ft) in diameter. Typically, most vessel types have two propellers, but larger vessels may occasionally have three. Thus, we expect large tugboats, cargo vessels, and tankers to have a substantially larger zone of influence than recreational or smaller fishing vessels. Maynord (2000) showed that the inflow zone of a propeller surrounds the vessel in an area limited to roughly the size of the cross section of the vessel (i.e., similar to the width of the vessel). As an example, a tow with a draft of 2.7 m (8.9 ft) pushing three barges side by side (total width of 32 m (105 ft)) in 4.3 to 12 m (14 to 40 ft) deep water and a speed (relative to water) of 2 m/s (3.9 knots) had an inflow zone of about 25 m (82 ft) on either side of the center line. Thus, water within a 50 m (164 ft) wide zone could go through the propeller. Besides vessel specifications, the depth relative to draft determines the propeller's lateral zone of influence. In Maynord's calculations, bottom water at depths of 9.8 m (32.1 ft) or greater were not drawn into the 2.4-m (7.9 ft) diameter propeller (for a towboat with a 2.7 m (8.9 ft) draft) while water at depths of 5.6 m (18 ft) or less was drawn into the propeller, though not all flow within this zone would go through it. Therefore, a demersal sturgeon below a large vessel with a clearance of 6 m (19.7 ft) or less would be exposed to water drawn through the vessel's propeller(s). Further, while sturgeon are benthic feeders, they also use the upper water column during non-foraging movements and migrations and sometimes jump out of the water. Therefore, we consider all sturgeon in the path of a large vessel (the width of the path being equal to the width of the vessel) to be located in the water column where the moving vessel will expose them to the water drawn through its propellers.

Whether a fish is able to avoid entrainment depends on its location relative to the velocity of the water moved by the propeller and its swimming ability relative to that velocity. It is unclear what the response of a sturgeon will be when exposed to the hydrology around the hull and propeller of a moving or maneuvering vessel. For a vessel at cruising speed, the suction in front of the propeller is moderate, but it is more pronounced if the propeller diameter is relatively small – as it often is for ships designed for operation in rivers (e.g., tugboats) and other areas with draft limitations, or if the forward speed of the ship is slow (Steen 2021). We do not have calculations of the approach velocity of water in front of the propellers of the delivery and installation vessels or the tugboats; therefore, we cannot evaluate a sturgeon's ability to escape entrainment through the propeller of these specific vessels. However, Steen theorizes that the propellers of large vessels can entrain even large sturgeon.

Not all fish entrained by a propeller will necessarily be injured or killed. Killgore *et al.* (2011) in a study of fish entrained in the propeller wash (two four-blade propellers that were 2.77 m (9 ft) in diameter) from a towboat in the Mississippi River found that 2.4 percent of all fish entrained and 30 percent of shovelnose sturgeon entrained showed direct signs of propeller impact (only estimated for specimens ≥12.5 cm (≥5 in) TL). The most common injury was a severed body, severed head, and lacerations. This is consistent with injuries reported for sturgeon carcasses in the Delaware River and James River (Balazik *et al.* 2017a, Brown and Murphy 2010).

Killgore *et al.* (2011) found that the probability of propeller-induced injury (i.e., propeller contact with entrained fish) depends on the propellers revolution per minute (RPM) and the length of the fish. Simply put, the faster the propeller revolves around its axis, the less time a fish has to move through the propeller without being struck by a blade. Similarly, the longer the fish is, the longer time it needs to move through the propeller, thereby increasing the chance that a blade hits it. The injury probability model developed by Killgore *et al.* (2011) shows a sigmoid (or "S" shaped) relationship between fish length and injury rate at a given RPM. The model estimates probability of injury at about 150 RPM for the towboat in their study increased from 1 percent for a 12.5 cm (5 in) fish to 5 percent for a 35 cm (13.8 in) long fish, and from 50 percent for a 72 cm (28.3 in) long fish to 80 percent for a 90 cm (35.4 in) long fish. However, Killgore *et al.* (2011) did not find that the number of fish entrained by the propeller was dependent on RPM even though the percentage of fish killed increased with increasing RPM.

As described in the baseline section, recreational and smaller commercial vessels (e.g., fishing boats or vessels used for shellfish husbandry) have smaller diameter propellers, entrain smaller volume of water, and have a shallow draft. Consequently, they are extremely unlikely to entrain a larger juvenile, subadult, or adult sturgeon. Large vessels have been typically implicated because of their deep draft relative to smaller vessels, which increases the probability of vessel collision with demersal fishes like sturgeon, even in deep water (Balazik *et al.* 2012d, Brown and Murphy 2010). Larger vessels also draw more water through their propellers given their large size and, therefore, may be more likely to entrain sturgeon in the vicinity.

Miranda and Killgore (2013) indicates that heavy large-towboat traffic on the Mississippi River (vessels with an average propeller diameter of 2.5 m, a draft of up to 9 ft, and travel at approximately the same speed as tugboats (less than 10 knots)), kill a large number of fish by drawing them into the propellers. The study demonstrates that shovelnose sturgeon (*Scaphirhynchus platorynchus*), a small sturgeon (~50-85 cm (~19.7-33.5 in) in length) with a similar life history to shortnose sturgeon, were being killed at a rate of 0.02 individuals per kilometer traveled by the towboats. As the geomorphology and depth of the Mississippi River – including its reaches and navigation channel where the study was conducted - differ substantially from the action area, and as shovelnose sturgeon is a common species in the Mississippi River with densities that are likely not comparable to Atlantic sturgeon and shortnose sturgeon populations in the Delaware River, this estimate cannot directly be used for this analysis. We also cannot modify the rate for this analysis because the type of vessels traveling on the two rivers differs and we do not know (a) the difference in density of shovelnose sturgeon and shortnose and/or Atlantic sturgeon and (b) if there are risk factors that increase or decrease the likelihood of strike in the Delaware. However, this information does suggest that high vessel traffic can be a major source of sturgeon mortality. A similarly sized tugboat moving about 11 knots was observed striking and killing an adult Atlantic sturgeon female in the Federal Navigation Channel of the Delaware River in 2016 (Park 2017).

Other factors affect the probability of vessel interactions with sturgeon. For example, narrow channels can concentrate both sturgeon and vessels into smaller areas and thus increase the risk of vessel strike. (Balazik *et al.* 2012d) notes that there is an inverse relationship between channel width and the number of observed vessel strike mortalities in the James River. Sturgeon are likely to use the navigation channels during spawning migrations as well as seasonal movements between summer and overwintering areas (Fisher 2011, Hondorp *et al.* 2017). Because of these behaviors, a higher number of adult Atlantic sturgeon vessel mortalities occur in the Delaware River during spring months (see Baseline section). Besides adults and subadults being exposed to vessels during these months, it has also been suggested that sturgeon swimming higher in the water column during migration increases their exposure to vessels (Balazik *et al.* 2017a, Brown and Murphy 2010, Fisher 2011). In our previous biological opinion, we concluded that the small number of vessel trips (26) within the Federal Navigation Channel during dredging and pile driving was extremely unlikely to result in a vessel strike because vessel strikes are generally rare and stochastic events for any one vessel. The construction and associated vessel traffic has been completed and, therefore, this section does not analyze the consequences of construction related vessel traffic as part of the proposed action.

This section considers the effects to sturgeon from vessel traffic on the River and in the Bay associated with operation of the Paulsboro RoRo Berth over the approximate 10-year lifetime of the project. First, we evaluated the factors determining the risk of vessel strikes by vessels. We then used the calculated number of expected sturgeon mortalities relative to vessel activity (vessel trips) from section 6.3. This is the calculated baseline mortality rate. We then used this baseline mortality rate to calculate an estimate of the number of sturgeon killed by project related vessel activity (i.e., vessel trips during Berth operation).

8.1.2 Vessel Activity

As explained in the Project Description above, the proposed project will result in the maneuvering and movement of vessels within the Berth's access channel and the Philadelphia to the Sea Navigation Channel during the 10-year operational lifespan of the Berth. The USACE expects that a minimum of 540 to a maximum of 880 vessel river trips will occur during the Berth's operation through 2032 (section 3.4.1).

Most of the river trips will occur between the Paulsboro Marine Terminal and the offshore wind facility location; however, shorter trips between other ports may also occur. The USACE have indicated that they cannot predict which additional offshore wind facilities vessels may travel to, or where the vessels will travel to or from beyond the pilot area at the mouth of the Delaware Bay. Thus, we only consider the effects of vessel traffic between the Paulsboro Ro/Ro Berth and the offshore pilot area. The length of the river trips are approximately 167 kilometers one-way from the Paulsboro RoRo Berth marine facility to the offshore Pilot Area, using the Federal Navigation Channel of the Delaware River. The vessels calling on the Berth during operation will use Azipods for propulsion and maneuvering so tugboat assistance will not be needed during docking.

Offshore cargo vessels are approximately 168 m (550 ft) in length with a draft of approximately 7.3 m (24 ft). The USACE and Applicant expect up to 50 vessel calls annually. Fifty vessel calls will result in an additional 100 large vessel trips per year in the river between the proposed RoRo Berth in Paulsboro and offshore Pilot Area. Cargo vessels will use the Philadelphia to the Sea Federal Navigation Channel to travel between the Berth and the mouth of Delaware Bay.

8.1.3 Risk Calculations

There are neither quantitative scientific surveys regarding vessel strike mortalities nor an annual index survey that provides a time series of the relative number of vessel strikes per year. This complicates any evaluation of the relationship between vessel densities and sturgeon mortalities. The biological assessment assumes that the increase in vessel traffic in addition to the baseline resulting from the proposed Paulsboro RoRo Berth will increase the risk of vessel strike to shortnose and Atlantic sturgeon. Additionally, this increased risk will result in a corresponding increase in the number of sturgeon struck and killed in the Delaware River.

We expect that the data for waterborne commerce vessel trips adequately represent the potential for sturgeon to be exposed to vessel strike within the Delaware River. We consider vessel trips of self-propelled vessels to calculate risk of vessel strike because we expect interaction with a propeller to be the main source of mortality. As we discussed in section 6.3, this is a reasonable approximation as the Waterborne Commerce data used included self-propelled vessels of all drafts. We also consider smaller vessels to be less of a threat to sturgeon and account for an extremely small fraction of reported sturgeon mortalities. Thus, even though the data does not account for the recreational vessels and smaller fishing vessels that operate on the Delaware River and in the bay, we believe that the commerce data provides a close approximation of the number of vessels that are a threat to sturgeon.

In our previous Opinion, we used DNREC data for the period of 2012 to 2019 to represent vessel-induced mortalities within the action area. On June 16, 2022, the NJFW provided us with a spreadsheet that listed sturgeon mortalities reported from New Jersey for the years from 2013 to 2021 (see section 6.3.2.1). Therefore, the following analysis uses the vessel strike risk for the combined DNREC and NJFW data for the years 2013 to 2019 as calculated in section 6.3.2.3 and 6.3.2.4.

Since the DNREC and NJFW data does not directly distinguish between sturgeon killed in the Philadelphia to Trenton reach of the river and the Philadelphia to the Sea reach, we have to use the number of observed dead Atlantic sturgeon considered killed by vessels between Trenton and the mouth of the Delaware Bay. Similarly, we also have to use Waterborne Commerce data (2013 through 2019) for the whole Federal Navigation Project from Trenton to the Sea to calculate the number of vessel trips during this period (see section 6.3.1.2). While cause of death cannot be determined with reasonable certainty for many carcasses, it is likely that most of them, as we described in section 6.3.2, and as noted by Brown and Murphy (2010), were the result of vessel strikes. Thus, this analysis as well as the one conducted by the USACE's BA includes sturgeon with unknown causes of death to support a likely estimate of vessel mortalities.

Last, our analysis has to account for the fact that most sturgeon mortalities are likely never found and/or reported. Consistent with (Fox *et al.* 2020), here we use a reporting rate of 0.0476 to adjust the observed reporting rate as described in the baseline section of this biological opinion. We also note that Fox *et al.* (2020) did a second study to calculate reporting rates of carcasses placed in the river to float. However, they had zero back-reports of carcasses placed in the river and, therefore, they could not estimate the number of sturgeon carcasses that may never end up on the shoreline since some carcasses likely sink and remain on the bottom. Therefore, the calculated reporting rate does not account for carcasses that sink before ending up on a shoreline.

8.1.4 Atlantic Sturgeon

Juvenile and subadult Atlantic sturgeon may occur in the action area throughout the year, and adults are known to occur there seasonally. Therefore, the vessel traffic related to operation of the proposed Berth could interact with these life stages of Atlantic sturgeon and result in vessel strike mortalities.

8.1.4.1 Exposure

Temporal and spatial distribution of Atlantic sturgeon life stages are described in section 6.2.2.1 and is summarized in section 6.2.2.1.1. Vessels calling at the Paulsboro RORO Berth during the

10 years of Berth operation will travel more than 145 km (90 mi) between the Berth and the pilot area at the mouth of the Delaware Bay at any time of the year. Transport of monopile segments and finished monopiles to offshore wind project destinations by the heavy lift vessels will overlap with presence of adult Atlantic sturgeon during spawning migrations from April into July. During the same period, the vessel traffic will also overlap with spawning that occurs in the Philadelphia to the Sea Navigation Channel at Chester, PA. Vessels will also travel through the reach from Marcus Hook and downstream to the mouth of the river where juvenile Atlantic sturgeon occur in high densities throughout the year. They will also travel through the reach by Artificial Island where aggregations of subadult and adult sturgeon occur in late-summer and fall.

Monopile delivery and installation vessels will travel through the Delaware Bay mouth all year. During spring, summer and early fall months, subadult and adult Atlantic sturgeon aggregate and reside in areas at the mouth of the bay (section 6.2.2). These areas are relatively deep and Atlantic sturgeon at the seabed are unlikely to be exposed to the hydrology around the hull and propellers of the vessels. However, Atlantic sturgeon surfacing behavior may expose individuals to vessels and vessel strike mortality (Watanabe *et al.* 2013). Surfacing represents a small fraction of an individual's total behavior, but the chance that a vessel may interact with an individual increases when sturgeon aggregate. The Bay mouth is an area where higher densities and potentially large aggregations of Atlantic sturgeon occur (Breece *et al.* 2018). Thus, vessel traffic that would not occur but for the proposed action overlap in space and time with high concentrations of subadult and adult Atlantic sturgeon, and, therefore, the chance of a vessel interacting with a surfacing Atlantic sturgeon is relatively high.

During early spring, mature adults migrate through the bay mouth during the spawning migration. Additionally, both subadults and adults move through the mouth during seasonal migrations to and from areas of residency within the Delaware Bay (Breece *et al.* 2018). However, during the same time-period, non-spawning Atlantic sturgeon may remain in the Bay. Kuntz (2021) found a large number of Atlantic sturgeon concentrated from late spring through the fall in two locations in the lower Delaware Bay. We expect that the spawning Atlantic sturgeon will move in a relatively straight line during spawning migration through the Delaware Bay. This path largely corresponds with the Philadelphia to the Sea Federal Navigation Channel. Hondorp *et al.* (2017) found that lake sturgeon selected the higher-flow and deeper navigation channels over alternative migration pathways in the Detroit River. Use of the navigation channel likely occurs because channelization modifies current direction, current velocity, and discharge that sturgeon use as hydrologic cues during riverine migration. Thus, as Atlantic sturgeon enter the Delaware River during the spawning season, they may use the Philadelphia to the Sea Navigation Channel for up and downstream spawning migration. Atlantic sturgeon swim closer to the surface during migration and during other directed movements (e.g., foraging or avoidance) (Balazik *et al.* 2012d, Fisher 2011, Reine *et al.* 2014). Consequently, in addition to being exposed to the propellers of deep draft vessels (e.g., cargo vessels) during foraging, staging, etc., Atlantic sturgeon are likely to occur at a depth that overlaps with the depth of the propeller of medium draft vessels (e.g., tugs) during active movements such as spawning migration and seasonal movements between habitats.

Given that the proposed action will meaningfully increase vessel traffic over baseline conditions, that the vessels will travel more than 145 km between the mouth of the Delaware Bay and the Berth, that the vessels are large with large diameter propellers, that the vessels will have a limited clearance between their hull and the riverbed, that Atlantic sturgeon adults and subadults use the bay and river as a migratory corridor, and that high densities of juvenile and older Atlantic sturgeon occur in the action area, we conclude that there is a high probability that Atlantic sturgeon will interact with the vessels. This exposure would not occur but for the proposed action.

8.1.4.2 Species' Response

Vessel traffic, consisting of commercial cargo ships, tankers, and tug boats have been identified as a significant source of Atlantic sturgeon mortality in the Delaware and James Rivers (Balazik *et al.* 2012d, Brown and Murphy 2010). Many of the documented mortalities involve large Atlantic sturgeon with severe injuries (e.g., lacerations and amputations). Given the size of the fish and the nature of the injuries, these mortalities are likely caused by deep- and medium-draft commercial vessels with large propellers that draw large volumes of water, thus entraining sturgeon.

As discussed above, we expect that sturgeon exposed to vessels and their propellers are at risk of being killed. Killgore *et al.* (2011) found that the risk of injury or mortality of fish going through the propeller of a tugboat increased with the size of the fish. Based on a relationship between fish size and injury risk for entrainment through the propeller developed by Killgore *et al.* (2011), entrainment through a propeller could kill from 50 to over 80 percent of juvenile sturgeon and adult shortnose sturgeon while entrainment of a subadult and adult Atlantic sturgeon may result in close to hundred percent mortality. In addition, the vessels calling at the proposed Berth have large propellers that rotate with considerable force. Therefore, we find it unlikely that a sturgeon exposed to the vessels and their propellers will survive, and we consider all sturgeon interacting with the vessels traveling to and from the Berth will be fatal.

8.1.4.3 Risk

Given that it is highly likely that Atlantic sturgeon are exposed to propellers of vessels moving to and from the mouth of the Delaware Bay and the Berth and that a propeller striking an Atlantic sturgeon will kill it, we conclude that there is a high risk of the vessel traffic associated with the proposed action killing Atlantic sturgeon. This mortality would not occur but for the proposed action.

8.1.4.4 Determinations

In our previous biological opinion, we estimated that one Atlantic sturgeon vessel mortality may occur for every 128 vessel trips during project construction. Thus, we expected operation of the Berth to kill up to seven (7) Atlantic sturgeon. For that calculation, we relied solely on information about reported sturgeon mortalities provided by DNREC. Here we incorporated the results of additional sturgeon mortality data that the NJFW provided to us.

In section 6.3.2, we calculated that the adjusted annual baseline mortality rate (or Atlantic sturgeon killed per vessel trip on average) is 0.0091[24]. This also equates to one vessel strike per approximately 110 vessel trips. The USACE estimates that the operation of the proposed terminal will add up to 880 new vessel trips in the Delaware River (i.e. vessel trips that would not occur but for the proposed marine terminal) over the 10-year life span of the project. The additional 880 vessel trips will result in the vessel strike mortality of eight (8.0) Atlantic sturgeon (i.e., 880 vessel trips * 0.0091 killed per trip) during the 10-year life span of the Berth.

We have considered the best available information in order to determine from which DPSs adult individuals that will be killed are likely to have originated. To determine the likely number of Atlantic sturgeon originating from each DPS, we first have to estimate how many of the killed sturgeon will be adult and subadults. Studies by Murphy and Brown (2010) determined that 61 percent of Atlantic sturgeon vessel strike mortalities in the Delaware River were of adult size (150 cm TL). However, because Brown and Murphy (2010) did not differentiate between subadult and non-migrant juveniles for the remaining non-adults, we must use the information from the vessel strike databases. As discussed in section 6.3.2, the vessel strike databases from DNREC and NJFW are considered the best available source of information from which we can estimate the life stages of Atlantic sturgeon vessel strike mortalities and of undetermined cause of death. However, the vessel strike databases are limited in their applicability due to limitations in identifying sturgeon lengths from damaged, often decayed remains. Therefore, it is not always possible to distinguish life stages, and the identification of life stages was limited to those with enough of a body to identify approximate length (or enough of a body to identify maturity stage where possible).

In addition, the databases cover different time intervals. The DNREC data spans the years 2005 to 2019 while the NJFW database includes reports from the years January 2013 to May 2022. Thus, the DNREC and NJFW data only overlap between 2013 and 2019, which is the period NEFSC used for their analysis. For the years 2013 through 2019, the NEFSC assigned life stages to 78 Atlantic sturgeon in the DNREC data, and 11 from the NJFW database.

NEFSC's analysis of the Atlantic sturgeon vessel strike data from DNREC determined that 44 were adults, 15 subadults, and 19 juveniles. Of the 11 Atlantic sturgeon in the NJFW data, NEFSC considered six to be adults and five to be subadults based on their length. None of the carcasses in the NJFW data were determined to be a juvenile. Therefore, of the 89 Atlantic sturgeon that NEFSC reviewed, 19 were assigned as juveniles, 50 as adults, and 20 as subadults. Thus, of the 89 carcasses with an assigned life stage, 56.18 percent were adults, 22.47 percent were subadults, and 21.35 percent were juveniles (Table 29).

[24] Mo = 109/252,091 = 0.00043, Ma = 0.00043/0.0476 = 0.0091. For description of calculations, see section 6.3.2.3

Table 29. Sturgeon vessel strike mortality by life stage in the Delaware River. Table originally from the NEFSC report.

Stage	All Sturgeon (n)	All Sturgeon (%)	DNREC Sturgeon (n)	DNREC Sturgeon (%)
Adult	50	56.18	44	56.41
Subadult	20	22.47	15	19.23
Juvenile	19	21.35	19	24.36

There are several reasons why larger sturgeon may be more frequently reported, including a reporting bias for larger carcasses, a longer persistence time in the environment, and an increased likelihood of propeller strike mortality due to body size (Killgore *et al*. 2011). However, we do not have information that makes it possible to evaluate or adjust life stage mortality rates based on reporting bias or carcass persistence time. Only considering carcasses with enough information to determine life stage, adults and subadults made up 78.65 percent of the vessel strikes reported to DNREC and NJFW. With the life stage rates derived from the Vessel Strike Database, we simply apply stage-specific rates to the estimates of takes as follows:

$$N_{stage} = N * S_{stage}$$

where N_{stage} is the number of sturgeon of a particular life stage killed over the operational period of a project, N is the total number of sturgeon killed over the operational period of a project, and S_{stage} is the percentage of sturgeon mortalities by life stage killed in the Delaware River and Bay by vessel strike. Thus, using the above percentage, we anticipate that six adult and/or subadult and two juveniles will be killed over the life of the project[25]. The juvenile Atlantic sturgeon will be from the New York Bight DPS.

Using the mixed stock analysis explained in section 6.2.2.2, we have determined that the six adult or subadult Atlantic sturgeon killed by vessel strike related to this project to originate from the five DPSs at the following frequencies:

- Up to 2 adult or subadult Atlantic sturgeon from New York Bight DPS
- Up to 2 adult or sub-adult Atlantic sturgeon from Chesapeake Bay DPS
- Up to 1 adult or sub-adult Atlantic sturgeon from South Atlantic DPS
- Up to 1 adult or sub-adult Atlantic sturgeon from Gulf of Maine DPS
- Zero from the Carolina DPS

[25] 8 vessel strike mortalities multiplied with 0.79 (i.e., 78.65% adults rounded up) gives 6.32 adults or subadults and 1.68 juveniles. Rounding to nearest whole number, this equals 6 adults and 2 juveniles.

8.1.5 Shortnose sturgeon

Juvenile and adult shortnose sturgeon may occur in the action area throughout the year. Therefore, the vessel traffic associated with the proposed Berth could interact with these life stages of Atlantic sturgeon and result in vessel strike mortalities.

8.1.5.1 Exposure

Shortnose sturgeon distribution within the action area is described in section 6.2.1. Vessel activity will occur from the Berth to the pilot area at the mouth of Delaware Bay during the ten years of operation of the Berth. Vessel activity will occur year round. Both juvenile and adult shortnose sturgeon occur from Trenton, NJ, downstream to the mouth of the Delaware River year round with high concentrations of juveniles below Little Tinicum Island occurring year round. Adults may occur frequently at the Cherry Island Flats, and can occasionally be present within Delaware Bay. Thus, inbound transport of monopile segments and outbound transport of assembled monopiles will result in temporal and spatial overlap between vessels and juvenile and adult shortnose sturgeon from the mouth of the Delaware River to the Paulsboro Marine Terminal, with additional potential exposure between heavy lift vessels and adult shortnose sturgeon within the Delaware Bay.

