NATIONAL MARINE FISHERIES SERVICE

ENDANGERED SPECIES ACT

BIOLOGICAL OPINION

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

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

GARFO-2022-00012

Conducted by: National Marine Fisheries Service

Greater Atlantic Regional Fisheries Office

Date Issued: 7/19/22

Approved by: Michael Pentony

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Contents

1 INTRODUCTION

This constitutes the 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). The applicant, the South Jersey Port Corporation (SJPC or applicant), proposes to construct a new RoRo Berth at the existing and under-development Paulsboro Marine Terminal deep-water import-export marine terminal along the Delaware River in Gloucester County, New Jersey. SJPC is applying to the U.S. Army Corps of Engineers (USACE), Philadelphia District, for permits 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 operation of the RoRo berth is expected to take place for 10 years (2022 through 2032).

The project involves both in-water activities at the existing Paulsboro Marine Terminal wharf 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 is also part of the action. This Opinion is based on the description of the effects of the proposed action on ESA-listed species and critical habitat that the USACE provided in their Biological Assessment (BA) on January 5, 2022. We initiated consultation on the same date. After initiating consultation, we received new information from the Northeast Fisheries Science Center (NEFSC) that informed several aspects of the analysis and Opinion for the project. Consequently, delivery of the final signed Opinion was delayed.

2 ESA CONSULTATION HISTORY

<u>August 2010 through July 2011</u>

On August 31, 2010, following the issuance of the initial Public Notice for 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.

<u>April 2018 through August 2018</u>

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 email included attached electronic copies of a signed letter requesting formal consultation and an associated 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, to ensure the analysis in our Opinion uses the best available information and receives a thorough internal technical review, we requested that USACE extend the delivery date of our final signed Opinion to July 29, 2022. USACE notified us that our request was relayed to the applicant who informed us that they wished to meet and discuss our request, which we did on May 17, 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 you the final, signed BO by July 29, 2022. The analysis in the BA, along with scientific literature and other sources of information as cited in the references section also contribute to the basis of this Opinion. A complete administrative record of this consultation will be kept at our NMFS Greater Atlantic Regional Fisheries Office.

3 PROJECT DESCRIPTION

The Proposed Action consists of the following construction activities and subsequent operational phase: (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 turning basin and mooring approach, and disposal of dredge materials; and (3) the placement of stone revetment to stabilize shoreline sediment slopes. Each of these three components and their related activities are described below.

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 marine 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. Phase 1 of the project has been completed and Phase 2 was completed in the fourth quarter of 2021. At full buildout, the currently permitted terminal (Phases 1 and 2) will include 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 Proposed Enhancements

To facilitate RoRo movements of offshore wind turbine monopile foundations for offshore wind turbines, the applicant proposes to enhance the Paulsboro Marine Terminal, which involves adding one additional berth at the downstream end of the existing wharf with mooring infrastructure. This new berth will be created by dredging a new turning basin and adding mooring infrastructure at the downriver (west) end of the existing wharf.

3.3.1 RoRo Berth Construction

The proposed berth will use the existing Paulsboro Marine Terminal wharf but will require additional structures and an increased draft to accommodate the class of vessel used to transport monopile foundations. All construction for the proposed RoRo Berth will be completed from the water on a construction barge held in place with spud legs. Barges will be maneuvered into position with tugs. Barges and other vessels are expected to be tied up to the existing berth when not in use, and equipment is expected to be refueled from land by a truck.

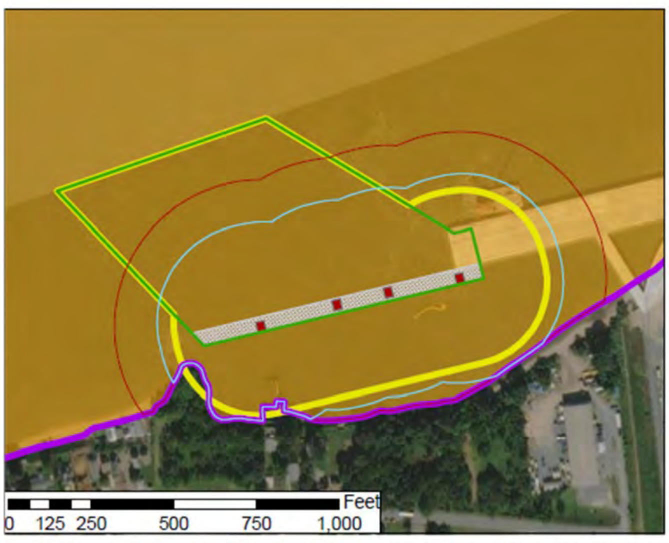
As part of the Proposed Action, four dolphins will be constructed. Dolphins are berthing and mooring structures located independently of the pier. The proposed dolphins will be constructed at the landward edge of the proposed berthing slip, to guide the vessels into the berth and secure them in position while loading and offloading. The permanent footprint of the mooring dolphins will be no more than approximately 0.0037 acres (160 square feet) of the Delaware River benthic habitat.

The two berthing dolphins will provide fendering and mooring capabilities. These are set along the fender line, which is the point of contact between the vessel and structure. The berthing dolphin will take the majority of the berthing load as vessels approach at an angle, and the berthing dolphin is the first structure with which the vessel comes in contact.

There also are two mooring dolphins set back from the fender line that only provide mooring points such as bollards, hooks, or cleats. Because the mooring dolphins are set back from the fender line, they have the potential of providing better mooring line angles for breast lines. Mooring dolphins do not come in to contact with the hull of the ship and are therefore not equipped with fenders.