Since all vessels will mostly travel within the 14-meter deep navigation channel, and foraging sturgeon are likely to remain close to the bottom, direct exposure to the propellers of the 7.3-meter-draft heavy lift vessels may occur infrequently. However, we expect shortnose sturgeon to move higher in the water column during other behaviors (i.e., moving to and from foraging and spawning areas, migrations) and this will likely place the fish in the water column at the same depth as the propellers of heavy lift vessels associated with the operation of the Berth. Based on the above information, there is a high likelihood that the operation of the Berth will expose juvenile and adult shortnose sturgeon to vessels and their propellers in a manner that would not occur but for the proposed action.

8.1.5.2 Response

We currently do not know of any studies regarding how shortnose sturgeon respond to approaching vessels, but we assume that they do not actively avoid them as has been demonstrated for Atlantic sturgeon. We also expect that the water current moving through the propellers of tugs and larger vessels can entrain shortnose sturgeon, similarly to Atlantic sturgeon, exposing them to the rotating propellers. Smaller shortnose sturgeon may go through a propeller without interacting with the blades, whereas propeller blades are likely to strike entrained older, larger adult sturgeon (section 8.5.1). As with Atlantic sturgeon, we anticipate that any interaction with propeller blades of large vessels will be lethal.

8.1.5.3 Risk

Given that it is likely that shortnose sturgeon are exposed to propellers and that a propeller striking a shortnose sturgeon will kill it, we conclude that the vessel traffic associated with the proposed action will kill shortnose sturgeon. These mortalities would not occur but for the proposed action.

8.1.5.4 Calculation of Take

Vessel strikes on shortnose sturgeon are not well documented. The DNREC data (2005 through 2019) identifies 13 shortnose sturgeon mortalities and the NJFW data (2013 to 2022) identifies four (4) shortnose sturgeon mortalities. Vessel strike was considered the cause of death for eight of the DNREC shortnose sturgeon and the cause of death is unknown for the remaining five. The four shortnose sturgeon in the NJFW spreadsheet were also unknown causes of death. However, we consider all 17 were likely vessel strike mortalities based on considerations described in section 6.3.2.4. For the seven-year period from 2013 through 2019, 12 shortnose sturgeon carcasses were reported to DNREC and NJFW. Again, assuming that vessel strike caused all mortalities and that only 4.76 percent of all vessel mortalities are reported, we calculate that 252 vessel mortalities occurred during the seven years. Thus, one shortnose sturgeon is killed per 1,000 vessel trips or an adjusted mortality rate of 0.001[26]. Using the same calculation as above (adjusted mortality rate multiplied with number of vessel trips during operation of the Berth), we expect that vessel activity related to the operation of the Berth will kill one (0.88 rounded up) shortnose sturgeon over the 10 years of operation of the Berth. We do not have data to calculate the probability of the shortnose sturgeon being a juvenile or adult. Nor do we have enough data to predict the chance of a vessel strike being a female or male. Thus, the vessel strike may be a juvenile or an adult shortnose sturgeon of either sex.

8.1.6 Summary of Consequences of Vessel Traffic

Based on information in the biological assessment, the operation of the Berth will add up to 880 vessel trips over a 10-year period (from 2023 to 2032) to the number of baseline vessel trips. We expect the additional vessel traffic in the action area due to the operation of the Berth will increase the risk of vessel strike in the action area and, therefore, an increase in the number of sturgeon killed by vessels. We assume that vessels calling at the Berth will stay constant and that the risk will not increase during the years of operation. Based on this we have estimated that one shortnose sturgeon and eight Atlantic sturgeon that will be killed as a consequence of the proposed action. We used the Estuarine/Riverine Zone 3 breakdown of DPS from Damon-Randall *et al.* (2013) to estimate how many Atlantic sturgeon of each DPS we expect will be killed by vessel strike. Table 30 summarizes the number of sturgeon vessel strike mortalities by species and DPS.

Table 30. Number of shortnose sturgeon and Atlantic sturgeon of each DPS expected killed by vessel traffic because of ten years of operating the proposed RoRo Berth.

Species	DPS	Juvenile	Subadult/Adult	Either juvenile or adult/subadult
Atlantic sturgeon	GOM	0	1	0
	NYB	2	2	0
	CB	0	2	0
	SA	0	1	0
	Carolina	0	0	0
Shortnose sturgeon	N/A	-	-	1

[26] Mo = 6/282,891 = 0.0000476, Ma = 0.000048/0.0476 = 0.001. For description of calculations, see section 6.3.2.4.

We have made a number of assumptions (as identified above) in our analysis in light of the uncertainty surrounding a number of issues. These include:

- The number of vessel strike mortalities by recreational vessels is very small and thus, the contribution of recreational vessels to total vessel traffic in the action area was not considered, which could alter the level of risk of vessel mortalities per trip if recreational vessels are a larger threat than assumed.
- That all vessels are equally likely to strike a sturgeon and that the effects of that strike would be the same, which could result in an underestimate or overestimate if not true.
- That the sturgeon recorded in the DNREC and NJFW databases without any identified cause of death were considered vessel strike mortalities, which would overestimate the risk of vessel strike if many of these were actually not killed by interaction with vessels.
- That the DNREC and NJFW databases includes only 4.76 percent of actual sturgeon mortalities in the Delaware River and Bay, which would result in overestimate of vessel strikes if a higher proportion is reported and an underestimate if even less are reported.
- The use of annual vessel activity and sturgeon mortalities to calculate vessel strike risk as most mortalities are reported during spring, which could either over- or under estimate (depending on baseline vessel activity during different months) the risk of vessels striking a sturgeon.

We have used the best available information and professional judgment and made reasonable likely assumptions to address uncertainty and produce an analysis that results in an estimate of the number of interactions between sturgeon and vessels that are reasonably certain to occur.

8.2 Ballast

Vessels calling at the proposed Berth are likely to exchange ballast during on- and offloading of cargo. However, it is unclear where exactly exchange of ballast will occur. Thus, we assume that exchange of ballast could occur within the Federal Navigation Channel as well as within the Berth. As Atlantic sturgeon and shortnose sturgeon may occur in the action area, these species could potentially be affected by entrainment in the water intake during exchange of ballast water operation of the proposed Berth. Juveniles and older sturgeon life stages in the action area are too large to potentially be entrained and have sufficient swimming capabilities to avoid impingement during ballast water withdrawal (NMFS 2017a). Fish eggs and larvae have the potential to be entrained during the intake of ballast water. Sturgeon eggs, YSL, and PYSL are not expected to occur within the Paulsboro RoRo Berth and its access channel. However, intake of ballast water when the vessel is in the Federal Navigation Channel could expose PYSL and young juveniles to water drawn into the ballast intake.

Prakash *et al.* (2014) developed a 3-dimensional hydrodynamic model for the withdrawal of ballast water by a liquefied natural gas (LNG) carrier for the proposed (now de-authorized) Crown Landing project on the Delaware River. Based on a ballast pumping rate of 2,500 m3/hr, they calculated a zone of influence with a vertical dimension of 5 to 6 m (16.4 to 19.7 ft) and a horizontal dimension of approximately 50 m (164 ft). Velocity was calculated to be 50 cm/sec at the intake opening and decreased exponentially with distance from the intake. Assuming that the area of the intake opening was similar, the zone of influence of a ballast water intake on a container ship would be smaller because of a lower pumping rate, which NRC (1996) indicates would be in the range of 1,000 to 2,000 m3/hr.

Applying the average sustained swim speed of 1.90 BL/sec determined by Wilkens *et al.* (2015) for small juvenile Atlantic sturgeon to a late-stage PYSL (~ 10 cm FL) yields a swim speed of 19 cm/sec. Burst swim speed would be substantially greater. Based on Figure 8 in Prakash *et al.* (2014), intake velocities of 20 cm/sec or higher extend only about 1.0 m (3.3 ft) from the intake opening of the LNG carrier. Assuming a similar intake open area, velocities of this magnitude would extend a lesser distance for a container ship pumping ballast water at 1,000 to 2,000 m3/hr.

Ballast water intakes are not located at the bottom of the vessel's hull, but are located further up the side, often amidships between the water line and the keel, to reduce the possibility of withdrawing sediment into a ballast tank (e.g., the intake in Prakash's LNG carrier model was 3.7 m (12.1 ft) above the keel). Therefore, the probability of an Atlantic sturgeon PYSL encountering the ballast water intake is further reduced by the benthic orientation of the larvae relative to the location of the ballast water intake. The small zone of influence and elevation in the water column of the ballast water intakes, combined with the unlikely occurrence of Atlantic sturgeon PYSL in the project area, suggests that the risk of entrainment of PYSL in ballast water at the Paulsboro RoRo Berth is too small to be meaningfully measured, detected, or evaluated and, therefore, insignificant.

Invasive species released in the action area could potentially affect sturgeon directly (e.g., a novel parasite) or affect their prey. However, based on anticipated vessel travel within the Delaware River during construction and operation, project vessels are unlikely to be carrying invasive species in their ballast tanks from the marine environment that would survive the tidal freshwater environment at the proposed Berth site and vice versa. Additionally, all Project vessels will be required to comply with the United States Environmental Protection Agency's Vessel General Permit program and with United States Coast Guard ballast water exchange regulations specified at 33 CFR 151.1510 to avoid introduction of invasive species through ballast discharge in the action area. Therefore, any effects of ballast water exchange on Atlantic sturgeon and shortnose sturgeon are extremely unlikely.

9 CUMULATIVE EFFECTS

Cumulative effects, as defined in 50 CFR § 402.02, are those effects of future State or private activities, not involving Federal activities, which are reasonably certain to occur within the action area. Future Federal actions are not considered in the definition of "cumulative effects."

Actions carried out or regulated by the States of New Jersey, Delaware and Pennsylvania within the action area that may affect shortnose and Atlantic sturgeon include the authorization of state fisheries and the regulation of point and non-point source pollution through the National Pollutant Discharge Elimination System (NPDES). Other than those captured in the Status of the Species and Environmental Baseline sections above, we are not aware of any local or private actions that are reasonably certain to occur in the action area that may affect listed species. It is important to note that the definition of "cumulative effects" in the Section 7 regulations is not the same as the NEPA definition of cumulative effects[27].

State Water Fisheries – Future recreational and commercial fishing activities in state waters may take shortnose and Atlantic sturgeon. In the past, it was estimated that over 100 shortnose sturgeon were captured annually in shad fisheries in the Delaware River, with an unknown mortality rate (O'Herron and Hastings 1985); no recent estimates of captures or mortality are available. Atlantic sturgeon were also likely incidentally captured in shad fisheries in the river; however, estimates of the number of captures or the mortality rate are not available. Recreational shad fishing is currently allowed within the Delaware River with hook and line only; commercial fishing for shad occurs with gill nets, but only in Delaware Bay. In 2012, only one commercial fishing license was granted for shad in New Jersey. Shortnose and Atlantic sturgeon continue to be exposed to the risk of interactions with this fishery; however, because increased controls have been placed on the shad fishery, impacts to shortnose and Atlantic sturgeon are likely less than they were in the past.

Information on interactions with shortnose and Atlantic sturgeon for other fisheries operating in the action area is not available, and it is not clear to what extent these future activities would affect listed species differently than the current state fishery activities described in the Status of the Species/Environmental Baseline section. However, this biological opinion assumes that future effects would be similar to those in the past and, therefore, are reflected in the anticipated trends described in the status of the species/environmental baseline section.

State PDES Permits – The states of New Jersey, Delaware and Pennsylvania have been delegated authority to issue NPDES permits by the EPA. These permits authorize the discharge of pollutants in the action area. Permit holders include municipalities for sewage treatment plants and other industrial users. The states will continue to authorize the discharge of pollutants through the State PDES permits. However, this biological opinion assumes effects in the future would be similar to those in the past and, therefore, are reflected in the anticipated trends described in the status of the species/environmental baseline section.

10 INTEGRATION AND SYNTHESIS

In our 2022 biological opinion for this action, we considered effects to listed species from construction of the proposed Berth. The applicant has completed all construction activities and

[27] Cumulative effects are defined for NEPA as "the impact on the environment, which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

we incorporate in this Opinion the effects analyses from the 2022 biological opinion by reference. In the previous biological opinion, we concluded that effects caused by proposed construction activities, including vessel traffic during construction, would be either insignificant or extremely unlikely to occur. We also concluded that the proposed project, including operation of the Berth, may affect but is not likely to adversely affect listed sea turtles and whales, and no take was anticipated or exempted for these species. We also concluded that the proposed project, including operation of the Berth, may affect but is not likely to adversely affect critical habitat designated for Atlantic sturgeon.

In the *Consequences of the Action* section of this Opinion, we considered potential consequences to shortnose sturgeon and Atlantic sturgeon during the operation of the Berth. This include consequences resulting from vessel traffic to and from the Berth and from intake and release of ballast water. We analyze the consequences of these stressors as they are added to baseline conditions. In section 7.2, we considered how climate change has affected baseline conditions and how we expect climate change to affect conditions in the future. In our analysis, we concluded that the 10-year period evaluated in this Opinion is too short to reasonably predict any effects of climate change on sturgeon numbers, density, or distribution within the action area that would affect our analysis of vessel strike.

We concluded that vessel traffic during operation of the facility will result in the mortality of eight Atlantic sturgeon and one shortnose sturgeon. As explained in the *Effects of the Action* section, effects to shortnose sturgeon and Atlantic sturgeon from intake and release of ballast water will be insignificant and/or extremely unlikely to occur.

In the discussion below, we consider whether the effects of the proposed action reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the listed species in the wild by reducing the reproduction, numbers, or distribution of the listed species that will be adversely affected by the action. The purpose of this analysis is to determine whether the proposed action, in the context established by the status of the species, environmental baseline, and cumulative effects, would jeopardize the continued existence of any listed species. In doing our analysis, we also consider the consequences of climate change both for the baseline and for the species as a whole.

In the U.S. FWS/NMFS Section 7 Handbook (U.S. FWS and NMFS 1998), for the purposes of determining jeopardy, survival is defined as, “the species’ persistence as listed or as a recovery unit, beyond the conditions leading to its endangerment, with sufficient resilience to allow for the potential recovery from endangerment. Said in another way, survival is the condition in which a species continues to exist into the future while retaining the potential for recovery. This condition is characterized by a species with a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, which exists in an environment providing all requirements for completion of the species’ entire life cycle, including reproduction, sustenance, and shelter.”

Recovery is defined as, "[i]mprovement in the status of listed species to the point at which listing is no longer appropriate under the criteria set out in Section 4(a)(1) of the Act." We summarize below the status of the species and consider whether the proposed action will result in reductions in reproduction, numbers, or distribution of these species and then consider whether any reductions in reproduction, numbers, or distribution resulting from the proposed action would reduce appreciably the likelihood of both the survival and recovery of these species, as those terms are defined for purposes of the ESA.

Shortnose Sturgeon

Historically, shortnose sturgeon are believed to have inhabited nearly all major rivers and estuaries along nearly the entire east coast of North America. Today, only 19 populations remain. The present range of shortnose sturgeon is disjunct, with northern populations separated from southern populations by a distance of about 400 km (248.5 mi). Population sizes range from under 100 adults in the Cape Fear and Merrimack Rivers to tens of thousands in the St. John and Hudson Rivers. As indicated in Kynard *et al.* (2016), adult abundance is less than the minimum estimated viable population abundance of 1,000 adults for 5 of 11 surveyed northern populations and all natural southern populations. The only river systems likely supporting populations close to expected abundance are the St John, Hudson and possibly the Delaware and the Kennebec (Kynard *et al.* 2016), making the continued success of shortnose sturgeon in these rivers critical to the species as a whole.

The Delaware River population of shortnose sturgeon is the second largest in the United States. Historical estimates of the size of the population are not available as historic records of sturgeon in the river did not discriminate between Atlantic and shortnose sturgeon. The most recent population estimate for the Delaware River is 12,047 (95% CI= 10,757-13,580) and is based on mark recapture data collected from January 1999 through March 2003 (ERC 2006a). Comparisons between the population estimate by ERC Inc. and the earlier estimate by Hastings *et al.* (1987) of 12,796 (95% CI=10,228-16,367) suggests that the population is stable, but not increasing.

While no reliable estimate of the size either of the shortnose sturgeon population in the Northeastern US or of the species throughout its range exists, it is clearly below the size that could be supported if the threats to shortnose sturgeon were removed. Based on the number of adults in population for which estimates are available, there are at least 104,662 adult shortnose sturgeon, including 18,000 in the Saint John River in Canada. The lack of information on the status of some populations, such as that in the Chesapeake Bay, adds uncertainty to any determination on the status of this species as a whole. Based on the best available information, we consider the status of shortnose sturgeon throughout their range to be stable.

As described in the *Status of the Species*, *Environmental Baseline*, and *Cumulative Effects* sections above, shortnose sturgeon in the Delaware River are affected by impingement at water intakes, habitat alteration, dredging, bycatch in commercial and recreational fisheries, water quality, in-water construction activities, and vessel traffic (e.g., data from DNREC (2005-2019) and NJFW (2013-2022), indicate that 8 sturgeon mortalities were attributable to vessel strikes (and an additional 9 had an unknown, but likely vessel strike cause of death)). It is difficult to quantify the total number of shortnose sturgeon that may be killed in the Delaware River each year due to anthropogenic sources. Through reporting requirements implemented under Section 7 and Section 10 of the ESA, we obtain some information on the number of incidental and directed takes of shortnose sturgeon each year from specific actions. Typically, scientific research results in the capture and collection of less than 100 shortnose sturgeon in the Delaware River each year, with little if any mortality. With the exception of the five shortnose sturgeon observed during cutterhead dredging activities in the 1990s; the three shortnose sturgeon killed by hopper dredge during 2017- 2019; the shortnose sturgeon injured during the pilot relocation study; and the six shortnose sturgeon killed during blasting (for the Philadelphia to the Sea FNP deepening project) we have no reports of interactions or mortalities of shortnose sturgeon in the Delaware River resulting from dredging or other in-water construction activities. We also have no quantifiable information on the consequences of habitat alteration or water quality. In general, water quality has improved in the Delaware River since the 1970s, when the CWA was implemented, with significant improvements below Philadelphia, which was previously considered unsuitable for shortnose sturgeon and is now well used. Shortnose sturgeon in the Delaware River have full, unimpeded access to their historic range in the river and appear to be fully utilizing all suitable habitat; this suggests that the movement and distribution of shortnose sturgeon in the river is not limited by habitat or water quality impairments. Impingement at the Salem nuclear power plant occurs occasionally, with typically less than one mortality per year. The shad fishery, primarily hook and line recreational fishing, has historically caught shortnose sturgeon as bycatch, particularly because it commonly occurred on the spawning grounds. However, little to no mortality was thought to occur and due to decreases in shad fishing impacts are thought to be less now than they were in the past. Despite these ongoing threats, the Delaware River population of shortnose sturgeon is stable at high numbers. Over the life of the action, shortnose sturgeon in the Delaware River will continue to experience anthropogenic and natural sources of mortality. However, we are not aware of any future actions that are reasonably certain to occur that are likely to change this trend or reduce the stability of the Delaware River population. If the salt line shifts further upstream, as is predicted in climate change modeling, the range of juvenile shortnose sturgeon is likely to be reduced compared to the current range of this life stage. However, because there is no barrier to upstream movement it is not clear if this will impact the stability of the Delaware River population of shortnose sturgeon. Therefore, we do not anticipate changes in distribution or abundance of shortnose sturgeon in the river due to climate change in the time period considered in this Opinion. As such, we expect that numbers of shortnose sturgeon in the action area will continue to be stable at high levels over the life of the proposed action.

We have estimated that the proposed activities will result in the following levels of take:

- Over the 10-year life span of the Berth, the operation of the Berth will result in the vessel strike mortality of one shortnose sturgeon adult or juvenile of either sex.

The one shortnose sturgeon that is likely to die as a result of as a result of the project, represents an extremely small percentage of the shortnose sturgeon population in the Delaware River, which is believed to be stable at high numbers, and an even smaller percentage of the total population of shortnose sturgeon range wide, which is also stable. The best available population estimates indicate that there are approximately 12,047 shortnose sturgeon in the Delaware River (ERC 2006b). While the mortalities associated with completed actions together with the estimated mortality associated with proposed activity will reduce the number of shortnose sturgeon in the population compared to the number that would have been present absent the proposed action, it is not likely that this reduction in numbers will change the status of this population or its stable trend as this loss represents a very small percentage of the population.

The reduction in the number of shortnose sturgeon in the Delaware River from this proposed action would have the effect of reducing the amount of potential reproduction in this system as the fish killed would have no potential for future reproduction (one shortnose sturgeon mortality would be approximately 0.008 percent of the total population). However, it is estimated that on average, approximately 1/3 of adult females spawn in a particular year and approximately 1/2 of males spawn in a particular year. Given that the best available estimates indicate that there are more than 12,000 shortnose sturgeon in the Delaware River, it is reasonable to expect that there are at least 5,000 adults spawning in a particular year. It is unlikely that the loss of one juvenile or adult shortnose sturgeon as a result of the operation of the RoRo Berth over a 10-year period would affect the success of spawning in any year. The small reduction in the number of male spawners (assuming the sturgeon killed by the proposed action is male) is not expected to affect production of eggs, as enough males will be present to fertilize eggs. Alternatively, this small reduction in a potential female spawner (if we assume that the sturgeon killed by the proposed action is female) is expected to result in a small reduction in the number of eggs laid or larvae produced in future years and, similarly, a very small effect on the strength of subsequent year classes. Even considering the potential future spawners that would be produced by the individual that would be killed as a result of the proposed action, any effect to future year classes is anticipated to be very small and would not change the stable trend of this population. Additionally, the proposed action will not adversely affect spawning habitat.

The proposed action is not likely to reduce distribution as the proposed Berth will not constitute a barrier to movement. Continued vessel traffic may diminish the availability of prey in the access channel and turning basin of the proposed Berth; however, this area represents a very small fraction of available foraging habitat within the action area and the river and we do not expect the reduction in available prey to limit prey available to sturgeon. We do not anticipate that any impacts to habitat will impact how sturgeon use the overall action area. As the one shortnose sturgeon likely to be killed as a result of the action as a whole is extremely small (0.008 percent of the Delaware River population), there is not likely to be a loss of any unique genetic haplotypes and it is unlikely to result in the loss of genetic diversity.

In general, the loss of a small number of individuals from a subpopulation or species can have an appreciable effect on the numbers, reproduction and distribution of the species. This is only likely to occur when there are very few individuals in a population, the individuals occur in a very limited geographic range or the species has extremely low levels of genetic diversity. This situation is not likely in the case of shortnose sturgeon because the species is widely geographically distributed, it is not known to have low levels of genetic diversity (see *Status of the Species*/*Environmental Baseline* section above), and there are thousands of shortnose sturgeon spawning each year.

Based on the information provided above, the death of up to one shortnose sturgeon juvenile or adult as a result of the proposed action will not reduce appreciably the likelihood of survival of this species (i.e., it will not decrease the likelihood that the species will continue to persist into the future with sufficient resilience to allow for the potential recovery from endangerment). The action will not affect shortnose sturgeon in a way that prevents the species from having a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, and it will not result in effects to the environment which would prevent shortnose sturgeon from completing their entire life cycle, including reproduction, sustenance, and shelter (i.e., it will not increase the risk of extinction faced by this species). This is the case because: (1) the population trend of shortnose sturgeon in the Delaware River is stable; (2) the estimated mortality of up to one shortnose sturgeon represents an extremely small percentage of the number of shortnose sturgeon in the Delaware River and an even smaller percentage of the species as a whole; (3) the loss of this shortnose sturgeon is likely to have such a small effect on reproductive output of the Delaware River population of shortnose sturgeon or the species as a whole that the loss of one shortnose sturgeon will not change the status or trends of the Delaware River population or the species as a whole; (4) the action will have no consequence on the distribution of the species throughout its range; and, (5) the action will have no consequence on the ability of shortnose sturgeon to shelter and only an insignificant consequence on individual foraging shortnose sturgeon.

In rare instances, an action that does not reduce appreciably the likelihood of a species' survival might affect its likelihood of recovery or the rate at which recovery is expected to occur. As explained above, we have determined that the proposed action will not reduce appreciably the likelihood that shortnose sturgeon will survive in the wild. Here, we consider the potential for the action to reduce the likelihood of recovery. As noted above, recovery is defined as the improvement in status such that listing under ESA Section 4(a) as "in danger of extinction throughout all or a significant portion of its range" (endangered) or "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (threatened) is no longer warranted. Thus, we have considered whether the proposed action will reduce appreciably the likelihood that shortnose sturgeon can rebuild to a point where they are no longer in danger of extinction through all or a significant part of their range.

A Recovery Plan for shortnose sturgeon was published in 1998 pursuant to Section 4(f) of the ESA. The Recovery Plan outlines the steps necessary for recovery and indicates that each population may be a candidate for downlisting (i.e., to threatened) when it reaches a minimum population size that is large enough to prevent extinction and will make the loss of genetic diversity unlikely. However, the plan states that the minimum population size for each population has not yet been determined. The Recovery Outline contains three major tasks: (1) establish delisting criteria; (2) protect shortnose sturgeon populations and habitats; and, (3) rehabilitate habitats and population segments. We know that in general, to recover, a listed species must have a sustained positive trend of increasing population over time. To allow that to happen for sturgeon, individuals must have access to enough habitat in suitable condition for foraging, migrating, resting, and spawning. Conditions must be suitable for the successful development of early life stages. Mortality rates must be low enough to allow for recruitment to all age classes so that successful spawning can continue over time and over generations. Habitat connectivity must also be maintained so that individuals can migrate between important habitats without delays that affect their fitness. Here, we consider whether this proposed action will affect the Delaware River population of shortnose sturgeon in a way that would affect the species' likelihood of recovery.

The Delaware River population of shortnose sturgeon is stable at high numbers. This action will not change the status or trend of the Delaware River population of shortnose sturgeon or the species as a whole. This is because the reduction in numbers will be small and the impact on reproduction and future year classes will also be small enough not to affect the stable trend of the population. The action will have only insignificant effects on habitat and forage and will not impact the river in a way that makes additional growth of the population less likely, that is, it will not reduce the river's carrying capacity. This is because the impacts to habitat will be limited to continued degradation of forage within the dredge footprint by propeller jet scour and revetment installation, increases in suspended sediment during passage of vessels, and increased water depth; however, we do not anticipate any changes to substrate type and the salinity regime. We do not anticipate that any impacts to habitat will affect how sturgeon use the action area.

The proposed action will not affect shortnose sturgeon outside of the Delaware River. Because it will not reduce the likelihood that the Delaware River population can recover, it will not reduce the likelihood that the species as a whole can recover. Therefore, the proposed action will not reduce appreciably the likelihood that shortnose sturgeon can be brought to the point at which they are no longer listed as endangered or threatened. We have also considered the effects of the proposed action in light of cumulative effects explained above, including climate change, and have concluded that even in light of the ongoing impacts of these activities and conditions; the conclusions reached above do not change. Based on the analysis presented herein, the proposed action, resulting in the mortality of up to one shortnose sturgeon over a 10-year period, is not likely to reduce appreciably the survival and recovery of the species.

10.1 Atlantic Sturgeon

We expect that up to eight Atlantic sturgeon will be killed by vessel strike operation of the proposed Berth.

10.1.1 Take by DPS, Life Stage, and Sex

Using mixed stock analysis explained in section 6.2.2.2, we determined in section 8.1.4.4 that the Atlantic sturgeon killed by vessel strike related to this project to originate from the five DPSs in the following numbers:

- Up to 2 juvenile Atlantic sturgeon from New York Bight DPS
- Up to 2 adult or sub-adult Atlantic sturgeon from New York Bight DPS
- Up to 2 adult or sub-adult Atlantic sturgeon from Chesapeake Bay DPS
- Up to 1 adult or sub-adult Atlantic sturgeon from South Atlantic DPS
- Up to 1 adult or sub-adult Atlantic sturgeon from Gulf of Maine DPS
- Zero from the Carolina DPS

Determination of sex ratio

We do not know about any general information about the sex ratio of Atlantic sturgeon in the Delaware River. The DNREC data report the sex for only five adult mortalities (all mortality causes) in the Delaware River (all years) while only one of the carcasses reported to the NJFW had a sex determination. Of these, two were determined to be female and four to be male. Given the small sample size and the absence of additional information, we assume the ratio of male to female Atlantic sturgeon in the Delaware River is even (i.e., 1:1) and that male sturgeon are equally likely to be struck and killed by a vessel as female sturgeon. Therefore, out of the four vessel strike mortalities estimated for the New York Bight DPS over 10 years of Berth operation, we anticipate two will be males and two will be females.

10.1.2 Gulf of Maine DPS

The Gulf of Maine DPS is listed as threatened, and while Atlantic sturgeon occur in several rivers of the Gulf of Maine region, recent spawning has only been physically documented in the Kennebec River. That said, spawning is suspected to occur in the Androscoggin, Piscataqua, and Merrimack Rivers, although not confirmed. Currently we do not have an estimate of the number of Atlantic sturgeon in any river nor is any currently available for the entire DPS; however, NEAMAP data indicates that the estimated ocean population of Gulf of Maine DPS Atlantic sturgeon subadults and adults is 7,455 individuals. Gulf of Maine origin Atlantic sturgeon are subject to numerous sources of human induced mortality and habitat disturbance throughout the riverine and marine portions of their range. There is currently not enough information to establish a trend for any life stage or for the DPS as a whole. The ASMFC stock assessment concluded that the abundance of the Gulf of Maine DPS is “depleted” relative to historical levels. The Commission also noted that the Gulf of Maine is particularly data poor among all five DPSs. The assessment concluded that there is a 51 percent probability that the abundance of the Gulf of Maine DPS has increased since implementation of the 1998 fishing moratorium. The Commission also concluded that there is a relatively high likelihood (74 percent probability) that mortality for the Gulf of Maine DPS exceeds the mortality threshold used for the assessment ASMFC (2017b). However, the Commission noted that there was considerable uncertainty related to these numbers, particularly concerning trends data for the Gulf of Maine DPS. For example, the stock assessment notes that it was not clear if: (1) the percent probability for the trend in abundance for the Gulf of Maine DPS is a reflection of the actual trend in abundance or of the underlying data quality for the DPS; and, (2) the percent probability that the Gulf of Maine DPS exceeds the mortality threshold actually reflects lower survival or was due to increased tagging model uncertainty owing to low sample sizes and potential emigration.

Here, we consider the consequences of the loss of one Atlantic sturgeon over a 10-year period from the Gulf of Maine DPS. The reproductive potential of the Gulf of Maine DPS will not be affected in any way other than through a reduction in numbers of individuals. The loss of one individual over a 10-year period will have the consequence of reducing reproduction potential within the DPS because any dead Gulf of Maine DPS Atlantic sturgeon has no potential for future reproduction. However, this small reduction in potential future spawners is expected to result in an extremely small reduction in the number of eggs laid or larvae produced in future years and similarly, an extremely small consequence on the strength of subsequent year classes. Even considering the potential future spawners that would be produced by the individual that will be killed as a result of the proposed action, any consequence to future year classes is anticipated to be extremely small and would not change the status of this species. The proposed action will also not affect the spawning grounds within the rivers where Gulf of Maine DPS fish spawn, because it will occur outside of those identified areas. Additionally, the action will not create any barrier to pre-spawning sturgeon accessing the overwintering sites or the spawning grounds used by Gulf of Maine DPS fish for the same reasons.

Because we do not have a population estimate for the Gulf of Maine DPS, it is difficult to evaluate the consequences of mortality on this species caused by this action. However, because the proposed action will result in the loss of no more than one individual over a 10-year period, it is unlikely that this death will have detectable consequences on the numbers and population trend of the Gulf of Maine DPS.

The proposed action is not likely to reduce distribution because the action will not impede Atlantic sturgeon from accessing any seasonal concentration areas, including foraging areas within the action area that may be used by Gulf of Maine DPS subadults or adults. Further, the action is not expected to reduce the river by river distribution of Atlantic sturgeon. Any consequences to distribution will be minor and temporary, and limited to the avoidance of the area where the impacts occur because of the action.

Based on the information provided above, the death of up to one Gulf of Maine DPS Atlantic sturgeon over a 10-year period will not appreciably reduce the likelihood of survival of the Gulf of Maine DPS (i.e., it will not decrease the likelihood that the species will continue to persist into the future with sufficient resilience to allow for the potential recovery from endangerment). The action will not affect Gulf of Maine DPS Atlantic sturgeon in a way that prevents the species from maintaining a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring. Additionally, it will not result in consequences to the environment which prevent Atlantic sturgeon from completing their entire life cycle, including reproducing, sustenance, and shelter. This is the case because: (1) the death of one Gulf of Maine DPS Atlantic sturgeon as a result of this action in any year will not change the status or trends of the species as a whole; (2) the loss of this one Gulf of Maine DPS Atlantic sturgeon as a result of this action is not likely to have consequences on the levels of genetic heterogeneity in the population; (3) the action will have only a minor and temporary consequence on the distribution of Gulf of Maine DPS Atlantic sturgeon in the action area and no consequence on the distribution of the species throughout its range; and, (4) the action will have no consequence on the ability of Gulf of Maine DPS Atlantic sturgeon to shelter with only an insignificant consequence on any foraging Gulf of Maine DPS Atlantic sturgeon.

In certain instances, an action that does not appreciably reduce the likelihood of a species' survival might affect its likelihood of recovery or the rate at which recovery is expected to occur. As explained above, we have determined that the proposed action will not appreciably reduce the likelihood that the Gulf of Maine DPS will survive in the wild. Here, we consider the potential for the action to reduce the likelihood of recovery. As noted above, recovery is defined as the improvement in status such that listing is no longer appropriate. Thus, we have considered whether the proposed action will affect the likelihood that the Gulf of Maine DPS can rebuild to a point where listing is no longer appropriate. No Recovery Plan for the Gulf of Maine DPS has been published at this time. As defined, a Recovery Plan will outline the steps necessary for recovery and the demographic criteria, which once attained would allow the species to be delisted. We know that in general, to recover, a species must have a sustained positive increasing population trend over time and an increase in population size. To allow those things to happen, a species must have enough habitat in suitable condition that allows all normal life functions to occur (i.e., spawning, foraging, resting) and must also have access to enough food. Next, we consider whether the proposed action will affect the population size and/or trend in a way that would affect the likelihood of recovery.

We do not expect the proposed action to modify, curtail, or destroy the range of the species since it will result in an extremely small reduction in the number and overall distribution of Gulf of Maine DPS Atlantic sturgeon. Any consequences to habitat will be insignificant and will not affect the ability of Atlantic sturgeon to carry out any necessary behaviors or functions. Any impacts to available forage will also be insignificant. The proposed action will result in an extremely small amount of mortality over 10 years (one individual) and a subsequent small reduction in future reproductive output. For these reasons, we do not expect the action to affect the persistence of the Gulf of Maine DPS of Atlantic sturgeon. The action will not change the status or trend of the Gulf of Maine DPS of Atlantic sturgeon, nor will a very small reduction in numbers and future reproduction resulting from the proposed action reduce the likelihood of improvement in the status. The consequences of the proposed action will not delay the recovery timeline or otherwise decrease the likelihood of recovery. The consequences of the proposed action will also not reduce the likelihood that the status of the species can improve to the point where it is recovered and could be delisted. Therefore, the proposed action will not appreciably reduce the likelihood that the Gulf of Maine DPS of Atlantic sturgeon can be brought to the point at which listing as threatened is no longer necessary. Based on the analysis presented herein, the proposed action is not likely to appreciably reduce the survival and recovery of this species.

Despite the threats faced by individual Gulf of Maine DPS Atlantic sturgeon inside and outside of the action area, the proposed action will not increase the vulnerability of individual sturgeon to these additional threats and exposure to ongoing threats will not increase susceptibility to consequences related to the proposed action. We have considered the consequences of the proposed action in light of cumulative effects explained above, including climate change, and have concluded that even in light of the ongoing impacts of these activities and conditions; the conclusions reached above do not change. Based on the analysis presented herein, the proposed action, resulting in the mortality of up to one Gulf of Maine DPS Atlantic sturgeon over a 10-year period, is not likely to appreciably reduce the survival and recovery of the species.

10.1.3 New York Bight DPS

The New York Bight DPS is listed as endangered and includes the following: all anadromous Atlantic sturgeon spawned in the watersheds that drain into coastal waters (including bays and sounds) from Chatham, MA to the Delaware-Maryland border on Fenwick Island. Our recent status review concluded that the status of the DPS has likely neither improved nor declined from what it was when we listed the DPS in 2012, that the DPS's demographic risk is "High," and that no changes to the listing status and listing recovery priority number are needed (NMFS 2022). As noted in the 5-year review and discussed in section 5.2, low productivity (e.g., relatively few adults compared to historical levels and irregular spawning success), low abundance (e.g., only a few known spawning populations and low DPS abundance, overall), and limited spatial distribution (e.g., limited spawning habitat within each of the few known rivers that support spawning) puts the New York Bight DPS at risk of extinction. There is also new information indicating genetic bottlenecks as well as low levels of inbreeding in the Hudson and Delaware spawning populations.

Within the New York Bight DPS range, Atlantic sturgeon historically spawned in the Connecticut, Delaware, Hudson, and Housatonic Rivers (ASSRT 2007, Murawski and Pacheco 1977, Secor and Niklitschek 2002). While Atlantic sturgeon occur in several rivers in the New York Bight, recent spawning has only been physically documented in the Hudson and Delaware Rivers. The essential physical features necessary to support spawning and recruitment are also present in the Connecticut and Housatonic Rivers (82 FR 39160; August 17, 2017). However, there is no current evidence that spawning is occurring nor are there studies underway to investigate spawning occurrence in those rivers; except one recent study where YOY fish of were captured in the Connecticut River (Savoy *et al.* 2017). Genetic analysis suggests that the YOY belonged to the South Atlantic DPS and at this time we do not know if these fish were the result of a single spawning event due to unique straying of the adults from the South Atlantic DPS's spawning rivers.

Here we evaluate the consequences to the New York Bight DPS of Atlantic sturgeon as a result of the lethal take of two subadult or adult and two juveniles Atlantic sturgeon over 10 years of operation of the Berth. We have limited information from which to determine the percentage of New York Bight DPS adult and subadult fish within the action area that are likely to originate from the Delaware River versus the Hudson River. Further, it is reasonable to assume that the location of a vessel strike (e.g., at the mouth of the Delaware Bay, within the Bay, in the lower reaches of the river, or in the upper reaches of the river) informs the natal river of the Atlantic sturgeon killed. As we have previously noted, in the Bay and the lower reaches of the river, Atlantic sturgeon from any DPS may occur. However, we expect that mostly Delaware River fish occur in the upper reaches of the river. At this time, however, we cannot reasonably predict where vessel strikes will occur. Given this uncertainty and the lack of information to determine the relative presence of Delaware River and Hudson River fish within the action area, to be comprehensive we will analyze the consequences as if both adult or subadult Atlantic sturgeon are of Delaware River origin and alternatively, if both are of Hudson River origin when analyzing consequences to river populations.

Review of sturgeon carcasses reports available to us from the Delaware River and Bay show that the majority of Atlantic sturgeon vessel strikes are adults (Section 6.3.2.3, Table 18). Therefore, it is reasonable to assume that it is likely that both non-juvenile vessel strikes are adults or subadults.

Small populations are susceptible to threats such as inbreeding, genetic drift (allele frequencies of a population changing over generations due to chance), demographic stochasticity (chance independent events of individual mortality and reproduction, causing random fluctuations in population growth rate), and Allee effect (individual fitness in a population increases/decreases with increasing/decreasing population size because of undercrowding). These factors have substantial influence on the growth of small populations and therefore their extinction risk. The specific biology and life history of a species influence the population size needed to remain viable, but as a rule of thumb, an effective population size, N_e, of 50 breeding individuals are needed for a short-term minimum viable population (MVP) and a N_e size of 500 breeding individuals for retaining evolutionary potential (and long-term MVP) (Franklin 1980). The effective population "rule of thumb" for a Ne of 50 takes into account inbreeding while the latter considers genetic drift[28].

There are no abundance estimates for the entirety of the New York Bight DPS nor for either the Hudson or Delaware River populations. There are, however, some abundance estimates for specific life stages (e.g., natal juvenile abundance, spawning run abundance, and effective population size). As noted in the *Status of the Species* section (section 5), both the Delaware River and the Hudson River current abundance is believed to be a fraction of historic levels (also

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[28] The N_e needed to balance between loss of additive genetic variation through genetic drift and creation of new genetic variation through mutation for a population to retain sufficient quantitative genetic variation to allow future adaptive change or evolutionary potential.

see Secor (2002) and Kahnle *et al.* (2007)). Although we do not have data to estimate the current adult population of Delaware River Atlantic sturgeon, we do have information that spawner runs consist of between 125 to 250 spawners (section 5.2.2). An estimated 3,656 age-1 individuals used the Delaware Estuary as a nursery in 2014 (since oceanward migration begins at age two or older, these juveniles would be of Delaware River origin). An estimate of the mean annual number of mature adults (863 total; 596 males and 267 females) was calculated for the Hudson River riverine population based on fishery-dependent data collected from 1985-1995 (Kahnle *et al.* 2007). In a more recent study, Kazyak *et al.* (2020) estimated the 2014 Hudson River spawning run size to be 466 sturgeon (95 percent CRI = 310-745). In our analysis below, we use a Delaware River spawner abundance of between 125 and 250 adults and a Hudson River spawner abundance of between 400 and 500 adults.

Based on genetic analyses of two different life stages, subadults and natal juveniles, Ne for the Delaware River population has been estimated to be 108.7 (95% CI=74.7-186.1) (O'Leary *et al.* 2014) and 40 (95% CI=34.7-46.2) (Waldman *et al.* 2019), respectively. Estimates of Ne for the Hudson River spawning population from the same studies are 198 (95% CI=171.7-230.7; (O'Leary *et al.* 2014)) and 156 (95% CI=138.3-176.1) (Waldman *et al.* 2019), respectively. Given the low Ne, genetic drift poses a threat to future genetic diversity of these populations. Still,O'Leary *et al.* (2014) concluded that the populations likely would retain 95 percent of their alleles over the next century under current conditions. However, a decrease in longevity of mature adults would result in severe loss of genetic diversity (O'Leary *et al.* 2014).

The differences in estimated population size for the Hudson and Delaware River spawning populations and in Ne estimates of particular life stages further support the notion that the Hudson River spawning population is the more robust of the two spawning groups. This is also supported by the fact that Atlantic sturgeon originating from the Hudson River spawning population are more prevalent in mixed aggregations than sturgeon originating from the Delaware River spawning population as noted above. Still, while the size of the Delaware River and Hudson River populations cannot be determined with reasonable certainty, all available information indicates that both populations are below what is needed to retain genetic integrity, as described above, in the long-term. However, Grunwald *et al.* (2008)concluded that available information suggests that the straying rate is moderate (1.7 and 5.4 migrants/generation) between these rivers and even a straying rate of one per generation (given it includes successful reproduction) can mitigate genetic risks from genetic drift and inbreeding. Thus, the moderate exchange between the two rivers may mitigate some of the genetic risks associated with small populations (Mills and Allendorf 1996). However, this does not take into account other risks to small populations such as demographic stochasticity and catastrophic events.

We estimated that operation of the proposed marine terminal will add two juvenile and two non-juvenile Atlantic sturgeon vessel mortalities from the New York Bight DPS to the baseline vessel mortality rate over the next 10 years. The loss of juveniles will reduce the number of adults in the future. However, the loss of two juveniles is an extremely small percentage of the number of juveniles we expect occur in the Delaware River and the Hudson River. The probability of a juvenile contributing to the adult population in the future is also small when taking into account mortality en route to maturity. Thus, we do not expect the loss of the juvenile Atlantic sturgeon to measurably affect future population growth of the Delaware River population. We do not have information about the total population or number of adults of either the Delaware or Hudson Rivers. However, using available information, we expect that the Delaware River spawning runs consist of between 125 and 250 individuals and the Hudson River runs consist of approximately 400 to 500 individuals (section 5). We expect that the operation of the Berth will remove up to two adults, subadults, or one from each of the two life stages from the Delaware River or the Hudson River population over 10 years. We anticipate that this reduction in numbers from either river will be spread out over 10 years and is too small to affect genetic drift or inbreeding in a way that can be meaningfully evaluated. This is because of variation in the biological characteristics (number of progeny, male contribution, sex ratio, and population size) that affects the Ne and it is not possible to evaluate the contribution of one individual or the effect of losing a few individuals over ten years. Further, while the Delaware and Hudson populations are genetically distinct they are not genetically isolated. Even a small number of immigrants per generation is likely to reduce the risk of genetic drift (Mills and Allendorf 1996).

We also consider the reduction in the adult Delaware River or the Hudson River population with up to two adults over 10 years to be too small to increase the populations' vulnerability to demographic stochasticity, Allee effect, or other small population impacts on population genetics in a way that we can meaningfully measure or determine for either river or for the DPS as a whole. We expect that any vulnerability to catastrophic events will mostly depend on spatial structure of the populations and life history of the species. Current information from both the Delaware and Hudson River indicate that both rivers have multiple spawning sites. The loss of two adults in the Delaware or Hudson River over 10 years is unlikely to measurably increase the vulnerability during an in-river catastrophic event. This is because we expect the effects of a catastrophic event (e.g., oil spill, pollutant release, etc.) to be more related to the concentration of spawners within a particular area than to the total number of spawners, and it is not possible to evaluate how a loss of two spawners spread out over 10 years will increase the vulnerability from a catastrophic event. Since Atlantic sturgeon adults do not spawn every year, migrating adults will buffer against catastrophic loss of a spawning population by reintroducing spawning individuals in following years.

At the DPS level, the loss of two adults, subadults, or a mix of the two life stages from the New York Bight DPS over 10 years is not expected to reduce the ability of adults at large to reintroduce spawning in the event of a catastrophic loss of spawners. Assuming all vessel strike mortalities are females from the Delaware River or Hudson River, then two females will be lost over the 10-year period. Young-of-the-year and, to some extent, juveniles, typically aggregate and rear in waters with low salinity just above the River's salt front (e.g., the Marcus Hook range in the Delaware River). Any catastrophic event in a specific area (such as an aggregation area) could result in loss of all or most of that years' young-of-the-year as well as many juveniles in that area. However, even if there was a catastrophic event affecting Atlantic sturgeon spawning areas, we do not expect that the loss of up to two adult females from the Delaware River or the Hudson River populations over 10 years would significantly affect the outcome and consequences of a catastrophic event in either river considering the number of expected spawners in both the Delaware River and Hudson River together with the fecundity of adult female sturgeon and multiple rearing sites.

We have determined that the probability that the loss of four individuals over the life of the project will reduce genetic diversity is extremely small. Further, because the loss of two adults, subadults, or a mix of the two and two juveniles constitute a small loss in numbers over 10 years, it is unlikely that this loss will reduce the number of sexually mature individuals to an extent that will reduce the current ability of either of the two river populations' or the DPS as a whole to exist into the future while retaining the potential for recovery.

For a population to recover, production (i.e., population growth rate) has to be positive. A population with a negative population growth will eventually go extinct. However, a species remains prone to extinction as long as they remain small and, thus, the rate of population growth, even if positive, will influence survival and recovery. Blackburn *et al.* (2019) found that population growth of White Sturgeon in the Sacramento-San Joaquin Basin (SSJ) in California was most influenced by the survival of sexually mature adults. The population model suggested that White Sturgeon in the SSJ could reach the replacement rate (i.e., $\lambda \geq 1.00$) if total annual mortality for age-3 and older fish does not exceed 6 percent. Low levels of exploitation (i.e., <3 percent) would likely be required to maintain a stable population. For Atlantic sturgeon, ASMFC (2007) concluded that a 5 percent bycatch mortality of adults was not sustainable based on an Egg-per-recruit (EPR) model. Brown and Murphy (2010) similarly developed an EPR model and concluded that the loss of 2.5 percent of females per year from vessel strikes would hamper recovery of the Delaware River Atlantic sturgeon population. Further, variation in abundance over time affects extinction risk. Higher variation increases the probability of population bottlenecks that may decrease genetic variation and population fitness, the probability of the population being reduced to levels where its productivity is at or below depensation (i.e., a decrease in breeding individuals reduced production and survival of offspring), and increases the risk of real (i.e., no living members of a population remain) or functional extinction (i.e., the population has individuals still living, but the numbers are too small to support recovery). Mortality, fecundity, and generation time determines population growth. Variations of any of these three factors can result in variations in abundance over time.

No data exists that can be used to determine productivity for the Delaware River since the time the New York Bight DPS was listed. However, DO conditions in the river have improved markedly over past decades such that sturgeon are now able to use previously degraded spawning and rearing areas in the lower tidal river. This may have increased access to spawning areas and improved juvenile survival and productivity. However, significant vessel traffic, industrial activity, and contaminated bottom substrate in these reaches exposes sturgeon to multiple threats (section 6).