The berthing and mooring piles will be driven to a depth of between -13.7 m (-45 ft) and -33.5 m (-110 ft) beneath the mudline in the area that will later become the revetment slope. Three 48-in-diameter steel pipe piles will support each of the four (4) dolphins, with a single 30-in-diameter steel pipe pile providing support at three intermediate locations along the platform (cat walk). Piles will be installed using a barge-mounted crane (approximately 9 m (30 ft) wide, 21.3 m (70 ft) long, with 1.8 m (6 ft) draft). Pile driving will occur with a soft start using a reduced driving force on piles. A pile driving cap will be employed to further reduce noise levels. The proposed location of the mooring dolphin construction is shown on Figure 1. A pile driving schedule listing the number and size of piles proposed for the dolphins and catwalk is provided in Table 1.

Figure 1. Proposed location of mooring dolphins



As mentioned above, all pile driving will be conducted from a barge. In addition, the pile reinforcement cage, concrete cap, and installation of the fender and mooring equipment will be completed from a barge. Based on the information contained in the BA, subsequent email correspondence, and updated project timelines that have emerged during the consultation process, pile driving is expected to commence after July 1, 2022, and last for approximately 15 to 20 workdays spread over one month. Duration of dolphin construction, including the overwater work (pile cap forming/pouring, installing fenders, walkways, and lighting), is anticipated to be 2 to 3 months, in order to comply with the March 15 to June 30 Time of Year Restriction (TOYR) on in-water work during the applicable fish migration and spawning seasons. After the piles have been installed, the above-water components of the dolphins will be constructed. The concrete caps will be either cast-in-place or made of precast concrete and craned into position. Pile caps will be installed immediately after pile driving. It is also expected to take approximately one month to complete capping, depending on the construction method. Once the pile caps are in place, installation of bollards, fenders and the walkways will occur. This work is all overwater and will be conducted from a barge of similar dimensions to the pile driving barge (21.3 m (70 ft) long, 9.1 m (30 ft) wide, and 1.8 m (6 ft) draft).

Table 1. Pile Schedule – Dolphins and Platform

Structure Component*	No of Piles	Diameter (inches)	Total Length (feet)	Mud Depth (feet)
Mooring Dolphin 1 (MD-1)	3	48	140	110
Mooring Dolphin 2 (MD-2)	3	48	140	110
Berthing Dolphin 1 (BD-1)	3	48	140	110
Berthing Dolphin 2 (BD-2)	3	48	140	110
Platform Catwalk Supports	3	30	75	45

* Includes piles for the permitted activities. Does not include piles installed under existing or previous permits

3.3.2 Dredging for Berthing Slip and Turning Basin

Dredging will be performed to deepen the proposed berthing slip for RoRo vessels and create a turning basin to connect the Berth to the Federal Navigation Channel. All dredging will be outside of the intertidal zone and below the subtidal zone (-1.8 m (-6 ft) mean lower low water (MLLW)). The dredged area will be approximately 8.9 acres (roughly 387,553 square ft) with dredging occurring to a depth of -9.5 m (-31 ft) MLLW plus up to -0.6 m (-2 ft) of overdredge for a maximum depth of -10 m (-33 ft) MLLW. The proposed dredging will remove approximately 140,900 cubic yards (cy) (~10,300 cy of fine-grained Holocene surface material and ~ 130,600 cy of Pleistocene, coarser-grained material with consolidated virgin clay) of material.

Similar to pile driving, based on updated project timelines and correspondence between NMFS and the USACE, dredging is expected to commence after July 1, 2022, and have a duration of 30 to 50 days depending on technique, with hydraulic dredging having a higher production rate and therefore faster material removal. Dredging will be suspended during peak Atlantic sturgeon migration in the Delaware River between March 15 and June 30.

<u>Equipment used</u>

A clamshell bucket will be used to mechanically dredge fine-grained materials, which generally encompass the top several feet of a dredge area. Underlying sandy and more coarsely grained materials may be dredged using either a mechanical dredge (clamshell or excavator) mounted on a barge (9 m (30 ft) wide by 30.5 m (100 ft) long by 1.8 m (6 ft) draft), or hydraulic cutterhead dredge.

As the name suggests, the mechanical bucket dredge utilizes a bucket to excavate sediments. The sediments are placed in scows or barges that are towed or pushed to the dredged material placement or disposal site. Bucket dredges include clamshell, orange-peel, and dragline types. The crane that operates the bucket can be mounted on a flat-bottomed barge, on fixed-shore installations, or on a crawler mount. In most cases, spuds, or anchors in conjunction with spuds are used to position the plant. Dredging suspends when a barge is fully loaded, at which point it is moved away and replaced with another empty scow or barge. Dredging may resume once a new empty barge/scow is in place. The opening of the bucket is controlled by the closing and hoisting wires or by hydraulic cylinders. The bucket is lowered into the water and is opened to grab the sediments on the bottom. Only a small area is impacted at any given time and the bucket is lifted up and emptied between each grab.

Hydraulic dredging typically consists of a shallow draft ship (barge-like hull) that utilizes hydraulic pumps to suction a mix of sediments and water from the river bottom and pump the effluent through a discharge pipe up to several miles away. A suction intake contains a cutter head that rotates to disturb, or dig, the soil and sediment and mixes the cuttings with the suction water for removal. The soil-water slurry then travels though the pump and piping until it discharges to the storage location. The dredge discharge pipe is typically oriented to discharge into a Confined Disposal Facility (CDF). The ship sweeps though the proposed dredge area, cutting away 0.6 to 0.9 m (2 to 3 ft) sections of material per pass. The slurry material generally contains 25 to 30% sediment and 70 to 75% water based on USACE Engineering Manuals.

3.3.2.1 Dredged Volume and Dredge Material Disposal

The dredging for the berth and turning basin is anticipated to require removal of approximately 140,900 cy of river sediments and underlying soils. Sediments will be mechanically unloaded from the scows to the Paulsboro Marine Terminal wharf and then into trucks, which will take them to the stockpile area in the northwest corner of the Paulsboro Marine Terminal for mixing with Portland cement as necessary to dewater the sediments for transport and stabilize them for disposal or reuse. Contaminated sediments that cannot be reused onsite, will be taken to the Gloucester County Solid Waste Complex.

Soft sediments may also be transported in dredge scows directly to disposal facilities adjacent to the Delaware River, namely Biles Island in Fairless Hills, Pennsylvania, operated by Waste Management, or to Whites Basin, located in Logan Township, New Jersey, operated by Weeks Marine. Biles Island is located approximately 68 RKM (42 RM) upstream of the project dredge area, and Whites Basin is located approximately 10 RKM (6 RM) downstream of the project dredge area. Material will be pumped upland into CDFs at either facility, and both facilities are permitted by the USACE and the New Jersey Department of Environmental Protection to accept dredged material. Regardless of destination, all dredged material not reused onsite will be placed at permitted upland sites; therefore, the effects of placement will not be considered further.

3.3.2.2 Dredging period and timing

Dredging for the Paulsboro Marine Terminal RoRo Berth is expected to commence after July 1, 2022, and, depending on technique, have a duration of 30 to 50 days, with no in-water work occurring between March 15 and June 30. Dredging will be performed with one mechanical dredge (clamshell or excavator) and a cutterhead dredge. Vessels used during dredging activities will include up to two dredge barge/scows, one crewboat (6.1 to 9.1 m (20 to 30 ft) long, 1.5 m (5-ft) draft), and up to two tugboats (6.1 to 12.2 m (20 to 40 ft) long, 2.4 m (8-ft) draft) for assisting with barge transport and dredge movements. The vessels will berth at the existing Paulsboro Marine Terminal facility and will remain in the action area conducting dredging activities 24 hours per day, 7 days per week until completion.

3.3.3 Shoreline Stabilization

After dredging is completed, about 2,000 cy of armor stone will be placed around the dolphin piles to form the revetment, which will provide shore protection. Armor stone will be placed with a clamshell bucket from a barge-mounted crane (9.1 m (30 ft) wide by 30.5 m (100 ft) long by 1.8 m (6 ft) draft), and rock scow similar in size and draft to the dredge scows. A 0.6 m (2-ft) layer of armor stone (15.2 to 38.1 cm (6 to 15 in) diameter) will be placed on the graded revetment slope ranging from the existing sediment surface at an approximate depth of -2.1 m (-7 ft) MLLW down to -10 m (-33 ft) MLLW to meet the dredged area. The constructed revetment will have a slope of 1 vertical: 1.5 horizontal.

3.4 Project Vessels and Project-Related Vessel Traffic

3.4.1 Vessels during construction

As discussed, dredging and in-water construction for the Paulsboro Marine Terminal RoRo Berth is expected to occur start after July 1, 2022, and take approximately 140 days to complete (pile driving and dredging), with no in-water work between March 15 and June 30. Vessels used during dredging activities will include up to two dredge barge/scows, one crewboat (6.1 to 9.1 m (20 to 30 ft) long, 1.5 m (5-ft) draft), and up to two tugboats (6.1 to 12.2 m (20 to 40 ft) long, 2.4 m (8-ft) draft) for assisting with barge transport and dredge movements. The vessels will berth at the existing Paulsboro Marine Terminal facility and will remain in the action area conducting dredging activities 24 hours per day, 7 days per week until completion. We assume that all vessels (two tugs, two barges and one crew boat) have homeports located within the Delaware River basin. Thus, the transit of these vessels to the project site at the beginning of construction and return to their homeport (or another work assignment) once construction is finished will result in six (6) vessel trips (two tugs with barges and one crew boat) on the Delaware River. While within the construction area, the vessels will generally be stationary, moored with engines off or idling. Vessel transits during dredging will be minimized by stockpiling and decanting dredged sediments immediately adjacent to the construction area, on the upland portion of the Paulsboro Marine Terminal. Crews will be replaced twice daily for shift changes via crew boats berthing at the Paulsboro Marine Terminal. Tug and crew boat activity supporting dredging at the project site will be confined to the area between the southern edge of the Federal Navigation Channel and the existing Paulsboro Marine Terminal. When transporting dredge materials, barges (dredge and scows) will be pushed or towed by one tugboat for each barge/scow.

Tugboats may also be used to assist transport of soft sediments in barges directly to disposal facilities adjacent to the Delaware River, at Biles Island in Fairless Hills, Pennsylvania, 68 RKM (42 RM) upstream of the project dredge area, and Whites Basin in Logan Township, New Jersey, located approximately 10 RKM (6 RM) downstream of the project dredge area. The transport of dredge material to approved offsite dredge disposal sites would result in an increase of 6 to 8 barge and tug transits from the RoRo berth dredge area, resulting in a maximum of 16 vessel trips during construction within the Federal Navigation Channel.

Pile driving for the Berth will be performed from a single barge-mounted crane anchored with spuds, construction barge, tugboat (6.1 to 12.2 m (20 to 40 ft) long, 2.4 m (8-ft) draft), and a crewboat (6.1 to 9.1 m (20 to 30 ft) long, 1.5 m (5-ft) draft). At this time, we do not have information regarding the homeport of the tug, barges, and crew boat. However, we assume that pile driving will result in two vessel trips (one tug pushing the barges and one crew boat) on the Delaware River from the homeport to the construction site at the start of construction and two vessel trips at the end of construction for a total of four vessel trips. Tug and crew boat activity supporting pile driving at the project site will be confined to the area between the southern edge of the Federal Navigation Channel and the existing Paulsboro Marine Terminal. While at the project site, these vessels will also berth at the Paulsboro Marine Terminal, minimizing the distance of transits and the use of the Federal Navigation Channel, and piles will be loaded onto barges at the Paulsboro Marine Terminal. Pile construction is scheduled to occur before dredging. Similar to the dredging vessels, movement of pile driving construction vessels will be slow (<10 knots) with additional movements limited to repositioning, as needed. Pile driving construction is estimated to take place over 15 to 20 days spread across a one-month period, with overwater construction taking an additional six to eight weeks.