The Commission's 2017 benchmark stock assessment concluded that there was a relatively high probability that the abundance of the New York Bight DPS has increased since the implementation of the 1998 fishing moratorium (ASMFC 2017b). However, there was considerable uncertainty expressed in the stock assessment and in its peer review report. New information suggests that the conclusion about the New York Bight DPS primarily reflects the status and trend of only the DPS's Hudson River spawning population (NMFS 2022). Annual NYDEC surveys for Atlantic sturgeon juveniles in the Hudson River since 2004 suggests that the catch rate of juvenile Atlantic sturgeon increased significantly during the period from 2005 to 2015 and that the average catch rate for the period from 2012-2019 doubled compared to the previous eight years from 2004-2011 (DuFour and Qian 2023, Pendleton and Adams 2021). However, this does not provide enough information to discern the overall trend in the Hudson River population's growth rate. Nevertheless, given the results of the benchmark stock assessment and the NYDEC surveys, the Hudson River population may have a positive growth rate.

The proposed project will not affect the reproductive potential of the Delaware River and Hudson River populations in any way other than through a reduction in numbers of individuals over a relative short period. We determined that the operation of the Berth will result in the mortality of two juveniles and two adults or subadults (or a mix of the two) New York Bight DPS Atlantic sturgeon. Mortalities have the potential consequence of reducing reproduction potential, as any dead New York Bight DPS Atlantic sturgeon has no potential for future reproduction.

The loss of two juveniles is a very small contribution to a cohort as the current spawning in the Delaware River likely produces several thousand juveniles each year and the expected contribution to population growth by a single juvenile is relatively small when taking into account mortality en route to maturity. Therefore, this represents a small reduction in potential future female spawners for the Delaware River and in the number of eggs laid or larvae produced by the population in future years. Assuming that the Delaware River adult population consists of 75 to 125 spawning females (using results from White *et al.* (2022) with a 50/50 sex ratio), then the annual loss of greater than 2.5 percent of female sturgeon from vessel strikes could be detrimental to the population (Brown and Murphy 2010). The operation of the Berth could cause the mortality of up to two adult females from the Delaware River or the Hudson River population over 10 years. Though vessel strike mortalities may not be evenly distributed over the 10 years, they equal a potential average of 0.3 adult, female sturgeon every year, which constitutes an annual loss of 0.4 to 0.24 percent of Delaware River female spawners over a 10-year period. Either way, for both river populations, the mortality does not exceed what was considered unsustainable in the studies referenced above. These calculations do not take into account that the female population also includes non-spawning females and that the models considered mortality of females three years of age and older. Thus, we expect the actual total female population to be substantially higher for both rivers. If one considers the consequences for the New York Bight DPS as a whole, then the loss constitutes an extremely small percentage. Using the NEAMAP study, we concluded that the DPS consists of approximately 8,642 adults (Table 13). If two vessel strike mortalities over the 10-year period are adults then the proposed project will kill an extremely small percentage (0.023%) of New York Bight DPS adults over 10 years. We also note that the above EPR models consider a long-term ongoing loss of subadults and adults from the population while the consequences of the proposed project is temporary and will only result in losses over a 10-year period. We expect the loss of the two juvenile and two adults (or subadults or a mix) over a 10-year period to be too small to affect the population growth rate or increase variation in abundances over time to such an extent that it can be meaningfully measured or evaluated.

Here, we consider how these mortalities will affect productivity when added to other anthropogenic mortalities of females from the two river populations. New York Bight DPS origin Atlantic sturgeon are subject to numerous sources of human induced mortality and habitat disturbance throughout the riverine and marine portions of their range. Bycatch in federal fisheries accounts for one of the largest known number of anthropogenic mortalities, but our review concluded that bycatch is not likely to jeopardize the continued existence of the Atlantic sturgeon New York Bight DPS (NMFS 2021)[29]. Bycatch and mortality also occur in state fisheries; however, the primary fishery that impacted juvenile sturgeon (the shad fishery) has now been closed in the Hudson River and there is no indication that it will reopen. A commercial shad fishery continues in the Delaware Bay but is closed in the Delaware River. New York Bight DPS Atlantic sturgeon are killed as a result of other anthropogenic activities in the Hudson, Delaware, and other rivers within the DPS as well, which may impact early life stages and natal juveniles as well as migratory subadults and adults. Sources of mortality in particular include vessel strikes (e.g., section 6.3.2). Other anthropogenic mortalities include occasional entrainment in dredges and entrainment in cooling water intakes at power stations. These activities are ongoing, thus influencing the baseline upon which this analysis is founded. While we do not have an estimate of the total number of anthropogenic mortalities per year, we do not expect that the additional mortality of two adults or subadults and two juveniles from this proposed action will change the status of either river population or the DPS as a whole. This is because they contribute a very small number of mortalities relative to both the abundance of river populations and of the DPS. Further, the mortalities will occur over a finite number of years. Therefore, we cannot meaningfully evaluate or measure how these mortalities when added to existing anthropogenic mortalities will affect productivity of either the Delaware River or Hudson River populations or the DPS as a whole. We have not identified any cumulative effects that will substantially affect productivity.

In conclusion, even considering the potential future spawners that would be produced by an individual that would be killed as a result of the proposed action, any consequences to future year classes of both riverine populations and the New York Bight as a whole is anticipated to be small and would not change the status of this species. The proposed action will not affect the

[29] This consultation is being reinitiated.

spawning grounds within the rivers where New York Bight DPS fish spawn, as we do not expect the proposed action to affect spawning substrate or salinity. The action will also not create any barrier to pre-spawning sturgeon accessing the overwintering sites or the spawning grounds used by New York Bight DPS fish. Thus, the proposed action will not result in a loss of individuals or cause impacts to the environment that will reduce the number of sexually mature individuals producing viable offspring to an extent that will reduce either population's current ability to exist into the future while retaining the potential for recovery.

The proposed action is not likely to reduce distribution because the action will not impede New York Bight DPS Atlantic sturgeon from accessing any seasonal concentration areas, including foraging, spawning, or overwintering grounds in the Delaware River or elsewhere. Any effects to distribution will be minor and limited to the nearshore area where bottom habitat was lost due to construction of the three dolphins.

Last, we have considered if climate change will affect our above conclusions with regard to the consequences to survival and recovery of losing two juveniles and two adults (or subadults or a mix). As described in section 7.2.1, over the long term, global climate change may affect New York Bight DPS Atlantic sturgeon by affecting the location of the salt wedge, distribution of prey, water temperature, and water quality. Any activities occurring within and outside the action area that contribute to global climate change are also expected to affect New York Bight DPS Atlantic sturgeon in the action area. However, there is significant uncertainty, due to a lack of specific scientific data, on the degree to which these effects may be experienced and the degree to which New York Bight DPS Atlantic sturgeon will be able to successfully adapt to any such changes. We concluded that the small number of New York Bight DPS Atlantic sturgeon taken is unlikely to reduce further the viability of the Delaware or Hudson River populations and no habitat modifications are expected. While we can make some predictions on the likely effects of climate change on Atlantic sturgeon and the habitat it depends on, the period (10 years) considered in this Opinion is short relative to the period considered in climate change modeling and the scientific data used, and any predictions remain speculative. Based on these factors, we have concluded that the occurrence of climate change will not change our determinations.

The New York Bight DPS origin Atlantic sturgeon are affected by numerous sources of human induced mortality and habitat disturbance throughout the riverine and marine portions of their range. There is currently not enough information to establish a trend for any life stage or for the DPS as a whole. However, since the proposed Berth is unlikely to affect the viability of the Delaware River or Hudson River populations, we do not expect the estimated loss of two juveniles and two adults (or subadults or a mix) to diminish the DPS' numbers, reproduction, or distribution so that the likelihood of survival is appreciably reduced.

Based on the above, we have determined that the action will not affect New York Bight DPS Atlantic sturgeon in a way that will change the status of the DPS or prevent the species from achieving a sufficient population represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring. It also will not result in effects to the environment which would prevent Atlantic sturgeon from completing their entire life cycle, including reproduction, sustenance, and shelter. This is the case because: (1) the death of these New York Bight DPS Atlantic sturgeon as a result of this action over a 10-year period will not reduce the current status the Delaware River and Hudson River populations; (2) the death of these New York Bight DPS Atlantic sturgeon will not change the status or trends of the species as a whole; (3) the loss of these New York Bight DPS Atlantic sturgeon is not likely to have effects on the levels of genetic heterogeneity in the species; (4) the loss of these New York Bight DPS Atlantic sturgeon is likely to have such small effects on reproductive output that the loss of these individuals will not change the status or trends of the species; (5) the action will have only a minor and temporary consequence on the distribution of New York Bight DPS Atlantic sturgeon in the action area and no consequence on the distribution of the species throughout its range; and (6) the action will have no consequence on the ability of New York Bight DPS Atlantic sturgeon to shelter with only an insignificant consequence on individual foraging New York Bight DPS Atlantic sturgeon.

In certain instances, an action that does not appreciably reduce the likelihood of a species' survival might affect its likelihood of recovery or the rate at which recovery is expected to occur. As explained above, we have determined that the proposed action will not appreciably reduce the likelihood that the New York Bight DPS will survive in the wild. Here, we consider the potential for the action to reduce the likelihood of recovery. As noted above, recovery is defined as the improvement in status such that listing is no longer appropriate. Thus, we have considered whether the proposed action will affect the likelihood that the New York Bight DPS can rebuild to a point where listing is no longer appropriate. No Recovery Plan for the New York Bight DPS has been published, at this time. As defined, the Recovery Plan will outline the steps necessary for recovery and the demographic criteria, which once attained, will allow the species to be delisted. We know that in general, to recover, a listed species must have a sustained positive population trend over time and an increase in population size. To allow that to happen, a species must have enough habitat in suitable condition that allows all normal life functions to occur (i.e., spawning, foraging, resting) and have access to enough food. Next, we consider whether this proposed action will affect the population size and/or trend in a way that will affect the likelihood of recovery.

The proposed action is not expected to modify, curtail, or destroy the range of the species because it will result in an extremely small reduction in the number of New York Bight DPS Atlantic sturgeon over time and will not affect the overall distribution of New York Bight DPS Atlantic sturgeon. Any consequences to habitat will be insignificant and will not affect the ability of Atlantic sturgeon to carry out any necessary behaviors or functions. Any impacts to available forage will also not limit forage to the species as ample forage exists to support the Atlantic sturgeon using the Delaware River estuary. The proposed action will result in a small amount of mortality (no more than four individuals over 10 years) and a subsequent small reduction in future reproductive output. For these reasons, the action is not expected to affect the persistence of the New York Bight DPS of Atlantic sturgeon. Additionally, the action will not change the status or population trend of the New York Bight DPS of Atlantic sturgeon. The very small reduction in numbers and future reproduction resulting from the proposed action will not reduce the likelihood of improvement in the status of the New York Bight DPS of Atlantic sturgeon. The consequences of the proposed action will not delay the recovery timeline or otherwise decrease the likelihood of recovery. The consequences of the proposed action will also not reduce the likelihood that the status of the species can improve to the point where it is recovered and could be delisted. Therefore, the proposed action will not appreciably reduce the likelihood that the New York Bight DPS of Atlantic sturgeon can be brought to the point at which they are no longer listed as endangered or threatened. Based on the analysis presented herein, the proposed action is not likely to appreciably reduce the survival and recovery of this species.

Despite the threats faced by individual New York Bight DPS Atlantic sturgeon inside and outside of the action area, the proposed action will not increase the vulnerability of individual sturgeon to these additional threats and exposure to ongoing threats will not increase susceptibility to consequences related to the proposed action. We have considered the consequences of the proposed action in light of cumulative effects explained above, including climate change and have concluded that even in light of the ongoing impacts of these activities and conditions; the conclusions reached above do not change. Based on the analysis presented herein, the proposed action, resulting in the mortality of up to four New York Bight DPS Atlantic sturgeon over a 10-year period, is not likely to appreciably reduce the survival and recovery of this species.

10.1.4 Chesapeake Bay DPS

The Chesapeake Bay DPS is listed as endangered and Atlantic sturgeon occur in and may potentially spawn in several rivers connected to the Chesapeake Bay. There is evidence of spawning in the James River (confirmed); Pamunkey River, a tributary of the York River; and Nanticoke River and its tributary Marshyhope Creek (section 5.2.2.8). In addition, detections of acoustically-tagged adult Atlantic sturgeon in the Mattaponi and Rappahannock Rivers during the spawning window have occurred. Historical evidence for these rivers as well as the Potomac River supports the likelihood that Atlantic sturgeon spawning populations are present in the Mattaponi, Rappahannock, and Potomac Rivers (NMFS 2017b).

Chesapeake Bay origin Atlantic sturgeon are affected by numerous sources of human induced mortality and habitat disturbance throughout the riverine and marine portions of their range. There is currently no census nor enough information to establish a trend, for any life stage, for the James River spawning population, or for the DPS as a whole. However, the NEAMAP data indicates that the estimated ocean population of Chesapeake Bay DPS Atlantic sturgeon is 8,811 sub-adult and adult individuals. The ASMFC (2017b) stock assessment determined that abundance of the Chesapeake Bay DPS is “depleted” relative to historical levels. The assessment, while noting significant uncertainty in trend data, also determined that there is a relatively low probability (36 percent) that abundance of the Chesapeake Bay DPS has increased since the implementation of the 1998 fishing moratorium, and a 30 percent probability that mortality for the Chesapeake Bay DPS exceeds the mortality threshold used for the assessment (ASMFC 2017b).

We anticipate the mortality of up to two adult or subadult Chesapeake Bay DPS Atlantic sturgeon as a result of vessel interactions during the 10-year period. Take of Chesapeake Bay DPS is anticipated during the 10 years of operations at the Berth. Thus, here, we consider the consequences of the loss of up to two Atlantic sturgeon over a 10-year period from the Chesapeake Bay DPS. The reproductive potential of the Chesapeake Bay DPS will not be affected in any way other than through a reduction in numbers of individuals. The loss of up to two individuals over a 10-year period will have the consequence of reducing the amount of reproduction potential as any dead Chesapeake Bay DPS Atlantic sturgeon has no potential for future reproduction. However, this small reduction in potential future spawners is expected to result in an extremely small reduction in the number of eggs laid or larvae produced in future years and similarly, extremely small consequences on the strength of subsequent year classes. Even considering the potential future spawners that would be produced by two Chesapeake Bay DPS Atlantic sturgeon that could be killed as a result of the proposed action, any consequence to future year classes is anticipated to be extremely small and would not change the status of this species. The proposed action will also not affect the spawning grounds within the rivers where Chesapeake Bay DPS fish spawn, as they are outside of the action area. The action will also not create any barrier to pre-spawning sturgeon accessing the overwintering sites or the spawning grounds used by Chesapeake Bay DPS fish for the same reasons.

Because we do not have a population estimate for the Chesapeake Bay DPS, it is difficult to evaluate the consequences of the mortality caused by this action on the species. However, because the proposed action will result in the loss of no more than two individual sturgeon over the 10 years of Berth operation, it is unlikely that these deaths will have a detectable consequence on the abundance and population trend of the Chesapeake Bay DPS.

The proposed action is not likely to reduce distribution of the Chesapeake Bay DPS because the action will not impede Atlantic sturgeon from accessing any seasonal concentration areas, including foraging areas within the action area that may be used by Chesapeake Bay DPS subadults or adults. Further, the action is not expected to reduce the river-by-river distribution of Atlantic sturgeon. Any consequences to distribution will be minor and temporary and limited to the avoidance of the area where impacts of the action occur.

Based on the information provided above, the death of up to two Chesapeake Bay DPS Atlantic sturgeon over 10 years of Berth operations will not appreciably reduce the likelihood of survival of the Chesapeake Bay DPS (i.e., it will not decrease the likelihood that the species will continue to persist into the future with sufficient resilience to allow for the potential recovery from endangerment). The action will not affect Chesapeake Bay DPS Atlantic sturgeon in a way that prevents the species from maintaining a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring. It will also not result in consequences to the environment which would prevent

Atlantic sturgeon from completing their entire life cycle, including reproduction, sustenance, and shelter. This is the case because: (1) the death of up to two Chesapeake Bay DPS Atlantic sturgeon will not change the status or trends of the species as a whole; (2) the loss of these Chesapeake Bay DPS Atlantic sturgeon is not likely to have consequences on the levels of genetic heterogeneity in the population; (3) the action will have only a minor and temporary consequence on the distribution of Chesapeake Bay DPS Atlantic sturgeon in the action area and no consequence on the distribution of the species throughout its range; and, (4) the action will have no consequence on the ability of Chesapeake Bay DPS Atlantic sturgeon to shelter with only an insignificant consequence on any foraging Chesapeake Bay DPS Atlantic sturgeon.

In certain instances, an action that does not appreciably reduce the likelihood of a species' survival might appreciably reduce its likelihood of recovery or the rate at which recovery is expected to occur. As explained above, we have determined that the proposed action will not appreciably reduce the likelihood that the Chesapeake Bay DPS will survive in the wild. Here, we consider the potential for the action to reduce the likelihood of recovery. As noted above, recovery is defined as the improvement in status such that listing is no longer appropriate. Thus, we have considered whether the proposed action will affect the likelihood that the Chesapeake Bay DPS can rebuild to a point where listing is no longer appropriate. No Recovery Plan for the Chesapeake Bay DPS has been published at this time. As defined, the Recovery Plan will outline the steps necessary for recovery and the demographic criteria, which once attained, would allow the species to be delisted. We know that in general, to recover, a listed species must have a sustained positive population trend over time and an increase in population size. To allow that to happen, a species must have enough habitat in suitable condition that allows all normal life functions to occur (i.e., spawning, foraging, resting) and have access to enough food. Next, we consider whether the proposed action will affect the population size and/or trend in a way that would affect the likelihood of recovery.

We do not expect the proposed action to modify, curtail, or destroy the range of the species because it will result in an extremely small reduction in the number of Chesapeake Bay DPS Atlantic sturgeon and it will not affect the overall distribution of Chesapeake Bay DPS Atlantic sturgeon. Any consequences to habitat will be insignificant and will not affect the ability of Atlantic sturgeon to carry out any necessary behaviors or functions. Any impacts to available forage will also be insignificant. The proposed action will result in an extremely small amount of mortality over the next 10 years and a subsequent small reduction in future reproductive output. For these reasons, we do not expect the action to affect the persistence of the Chesapeake Bay DPS of Atlantic sturgeon. This action will not change the status or trend of the Chesapeake Bay DPS of Atlantic sturgeon. The very small reduction in numbers and future reproduction resulting from the proposed action will not reduce the likelihood of improvement in the status of the Chesapeake Bay DPS of Atlantic sturgeon. The consequences of the proposed action will not delay the recovery timeline or otherwise decrease the likelihood of recovery. The consequences of the proposed action will also not reduce the likelihood that the status of the species can improve to the point where it is recovered and could be delisted. Therefore, the proposed action will not appreciably reduce the likelihood that the Chesapeake Bay DPS of Atlantic sturgeon can be brought to the point at which they are no longer listed as endangered or threatened. Based on the analysis presented herein, the proposed action is not likely to appreciably reduce the survival and recovery of this species.

Despite the threats faced by individual Chesapeake Bay DPS Atlantic sturgeon inside and outside of the action area, the proposed action will not increase the vulnerability of individual sturgeon to these additional threats and exposure to ongoing threats will not increase susceptibility to consequences related to the proposed action. We have considered the consequences of the proposed action in light of cumulative effects explained above, climate change, and have concluded that even in light of the ongoing impacts of these activities and conditions; the conclusions reached above do not change. Based on the analysis presented herein, the proposed action, resulting in the mortality of up to two Chesapeake Bay DPS Atlantic sturgeon over a 10 year period, is not likely to appreciably reduce the survival and recovery of this species.

10.1.5 South Atlantic DPS

The South Atlantic DPS is listed as endangered and Atlantic sturgeon originate from at least six rivers where spawning potentially still occurs. Secor (2002) estimates that 8,000 adult females were present in South Carolina prior to 1890. In Georgia, prior to the collapse of the fishery in the late 1800s, the sturgeon fishery was the third largest fishery. Secor (2002) estimated from U.S. Fish Commission landing reports that approximately 11,000 spawning females were likely present in Georgia prior to 1890. At the time of listing, only six spawning subpopulations were thought to have existed in the South Atlantic DPS: Combahee River, Edisto River, Savannah River, Ogeechee River, Altamaha River (including the Oconee and Ocmulgee tributaries), and the Satilla River. Three of the spawning subpopulations in the South Atlantic DPS are relatively robust and are considered the second (Altamaha River) and third (Combahee/Edisto River) largest spawning subpopulations across all five DPSs. Peterson *et al.* (2008) estimated the number of spawning adults in the Altamaha River was 324 (95 percent CI: 143-667) in 2004 and 386 (95 percent CI: 216-787) in 2005. Bahr and Peterson (2016) estimated the age-1 juvenile abundance in the Savannah River from 2013-2015 at 528 in 2013, 589 in 2014, and 597 in 2015. No census of the number of Atlantic sturgeon in any of the other spawning rivers or for the DPS as a whole is available. However, the NEAMAP data indicates that the estimated ocean population of South Atlantic DPS Atlantic sturgeon sub-adults and adults is 14,911 individuals.

The 2017 ASMFC stock assessment determined that abundance of the South Atlantic DPS is “depleted” relative to historical levels (ASMFC 2017b). Due to a lack of suitable indices, the assessment was unable to determine the probability that the abundance of the South Atlantic DPS has increased since the implementation of the 1998 fishing moratorium. However, it was estimated that there is a 40 percent probability that mortality for the South Atlantic DPS exceeds the mortality threshold used for the assessment (ASMFC 2017b).

We anticipate the mortality of up to one South Atlantic DPS adult or sub-adult Atlantic sturgeon as a result of the proposed project. Take of South Atlantic DPS is only anticipated during the 10 years of operation of the Berth. Thus, here, we consider the consequences of the loss of up to one South Atlantic DPS Atlantic sturgeon over a 10-year period. The reproductive potential of the South Atlantic DPS will not be affected in any way other than through a reduction in numbers of individuals. The loss of up to one individual sturgeon over a 10-year period would have the consequence of reducing the amount of reproduction potential, as dead South Atlantic DPS Atlantic sturgeon have no potential for future reproduction. However, this small reduction in potential future spawners is expected to result in an extremely small reduction in the number of eggs laid or larvae produced in future years and similarly, an extremely small consequence on the strength of subsequent year classes. Even considering the potential future spawners that would be produced by any individual that is killed as a result of the proposed action, any consequence to future year classes is anticipated to be extremely small and will not change the status of this species. The proposed action will also not affect the spawning grounds within the rivers where South Atlantic DPS fish spawn because they are outside of the action area. The action will also not create any barrier to pre-spawning sturgeon accessing the overwintering sites or the spawning grounds used by South Atlantic DPS fish for the same reasons.

Because we do not have a population estimate for the South Atlantic DPS, it is difficult to evaluate the consequences of the mortality caused by this action on the species. However, because the proposed action will result in the loss of no more than one individual over a 10-year period, it is unlikely that this death will have a detectable consequence on the numbers and population trend of the South Atlantic DPS.

The proposed action is not likely to reduce distribution because it will not impede Atlantic sturgeon from accessing any seasonal concentration areas, including foraging areas within the action area that may be used by South Atlantic DPS subadults or adults. Further, the action is not expected to reduce the river-by-river distribution of Atlantic sturgeon. Any consequences to distribution will be minor and temporary and limited to the avoidance of the action area where impacts occur.

Based on the information provided above, the death of up to one South Atlantic DPS Atlantic sturgeon over a 10-year period will not appreciably reduce the likelihood of survival of the South Atlantic DPS (i.e., it will not decrease the likelihood that the species will continue to persist into the future with sufficient resilience to allow for the potential recovery from endangerment). The action will not affect South Atlantic DPS Atlantic sturgeon in a way that prevents the species from maintaining a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, and it will not result in consequences to the environment which would prevent South Atlantic DPS Atlantic sturgeon from completing their entire life cycle, including reproduction, sustenance, and shelter. This is the case because: (1) the death of up to one South Atlantic DPS Atlantic sturgeon will not change the status or trends of the species as a whole; (2) the loss of this one South Atlantic DPS Atlantic sturgeon is not likely to have consequences on the levels of genetic heterogeneity in the population; (3) the loss of this South Atlantic DPS Atlantic sturgeon over a 10-year period is likely to have such a small consequence on reproductive output that the loss of this individual will not change the status or trends of the species; (4) the action will have only a minor and temporary consequence on the distribution of South Atlantic DPS Atlantic sturgeon in the action area and no consequence on the distribution of the species throughout its range; and, (5) the action will have no consequence on the ability of South Atlantic DPS Atlantic sturgeon to shelter with only an insignificant consequence on any foraging South Atlantic DPS Atlantic sturgeon.

In certain instances, an action that does not appreciably reduce the likelihood of a species' survival might affect its likelihood of recovery or the rate at which recovery is expected to occur. As explained above, we have determined that the proposed action will not appreciably reduce the likelihood that the South Atlantic DPS of Atlantic sturgeon will survive in the wild. Here, we consider the potential for the action to reduce the likelihood of recovery. As noted above, recovery is defined as the improvement in status such that listing is no longer appropriate. No Recovery Plan for the South Atlantic DPS has been published at this time. As defined, the Recovery Plan will outline the steps necessary for recovery and the demographic criteria, which once attained, would allow the species to be delisted. We know that, in general, to recover, a species must have a sustained positive population trend over time and an increase in population size. To allow that to happen, a species must have enough habitat in suitable condition that allows all normal life functions to occur (i.e., spawning, foraging, resting) and have access to enough food. Next, we consider whether the proposed action will affect the population size and/or trend in a way that would affect the likelihood of recovery.

We do not expect the proposed action to modify, curtail, or destroy the range of the species because it will result in an extremely small reduction in the number of South Atlantic DPS Atlantic sturgeon and it will not affect the overall distribution of South Atlantic DPS Atlantic sturgeon. Any consequences to habitat will be insignificant and will not affect the ability of Atlantic sturgeon to carry out any necessary behaviors or functions. Any impacts to available forage will also be insignificant. The proposed action will result in an extremely small amount of mortality (up to one individual) and a subsequent small reduction in future reproductive output. For these reasons, we do not expect the action to affect the persistence of the South Atlantic DPS of Atlantic sturgeon. This action will not change the status or trend of the South Atlantic DPS of Atlantic sturgeon. The very small reduction in numbers and future reproduction resulting from the proposed action will not reduce the likelihood of improvement in the status of the South Atlantic DPS of Atlantic sturgeon. The consequences of the proposed action will not delay the recovery timeline or otherwise decrease the likelihood of recovery. The consequences of the proposed action will also not reduce the likelihood that the status of the species can improve to the point where it is recovered and could be delisted. Therefore, the proposed action will not appreciably reduce the likelihood that the South Atlantic DPS of Atlantic sturgeon can be brought to the point at which they are no longer listed as threatened or endangered. Based on the analysis presented herein, the proposed action is not likely to appreciably reduce the survival and recovery of this species.

Despite the threats faced by individual South Atlantic DPS Atlantic sturgeon inside and outside of the action area, the proposed action will not increase the vulnerability of individual sturgeon to these additional threats and exposure to ongoing threats will not increase susceptibility to consequences related to the proposed action. We have considered the consequences of the proposed action in light of cumulative effects explained above, including climate change, and have concluded that even in light of the ongoing impacts of these activities and conditions; the conclusions reached above do not change. Based on the analysis presented herein, the proposed action, resulting in the mortality of up to one South Atlantic DPS Atlantic sturgeon over a 10-year period, are not likely to appreciably reduce the survival and recovery of this species.

11 CONCLUSION

After reviewing the best available information regarding the status of endangered and threatened species under our jurisdiction, the environmental baseline for the action area, the effects of the action, and the cumulative effects, it is our biological opinion that the proposed action may adversely affect, but is not likely to jeopardize the continued existence of shortnose sturgeon, or the GOM, NYB, CB, and SA DPSs of Atlantic sturgeon. It is also our biological opinion that the proposed project may affect but is not likely to adversely affect the Carolina DPS of Atlantic sturgeon.

12 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA prohibits the take of endangered species of fish and wildlife. “Fish and wildlife” is defined in the ESA “as any member of the animal kingdom, including without limitation any mammal, fish, bird (including any migratory, non-migratory, or endangered bird for which protection is also afforded by treaty or other international agreement), amphibian, reptile, mollusk, crustacean, arthropod or other invertebrate, and includes any part, product, egg, or offspring thereof, or the dead body or parts thereof” (16 U.S.C. § 1532(8)). “Take” is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. “Harm” is further defined by us to include any act that actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns including breeding, spawning, rearing, migrating, feeding, or sheltering. “Incidental take” is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. “Otherwise lawful activities” are those actions that meet all State and Federal legal requirements except for the prohibition against taking in ESA Section 9 (51 FR 19936, June 3, 1986), which would include any state endangered species laws or regulations. Section 9(g) makes it unlawful for any person “to attempt to commit, solicit another to commit, or cause to be committed, any offense defined [in the ESA].” (16 U.S.C. 1538(g)). A “person” is defined in part as any entity subject to the jurisdiction of the U.S., including an individual, corporation, officer, employee, department, or instrument of the Federal government (see 16 U.S.C. § 1532(13)). Under the terms of ESA section 7(b)(4) and section 7(o)(2), taking that is incidental to, and not the purpose of carrying out an otherwise lawful activity is not considered to be prohibited under the ESA provided that such taking is in compliance with the terms and conditions of this ITS. In issuing ITSs, NMFS takes no position on whether an action is an "otherwise lawful activity."

The USACE issued a 5-year permit under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act to the South Jersey Port Corporation (i.e., SJPC or applicant) for construction of a RoRo Berth at the existing Paulsboro Marine Terminal deep-water import-export marine terminal. The USACE permitted the in-water construction components of the Berth's facilities as well as the dredging of the Berth's turning basing and mooring approach. Vessel activity related to operation of the Berth would not occur but for the permitted construction. The USACE has authority to ensure compliance with RPMs and Terms and Conditions related to the federal action.

During operation of the Paulsboro Marine Terminal RoRo Berth, cargo vessels will call at the Berth. Vessels will have to travel between the pilot area at the mouth of Delaware Bay to and from the Berth site. As a result, we are reasonably certain that vessels traveling between the Berth and the mouth of the Delaware Bay will cause vessel strike mortalities of Atlantic sturgeon and shortnose sturgeon[30].

Because the anticipated vessel strike mortalities of sturgeon occur as a result of the USACE permit, all associated mortalities are considered "incidental take" for purposes of this biological opinion (see 50 CFR §402.02). While the USACE does not have authority over the long-term operation of the Berth or vessels calling at the Berth, the long-term use and traffic to and from the Berth by vessels would not occur but for the issuance of the permit. Thus, any vessel strikes by vessels calling at the Berth would be a consequence of activities directly resulting from the proposed action. The USACE has authority to ensure compliance with RPMs and Terms and Conditions related to collecting data about the number of vessels calling at the Berth during its operations. The Berth owner/operator has authority over vessels as they travel through the access channel to and from the Berth itself. They also have authority over operation of the Berth and number of vessel calls. As such, "applicant only" RPMs and Terms and Conditions, which are necessary and appropriate to monitor incidental take resulting from the expected 10 years of Berth operations, are the responsibility of the owner/operator of the Berth. To the extent the USACE exercises its authority in the form of permit conditions related to the construction, operation, and/or future maintenance of the Berth facilities, the USACE has responsibility for compliance with the RPMs and Terms and Conditions.

An incidental take statement (ITS) exempts action agencies and their permittees from the ESA's Section 9 penalties and prohibitions if they comply with the RPMs and the implementing terms and conditions of the ITS. An ITS must specify the amount or extent of any incidental taking of

[30] The proposed action may affect, but is not likely to adversely affect right whales, fin whales, green sea turtles, loggerhead sea turtles, Kemp's ridley sea turtles, leatherback sea turtles, and the Carolina DPS of Atlantic sturgeon; therefore, we do not anticipate any incidental take of those species.

endangered or threatened species. When we exempt incidental take, we must issue RPMs and Terms and Conditions to minimize/avoid (either the amount or the effect of that take, that is, the RPMs could reduce the number of takes or could minimize the potential for mortality of captured animals) and monitor take. The measures described below are non-discretionary, and must be undertaken by the USACE and the Berth owner/operator so that they become binding conditions for the exemption in section 7(o)(2) to apply. The USACE has a continuing duty to regulate the activity covered by this ITS. If the USACE (1) fails to assume and implement the terms and conditions or (2) fails to require any permittee, contractors and personnel to adhere to the terms and conditions of the ITS through enforceable terms that are added to contracts or other documents as appropriate, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the USACE and the Berth owner/operator must report on the progress of the action and its impact on ESA-listed species to NMFS GARFO PRD as specified in the ITS [50 CFR §402.14(i)(3)] (See U.S. FWS and NMFS's Joint Endangered Species Act Section 7 Consultation Handbook (1998) at 4-49).

12.1 Anticipated Amount or Extent of Incidental Take

As explained in this Opinion, the proposed action has the potential to result in the mortality of shortnose sturgeon and Atlantic sturgeon from vessel strike during operation of the RoRo Berth. The anticipated amount of take over the operational life span of the Berth is described below.

12.1.1 Take over the 10-year Life Span of the Berth

Take incidental to the proposed action and activities caused by the proposed project is outlined below. Incidental take from vessel activities during operation of the Port would not occur but for the proposed project. Vessel strike of listed species would be a consequence of vessel activities that are caused by the proposed action, and vessel strikes are reasonably certain to occur based on what we know about sturgeon biology and movement within the Delaware River and Bay, data on vessel traffic within the action area, and information on vessel traffic and sturgeon interactions.

<u>Sturgeon Take Incidental from Vessel Traffic During Operation</u>

We expect up to 9 lethal vessel strikes during operation of the Berth. Of these:

Up to 1 shortnose sturgeon juvenile or adult

Up to 2 juvenile Atlantic sturgeon from NYB DPS

Up to 2 adult and/or subadult Atlantic sturgeon from NYB DPS

Up to 2 adult and/or subadult Atlantic sturgeon from CB DPS

Up to 1 adult and/or subadult Atlantic sturgeon from SA DPS

Up to 1 adult or subadult Atlantic sturgeon from GOM DPS

Summary of Total Incidental Take

This level of take (1 shortnose sturgeon and up to 8 Atlantic sturgeon) is expected to occur over the entire period that comprises the operational lifespan of the Paulsboro RoRo Berth (e.g., from 2023 through 2032), and is not likely to jeopardize the continued existence of listed species.

This incidental take is for the whole period of operation considered in this Opinion and the RPMs and TCs apply to the USACE proposed issuance of a permit and should be incorporated into the permit. The ITS incorporates the incidental take summarized above and the RPMs and TCs and take exemption would be operative upon permit issuance. In the absence of a permit, the applicant is responsible for providing the information.

12.2 Monitoring Incidental Take by Vessel Strike

In the *Effects of the Action*, section 8.5, we analyze the effects of vessel activities that are caused by the proposed action. We anticipate that interaction with vessels traveling to and from the Berth will result in incidental lethal take of shortnose sturgeon and Atlantic sturgeon. In our analysis, we estimate the number of vessel strike mortalities occurring during operation of the RoRo Berth based on the anticipated annual number of vessel calls at the Berth. Based on this analysis, we estimate that vessels calling at the Port and associated support tugs will cause one shortnose sturgeon and up to eight Atlantic sturgeon vessel strike mortalities over a 10-year period of Berth operation. However, in all or the majority of cases, it is not possible to document vessel strikes as they are unlikely to be observed. Carcasses are occasionally found floating in the river or along the shorelines, and state biologists may collect these carcasses and determine the cause of mortality (e.g., whether it was likely to be a vessel strike mortality). Under most circumstances, when a sturgeon carcass is found and determined to be a vessel strike mortality, it is impossible to determine which vessel was involved in the incident.

As explained in the Effects of the Action, we anticipate that on average one Atlantic sturgeon will be killed for every 110 vessel trips and a shortnose sturgeon for every 1,000 vessel trips. This estimate provides a surrogate for monitoring the amount of incidental take during operation of the Berth. Therefore, in discussions with the USACE and SJPC, we concluded that incidental take associated with operation of the Berth can be monitored by the USACE reporting the annual number of vessel calls at the Berth. This will be used as the primary method of determining the amount of incidental take and whether it has been exceeded. A few vessel strikes have been directly observed within the Delaware River and Bay, and there is a possibility that an Atlantic sturgeon or shortnose sturgeon vessel strike can be associated with a particular vessel. In those cases, the vessel strike mortality will be included in (i.e., not in addition to) the number of vessel strikes that are based on number of vessel calls at the Berth.

As soon as the estimated total number of shortnose sturgeon or Atlantic sturgeon that are observed or believed to have been taken equals the allowable take threshold (i.e., the total is 8 Atlantic sturgeon takes or one shortnose sturgeon take via surrogate),

- any additional vessel call, or
- any additional observed take that is counted as caused by project activities will be considered to exceed the exempted level of take.

12.3 Reasonable and Prudent Measures, Terms and Conditions, and Justifications

The following RPMs found in Table 38 are necessary and appropriate to minimize, avoid, and monitor impacts of incidental take resulting from the proposed action. In order to be exempt from prohibitions of Section 9 of the ESA, you must comply with the following terms and conditions found in Table 31, which implement the RPMs described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

The RPMs, with their implementing terms and conditions, are designed to avoid and minimize take, and monitor the impact of incidental take that might otherwise result from the proposed action. Specifically, these RPMs and Terms and Conditions will keep us informed of the number of Berth related vessel trips and will require the USACE to report any take in a reasonable amount of time. Additionally, you must implement measures to monitor the number of sturgeon mortalities from vessel strikes. The third column below explains why each of these RPMs and Terms and Conditions are necessary and appropriate to avoid or minimize and/or monitor the level of incidental take associated with the proposed action and how they represent only a minor change to the action as proposed by USACE.

Table 31. Reasonable and Prudent Measures and Terms & Conditions applicable to the USACE and the Applicant. Referenced forms and documents can be found on the NOAA GARFO website at URL https://www.fisheries.noaa.gov/new-england-mid-atlantic/consultations/section-7-take-reporting-programmatics

Reasonable and Prudent Measures (RPMs)	Terms and Conditions (TCs)	Justifications for RPMs & TCs
RPMs Applicable to Vessel Traffic		
1. USACE shall track number of vessel calls at the Berth to estimate take of sturgeon to assure that take is not exceeded.	1. Until the end of operations of the RoRo Berth and not to exceed 10 years, at the beginning of each calendar year and no later than March 1, the USACE during the life of the permit (CENAP-OPR-2007-1125-39) or in the event that there is no USACE permit in effect, then the Applicant/ port owner/operator shall contact us at nmfs.gar.incidental-take@noaa.gov to provide us with: a. The total number of vessel calls at the Berth the previous year b. The number of vessels that called at the Berth by month c. Type of vessels and their drafts that called at the Berth The correspondence must reference the name of the project (i.e. Paulsboro) and our file number (GARFO-2022-00012). We shall have the final say in determining if the take should count towards the Incidental Take Statement.	This RPM and these TCs are necessary and appropriate because we used an estimate of sturgeon vessel strike mortalities per vessel trip to calculate take. The RPM and TC serve to ensure that we can monitor the level of take associated with the proposed action. Further, they are necessary because they serve to ensure that we are aware of the months when vessel activity occurs, which will allow us to evaluate the threat of vessel strikes during Atlantic sturgeon spawning migrations. This is only a minor change because it is not expected to result in any delay to the project, result in any additional cost, and will merely involve occasional e-mails between the Applicant or Berth owner/operator and USACE and our staff.
RPMs Applicable for All Activities		
2. Any sturgeon observed injuries or mortalities in the Paulsboro Marine Terminal area must be reported to us within 24 hours.	2. In the event of any injuries of shortnose sturgeon or Atlantic sturgeon (lethal or non-lethal), USACE must ensure that the Applicant follows the Sturgeon Take Standard Operating Procedures (SOPs) that can be downloaded from our website **(https://www.fisheries.noaa.gov/new-england-mid-atlantic/consultations/section-**	This RPM and these TCs are necessary and appropriate to ensure the documentation of any interactions with listed species as well as requiring that these interactions are reported to us in a timely manner with all of the necessary information. In some cases, when the cause of death is uncertain, a necropsy may be necessary to aid in the

Reasonable and Prudent Measures (RPMs)	Terms and Conditions (TCs)	Justifications for RPMs & TCs
	7-consultations-greater-atlantic-region) USACE must submit a completed Take Report Form for ESA-Listed Species within 24 hours of any observation and collection of dead sturgeon. **The form can be downloaded from our website**. The completed Take Report Forms, together with any supporting photos or videos must be submitted to nmfs.gar.incidental-take@noaa.gov with "Take Report Form" in the subject line. 3. In the event of any potential vessel strike by a vessel traveling to or from the RoRo Berth of shortnose sturgeon or Atlantic sturgeon, any dead specimens or body parts must be photographed, measured, and preserved (refrigerated, not frozen) until disposal procedures are discussed with us. For each observed injured or dead sturgeon, the information shall also include the date the sturgeon was first observed and, if applicable, collected; the species of the sturgeon; the size of the sturgeon; a description of injuries; and any other pertinent information such as, for instance, observation of eggs. USACE must also notify us of the location where the dead or injured sturgeon was observed and collected. 4. The USACE shall notify us of any suspected sturgeon vessel strikes. The Applicant shall provide to the USACE the number and type of vessels leaving and entering the RoRo Berth during the last 24 hours prior to when the sturgeon was first observed. The Applicant shall provide the information to the USACE	determination of whether or not a mortality should count toward the ITS. This is essential for monitoring the level of incidental take associated with the proposed action. These RPMs and TCs represent only a minor change as compliance will not delay of the project, result in any additional cost.

Reasonable and Prudent Measures (RPMs)	Terms and Conditions (TCs)	Justifications for RPMs & TCs
	as soon as it is available to the Applicant. We shall have the final say in determining if the take should count towards the Incidental Take Statement.	
3. Any dead sturgeon must be held until proper disposal procedures can be discussed with us. The fish should be held in cold storage.	5. In the event a dead sturgeon is collected that potentially was killed by interaction with a vessel traveling to or leaving the RoRo Berth and USACE requests concurrence that this take should not be attributed to the Incidental Take Statement but we do not concur, or if it cannot be determined whether a vessel strike was the cause of death, then the dead sturgeon must be transferred to an appropriately permitted research facility identified by us so that a necropsy can be undertaken to attempt to determine the cause of death. NMFS will have the mortality assigned to the incidental take statement if the necropsy determines that the death was due to injuries sustained from an interaction with a vessel traveling to or from the RoRo Berth. We shall have the final say in determining if the take should count towards the Incidental Take Statement.	These RPMs and TCs are necessary and appropriate to ensure the documentation of any interactions with listed species as well as requiring that these interactions are reported to us in a timely manner with all of the necessary information. In some cases, when the cause of death is uncertain, a necropsy may be necessary to aid in the determination of whether or not a mortality should count toward the ITS. This is essential for monitoring the level of incidental take associated with the proposed action. These RPMs and TCs represent only a minor change as compliance will not result in any increased cost.
4. All Atlantic sturgeon over 75 cm total length that are found dead within the project area and are believed to have interacted with a vessel must have a fin clip taken for genetic analysis. This sample must be transferred to a NMFS-	6. USACE must ensure that fin clips are taken according to the procedure outlined in the "Procedure for Obtaining Sturgeon Fin Clips" found on our website (https://www.fisheries.noaa.gov/new-england-mid-atlantic/consultations/section-7-take-	This RPM and this TC is necessary and appropriate to ensure the proper handling and documentation of any interactions with listed species as well as requiring that these interactions are reported to us in a timely manner with all of the necessary

Reasonable and Prudent Measures (RPMs)	Terms and Conditions (TCs)	Justifications for RPMs & TCs
approved laboratory capable of performing the genetic analysis.	reporting-programmatics-greater-atlantic). The fin clips shall be sent to a NMFS approved laboratory capable of performing genetic analysis. Fin clips must be taken prior to preservation of other fish parts or whole bodies. To the extent authorized by law, you are responsible for the cost of the genetic analysis. A copy of forms when submitting a tissue sample and results of genetic analysis once completed must be submitted to nmfs.gar.incidental-take@noaa.gov with "Sturgeon Genetic Sampling" in the subject line.	information. This is essential for monitoring the level of incidental take associated with the proposed action. Genetic analysis must be conducted on Atlantic sturgeon samples to determine the appropriate DPS of origin and accurately record take of this species. This RPM and TC represent only a minor change as compliance will not result in delay of the project or decrease in the efficiency of the dredging operations. The RPM and TC will only result in a minor cost to the project and will not significantly increase in the cost of the project, as the cost of genetic analysis is extremely small relative to the cost of the project.

13 CONSERVATION RECOMMENDATIONS

In addition to Section 7(a)(2), which requires agencies to ensure that all projects will not jeopardize the continued existence of listed species, 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." Conservation Recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. As such, we recommend that USACE consider the following Conservation Recommendations:

(1) USACE should support the reporting and tracking of sturgeon carcasses in the Delaware River. These reports offer valuable insights into the causes of sturgeon deaths in the Delaware River basin and the New Jersey coast. They are also crucial for understanding and estimating the effects of proposed USACE actions. USACE should work with state agencies and NMFS to develop a central multi-state reporting database. This database should standardize the procedures for reporting and tracking sturgeon carcasses.

(2) USACE should support studies that provide information about effects to Atlantic sturgeon rearing and foraging habitat from dredging. This should include follow up studies after dredging of areas have been completed to assess if Atlantic sturgeon use of those areas have changed.

(3) USACE should continue to support studies of Atlantic and shortnose sturgeon spawning and early life stages in the Delaware River. This include studies to identify spawning locations and studies to understand the temporal and spatial presence of early life stages. Such information is currently lacking but is needed to understand overlap between dredging and earl life stages and would help us to develop measures to avoid and minimize effects to spawning, eggs, yolk-sac larvae, and post yolk-sac larvae.

(4) Population estimates are lacking for Atlantic sturgeon. USACE should continue to support studies that provides information that researchers need to develop a population estimate for the NYB DPS. Such information would help us analyze the consequences to sturgeon caused by projects authorized, funded, or carried out by the USACE.

(5) Prior to finalizing contract specifications and initiating contract solicitation processes for new cutterhead dredging projects, USACE should work with us to develop monitoring plans for cutterhead dredges and/or dredged material disposal sites. The goal of the monitoring plan will be to accurately determine entrainment of shortnose sturgeon and Atlantic sturgeon in future cutterhead dredging projects.

(6) USACE should conduct studies at the upland dredged material disposal areas to assess the potential for improved screening to: (1) establish the type and size of biological material that may be entrained in the cutterhead dredge, and (2) verify that monitoring the disposal site without screening is providing an accurate assessment of entrained material.

14 REINITIATION OF CONSULTATION

This concludes formal consultation on your proposal to issue a Section 10/404 Individual Permit to SJPC associated with construction and operation of the Paulsboro Marine Terminal Roll on/Roll off Berth. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of taking specified in the incidental take statement is exceeded; (2) new information reveals effects of the action that may not have been previously considered; (3) the identified action is subsequently modified in a manner that causes an effect to listed species; or (4) a new species is listed or critical habitat designated that may be affected by the identified action. In instances where the amount or extent of incidental take is exceeded, Section 7 consultation must be reinitiated immediately.

15 REFERENCES

Altenritter, M. E., G. B. Zydlewski, M. T. Kinnison, J. D. Zydlewski, and G. S. Wippelhauser. 2017a. Understanding the basis of shortnose sturgeon (*Acipenser brevirostrum*) partial migration in the Gulf of Maine. Canadian Journal of Fisheries and Aquatic Sciences: 1-10.

Altenritter, M. N., G. B. Zydlewski, M. T. Kinnison, and G. S. Wippelhauser. 2017b. Atlantic sturgeon use of the Penobscot River and marine movements within and beyond the Gulf of Maine. Marine and Coastal Fisheries **9**(1): 216-230.

Altiok, T., O. A. Almaz, and A. Ghafoori. 2012. Modeling and analysis of the vessel traffic in the Delaware River and Bay Area: Risk assessment and mitigation. Center for Advanced Infrastructure and Transportation (CAIT), Rutgers, The State University of New Jersey, Piscataway, New Jersey. Dated January 2012. Report No. 204-RU6532.

Armstrong, J. and J. Hightower. 2002. Potential for restoration of the Roanoke River population of Atlantic sturgeon. Journal of Applied Ichthyology **18**(4-6): 475-480.

ASMFC. 1998. Atlantic sturgeon stock assessment peer review report. Atlantic States Marine Fisheries Commission, Arlington, Virginia. Dated March 1998 No. NOAA Award NA87 FGO 025.

ASMFC. 2002. Amendment 4 to the interstate fishery management plan for weakfish. Atlantic States Marine Fisheries Commission. Dated November 2002. Report No. 39.

ASMFC. 2007. Estimation of Atlantic sturgeon bycatch in coastal Atlantic commercial fisheries of New England and the Mid-Atlantic. Atlantic Statems Marine Fisheries Commission, Arlington, Virginia. Dated August. Special Report to the ASMFC Atlantic Sturgeon Management Board.

ASMFC. 2010. Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring. Atlantic States Marine Fisheries Commission, Arlington, Virginia.