Table 2. Vessel Activity in the Delaware River During Construction.

Vessel Type	Activities	Number of Vessels	Number of Trips	Length (ft)	Width (ft)	Draft (ft)	Prop Size (in)
Barge-mounted crane or Pile driving barge[a]	Pile Driving. Dredging, Revetment	1	2	70	30	6	--
Construction barge[a]	Pile Driving	1	2	70	30	6	--
Backhoe excavator dredge barge[b or] Clamshell barge-mounted crane[b]	Dredging, Revetment	1	2	100	30	6	--
Dredge material barge/scow	Dredging	2	20	150	37.5	10	--
Crew boats	Pile Driving, Dredging	1	4	20-30	10-15	5	12 - 15
Tugboat	Pile Driving, Dredging	2	22	20-40	15-18	8	18 - 24

[a] Pile driving and construction barge would not be simultaneously operating and may be same vessel.

[b] Backhoe excavator dredge and dredge material barge would not be simultaneously operating.

3.4.2 Vessels during port 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 3 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 3. Range of vessel calls for each year of operation

Year	Vessel Calls	Purpose	Trips
2022	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. The RoRo Berth may be used beyond this 10-year horizon, but its use is highly dependent upon the projections of offshore wind energy development within the mid-Atlantic. The operational capacity of the monopole manufacturing facility currently being constructed limits the annual number of piles produced, and therefore fixes the ceiling of vessel calls at 50.

3.5 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.

3.6 Best Management Practices

The proposed action will employ practices that avoid or minimize potential adverse impacts to endangered species. Best management practices, such as the following, are outlined in the Dredge Material Management Plan and will be used during construction to reduce impacts to the Atlantic and shortnose sturgeon:

- Dredging will not be performed during the spring sturgeon spawning season (March 15 to June 30).
- Use of sealed dredged materials scows that prohibit overflow.
- Use an environmental bucket dredge to reduce sediment resuspension.
- Use a signal light to verify environmental bucket closure and seal.
- Use bucket penetration/depth sensors.
- Place dredged material deliberately in barge to prevent spillage.
- Operate dredge to maximize the bite of the environmental bucket.
- Observe bucket hoist speed limitations.
- Do not allow barge overflow of dredged sediments.
- Decant water from barges allowing 24 hours for settling prior to disposal.
- Use barges or scows that are solid hull construction or sealed to transport sediments.
- Do not rinse or hose gunwales of the dredge scows during dredging.
- Lower bucket to the level of barge gunwales prior to release of the bucket load.
- The cutterhead dredge and suction pumps will not be started or operated until the cutterhead is in contact with river bottom sediments to reduce the potential for the cutterhead to injure sturgeon or suction entrap or entrain young sturgeon. The suction pump and cutterhead will be shutdown prior to lifting the cutterhead above the river bottom sediments.
- Use a confined disposal facility during hydraulic dredging to contain the sediments until they are watered.
- Manage return water from the confined disposal facility to minimize sedimentation and turbidity.
- Gravity-drain return water from the confined disposal facility back to the Delaware River near the dredge area.

During pile driving, the following measures will be implemented to avoid or minimize adverse impacts:

- Prohibiting work in the waterway between March 15 and June 30 of any year.

- Cushion blocks will be used to reduce noise generated by impact pile driving.
- Using a soft start, which involves having the hammer commencing work at reduced power, for a minimum of 15 to 30 minutes; after this time period, the hammer can be used at full power.

The following measures will be implemented to reduce the impacts from vessel traffic during construction:

- Restrict construction activities based on time of year, prohibiting work between March 15 and June 30.
- Fuel equipment from land using trucks.
- Vessels used during pile driving activities will include a single barge-mounted crane, a tugboat, and a crew boat. These vessels will also berth at the Paulsboro Marine Terminal minimizing the distance of transits and the use of the Federal Navigation Channel.
- Vessels will be stationary, or moving at slow speeds to adjust position as needed within the action area.

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 is determined by construction activities, vessel traffic during construction and operation of the Berth, and stressors associated with these activities. The components of the action area relative to the Berth are: the area directly affected by construction of the Berth (“Construction Area”) (0.0037 acres) and dredging activities (“Dredging Area”) (8.9 acres). In addition, the action area includes the areas that will be transited by tugs transporting barges to the Biles Island disposal site during construction and vessels calling at the Paulsboro Marine Terminal when the Berth is operating: the Delaware River Federal Navigation Channel from RKM 5 to 214.5 (RM 3.1 to 133.3) (~11,568 acres) (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. As mentioned above, this action area also encompasses the area where vessels will travel between the Channel and the proposed Berth during construction. As the dredged material will be disposed of on land, no additional in-water areas will be affected by dredged material disposal; however, tugs may use the Federal Navigation Channel to transport barges carrying dredge materials to disposal sites at Biles Island (approximately 68 RKM (42 RM) upstream of the project area) and Whites Basin (approximately 10 RKM (6 RM) downstream of the project dredge area). The action area for the project is shown in Figure 2.