ASMFC. 2016. Weakfish benchmark stock assessment and peer review report. Atlantic States Marine Fisheries Commission, Arlington, Virginia. Dated May.

ASMFC. 2017a. Amendment 3 to the Interstate Fishery Management Plan for Northern Shrimp. Atlantic States Marine Fisheries Commission. Dated October.

ASMFC. 2017b. Atlantic sturgeon benchmark stock assessment and peer review report. Atlantic States Marine Fisheries Commission, Arlington, Virginia. Dated October 18, 2017.

ASMFC. 2019. Review of the Interstate Fishery Management Plan for Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) for 2017. Atlantic States Marine Fisheries Commission, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 1998. Atlantic sturgeon stock assessment peer review report. Atlantic States Marine Fisheries Commission, Arlington, Virginia. Dated March 1998 No. NOAA Award NA87 FGO 025.

ASMFC (Atlantic States Marine Fisheries Commission). 2011. Assessment report for Gulf of Maine northern shrimp - 2011. Prepared by the Northern Shrimp Technical Committee, Atlantic States Marine Fisheries Commission, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2019. 2019 Horseshoe crab benchmark stock assessment and peer review report. Atlantic States Marine Fisheries Commission, Arlington, Virginia.

ASSRT. 2007. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Atlantic Sturgeon Status Review Team, National Marine Fisheries Service, Northeast Regional Office, Gloucester, Massachusetts. Dated February 23.

Bahr, D. L. and D. L. Peterson. 2016. Recruitment of juvenile Atlantic sturgeon in the Savannah River, Georgia. Transactions of the American Fisheries Society **145**(6): 1171-1178.

Bain, M. B. 1997. Atlantic and shortnose sturgeons of the Hudson River: Common and divergent life history attributes. Environmental Biology of Fishes **48**(1): 347-358.

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

Balazik, M., M. Barber, S. Altman, K. Reine, A. Katzenmeyer, A. Bunch, and G. Garman. 2020. Dredging activity and associated sound have negligible effects on adult Atlantic sturgeon migration to spawning habitat in a large coastal river [online]. PLoS ONE **15**(3): e0230029. DOI: 10.1371/journal.pone.0230029.

Balazik, M. T. 2017. First verified occurrence of the shortnose sturgeon (*Acipenser brevirostrum*) in the James River, Virginia. Fishery Bulletin **115**(2): 196-200.

Balazik, M. T. 2018. Preliminary results of studies to determine sturgeon vessel strike risk and behavioral response to approaching vessels. [Personal Communication: Verbal] Recipient NMFS, Greater Atlantic Regional Fisheries Office. USACE, Engineer Research and Development, Vicksburg, Mississippi, July 26, 2018.

Balazik, M. T., M. R. Barber, and G. C. Garman. 2017a. Vessel related threats to reproductively active Atlantic sturgeon in a large coastal river system Spring-2017 NOAA Grant NA16NMF4720358 - Final Report. Virginia State University.

Balazik, M. T., D. J. Farrae, T. L. Darden, and G. C. Garman. 2017b. Genetic differentiation of spring-spawning and fall-spawning male Atlantic sturgeon in the James River, Virginia [online]. PLoS ONE **12**(7): e0179661. DOI: 10.1371/journal.pone.0179661.

Balazik, M. T., G. C. Garman, M. L. Fine, C. H. Hager, and S. P. McIninch. 2010. Changes in age composition and growth characteristics of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) over 400 years. Biology Letters **6**(5): 708-710.

Balazik, M. T., G. C. Garman, J. P. Van Eenennaam, J. Mohler, and L. C. Woods. 2012a. Empirical evidence of fall spawning by Atlantic sturgeon in the James River, Virginia. Transactions of the American Fisheries Society **141**(6): 1465-1471.

Balazik, M. T., S. P. McIninch, G. C. Garman, M. L. Fine, and C. B. Smith. 2012b. Using energy dispersive x-ray fluorescence microchemistry to infer migratory life history of Atlantic sturgeon. Environmental Biology of Fishes **95**(2): 191-194.

Balazik, M. T., S. P. McIninch, G. C. Garman, and R. J. Latour. 2012c. Age and growth of Atlantic sturgeon in the James River, Virginia, 1997–2011. Transactions of the American Fisheries Society **141**(4): 1074-1080.

Balazik, M. T. and J. A. Musick. 2015. Dual annual spawning races in Atlantic sturgeon. PLoS ONE **10**(5): e0128234.

Balazik, M. T., K. J. Reine, A. J. Spells, C. A. Fredrickson, M. L. Fine, G. C. Garman, and S. P. McIninch. 2012d. The potential for vessel interactions with adult Atlantic sturgeon in the James River, Virginia. North American Journal of Fisheries Management **32**(6): 1062-1069.

Batiuk, R. A., D. L. Breitburg, R. J. Diaz, T. M. Cronin, D. H. Secor, and G. Thursby. 2009. Derivation of habitat-specific dissolved oxygen criteria for Chesapeake Bay and its tidal tributaries. Journal of Experimental Marine Biology and Ecology **381**(Supplement): S204-S215.

Beardsall, J., M. Stokesbury, L. Logan-Chesney, and M. Dadswell. 2016. Atlantic sturgeon *Acipenser oxyrinchus* Mitchill, 1815 seasonal marine depth and temperature occupancy and movement in the Bay of Fundy. Journal of Applied Ichthyology **32**(5): 809-819.

Beardsall, J. W., M. F. McLean, S. J. Cooke, B. C. Wilson, M. J. Dadswell, A. M. Redden, and M. J. W. Stokesbury. 2013. Consequences of incidental otter trawl capture on survival and physiological condition of threatened Atlantic sturgeon. Transactions of the American Fisheries Society **142**(5): 1202-1214.

Berlin, W. H., R. J. Hesselberg, and M. J. Mac. 1981. Growth and mortality of fry of Lake Michigan lake trout during chronic exposure to PCB's and DDE. In *Chlorinated hydrocarbons as a factor in the reproduction and survival of lake trout (Salvelinus namaycush) in Lake Michigan* (pp. 11-22). U.S. Fish and Wildlife Service, Washington, D.C.

Bigelow, H. B. and W. C. Schroeder. 1953a. Fishes of the Gulf of Maine. Fishery Bulletin 74. United States Government Printing Office, Washington D.C. DOI: https://doi.org/10.5962/bhl.title.6865.

Bigelow, H. B. and W. C. Schroeder. 1953b. Sawfishes, guitarfishes, skates, and rays. In J. Tee-Van, J., Breder, C.M., Parr, A.E., Schroeder, W.C. and Schultz, L.P. (Eds.), *Fishes of the Western North Atlantic, Part Two*. Sears Foundation for Marine Research, New Haven, CT.

Bigelow, H. B. and W. C. Schroeder. 2002 (revised). Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service 53.

Bjorndal, K. A., A. B. Bolten, D. A. Johnson, and P. J. Eliazar. Proceedings for the fourteenth annual symposium on sea turtle biology and conservation. 1 - 5 March, 1994. Hilton Head, South Carolina, August, 1994. NOAA Technical Memorandum NMFS-SEFSC-351: 323. National Marine Fisheries Service, Miami Labratory, Miami, Florida.

Blackburn, S. E., M. L. Gingras, J. DuBois, Z. J. Jackson, and M. C. Quist. 2019. Population Dynamics and Evaluation of Management Scenarios for White Sturgeon in the Sacramento–San Joaquin River Basin. North American Journal of Fisheries Management **39**(5): 896-912.

Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Environmental Biology of Fishes **48**(1): 399-405.

Borodin, N. 1925. Biological Observations on the Atlantic Sturgeon (*Acipenser sturio*). Transactions of the American Fisheries Society **55**(1): 184-190.

Bowen, B. and J. Avise. 1990. Genetic structure of Atlantic and Gulf of Mexico populations of sea bass, menhaden, and sturgeon: influence of zoogeographic factors and life-history patterns. Marine Biology **107**(3): 371-381.

Bowers-Altman, J. and H. M. Brundage. 2015. Section 1 - Identification of Shortnose Sturgeon spawning sites and characterization of early life history habitats in the non-tidal Delaware River. Delaware Division of Fish and Wildlife, Smyrna, Delaware. Sturgeons in the Mid-Atlantic Region: A Multi-State Collaboration of Research and Conservation.

Breece, M., A. Higgs, and D. Fox. 2021. Spawning intervals, timing, and riverine habitat use of adult Atlantic sturgeon in the Hudson River. Transactions of the American Fisheries Society **150**(4): 528-537.

Breece, M. W., D. A. Fox, K. J. Dunton, M. G. Frisk, A. Jordaan, and M. J. Oliver. 2016. Dynamic seascapes predict the marine occurrence of an endangered species: Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus*. Methods in Ecology and Evolution **7**(6): 725-733.

Breece, M. W., D. A. Fox, D. E. Haulsee, I. I. Wirgin, and M. J. Oliver. 2017. Satellite driven distribution models of endangered Atlantic sturgeon occurrence in the mid-Atlantic Bight. ICES Journal of Marine Science **NA**: fsx187-fsx187.

Breece, M. W., D. A. Fox, and M. J. Oliver. 2018. Environmental drivers of adult Atlantic sturgeon movement and residency in the Delaware Bay. Marine and Coastal Fisheries **10**(2): 269-280.

Breece, M. W., M. J. Oliver, M. A. Cimino, and D. A. Fox. 2013. Shifting distributions of adult Atlantic sturgeon amidst post-industrialization and future impacts in the Delaware River: A maximum entropy approach. PLoS ONE **8**(11): e81321.

Brickman, D., M. A. Alexander, A. Pershing, J. D. Scott, and Z. Wang. 2021. Projections of physical conditions in the Gulf of Maine in 2050. Elem Sci Anth **9**(1): 15.

Brown, J. J. and G. W. Murphy. 2010. Atlantic sturgeon vessel-strike mortalities in the Delaware estuary. Fisheries **35**(2): 72-83.

Brundage, H. M. 2018. Monitoring of acoustically-tagged shortnose sturgeon in the vicinity of the Scudder Falls Bridge replacement project. ACT Engineers, Inc., Robbinsville, New Jersey. Dated July 30, 2018.

Brundage, H. M., III. 1986. Radio tracking studies of shortnose sturgeon (*Acipenser brevirostrum*) in the Delaware River for the Merrill Creek Reservoir project. V.J. Schuler Associates, Inc., Middletown, Delaware. Dated September.

Brundage, H. M., III and R. E. Meadows. 1982. The Atlantic sturgeon, *Acipenser oxyrhynchus*, in the Delaware River estuary. Fisheries Bulletin **80**: 337-343.

Brundage, H. M., III and J. O. O'Herron, II. 2009. Investigations of juvenile shortnose and Atlantic sturgeon in the Lower Tidal Delaware River. Bulletin New Jersey Academy of Science **52(**2): 1-8.

Buckley, J. and B. Kynard. 1981. Spawning and Rearing of Shortnose Sturgeon from the Connecticut River. The Progressive Fish-Culturist **43**(2): 74-76.

Buckley, J. and B. Kynard. 1985. Yearly movements of shortnose sturgeon in the Connecticut River. Transactions of the American Fisheries Society **114**: 813-820.

Busch, C. M. 2022. Genetic analysis and telemetry study of migration habits of the endangered Atlantic sturgeon. Unpublished Masters of Science, Davis College of Agriculture, Natural Resources, and Design, West Virginia University: Morgantown, West Virginia.

Bushnoe, T. M., J. A. Musick, and D. S. Ha. 2005. Essential Spawning and Nursery Habitat of Atlantic Sturgeon (*Acipenser oxyrinchus*) in Virginia. Essential fish habitat of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) in the southern Chesapeake Bay.

Calvo, L., H. M. Brundage, D. Haidvogel, D. Kreeger, R. Thomas, J. C. O'Herron, II, and E. N. Powell. 2010. Effects of flow dynamics, salinity, and water quality on the Atlantic sturgeon, the shortnose sturgeon and the eastern oyster in the oligohaline zone of the Delaware Estuary. Final report project year 2008-2009. Seaboard Fisheries Institute, Bridgeton, New Jersey. Dated September 2010. Prepared for the U.S. Army Corps of Engineers, Philadelphia District. Report No. 151265.

Cameron, P., J. Berg, V. Dethlefsen, and H. Von Westernhagen. 1992. Developmental defects in pelagic embryos of several flatfish species in the Southern North sea. Netherlands Journal of Sea Research **29**(1): 239-256.

Carlson, D. M. and K. W. Simpson. 1987. Gut Contents of Juvenile Shortnose Sturgeon in the Upper Hudson Estuary. Copeia **1987**(3): 796-802.

Caron, F., D. Hatin, and R. Fortin. 2002. Biological characteristics of adult Atlantic sturgeon (*Acipenser oxyrinchus*) in the St. Lawrence River estuary and the effectiveness of management rules. Journal of Applied Ichthyology **18**(4-6): 580-585.

Chambers, R. C., D. D. Davis, E. A. Habeck, N. K. Roy, and I. Wirgin. 2012. Toxic effects of PCB126 and TCDD on shortnose sturgeon and Atlantic sturgeon. Environmental Toxicology and Chemistry **31**(10): 2324-2337.

Chesapeake Bay Foundation. 2020. State of the bay 2020.

Cobb, J. N. 1899. The sturgeon fishery of Delaware River and Bay. In *U.S. Fish Commission Report* (pp. 369-380).

Colette, B. B. and G. Klein-MacPhee. 2002. Bigelow and Schroeder's Fishes of the Gulf of Maine. Smithsonian Institution Press, Washington, DC.

Collier, C. R. 2011. Climate change: One more reason to change the way we manage water. Water Resources IMPACT **13**(1): 16-18.

Collins, M. R. and T. I. J. Smith. 1993. Characteristics of the adult segment of the Savannah River population of shortnose sturgeon (*Acipenser brevirostrum*). South Carolina Marine Resources Center, Charlston, South Carolina. Report No. 328.

Collins, M. R. and T. I. J. Smith. 1997. Management briefs: Distributions of shortnose and Atlantic sturgeons in South Carolina. North American Journal of Fisheries Management **17**(4): 995-1000.

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**(4): 982-988.

Crance, J. H. Habitat suitability index curves for anadromous fishes. *In* Common Strategies of Anadromous and Catadromous Fishes. Symposium 1. Bethesda, Maryland, 1987. *Compiled by* Dadswell, M.J.: 554. American Fisheries Society.

Dadswell, M., S. Wehrell, A. Spares, M. Mclean, J. Beardsall, L. Logan-Chesney, G. Nau, C. Ceapa, A. Redden, and M. Stokesbury. 2016. The annual marine feeding aggregation of Atlantic Sturgeon *Acipenser oxyrinchus* in the inner Bay of Fundy: population characteristics and movement. Journal of Fish Biology **89**(4): 2107-2132.

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**(11): 2186-2210.

Dadswell, M. J. 2006. A review of the status of Atlantic sturgeon in Canada, with comparisons to populations in the United States and Europe. Fisheries **31**(5): 218-229.

Dadswell, M. J., B. D. Taubert, T. S. Squiers, D. Marchette, and J. Buckley. 1984. Synopsis of biological data on shortnose sturgeon, *Acipenser brevirostrum* LeSueur 1818. National Marine Fisheries Service, Silver Spring, Maryland. Dated October 1984. NOAA Technical Report NMFS No. 14 and FAO Fisheries Synopsis No. 140.

Damon-Randall, K., R. Bohl, S. Bolden, D. A. Fox, C. Hager, B. Hickson, E. Hilton, J. Mohler, E. Robbins, T. Savoy, and A. J. Spells. 2010. Atlantic sturgeon research techniques. NOAA Technical Memorandum NMFS-NE-215: 64. National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusets.

Damon-Randall, K., M. Colligan, and J. Crocker. 2013. Composition of Atlantic sturgeon in rivers, estuaries, and marine waters. National Marine Fisheries Service, Greater Atlantic Region Fisheries Office, Gloucester, Massachusetts. Dated February 2013.

Delaware River and Bay Oil Spill Advisory Committee. 2010. Delaware River and Bay Oil Spill Advisory Committee report. Dated December 2010.

Demetras, N. J., B. A. Helwig, and A. S. Mchuron. 2020. Reported vessel strike as a source of mortality of White Sturgeon in San Francisco Bay. California Fish and Wildlife **106**(1): 59-65.

DeVries, R. J. 2006. Population dynamics, movements, and spawning habitat of the shortnose sturgeon, Acipenser brevirostrum, in the Altamaha River system, Georgia. Unpublished Master of Science, University of Georgia: Athens, Georgia.

DiJohnson, A. M. 2019. Atlantic sturgeon (Acipencer oxyrinchus oxyrinchus) behavioral response to vessel traffic and habitat use in the Delaware River, USA. Unpublished Master of Science, Delaware State University: Dover, Delaware.

DiJohnson, A. M., L. M. Brown, M. T. Fisher, and D. A. Fox. 2015. Behavioral response of adult Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) to commercial shipping in the Delaware River. (Abstract). Presented at the Annual meeting of North American Sturgeon and Paddlefish Society, Oshkosh, WI, October 20-22, 2015.

Dovel, W. L. and T. J. Berggren. 1983. Atlantic sturgeon of the Hudson estuary, New York. 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* Lesueur, 1818) in the Hudson River Estuary, New York. In Smith, C.L.

(Ed.), *Estuarine research in the 1980s* (pp. 187-216). State University of New York Press, Albany, New York.

DRBC. 2023. Delaware River salt front [Website]. Delaware River Basin Commission. Retrived October 10, 2023, from https://www.nj.gov/drbc/programs/flow/salt-front.html.

DuFour, M. R. and S. S. Qian. 2023. Evaluating population trends of juvenile Atlantic Sturgeon at low abundance in a dynamic estuarine environment (Hudson River, New York). Fisheries Management and Ecology **n/a**(n/a): 1-14.

Dunton, K. J., D. Chapman, A. Jordaan, K. Feldheim, S. J. O'Leary, K. A. McKown, and M. G. Frisk. 2012. Genetic mixed-stock analysis of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus* in a heavily exploited marine habitat indicates the need for routine genetic monitoring. J Fish Biol **80**(1): 207-217.

Dunton, K. J., A. Jordaan, D. O. Conover, K. A. McKown, L. A. Bonacci, and M. G. Frisk. 2015. Marine distribution and habitat use of Atlantic sturgeon in New York lead to fisheries interactions and bycatch. Marine and Coastal Fisheries **7**(1): 18-32.

Dunton, K. J., A. Jordaan, K. A. McKown, D. O. Conover, and M. G. Frisk. 2010. Abundance and distribution of Atlantic sturgeon (*Acipenser oxyrinchus*) within the Northwest Atlantic Ocean, determined from five fishery-independent surveys. Fishery Bulletin **108**(4): 450-465.

Dunton, K. J., A. Jordaan, D. H. Secor, C. M. Martinez, T. Kehler, K. A. Hattala, J. P. Van Eenennaam, M. T. Fisher, K. A. McKown, D. O. Conover, and M. G. Frisk. 2016. Age and growth of Atlantic sturgeon in the New York Bight. North American Journal of Fisheries Management **36**(1): 62-73.

EPA. 2008. National coastal condition report III. Environmental Protection Agency. Report No. EPA/842-R-08-002.

ERC. 2002. Contaminant analysis of tissues from two shortnose sturgeon (*Acipenser brevirostrum*) collected in the Delaware River. Environmental Research and Consulting, Inc., Kennett Square, Pensylvania. Prepared for NOAA Fisheries.

ERC. 2006a. Acoustic telemetry study of the movements of shortnose sturgeon in the Delaware River and Bay. Progress report for 2003-2004. Environmental Research and Consulting, Inc., Kennett Square, Pennsylvania. Dated March 20.

ERC. 2006b. Final report of shortnose sturgeon population studies in the Delaware River, January 1999 through March 2003. Environmental Research and Consulting, Inc., Kennett Square, Pennsylvania. Dated August 17.

ERC. 2008. Final report of investigations of shortnose sturgeon early life stages in the Delaware River, spring 2007 and 2008. Environmental Research and Consulting, Inc., Kennett Square, Pennsylvania. Dated December 9.

ERC. 2015. Report of a study to determine the feasibility of relocating sturgeons out of the blasting area for the Delaware River Main Channel Deepening Project. Prepared for Gahagan & Bryant Associates, Inc. Environmental Research and Consulting, Inc., Kennett Square, Pennsylvania. Dated June 16, 2014. Draft Report.

ERC. 2016. Report of sturgeon monitoring and protection during rock removal for the Delaware River main channel deepning project, December 2015 - March 2016. Prepared for Great Lakes Dredge and Dock Co., LLC. Environmental Research and Consulting, Inc., Kennet Square, Pennsylvania. Dated April 26.

ERC. 2017. Report of sturgeon monitoring and protection during rock removal for the Delaware River main channel deepening project, November 2016-March 2017. Environmental Research and Consulting, Inc., Kennet Square, Pennsylvania. Dated April 10, 2017.

ERC. 2018. Report of sturgeon monitoring and protection during rock removal for the Delaware River main channel deepening project, November 2017-February 2018. Environmental Research and Consulting, Inc., Kennett Square, Pennsylvania. Dated March 23, 2018.

ERC. 2019. Report of sturgeon monitoring and protection during rock removal for the Delaware River main channel deepening project, January-March 2019. Environmental Research and Consulting, Inc., Kennett Square, Pennsylvania. Dated April 15.

ERC. 2020a. Occurence of acoustically-tagged Atlantic and shortnose sturgeon in the vicinity of the proposed Hope Creek Marine Terminal. Enivronmental Research and Consulting, Inc., Kennet Square, Pennsylvania. Dated November 9.

ERC. 2020b. Report of sturgeon monitoring and protection during rock removal for the Delaware River main channel deepening project, December 2019-February 2020. Environmental Research and Consulting, Inc., Kennett Square, Pennsylvania. Dated March 24.

ERC, (Environmental Research and Consulting). 2007. Investigations of shortnose sturgeon early life stages in the Delaware River. Environmental Research and Consulting, ,Inc., Kennett Square, Pensylvania. Interim Progress Report.

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**(2): 356-365.

Fernandes, S. J. 2008. Population demography, distribution, and movement patterns of Atlantic and Shortnose Sturgsons in the Penobscot River estuary, Maine. Unpublished Master of Science, Ecology and Environmental Science, The University of Maine.

Fernandes, S. J., G. B. Zydlewski, J. D. Zydlewski, G. S. Wippelhauser, and M. T. Kinnison. 2010. Seasonal distribution and movements of shortnose sturgeon and Atlantic sturgeon in the

Penobscot River Estuary, Maine. Transactions of the American Fisheries Society **139**: 1436-1449.

Fisher, M. 2009. Atlantic sturgeon final progress report. Period December 16, 2008 to December 15, 2009. Delaware Division of Fish and Wildlife, Department of Natural Resources and Environmental Control, 4876 Hay Point Landing Rd, Smyrna, Delaware 19977. Dated December 2009. Report No. T-4-1.

Fisher, M. 2011. Atlantic Sturgeon Final Report. Period October 1, 2006 to October 15, 2010. Delaware Division of Fish and Wildlife, Department of Natural Resources and Environmental Control, Smyrna, Delaware. Report No. T-4-1.

Fleming, J. E., T. D. Bryce, and J. P. Kirk. 2003. Age, growth, and status of shortnose sturgeon in the lower Ogeechee River, Georgia. Proceedings of the annual conference / Southeastern Association of Fish and Wildlife Agencies **57**: 80-91.

Fox, D. A., M. W. Breece, and L. Brown. 2015. Section 5 - Spawning habitats and interbasin exchange rates of Atlantic Sturgeon in the New York Bight DPS. *Sturgeons in the Mid-Atlantic Region: A multi-state collaboration of research and conservation*. ESA Section 6 Species Recovery Grants: 35-42.

Fox, D. A., M. W. Breece, and D. L. Erickson. 2010. Habitat Use and Movements of Atlantic Sturgeon (*Acipenser oxyrichus oxyrinchus*) in Coastal Waters of the New York Bight. 19.

Fox, D. A., E. A. Hale, and J. A. Sweka. 2020. Examination of Atlantic sturgeon vessel strikes in the Delaware River Estuary. Final Report. Delaware State University, Dover, Delaware.

Franklin, I. R. 1980. Evolutionary change in small populations. In *Conservation biology: an evolutionary-ecological perspective* (pp. 135-149). Sinauer Associates, U.S.A., Sunderland, Massachusetts.

Fritts, M. W., C. Grunwald, I. Wirgin, T. L. King, and D. L. Peterson. 2016. Status and genetic character of Atlantic sturgeon in the Satilla River, Georgia. Transactions of the American Fisheries Society **145**(1): 69-82.