Figure 2. Paulsboro Action Area

The permanent footprint from the pile driving of the mooring dolphins will be no more than approximately 0.0037 acre; however, the action area also includes the area ensonified by underwater noise during pile driving. Based on the NOAA Fisheries GARFO Acoustic Tool, biologically significant sound levels could extend as far as 130 m (426.5 ft) from the mooring dolphin piles being driven. The action area also includes the 2,000 cubic yards of armor stone that will be placed around the dolphin piles to form a revetment. In addition, the action area includes the area occupied by sediment plumes associated with dredging, which extend beyond the ensonified area. The sediment plume could extend up to 732 m (2,401 ft) from the dredge area. In total, the portion of the action area where dredging (including sediment plumes), vessel traffic between the Federal Navigation Channel and the proposed Berth, and pile driving occurs occupies approximately 350 acres (Figure 3).[1]

[1] This acreage may be an overestimate of the size of the area impacted by construction and construction activities as this calculation includes circular areas affected by sediment plumes. In reality, sediment plumes would have an oblong shape. However, as the direction of the plume would be influenced by tidal conditions, circular areas were utilized to capture all possible drift directions and represent a worst-case scenario.

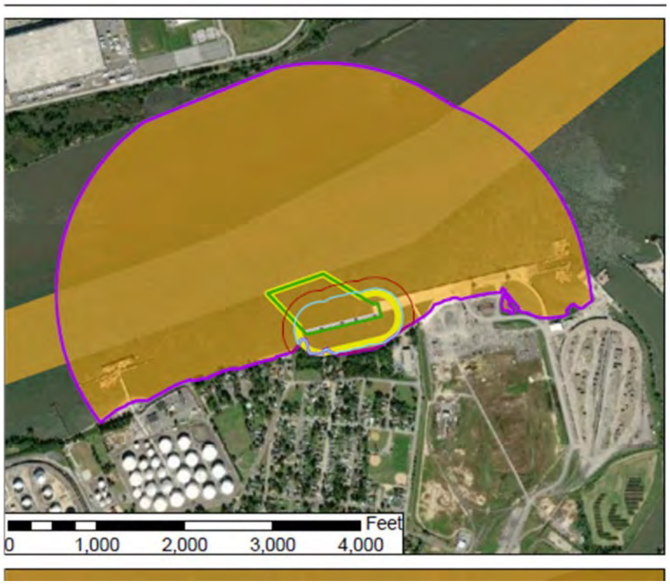


Figure 3. Map of action area where dredging (including sediment plumes), vessel traffic between the Federal Navigation Channel and the Port, and pile driving occurs

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 project site 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 and upstream to a dredge disposal location near Biles Island located approximately 68 km (42 mi) upstream of the project area.

4.1.1 Construction Area

The construction area consists of the nearshore waterfront portion of the project where the proposed Berth and revetment will be constructed. Aquatic habitat in the construction area 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 rip-rap, gabion baskets, and pilings (Miller, 2020). There are no vegetated wetlands (Duffield Associates, Inc., 2018) or submerged aquatic vegetation (SAV) (Miller, 2020) within the construction area.

4.1.2 Dredging Area

The dredging area consists of 8.9 acres outside of the intertidal zone and below the subtidal zone (-1.8 m (-6 ft) MLLW). Bottom substrate within the dredging 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) (Jacobs, 2021). There are no vegetated wetlands (Duffield Associates, Inc., 2018) or SAV (Miller, 2020) 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) (NOAA, 2019).

4.1.3 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 (Cronin et al., 1962; Polis and Kupferman, 1973).

5 STATUS OF LISTED SPECIES and CRITICAL HABITAT

5.1 Species and Critical Habitat Not Likely to be Adversely Affected by the Proposed Action

Although listed species and designated critical habitat may be present in the action area, the proposed project being considered in this Opinion is not likely to adversely affect the following ESA-listed species: leatherback, Kemp's ridley, the North Atlantic DPS of green sea turtles, the Northwest Atlantic distinct population segment (DPS) of loggerhead sea turtle, North Atlantic right whales, and fin whales (see Table 4). We present the rationale for this "not likely to adversely affect" determination below. No take is anticipated or exempted. The proposed action will not result in the destruction or adverse modification of designated critical habitat.

Table 4. NLAA listed species and critical habitat present within the Action Area and status

Listed Species Common Name/Critical Habitat Unit	Listed Species Scientific Name	Status
North Atlantic DPS green sea turtle	*Chelonia mydas*	Threatened
Northwest Atlantic Ocean DPS loggerhead sea turtle	*Caretta caretta*	Threatened
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
North Atlantic right whales	*Eubalaena glacialis*	Endangered
Fin whales	*Balaenoptera physalus*	Endangered
New York Bight DPS Atlantic sturgeon Critical Habitat Unit	*Acipenser oxyrinchus*	Designated

5.1.1 Sea Turtles

Sea turtles commonly occur in U.S. Atlantic waters throughout the inner continental shelf from Florida to Cape Cod, MA. Along the Atlantic coast of the United States, leatherback, green and loggerhead sea turtle nesting beaches occur from North Carolina south through Florida. Sea turtle nesting is rare north of North Carolina. There is occasional loggerhead sea turtle nesting in Virginia and a few green and loggerhead sea turtle failed nesting attempts have occurred on Delaware and New Jersey beaches, but there are no established nesting beaches further north.

Beaches in the two states do not support regular nesting of either species. In the United States, some Kemp's ridley turtle nesting has occurred along the coast of Texas, but most Kemp's ridley turtles nest in mass in Tamaulipas, Mexico, where nearly 95% of worldwide Kemp's ridley nesting occurs.

Northward and inshore movement into waters of the Greater Atlantic Region from southern nesting beaches begins in the springtime. Sea turtles arrive into mid-Atlantic waters including Delaware Bay and the Delaware River in May. Juvenile, and occasionally adult, sea turtles are expected to opportunistically forage in the Delaware Bay and Delaware River from May through the end of November. In the fall, as water temperatures cool, most sea turtles leave the region's waters by the end of November. Sea turtle presence in mid-Atlantic waters after this time is considered unlikely aside from cold-stunned individuals that fail to migrate south.

The functional ecology of these four sea turtle species is varied. Loggerhead sea turtles are primarily carnivorous feeding mainly on mollusks and crustaceans. Kemp's ridley sea turtles are omnivorous feeding primarily on crabs and crustaceans. Green sea turtles are herbivores feeding mainly on algae and seagrasses, although they may also forage on sponges and invertebrates. Leatherback sea turtles are specialized feeders and prey primarily upon jellyfish.

Additional background on life history and population status can be found in the recovery plans: loggerhead (NMFS and USFWS, 2008), Kemp’s ridley (NMFS et al. 2011), green (NMFS and USFWS, 1991), and leatherback (NMFS and USFWS, 1992).

5.1.1.1 Sea Turtle Presence in the Action Area

Adult and juvenile sea turtles are expected to be present within the action area. Specifically, in the Delaware Bay and the Delaware River below the Chesapeake & Delaware Canal (C&D Canal) at RKM 94.3 (RM 58.6) from May through the end of November, is where they may be foraging. The action area is outside the range of sea turtle nesting, therefore, no sea turtle hatchlings are expected to be present within the action area.

5.1.1.2 Effects of the Proposed Action on Sea Turtles

Leatherback, green, Kemp’s ridley, and loggerhead sea turtles may occur in the Delaware River and Delaware Bay and be exposed to the effects of vessel traffic associated with the operation of the Berth.

5.1.1.2.1 Vessel Traffic

Vessel strikes remain a relatively rare cause of mortality to sea turtles and an increase in vessel traffic in the action area would not necessarily translate into an increase in vessel strikes. However, although rare, interactions with vessel traffic related to the proposed Berth operation could potentially injure or kill sea turtles. Interactions between vessels and sea turtles are not well understood; however, collisions appear to be correlated with recreational boat traffic (NRC

1990) and the speed of the vessel (Hazel *et al.* 2007, Sapp 2010). Sea turtles are thought to be able to avoid injury from slower moving vessels because they may be able to maneuver and avoid the vessel (Sapp 2010). Stetzar (2002) reports that 33 of 109 sea turtles stranded along the Delaware Estuary from 1994-1999 had evidence of boat interactions (hull or propeller strike); however, it is unknown how many of these strikes occurred after the sea turtle died. If we assume that all were struck prior to death, this suggests 5 to 6 strikes per year in the Delaware Estuary (Stetzar 2002). In addition to recreational vessels, there have been an annual average of 33,556 vessel trips by self-propelled vessels from Philadelphia to the Atlantic Ocean over the period from 2010 to 2019 (USACE, Waterborne Commerce Data). However, sea turtles are thought to be able to avoid large cargo vessels or to be pushed out of the impact zone by propeller wash or bow wake without being harmed (NMFS 2013). Based on the best available information, the likelihood of an interaction between a sea turtle and one of the large cargo vessels transiting to or from the proposed Berth is extremely unlikely to occur.

5.1.2 Whales

North Atlantic right whales are large baleen whales. Their primary food sources are zooplankton, including copepods, euphausiids, and cyprids. Right whales commonly feed at or just below the water's surface and at depth. They primarily occur in coastal or shelf waters, although movements over deep waters are known to occur. Right whales migrate to higher latitudes during spring and summer (NMFS 2005). In the mid-Atlantic, adult and juvenile right whales occur throughout the continental shelf and slope waters, possibly off shore of New Jersey and Virginia. Whales begin moving north along the coast in the vicinity of Delaware Bay during November to April while on their way to northern foraging areas. Right whales are commonly found foraging from January to October and overwintering from November to January in waters in and around Massachusetts Bay and north along the east coast into Canadian waters.

Fin whales are found in deep, offshore waters of all major oceans, primarily in temperate to polar latitudes, and less commonly in the tropics. During the summer, fin whales feed on krill, small schooling fish (e.g., herring, capelin, and sand lance), and squid, but fast in the winter while they migrate south to warmer waters. They occur year-round in a wide range of latitudes and longitudes, but the density of individuals in any one area changes seasonally. In the mid-Atlantic, foraging occurs year round in the mid-shelf area off the east end of Long Island. Fin whales use the nearshore coastal waters of the Atlantic Ocean as they migrate to and from calving and foraging grounds. There is evidence of wintering areas in mid-shelf areas east of New Jersey. Fin whale calving may take place offshore in mid-Atlantic waters from October to January. Fin whales may occupy both deep and shallow waters in and around Delaware Bay and are most abundant in spring, summer, and fall, but may have some presence during the winter months. Therefore, fin whales could be present year-round.

5.1.2.1 Whale Presence in the Action Area

Fin and right whales occur throughout the continental shelf and slopes of the mid-Atlantic (NMFS 2017c). In addition, right whale sightings have been documented at the mouth of the Delaware Bay and in a few rare occasions within the bay. No right whales have been observed inland of the COLREGS Demarcation Line at Delaware Bay since 2002 (NMFS 2017d). Right whales are most likely to occur in waters off the New Jersey coast between November and April as they migrate between northern foraging and southern calving grounds, but could be present year round (NMFS 2017d). Adult and juvenile fin whales could theoretically be present year round within the action area in Delaware Bay or at its mouth but they have never been observed in these waters. Given the lower salinity and shallower depths throughout most of the action area compared to offshore marine waters, right and fin whales are not present in the lower Delaware River. However, although unlikely, it is possible that migrating adult and juvenile whales may be seasonally present within the Delaware Bay.