Ganley, L. C., S. Brault, and C. A. Mayo. 2019. What we see is not what there is: estimating North Atlantic right whale *Eubalaena glacialis* local abundance. Endangered Species Research **38**: 101-113.

Giesy, J. P., J. Newsted, and D. L. Garling. 1986. Relationships between Chlorinated Hydrocarbon concentrations and rearing mortality of Chinook Salmon (*Oncorhynchus Tshawytscha*) eggs from Lake Michigan. Journal of Great Lakes Research **12**(1): 82-98.

Gilbert, C. R. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic Bight)--Atlantic and shortnose sturgeons. Dated

December. U.S. Fish and Wildlife Service Biological Report No. 82(11.122). Report No. USACE TR EL-82-4.

Greene, C. H., A. J. Pershing, T. M. Cronin, and N. Ceci. 2008. Arctic climate change and its impacts on the ecology of the North Atlantic. Ecology **89**(sp11): S24-S38.

Greene, K. E., J. L. Zimmerman, R. W. Laney, and J. C. Thomas-Blate. 2009. Atlantic coast diadromous fish habitat: A review of utilization, threats, recommendations for conservation, and research needs. Atlantic States Marine Fisheries Commission Habitat Management Series. ASMFC, Washington, D.C.

Greenlee, R., Balazik M., Bunch A., Fisher M.T., Garman G.C., Hilton E.J., McGrath P., McIninch S., and W. K.C. 2019. Assessment of critical habitats for recovering the Chesapeake Bay Atlantic sturgeon distinct population segment—Phase II: A collaborative approach in support of management. Virginia Department of Game and Inland Fisheries Final Report. p. 49.

Gross, M. R., J. Repka, C. T. Robertson, D. H. Secor, and W. Van Winkle. 2002. Sturgeon conservation: Insights from elasticity analysis. In Van Winkle, W., PhD, Andres, P.J., Secor, D.H., PhD and Dixon, D.A., PhD (Eds.), *Biology, Management, and Protection of North American Sturgeon*. American Fisheries Society Symposium 28. American Fisheries Society, Bethesda, Maryland.

Grunow, B., G. P. Franz, and K. Tönißen. 2021. In vitro fish models for the analysis of exotoxins and temperature increase in the context of global warming. Toxics **9**(11): 286.

Grunwald, C., L. Maceda, J. Waldman, J. Stabile, and I. Wirgin. 2008. Conservation of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus*: delineation of stock structure and distinct population segments. Conservation Genetics **9**(5): 1111-1124.

Grunwald, C., J. Stabile, J. R. Waldman, R. Gross, and I. Wirgin. 2002. Population genetics of shortnose sturgeon *Acipenser brevirostrum* based on mitochondrial DNA control region sequences. Molecular Ecology **11**(10): 1885-1898.

Guilbard, F., J. Munro, P. Dumont, D. Hatin, and R. Fortin. 2007. Feeding ecology of Atlantic sturgeon and lake sturgeon co-occurring in the St. Lawrence estuarine transition zone. In Munro, J., Hatin, D., Hightower, J.E., McKown, K., Sulak, K.J., Kahnle, A.W. and Caron, F. (Eds.), *Anadromous sturgeons: habitats, threats, and management*. American Fisheries Society Symposium 56: 85-104. American Fisheries Society, Bethesda, Maryland.

Hager, C., J. Kahn, C. Watterson, J. Russo, and K. Hartman. 2014. Evidence of Atlantic Sturgeon spawning in the York river system. Transactions of the American Fisheries Society **143**(5): 1217-1219.

Hale, E. A., I. A. Park, M. T. Fisher, R. A. Wong, M. J. Stangl, and J. H. Clark. 2016. Abundance estimate for and habitat use by early juvenile Atlantic Sturgeon within the Delaware River Estuary. Transactions of the American Fisheries Society **145**(6): 1193-1201.

Hanna, E. and T. E. Cropper. 2017. North Atlantic oscillation. In *Oxford Research Encyclopedia of Climate Science*. Oxford University Press. https://doi.org/10.1093/acrefore/9780190228620.013.22.

Hansen, L. P. and P. Pethon. 1985. The food of Atlantic salmon, *Salmo salar* L,, caught by long-line in northern Norwegian waters. J. Fish Biol **26**: 553-562.

Hare, J. A., W. E. Morrison, M. W. Nelson, M. M. Stachura, E. J. Teeters, R. B. Griffis, M. A. Alexander, J. D. Scott, L. Alade, R. J. Bell, A. S. Chute, K. L. Curti, T. H. Curtis, D. Kircheis, J. F. Kocik, S. M. Lucey, C. T. McCandless, L. M. Milke, D. E. Richardson, E. Robillard, H. J. Walsh, M. C. McManus, K. E. Marancik, and C. A. Griswold. 2016. A vulnerability assessment of fish and invertebrates to climate change on the Northeast U.S. Continental Shelf. PLoS ONE **11**(2): e0146756.

Hastings, R. W., J. C. O'Herron, K. Schick, and M. A. Lazzari. 1987. Occurrence and distribution of shortnose sturgeon,Acipenser brevirostrum, in the upper tidal Delaware River. Estuaries **10**(4): 337-341.

Hatin, D., R. Fortin, and F. Caron. 2002. Movements and aggregation areas of adult Atlantic sturgeon (*Acipenser oxyrinchus*) in the St Lawrence River estuary, Québec, Canada. Journal of Applied Ichthyology **18**(4-6): 586-594.

Hatin, D., S. LaChance, and D. Fournier. 2007a. Effect of dredged sediment deposition on use by Atlantic sturgeon and lake sturgeon at an open-water disposal site in the St. Lawrence Estuarine Transition Zone. In Munro, J., Hatin, D., Hightower, J.E., McKown, K.A., Sulak, K.J., Kahnle, A.W. and Caron, F. (Eds.), *Anadromous Sturgeons: Habitats, Threats, and Management*. American Fisheries Society Symposium 56: 235-255. American Fisheries Society, Bethesda, Maryland.

Hatin, D., J. Munro, F. Caron, and R. D. Simons. 2007b. Movements, home range size, and habitat use and selection of early juvenile Atlantic Sturgeon in the St. Lawrence Estuarine Transition Zone. In Munro, J., Hatin, D., Hightower, J.E., McKown, K.A., Sulak, K.J., Kahnle, A.W. and Caron, F. (Eds.), *Anadromous Sturgeons: Habitats, Threats, and Management*. American Fisheries Society, Symposium 56: 129-155. American Fisheries Society, Bethesda, Maryland.

Haulsee, D. E., D. A. Fox, and M. J. Oliver. 2020. Occurrence of commercially important and endangered fishes in Delaware Wind Energy Areas using acoustic telemetry. U.S. Department of the Interior, Bureau of Ocean Energy Management, Lewes, Delaware. OCS Study BOEM 2020-020.

Heidt, A. R. and R. J. Gilbert. 1979. The shortnose sturgeon in the Altamaha River drainage, Georgia. *In* Proceedings of the Rare and Endangered Wildlife Symposium. Athens, Georgia, August 3-4, 1978. *Compiled by* Odom, R.R. and Landers, L. Technical Bulletin - Georgia

Department of Natural Resources, Game and Fish Division WL 4: 54-60. Georgia Department of Natural Resources.
Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. 376.

Hilton, E. J., B. Kynard, M. T. Balazik, A. Z. Horodysky, and C. B. Dillman. 2016. Review of the biology, fisheries, and conservation status of the Atlantic sturgeon, (*Acipenser oxyrinchus oxyrinchus* Mitchill, 1815). Journal of Applied Ichthyology **32**(S1): 30-66.

Holton, J. W. and J. B. Walsh. 1995. Long-term dredged material management plan for the upper James River, Virginia. United States Army Corps of Engineers Norfolk District.

Hondorp, D. W., D. H. Bennion, E. F. Roseman, C. M. Holbrook, J. C. Boase, J. A. Chiotti, M. V. Thomas, T. C. Wills, R. G. Drouin, S. T. Kessel, and C. C. Krueger. 2017. Use of navigation channels by Lake Sturgeon: Does channelization increase vulnerability of fish to ship strikes? [online]. PLoS ONE **12**(7): e0179791. DOI: 10.1371/journal.pone.0179791.

Horseshoe Crab Plan Review Team. 2019. 2019 Review of the Atlantic States Marine Fisheries Commission fishery management plan for horseshoe crab (*Limulus polyphemus*), 2018 fishing year. Atlantic States Marine Fisheries Commission, Alexandria, Virginia.

Hulme, P. E. 2005. Adapting to climate change: is there scope for ecological management in the face of a global threat? Journal of Applied Ecology **42**(5): 784-794.

Hylton, S. N., A. M. Weissman, G. S. Wippelhauser, and J. A. Sulikowski. 2018. Identification of potential wintering habitat for threatened Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus* in Saco Bay, Maine, USA. Endangered Species Research **37**: 249-254.

Ingram, E. C., R. M. Cerrato, K. J. Dunton, and M. G. Frisk. 2019. Endangered Atlantic sturgeon in the New York Wind Energy Area: implications of future development in an offshore wind energy site. Scientific reports **9**(1): 1-13.

IPCC. 2007. Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 996 pp.

IPCC (Intergovernmental Panel on Climate Change). 2018. A summary for policymakers. In Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (Eds.), *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty .)]. In Press.*

IPCC (Intergovernmental Panel on Climate Change). 2021. Summary for policymakers. In Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R. and Zhou, B. (Eds.), *Climate change 2021: The physical science basis. contribution of working group I to the sixth assessment report of the Intergovernmental Panel on Climate Change*.

Jamieson, I. G. and F. W. Allendorf. 2012. How does the 50/500 rule apply to MVPs? Trends in Ecology & Evolution **27**(10): 578-584.

Jay, A., D. R. Reidmiller, C. W. Avery, D. Barrie, B. J. DeAngelo, A. Dave, M. Dzaugis, M. Kolian, K. L. M. Lewis, K. Reeves, and D. Winner. 2018. Overview. In Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K. and Stewart, B.C. (Eds.), *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. doi: 10.7930/NCA4.2018.CH1* (pp. 33–71), Washington, D. C.

Jenkins, W. E., T. I. J. Smith, L. D. Heyward, and D. M. Knott. 1993. Tolerance of shortnose sturgeon, *Acipenser brevirostrum*, juveniles to different salinity and dissolved oxygen concentrations. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies **47**: 476-484.

Jonsson, B. and N. Jonsson. 2009. A review of the likely effects of climate change on anadromous Atlantic salmon *Salmo sala*, and brown trout *Salmo trutta*, with particular reference to water temperature and flow. Journal of Fish Biology **75**(10): 2381-2447.

Kahn, J., C. Hager, J. C. Watterson, J. Russo, K. Moore, and K. Hartman. 2014. Atlantic sturgeon annual spawning run estimate in the Pamunkey River, Virginia. Transactions of the American Fisheries Society **143**(6): 1508-1514.

Kahn, J. E. 2019. Adult Atlantic sturgeon population dynamics in the York River, Virginia, West Virginia University.

Kahnle, A. W., K. A. Hattala, and K. A. McKown. 2007. Status of Atlantic sturgeon of the Hudson River Estuary, New York, USA. In Munro, J., Hatin, D., Hightower, J.E., McKown, K.A., Sulak, K.J., Kahnle, A.W. and Caron, F. (Eds.), *Anadromous Sturgeons: Habitats, Threats, and Management*. American Fisheries Society Symposium 56: 347-363. American Fisheries Society, Bethesda, Maryland.

Kauffman, G. J., Jr. 2010. The Delaware River revival: Four centuries of historic water quality change from Henry Hudson to Benjamin Franklin to JFK. Pennsylvania History: A Journal of Mid-Atlantic Studies **77**(4): 432-465.

Kazyak, D. C., A. M. Flowers, N. J. Hostetter, J. A. Madsen, M. Breece, A. Higgs, L. M. Brown, J. A. Royle, and D. A. Fox. 2020. Integrating side-scan sonar and acoustic telemetry to estimate the annual spawning run size of Atlantic sturgeon in the Hudson River. Canadian Journal of Fisheries and Aquatic Sciences **77**(6): 1038-1048.

Kazyak, D. C., S. L. White, B. A. Lubinski, R. Johnson, and M. Eackles. 2021. Stock composition of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) encountered in marine and estuarine environments on the U.S. Atlantic Coast. Conservation Genetics.

Killgore, K. J., L. E. Miranda, C. E. Murphy, D. M. Wolff, J. J. Hoover, T. M. Keevin, S. T. Maynord, and M. A. Cornish. 2011. Fish entrainment rates through towboat propellers in the upper Mississippi and Illinois Rivers. Transactions of the American Fisheries Society **140**(3): 570-581.

Kocik, J., C. Lipsky, T. Miller, P. Rago, and G. Shepherd. 2013. An Atlantic sturgeon population index for ESA management analysis. National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts. Center Reference Document 13-06.

Kuntz, J. 2021. Atlantic sturgeon habitat utilization near the Delaware Bay mouth: Targeted approach using acoustic telemetry, sidescan sonar, bottom sampling, and gut content analyses. (Abstract). Presented at the Delaware Estuary Science and Environmental Summit, Virtual, March 1-3. 1 pp.

Kynard, B. 1997. Life history, latitudinal patterns, and status of the shortnose sturgeon, *Acipenser brevirostrum*. Environmental Biology of Fishes **48**(1): 319-334.

Kynard, B., S. Bolden, M. Kieffer, M. Collins, H. Brundage, E. J. Hilton, M. Litvak, M. T. Kinnison, T. King, and D. Peterson. 2016. Life history and status of shortnose sturgeon (*Acipenser brevirostrum* LeSueur, 1818). Journal of Applied Ichthyology **32(**Suppl. 1): 208-248.

Kynard, B., P. Bronzi, and H. Rosenthal (Eds.). 2012. *Life history and behaviour of Connecticut River shortnose and other sturgeons*. World Sturgeon Conservation Society: Norderstedt, Germany. 320 pp.

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 Biology of Fishes **63**(2): 137-150.

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**(2): 487-503.

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 Munro, J., Hatin, D., Hightower, J.E., McKown, K.A., Sulak, K.J., Kahnle, A.W. and Caron, F. (Eds.), *Anadromous sturgeons: Habitats, threats, and management*. American Fisheries Society, Symposium 56: 167-182. American Fisheries Society, Bethesda, Maryland.

Lazzari, M. A., J. C. O'Herron, and R. W. Hastings. 1986. Occurrence of juvenile Atlantic Sturgeon, *Acipenser oxyrhynchus*, in the Upper Tidal Delaware River. Estuaries **9**(4): 356-361.

Leland, J. G. 1968. A survey of the sturgeon fishery of South Carolina. Bears Bluff Laboratories, Wadmalaw Island, South Carolina. Contributions from Bears Bluff Laboratories No. 47.

Levins, R. 1969. Some Demographic and Genetic Consequences of Environmental Heterogeneity for Biological Control1. Bulletin of the Entomological Society of America **15**(3): 237-240.

Lichter, J., H. Caron, T. S. Pasakarnis, S. L. Rodgers, T. S. Squiers, Jr., and C. S. Todd. 2006. The ecological collapse and partial recovery of a freshwater tidal ecosystem. Northeatern Naturalist **13**(2): 153-178.

Little, C. 2013a. Assessing the habitat use, diet, and sex ratios of Atlantic (*Acipenser oxyrinchus*) and Shortnose sturgeon (*Acipenser brevirostrum*) in the Saco River, ME, University of New England.

Little, C. E., M. Kieffer, G. Wippelhauser, G. Zydlewski, M. Kinnison, L. A. Whitefleet-Smith, and J. A. Sulikowski. 2013b. First documented occurrences of the shortnose sturgeon (*Acipenser brevirostrum*) in the Saco River, Maine, USA. Journal of Applied Ichthyology: 1-4.

Logan-Chesney, L. M., M. J. Dadswell, R. H. Karsten, I. Wirgin, and M. J. W. Stokesbury. 2018. Atlantic sturgeon *Acipenser oxyrinchus* surfacing behaviour. Journal of Fish Biology **92**(4): 929-943.

Longwell, A. C., S. Chang, A. Hebert, J. B. Hughes, and D. Perry. 1992. Pollution and developmental abnormalities of Atlantic fishes. Environmental Biology of Fishes **35**(1): 1-21.

Loyd, L. 2017. Philly port is poised to get new cranes, bigger ships, more cargo, and more jobs [online]. The Philadelphia Inquirer.

Mac, M. J. and C. C. Edsall. 1991. Environmental contaminants and the reproductive success of lake trout in the great lakes: An epidemiological approach. Journal of Toxicology and Environmental Health **33**(4): 375-394.

Mangold, M., S. M. Eyler, and S. Minkkinen. 2007. Atlantic sturgeon reward program for Maryland waters of the Chesapeake Bay and tributaries 1996-2006. U.S. Fish and Wildlife Service, Maryland Fishery Resources Office, Annapolis, Maryland. Dated November 2007.

Markin, E. L. and D. H. Secor. 2020. Growth of juvenile Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) in response to dual-season spawning and latitudinal thermal regimes. Fishery Bulletin **118**(1): 74-87.

Maynord, S. T. 2000. Inflow zone and discharge through propeller jets. U.S. Army Corps of Engineers. Dated September 2000. ENV Report No. 25.

McCord, J. W., M. R. Collins, W. C. Post, and T. I. J. Smith. 2007. Attempts to develop an index of abundance for age-1 Atlantic sturgeon in South Carolina, USA. In Munro, J., Hatin, D., Hightower, J.E., McKown, K.A., Sulak, K.J., Kahnle, A.W. and Caron, F. (Eds.), *Anadromous Sturgeons: Habitats, Threats, and Management*. American Fisheries Society, Symposium 56: 397-404. American Fisheries Society, Bethesda, Maryland.

McLean, M. F., M. J. Dadswell, and M. J. W. Stokesbury. 2013. Feeding ecology of Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchill, 1815 on the infauna of intertidal mudflats of Minas Basin, Bay of Fundy. Journal of Applied Ichthyology **29**(3): 503-509.

Mills, L. S. and F. W. Allendorf. 1996. The one-migrant-per-generation rule in conservation and management. Conservation Biology **10**(6): 1509-1518.

Miranda, L. E. and K. J. Killgore. 2013. Entrainment of shovelnose sturgeon by towboat navigation in the Upper Mississippi River. Journal of Applied Ichthyology **29**(2): 316-322.

Moberg, T. and M.-B. DeLucia. 2016. Potential impacts of dissolved oxygen, salinity and flow on the successful recruitment of Atlantic sturgeon in the Delaware River. The Nature Conservancy, Harrisburg, Pennsylvania.

Mohler, J. W. 2003. Culture manual for the Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus*. U.S. Fish and Wildlife Service, Region 5, 300 Westgate Center Drive, Hadley, Massachusetts.

Muhling, B. A., C. F. Gaitán, C. A. Stock, V. S. Saba, D. Tommasi, and K. W. Dixon. 2017. Potential Salinity and Temperature Futures for the Chesapeake Bay Using a Statistical Downscaling Spatial Disaggregation Framework [online]. Estuaries and Coasts. DOI: https://doi.org/10.1007/s12237-017-0280-8.

Murawski, S. A. and A. L. Pacheco. 1977. Biological and fisheries data on Atlantic sturgeon, *Acipenser oxyrhynchus* (Mitchill). National Marine Fisheries Service, Northeast Fisheries Science Center, Sandy Hook Laboratory, Highlands, New Jersey. Dated August 1977. Technical Series Report 10 No. 10.

Murdoch, P. S., J. S. Baron, and T. L. Miller. 2000. Potential effects of climate change on surface-water quality in North America. JAWRA Journal of the American Water Resources Association **36**(2): 347-366.

Musick, J., R. Jenkins, and N. Burkhead. 1994. Sturgeons, family Acipenseridae. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, MD: 183-190.

NAST, (National Assessment Synthesis Team). 2000. Climate change impacts on the United States: The potential consequences of climate variability and change. Overview. U.S. Global Change Research Program, Washington D.C.

NEFSC (Northeast Fisheries Science Center). 2020. 2020 State of the Ecosystem: New England.

Niklitschek, E. J. 2001. Bioenergetics modeling and assessment of suitable habitat for juvenile Atlantic and shortnose sturgeons (*Acipenser oxyrinchus and A. brevirostrum*) in the Chesapeake Bay. Unpublished Doctor of Philosophy, Faculty of the Graduate School, University of Maryland: College Park, Maryland.

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**(1): 135-148.

Niklitschek, E. J. and D. H. Secor. 2010. Experimental and field evidence of behavioural habitat selection by juvenile Atlantic Acipenser oxyrinchus oxyrinchus and shortnose Acipenser brevirostrum sturgeons. Journal of Fish Biology **77**(6): 1293-1308.

NMFS. 1998. Final recovery plan for the shortnose sturgeon (*Acipenser brevirostrum*). Prepared by the Shortnose Sturgeon Recovery Team for the National Marine Fisheries Service. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, Maryland. Dated December 1998.

NMFS. 2013. Endangered Species Act section 7 consultation on the continued implementation of management measures for the Northeast multispecies, monkfish, spiny dogfish, Atlantic bluefish, northeast skate complex, mackerel/squid/butterfish, and summer flounder/scup/black sea bass fisheries. National Marine Fisheries Service, Northeast Regional Office. Dated December 16. Biological Opinion NER-2012-01956.

NMFS. 2014. Continued operation of Salem and Hope Creek nuclear generating station. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. Dated July 17. Biological Opinion No. NER-2010-6581.

NMFS. 2015. Deepening of the Delaware River Federal Navigation Channel (Reinitiation). National Marine Fisheries Service, Greater Atlantic Region Fisheries Office, Gloucester, Massachusetts. Dated November 20. Biological Opinion No. NER-2015-12624.

NMFS. 2017a. CENAP-OP-R- 2016-0181-39 DRP Gibbstown shipping terminal and logistic center. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. Dated December 8. Biological Opinion No. NER-2017-14371.

NMFS. 2017b. Designation of critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay Distinct Population Segments of Atlantic sturgeon : ESA Section 4(b)(2) Impact Analysis and Biological Source Document with the Economic Analysis and Final Regulatory Flexibility Analysis Finalized June 3, 2017. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts.

NMFS. 2017c. Endangered Species Act - Section 7 Consultation on the Tappan Zee Bridge Replacement NER-2017-14375. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. Dated November 1. Biological Opinion No. GARFO-2017-01421. DOI: 10.25923/vr51-j342.

NMFS. 2018. Reinitiation of the Delaware River federal navigation channel deepening and maintenance project. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. Dated December 10. Biological Opinion, Environmental Consultation Organizer No. GARFO-2018-00242.

NMFS. 2019a. Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) [Website]. National Marine Fisheries Service. Retrived March 15, 2019, from https://www.fisheries.noaa.gov/species/atlantic-sturgeon.

NMFS. 2019b. Endangered Species Act Section 7(a)(2) Biological Opinion - Deepening and maintenance of the Delaware River federal navigation channel. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts No. GARFO-2019-01942. DOI: https://doi.org/10.25923/49h0-c696.

NMFS. 2020. Biological Opinion on the Issuance of Incidental Take Permit No. 23148 to Exelon Generating Company, LLC, for Operation of Eddystone Generating Station. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, Maryland. Dated June 19 No. OPR-2019-03367. DOI: https://doi.org/10.25923/kh0z-qg97.

NMFS. 2021. Endangered Species Act Section 7 Consultation on the: (a) Authorization of the American Lobster, Atlantic Bluefish, Atlantic Deep-Sea Red Crab, Mackerel/Squid/Butterfish, Monkfish, Northeast Multispecies, Northeast Skate Complex, Spiny Dogfish, Summer Flounder/Scup/Black Sea Bass, and Jonah Crab Fisheries and (b) Implementation of the New England Fishery Management Council's Omnibus Essential Fish Habitat Amendment 2. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. Dated May 27, 2021. Biological Opinion, Consultation No. No. GARFO-2017-00031. DOI: https://doi.org/10.25923/cfsq-qn06.

NMFS. 2022. New York Bight Distinct Population Segment of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. Dated February 17.

NMFS (National Marine Fisheries Service). 2011. Bycatch Working Group discussion notes. Presented at the NMFS Sturgeon Workshop, Alexandria, VA. February 11, 2011., February 11, 2011.

NMFS (National Marine Fisheries Service) and U.S. FWS (U.S. Fish and Wildlife Service). 1998. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Report to National Marine Fisheries Service and U.S. Fish and Wildlife Service. Dated July 24, 1998.

Novak, A. J., A. E. Carlson, C. R. Wheeler, G. S. Wippelhauser, and J. A. Sulikowski. 2017. Critical foraging habitat of Atlantic sturgeon based on feeding habits, prey distribution, and movement patterns in the Saco River estuary, Maine. Transactions of the American Fisheries Society **146**(2): 308-317.