5.1.2.2 Effects of the Proposed Action on Whales

ESA listed species of whales will not occur in the areas of the Delaware River where pile driving, dredging, and habitat modification will occur and, thus, will not be exposed to any effects of pile driving, dredging, or habitat modification. Although rare and unlikely, fin and North Atlantic right whales may be present where increased vessel traffic will occur at and off shore of the mouth of the Delaware Bay. As such, this section will only address the effects of vessel traffic to whales.

5.1.2.2.1 Vessel Traffic

Once operational, we anticipate that the proposed Berth will receive up to 50 new vessel calls (100 trips) annually. These vessels will travel to and from the Berth through the mouth of the Delaware Bay. Collision with vessels remains a source of anthropogenic mortality for whales and project-related vessels would increase vessel traffic in the action area. Despite being one of the primary known sources of direct anthropogenic mortality to whales, vessel strikes remain relatively rare, stochastic events, and an increase in vessel traffic in the action area would not necessarily translate into an increase in vessel strike events. In this subsection, we evaluate whether vessel traffic caused by the proposed project would increase the risk of vessel strikes to listed species.

Fin and right whales occur throughout the continental shelf and slopes of the mid-Atlantic (NMFS 2017c). Sightings and satellite tracking data along the east coast indicate that endangered large whales such as right and fin whales rarely venture into bays, harbors, or inlets (Southall and Scholik-Schlomer 2007). However, right whale sightings have been documented near the mouth of the Delaware Bay and in a few rare occasions within the bay. For instance, three right whale observations were reported at the mouth of the Delaware Bay during the two years of 2020 and 2021 (https://whalemap.org/WhaleMap/). Right whales are most likely to occur in waters off the New Jersey coast between November 1 and April 30 as they migrate between northern foraging and southern calving grounds (NMFS 2017d). Adult and juvenile fin whales could theoretically be present within the action area in the Delaware Bay or at its mouth but they have never been observed in these waters. Given the lower salinity and shallower depths than marine waters, right and fin whales are not present near the Berth site or in the upper Delaware River.

Vessels transporting materials for construction or supporting dredging and pile driving activities will travel within the Delaware River and not occur in the Delaware Bay or travel through its mouth. Thus, whales will not be exposed to these vessels. However, the transit of cargo vessels could expose any fin whales and right whales within the pilot area and precautionary area (just outside and inside of the Delaware Bay mouth, respectively) to vessel strike.

Injuries and mortalities from vessel strikes are a threat to North Atlantic right and fin whales. Reports from 2009 to 2018 indicate that right whales experienced four vessel strike mortalities and five serious injuries, two of which were prorated serious injuries, in the U.S. or in an unknown country of origin. The annual average of vessel strikes between 2012 and 2016 in U.S. waters was 1.4 for fin whales (Hayes 2019). Large whales, particularly right whales, are vulnerable to injury and mortality from ship strikes. Ship strike injuries to whales occur in two ways: (1) propeller wounds characterized by external gashes or severed tail stocks; and (2) blunt trauma injuries indicated by fractured skulls, jaws, and vertebrae, as well as massive bruises that sometimes lack external expression (Laist *et al*. 2001). Collisions with smaller vessels may result in propeller wounds or no apparent injury, depending on the severity of the incident. Laist *et al.* (2001) reports that of 41 ship strike accounts that reported vessel speed, no lethal or severe injuries occurred at speeds below ten knots, and no collisions have been reported for vessels traveling less than six knots. An analysis by Vanderlaan and Taggart (2007) showed that at speeds greater than 15 knots, the probability of a ship strike resulting in death of a whale increases asymptotically to 100%. At speeds below 11.8 knots, the probability of a vessel decreases to less than 50%, and at 10 knots or less, the probability is further reduced to approximately 30%. Most ship strikes have occurred at vessel speeds of 13-15 knots or greater (J. *et al.* 2021, Jensen and Silber 2003). Therefore, vessel strikes that injure or kill whales are most likely occur when vessels travel at speeds of 10 knots or more (Laist *et al.* 2001, Pace and Silber 2005, Vanderlaan and Taggart 2007).

A Seasonal Management Area (SMA) was established in 2008 to reduce the likelihood of death and serious injuries to endangered right whales that result from collisions with ships (50 CFR 224.105). The areas are defined as the waters within a 20-nm area with an epicenter located at the midpoint of the COLREG demarcation line crossing the entry into the designated ports or bays. A mid-Atlantic SMA is located at the mouth of the Delaware Bay and is active from November 1 through April 30 of any given year. The timing of the SMA coincides with the seasonal migrations of right whales, which is when they are mostly likely to be in mid-Atlantic waters. Vessels 19.8 m (65 ft) or longer are required to operate at speeds of 10 knots or less when traveling through the SMA. Vessels anticipated with future Berth operations are expected to range in size from approximately 122 m (400 ft) to 167.6 m (550 ft) in length. These large cargo vessels are self-powered and expected to maneuver in to the Berth using Azipods without tug assist. Vessel calls may also be completed either by the heavy lift vessel described above or by barges. Barges will not have their own propulsion and will rely on tug assistance for berthing operations, and tug vessels are expected to be up to approximately 32 m (105 ft) in length. Therefore, the vessels traveling to and from the Berth must adhere to the speed requirements of 10 knots or less, thereby reducing vessel traffic impacts to whales. In addition, federal regulations, as specified in 50 CFR 222.32, require that a vessel steer a course away from a right whale and immediately leave the area at a slow safe speed if a whale is observed within 460 m (500 yards) of the vessel. Thus, measures to avoid vessel strike are already in place and will be applicable to the vessels associated with the Berth. Therefore, the speed of the vessels will not exceed 10 knots while transiting to/from the Atlantic Ocean from November 1 through April 30, thereby reducing the likelihood of vessel collision impacts during that time. Collisions with cargo vessels could occur, but the speed (up to 10 knots) during transit lessens the probability of a ship strike resulting in lethal or serious injuries. Requirements to steer a course away from a right whale may further reduce the risk of vessel-whale collisions. Once the vessels have entered the Delaware Bay, cargo vessels would travel at speeds of 10 to 20 knots in the Federal Navigation Channel. The risk of serious injury or death increases if the vessels travel at speeds above 10 knots. While there are no physical barrier preventing whales from entering the Delaware Bay, the probability of a whale being present within the Delaware Bay is extremely low.