O'Herron, J. C., K. W. Able, and R. W. Hastings. 1993. Movements of shortnose sturgeon (*Acipenser brevirostrum*) in the Delaware River. Estuaries **16**(2): 235-240.

O'Herron, J. C. and K. W. Able. 1985. A study of the endangered shortnose sturgeon (*Acipenser brevirostrum*) in the Delaware River. Period covered: March - September 14, 1985. Center for Coastal and Environmental Studies, Rutgers, New Brunswick, New Jersey. Dated December 13, 1985. Performance Report No. AFS-10-1.

O'Herron, J. C. and R. W. Hastings. 1985. A Study of the Shortnose Sturgeon (*Acipenser brevirostrum*) population in the upper tidal Delaware River: Assessment of impacts of maintenance dredging (Post- dredging study of Duck Island and Perriwig ranges), Draft final report. Center for Coastal and Environmental Studies, Rutgers, the State University of New Jersey, New Brunswick, New Jersey.

O'Leary, S. J., K. J. Dunton, T. L. King, M. G. Frisk, and D. D. Chapman. 2014. Genetic diversity and effective size of Atlantic sturgeon, *Acipenser oxyrhinchus oxyrhinchus* river spawning populations estimated from the microsatellite genotypes of marine-captured juveniles. Conservation Genetics **15**(5): 1173-1181.

Oakley, N. C. 2003. Status of shortnose sturgeon, *Acipenser brevirostrum*, in the Neuse River, North Carolina. Unpublished Master of Science, North Carolina State University: Raleigh, N.C.

Oliver, M. J., M. W. Breece, D. A. Fox, D. E. Haulsee, J. T. Kohut, J. Manderson, and T. Savoy. 2013. Shrinking the haystack: using an AUV in an integrated ocean observatory to map Atlantic Sturgeon in the coastal ocean. Fisheries **38**(5): 210-216.

Ong, T.-L., J. Stabile, I. Wirgin, and J. R. Waldman. 1996. Genetic divergence between *Acipenser oxyrinchus oxyrinchus* and *A. o. desotoi* as assessed by mitochondrial DNA sequencing analysis. Copeia **1996**(2): 464-469.

Palmer, M. A., C. A. Reidy Liermann, C. Nilsson, M. Flörke, J. Alcamo, P. S. Lake, and N. Bond. 2008. Climate change and the world's river basins: anticipating management options. Frontiers in Ecology and the Environment **6**(2): 81-89.

Park, I. A. 2017. Sturgeon salvage in the Delaware River and Bay. [Personal Communication: email] Recipient NMFS, Greater Atlantic Regional Fisheries Office. Delaware Department of Natural Resources and Environmental Control, Division of Fish and Wildlife, Smyrna, Delaware, June 15, 2017.

Parker, E. L. 2007. Ontogeny and life history of shortnose sturgeon (*Acipenser brevirostrum* Lesueur 1818): Effects of latitudinal variation and water temperature. Unpublished Ph.D., University of Massachusetts: Amherst, Massachusetts.

PDE. 2017. Technical report for the Delaware estuary and basin. Partnership for the Delaware Estuary, Wilmington, Delaware. Report No. 17-07.

Pendleton, R. M. and R. D. Adams. 2021. Long-term trends in juvenile Atlantic sturgeon abundance may signal recovery in the Hudson River, New York, USA. North American Journal of Fisheries Management **41**(4): 1170-1181.

Pershing, A. J., M. A. Alexander, C. M. Hernandez, L. A. Kerr, A. Le Bris, K. E. Mills, J. A. Nye, N. R. Record, H. A. Scannell, J. D. Scott, G. D. Sherwood, and A. C. Thomas. 2015. Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery. Science **350**: 809-812.

Peterson, D. L., P. Schueller, R. DeVries, J. Fleming, C. Grunwald, and I. Wirgin. 2008. Annual run size and genetic characteristics of Atlantic sturgeon in the Altamaha River, Georgia. Transactions of the American Fisheries Society **137**(2): 393-401.

Phelps, Q. E., S. J. Tripp, J. E. Garvey, D. P. Herzog, D. E. Ostendorf, J. W. Ridings, J. W. Crites, and R. A. Hrabik. 2010. Habitat use during early life history infers recovery needs for Shovelnose Sturgeon and Pallid Sturgeon in the Middle Mississippi River. Transactions of the American Fisheries Society **139**(4): 1060-1068.

PIANC. 2008. Considerations to reduce environmental impacts of vessels. PIANC Secrétariat Général, Brussels, Belgium. Report No. 99-2008.

Pikitch, E. K., P. Doukakis, L. Lauck, P. Chakrabarty, and D. L. Erickson. 2005. Status, trends and management of sturgeon and paddlefish fisheries. Fish and Fisheries **6**(3): 233-265.

Polis, D. F., S. L. Kupferman, and K.-H. Szekielda. 1973. Physical oceanography and chemical oceanography. Delaware Bay Report Series 4: 170. University of Delaware, Newark, Delaware.

Post, W. C., T. Darden, D. L. Peterson, M. Loeffler, and C. Collier. 2014. Research and management of endangered and threatened species in the southeast: riverine movements of shortnose and Atlantic sturgeon. South Carolina Department of Natural Resources, Project NA10NMF4720036, Final Report, Charleston.

Prakash, S., V. Kolluru, and C. Young. 2014. Evaluation of the zone of influence and entrainment impacts for an intake using a 3-dimensional hydrodynamic and transport model. Journal of Marine Science and Engineering **2**(2): 306-325.

Pyzik, L., J. Caddick, and P. Marx. 2004. Chesapeake Bay: Introduction to an ecosystem (Update). Chesapeake Bay Program, Annapolis, Maryland. Dated July 2004. Report No. CBP/TRS 232/00.

Quattro, J. M., T. W. Greig, D. K. Coykendall, B. W. Bowen, and J. D. Baldwin. 2002. Genetic issues in aquatic species management: the shortnose sturgeon (*Acipenser brevirostrum*) in the southeastern United States. Conservation Genetics **3**(2): 155-166.

Reine, K. J., D. Clarke, M. Balzaik, S. O'Haire, C. Dickerson, C. Fredrickson, G. Garman, C. Hager, A. J. Spells, and C. Turner. 2014. Assessing impacts of navigation dredging on Atlatntic sturgeon (*Acipenser oxyrinchus*). U.S. Army Corps of Eningeers, Engineer Research and Development Center, 3909 Halls Ferry Rd, Vicksburg, MS 39180. Dated November 2014. Dredging Operations Technical Support Program No. ERDC/EL TR-14-12.

Richardson, B. and D. Secor. 2016. Assessment of critical habitat for recovering the Chesapeake Bay Atlantic sturgeon distinct population segment. p. 75.

Rosenthal, H. and D. F. Alderdice. 1976. Sublethal effects of environmental stressors, natural and pollutional, on marine fish eggs and larvae. Journal of the Fisheries Research Board of Canada **33**(9): 2047-2065.

Ruelle, R. and C. Henry. 1992. Organochlorine compounds in pallid sturgeon. Dated June 1992. Contaminant Information Bulletin.

Ruelle, R. and K. D. Keenlyne. 1993. Contaminants in Missouri River pallid sturgeon. Bulletin of Environmental Contamination and Toxicology **50**(6): 898-906.

Saba, V. S., S. M. Griffies, W. G. Anderson, M. Winton, M. A. Alexander, T. L. Delworth, J. A. Hare, M. J. Harrison, A. Rosati, G. A. Vecchi, and R. Zhang. 2015. Enhanced warming of the Northwest Atlantic Ocean under climate change. Journal of Geophysical Research: Oceans **121**(1): 118-132.

Savoy, T. 2007. Prey eaten by Atlantic sturgeon in Connecticut waters. In Munro, J., Hatin, D., Hightower, J.E., McKown, K.A., Sulak, K.J., Kahnle, A.W. and Caron, F. (Eds.), *Anadromous Sturgeons: Habitats, Threats, and Management*. American Fisheries Society Symposium 56: 157-165. American Fisheries Society, Bethesda, Maryland.

Savoy, T., L. Maceda, N. K. Roy, D. Peterson, and I. Wirgin. 2017. Evidence of natural reproduction of Atlantic sturgeon in the Connecticut River from unlikely sources. PLoS ONE **12**(4): e0175085.

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.

Savoy, T. F. 2004. Population Estimate and Utilization of the Lower Connecticut River by Shortnose Sturgeon. In Jacobson, P.M., Dixon, D.A., Leggett, W.C., Barton C. Marcy, J. and Massengill, R.R. (Eds.), *The Connecticut River Ecological Study (1965-1973) Revisited: Ecology of the Lower Connecticut River 1973-2003*. American Fisheries Society Monograph: 245-352. American Fisheries Society, Bethesda, Maryland.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin **184**.

Sechler, D. R., Q. E. Phelps, S. J. Tripp, J. E. Garvey, D. P. Herzog, D. E. Ostendorf, J. W. Ridings, J. W. Crites, and R. A. Hrabik. 2012. Habitat for age-0 shovelnose sturgeon and pallid sturgeon in a large river: Interactions among abiotic factors, food, and energy intake. North American Journal of Fisheries Management **32**(1): 24-31.

Secor, D. H. 2002. Atlantic sturgeon fisheries and stock abundances during the late nineteenth century. In Van Winkle, W., PhD, Anders, P., Secor, D.H., PhD and Dixon, D., PhD (Eds.), *Biology, Management, and Protection of North American Sturgeon*. American Fisheries Society Symposium 28: 89-98. American Fisheries Society, Bethesda, Maryland.

Secor, D. H., P. J. Anders, W. Van Winkle, and D. A. Dixon. 2002. Can we study sturgeons to extinction? What we do and don't know about the conservation of North American sturgeons. In Van Winkle, W., PhD, Andres, P.J., Secor, D.H., PhD and Dixon, D.A., PhD (Eds.), *Biology, Management, and Protection of North American Sturgeon*. American Fisheries Society Symposium 28. American Fisheries Society, Bethesda, Maryland.

Secor, D. H. and T. E. Gunderson. 1998. Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon, *Acipenser oxyrinchus*. Fishery Bulletin **96**(2): 603-613.

Secor, D. H. and E. J. Niklitschek. 2002. Sensitivity of sturgeons to environmental hypoxia: A review of physiological and ecological evidence. Presented at the Fish Physiology, Toxiology, and Water Quality, Sixth International Symposium, La Paz, B.C.S. Mexico, January 22-26, 2001. 61-78 pp.

Secor, D. H., M. O'Brien, N. Coleman, A. Horne, I. Park, D. Kazyak, D. Bruce, and C. Stence. 2021. Atlantic sturgeon status and movement ecology in an extremely small spawning habitat: The Nanticoke River-Marshyhope Creek, Chesapeake Bay. Reviews in Fisheries Science & Aquaculture: 1-20.

Shirey, C., C. C. Martin, and E. J. Stetzar. 1999. Atlantic sturgeon abundance and movement in the lower Delaware River. Final Report to the National Marine Fisheries Service. Delaware Division of Fish and Wildlife, Dover, Delaware. Dated September 27, 1999. Report No. AFC-9.

Shirey, C. A., C. C. Martin, and E. J. Stetzar. 1997. Abundance of sub-adult Atlantic sturgeon and areas of concentration within the lower Delaware River. Time period covered August 1, 1996–September 30, 1997. Final report. Delaware Division of Fish and Wildlife, Dover, Delaware.

Simpson, P. C. 2008. Movements and habitat use of Delaware River Atlantic sturgeon. Unpublished Master of Science, Natural Resources Graduate Program, Delaware State University: Dover, Delaware.

Skjeveland, J. E., S. A. Welsh, M. F. Mangold, S. M. Eyler, and S. Nachbar. 2000. A Report of investigations and research on Atlantic sturgeon and shortnose sturgon in Maryland waters of the

Chesapeake Bay (1996-2000). U.S. Fish and Wildlife Service, Annapolis, Maryland. Dated October 10, 2000.

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

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**(1): 335-346.

Smith, T. I. J., D. E. Marchette, and R. A. Smiley. 1982. Life history, ecology, culture and management of Atlantic sturgeon, A*cipenser oxyrhynchus oxyrhynchus,* Mitchill, in South Carolina. South Carolina Wildlife Marine Resources. Resources Department, Final Report to U.S. Fish and Wildlife Service. Report No. AFS-9.

Sommerfield, C. K. and J. A. Madsen. 2003. Sedimentological and geophysical survey of the upper Delaware Estuary. Final report to the Delaware River Basin Commission. University of Delaware. Dated October 2003.

Spells, A. J. 1998. Atlantic sturgeon population evaluation utilizing a fishery dependent reward program in Virginia's major western shore tributaries to the Chesapeake Bay. An Atlantic Coastal Fisheries Cooperative Management Act report for National Marine Fisheries Service. U.S. Fish and Wildlife Service, Charles City, Virginia.

Squiers, T., M. Smith, and L. Flagg. 1979. Distribution and abundance of shortnose and Atlantic sturgeon in the Kennebec River estuary. Department of Marine Resources, Augusta, Maine. Research Reference Document No. 79/13.

Squiers, T. S. J. 2003. Completion report Kennebec River shortnose sturgeon population study 1998-2001. Maine Department of Marine Resources, Augusta, Maine. Dated February 26, 2003. NMFS Contracts No. 40-EANF-8-00053 and 43-EANF-0-00147.

SSSRT. 2010. A biological assessment of shortnose sturgeon (*Acipenser brevirostrum*). Shortnose Sturgeon Status Review Team. Dated November 1. Report to National Marine Fisheries Service, Northeast Regional Office.

Steen, S. 2021. Vessel hydrology and impacts to fish. [Personal Communication: email] Recipient Johnsen, P.B. Norwegian University of Science and Technology (NTNU), Norway, January 21 and 29.

Stein, A. B., K. D. Friedland, and M. Sutherland. 2004a. Atlantic sturgeon marine bycatch and mortality on the continental shelf of the Northeast United States. North American Journal of Fisheries Management **24**(1): 171-183.

Stein, A. B., K. D. Friedland, and M. Sutherland. 2004b. Atlantic sturgeon marine distribution and habitat use along the northeastern coast of the United States. Transactions of the American Fisheries Society **133**(3): 527-537.

Stetzar, E. J., T. Savoy, J. Bowers-Altman, H. Corbett, M. Fisher, D. Fox, J. Madsen, and M. Oliver. 2015. Sturgeons in the mid-Atlantic region: A multi-state collaboration of research and conservation final report. Section 6 Species Recovery Grants program. p. 204.

Stevenson, J. T. and D. H. Secor. 1999. Age determination and growth of Hudson River Atlantic sturgeon, Acipenser oxyrinchus. Fishery Bulletin **98**(1): 153-166.

Stewart, N., Y. Cormier, L. Logan-Chesney, G. Gibson, I. Wirgin, M. Dadswell, and M. Stokesbury. 2017. Natural stranding of Atlantic sturgeon (*Acipenser oxyrinchus* Mitchill, 1815) in Scot's Bay, Bay of Fundy, Nova Scotia, from populations of concern in the United States and Canada. Journal of Applied Ichthyology **33**(3): 317-322.

Stoschek, O., E. Precht, O. Larsen, M. Jain, L. Yde, N. Ohle, and T. Strotmann. 2014. Sediment resuspension and seabed scour induced by ship-propeller wash. Presented at the PIANC World Congress, San Fransisco, California.

Sweka, J. A., J. Mohler, M. J. Millard, T. Kehler, A. Kahnle, K. Hattala, G. Kenney, and A. Higgs. 2007. Juvenile Atlantic sturgeon habitat use in Newburgh and Haverstraw Bays of the Hudson River: Implications for population monitoring. North American Journal of Fisheries Management **27**(4): 1058-1067.

Taubert, B. D. 1980. Biology of shortnose sturgeon (*Acipenser brevirostrum*) in the Holyoke Pool, Connecticut River, Massachusetts. Unpublished Ph.D., Department of Forestry and Wildlife, University of Massachusetts: Amherst, MA.

Timoshkin, V. 1968. Atlantic sturgeon (*Acipenser sturio L.*) caught at sea. Journal of Ichthyology **8**(4): 598.

USFWS and NMFS. 1998. Endangered Species Act consultation handbook. Procedures for conducting section 7 consultations and conferences. Dated March 1998.

Van Eenennaam, J. P. and S. I. Doroshov. 1998. Effects of age and body size on gonadal development of Atlantic sturgeon. Journal of Fish Biology **53**(3): 624-637.

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.

Vladykov, V. D. and J. R. Greeley. 1963. Order *Acipenseroidei*. In Bigelow, H.B. (Ed.), *Fishes of the Western North Atlantic, Part 3*. Memoir (Sears Foundation for Marine Research) I: 630. Yale University, New Haven, Connecticut. DOI: 10.5962/bhl.title.7464.

Von Westernhagen, H., H. Rosenthal, V. Dethlefsen, W. Ernst, U. Harms, and P. D. Hansen. 1981. Bioaccumulating substances and reproductive success in baltic flounder *Platichthys flesus*. Aquatic Toxicology **1**(2): 85-99.

Waldman, J., S. E. Alter, D. Peterson, L. Maceda, N. Roy, and I. J. C. G. Wirgin. 2019. Contemporary and historical effective population sizes of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus*. **20**(2): 167-184.

Waldman, J. R., J. T. Hart, and I. I. Wirgin. 1996. Stock composition of the New York Bight Atlantic sturgeon fishery based on analysis of mitochondrial DNA. Transactions of the American Fisheries Society **125**(3): 364-371.

Waldman, J. R., T. King, T. Savoy, L. Maceda, C. Grunwald, and I. Wirgin. 2013. Stock origins of subadult and adult Atlantic sturgeon, *Acipenser oxyrinchus*, in a non-natal estuary, Long Island Sound. Estuaries and Coasts **36**(2): 257-267.

Waldman, J. R. and I. I. Wirgin. 1998. Status and restoration options for Atlantic sturgeon in North America. Conservation Biology **12**(3): 631-638.

Wang, J., E. Santiago, and A. Caballero. 2016. Prediction and estimation of effective population size. Heredity **117**(4): 193-206.

Watanabe, Y. Y., Q. Wei, H. Du, L. Li, and N. Miyazaki. 2013. Swimming behavior of Chinese sturgeon in natural habitat as compared to that in a deep reservoir: preliminary evidence for anthropogenic impacts. Environmental Biology of Fishes **96**(1): 123-130.

Weakfish Plan Review Team. 2019. 2019 Review of the Atlantic States Marine Fisheries Commission fishery management plan for weakfish (*Cynoscion regalis*), 2018 fishing year. Atlantic States Marine Fisheries Commission, Alexandria, Virginia.

Weber, W. 1996. Population size and habitat use of shortnose sturgeon, *Acipenser brevirostrum*, in the Ogeechee River sytem, Georgia. Unpublished Masters of Science, University of Georgia: Athens, Georgia.

Weber, W., C. A. Jennings, and S. G. Rogers. 1998. Population size and movement patterns of shortnose sturgeon in the Ogeechee River system, Georgia. Proceedings of the annual conference / Southeastern Association of Fish and Wildlife Agencies **52**: 18-28.

Welsh, S. A., M. F. Mangold, J. E. Skjeveland, and A. J. Spells. 2002. Distribution and movement of shortnose sturgeon (*Acipenser brevirostrum*) in the Chesapeake Bay. Estuaries **25**(1): 101-104.

White, S. L., R. L. Johnson, B. A. Lubinski, M. S. Eackles, and D. C. Kazyak. 2023. Genetic population assignments of Atlantic sturgeon provided to National Marine Fisheries Service, 2022. U.S. Geological Survey, Reston, Virginia. Open-File Report No. 2023–1054. DOI: https://doi.org/10.3133/ofr20231054.

White, S. L., D. Kazyak, T. L. Darden, D. J. Farrae, B. A. Lubinski, R. Johnson, M. Eackles, M. Balazik, H. Brundage, A. G. Fox, D. A. Fox, C. H. Hager, J. E. Kahn, and I. I. Wirgin. 2021.

Establishment of a microsatellite genetic baseline for North American Atlantic sturgeon (*Acipenser o. oxyrhinchus*) and range-wide analysis of population genetics. Conservation Genetics **22**(6): 977-992.

White, S. L., N. M. Sard, H. M. Brundage III, R. L. Johnson, B. A. Lubinski, M. S. Eackles, I. A. Park, D. A. Fox, and D. C. Kazyak. 2022. Evaluating sources of bias in pedigree-based estimates of breeding population size. Ecological Applications **32**(5): e2602.

Wilcox, D. B. 1991. Models for predicting impacts of vessel passage on young of year fish and fish populations. In Miller, A.C. and Payne, B.S. (Eds.), *An investigation of methods to measure and predict biological and physical effects of commercial navigation traffic: Workshop II*. Miscellaneous Paper EL-91-12: 22-27. USACE, Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Wilkens, J. L., A. W. Katzenmeyer, N. M. Hahn, J. J. Hoover, and B. C. Suedel. 2015. Laboratory test of suspended sediment effects on short-term survival and swimming performance of juvenile Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, Mitchill, 1815). Journal of Applied Ichthyology **31**(6): 984-990.

Wippelhauser, G. 2012. Summary of Maine Atlantic sturgeon data: Description of monitoring 1977-2001 and 2009-2011 in the Kennebec and Merrymeeting Bay Estuary System.

Wippelhauser, G. and T. S. Squiers. 2015. Shortnose sturgeon and Atlantic sturgeon in the Kennebec River System, Maine: a 1977-2001 retrospective of abundance and important habitat. Transactions of the American Fisheries Society **144**(3): 591-601.

Wippelhauser, G. S., J. Sulikowski, G. B. Zydlewski, M. A. Altenritter, M. Kieffer, and M. T. Kinnison. 2017. Movements of Atlantic sturgeon of the Gulf of Maine inside and outside of the geographically defined Distinct Population Segment. Marine and Coastal Fisheries **9**(1): 93-107.

Wirgin, I., M. W. Breece, D. A. Fox, L. Maceda, K. W. Wark, and T. King. 2015a. Origin of Atlantic Sturgeon collected off the Delaware coast during spring months. North American Journal of Fisheries Management **35(**1): 20-30.

Wirgin, I., C. Grunwald, E. Carlson, J. Stabile, D. L. Peterson, and J. Waldman. 2005. Range-wide population structure of shortnose sturgeon *Acipenser brevirostrum* based on sequence analysis of the mitochondrial DNA control region. Estuaries **28**(3): 406-421.

Wirgin, I. and T. King. 2011. Mixed stock analysis of Atlantic sturgeon from costal locals and a non-spawning river. Presented at the Sturgeon Workshop, Alexandria, Virginia, February 8-10, 2011.

Wirgin, I., L. Maceda, C. Grunwald, and T. L. King. 2015b. Population origin of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus* bycatch in U.S. Atlantic coast fisheries. Journal of Fish Biology **86**(4): 1251-1270.

Wirgin, I., L. Maceda, J. R. Waldman, S. Wehrell, M. Dadswell, and T. King. 2012. Stock origin of migratory Atlantic Sturgeon in Minas Basin, Inner Bay of Fundy, Canada, determined by microsatellite and mitochondrial DNA analyses. Transactions of the American Fisheries Society **141**(5): 1389-1398.

Wirgin, I., N. K. Roy, L. Maceda, and M. T. Mattson. 2018. DPS and population origin of subadult Atlantic sturgeon in the Hudson River. Fisheries Research **207**: 165-170.

Wirgin, I. I., J. R. Waldman, J. Stabile, B. A. Lubinski, and T. L. King. 2002. Comparison of mitochondrial DNA control region sequence and microsatellite DNA analyses in estimating population structure and gene flow rates in Atlantic sturgeon Acipenser oxyrinchus. Journal of Applied Ichthyology **18**(4-6): 313-319.

Woodland, R. J. and D. H. Secor. 2007. Year-class strength and recovery of endangered Shortnose Sturgeon in the Hudson River, New York. Transactions of the American Fisheries Society **136**(1): 72-81.

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 of University of New York Press, Albany, New York.

Ziegeweid, J. R., C. A. Jennings, D. L. Peterson, and M. C. Black. 2008. Effects of salinity, temperature, and weight on the survival of young-of-year shortnose sturgeon. Transactions of the American Fisheries Society **137**(5): 1490-1499.

Zydlewski, G. B., M. T. Kinnison, P. E. Dionne, J. Zydlewski, and G. S. Wippelhauser. 2011. Shortnose sturgeon use small coastal rivers: the importance of habitat connectivity. Journal of Applied Ichthyology **27**(Suppl. 2): 41-44.