Based on the rarity of whales within the action area, vessels that will travel at a speed of 10 knots or lower between November 1 and April 30, the likely absence of whales in the area between May 1 and October 31, and requiring vessels to keep a 460 m (500-yard) distance from an observed whale, we find it extremely unlikely that a whale will be exposed to a vessel strike. Therefore, effects from vessel traffic caused by the proposed action are extremely unlikely.

5.1.3 Atlantic Sturgeon Critical Habitat

On August 17, 2017, we issued a final rule to designate critical habitat for the threatened Gulf of Maine DPS of Atlantic sturgeon, the endangered New York Bight DPS of Atlantic sturgeon, the endangered Chesapeake Bay DPS of Atlantic sturgeon, the endangered Carolina DPS of Atlantic sturgeon, and the endangered South Atlantic DPS of Atlantic sturgeon (82 FR 39160). The rule was effective on September 18, 2017. The action area overlaps with the Delaware River critical habitat unit designated for the New York Bight DPS.

The conservation objective identified in the final rule is to increase the abundance of each DPS by facilitating increased successful reproduction and recruitment to the marine environment. We designated four critical habitat units to achieve this objective for the New York Bight DPS: (1) Connecticut River from the Holyoke Dam downstream for 140 RKMs to where the main stem river discharges at its mouth into Long Island Sound; (2) Housatonic River from the Derby Dam downstream for 24 RKMs to where the main stem discharges at its mouth into Long Island Sound; (3) Hudson River from the Troy Lock and Dam (also known as the Federal Dam) downstream for 246 RKMs to where the main stem river discharges at its mouth into New York City Harbor; and, (4) Delaware River at the crossing of the Trenton-Morrisville Route 1 Toll Bridge, downstream for 137 RKMs to where the main stem river discharges at its mouth into Delaware Bay. In total, these designations encompass approximately 547 km (340 mi) of aquatic habitat.

As identified in the final rule, the physical features that are essential to the conservation of the species and that may require special management considerations or protection are:

1) Hard bottom substrate (e.g., rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (i.e., 0.0 to 0.5 parts per thousand (ppt) range) for settlement of fertilized eggs, refuge, growth, and development of early life stages;

2) Aquatic habitat with a gradual downstream salinity gradient of 0.5 up to as high as 30 ppt and soft substrate (e.g., sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development;
3) Water of appropriate depth and absent physical barriers to passage (e.g., locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support:
   (i) Unimpeded movement of adults to and from spawning sites;
   (ii) Seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary; and
   (iii) Staging, resting, or holding of subadults or spawning condition adults.

   Water depths in main river channels must also be deep enough (e.g., at least 1.2 m) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river.
4) Water, between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support:
   (i) Spawning;
   (ii) Annual and interannual adult, subadult, larval, and juvenile survival; and
   (iii) Larval, juvenile, and subadult growth, development, and recruitment (e.g., 13 °C to 26 °C for spawning habitat and no more than 30 °C for juvenile rearing habitat, and 6 milligrams per liter (mg/L) dissolved oxygen (DO) or greater for juvenile rearing habitat).

The ESA Section 4(b)(2) Report for Atlantic sturgeon critical habitat (NMFS (National Marine Fisheries Service) 2017) provides background information on the current status and function of the four critical habitat units designated for the New York Bight DPS, and summarizes their ability to support reproduction, survival, and juvenile development, and recruitment. Information on the status of the Delaware River critical habitat unit can be found below.

As we described above, the Delaware River Critical Habitat Unit extends from the Trenton-Morrisville Route 1 Toll Bridge at approximately RKM 214.5 (RM 133.3), downstream to where the main stem river discharges into Delaware Bay at approximately RKM 78 (RM 48.5). The critical habitat designation within the Delaware River is bank-to-bank. The action area considered in this Opinion includes the Federal Navigation Channel from the mouth of the Bay (RKM 8 (RM 5) to RKM 214.5 (RM 133.3)) and the Berth site at RKM 145 (RM 90). Thus, from the site of the proposed Berth at RKM 145 (RM 90), the action area includes the Federal Navigation Channel downstream to the mouth of the river with the Delaware Bay at RKM 78 (RM 48.5) and upstream to the Biles Island CDF at RKM 211 (RM 131) and thus overlaps with critical habitat. In addition, the action area overlapping with critical habitat within the Delaware River contains PBFs 1, 2, 3, and 4.

In this analysis, we consider the direct and indirect effects of the construction activities and operation of the terminal (an interrelated action) on each of four physical and biological features (PBF) of the critical habitat. For each PBF, we identify the activities that may affect the PBF. For each feature that may experience effects of the action, we then determine whether those effects to the feature are adverse, insignificant, extremely unlikely or entirely beneficial. In making this determination, we consider the action's potential to affect how each PBF supports the species conservation needs in the action area. Part of this analysis is consideration of whether the action will have effects to the ability of Atlantic sturgeon to access the feature, temporarily or permanently, and consideration of the effects of the action on the action area's ability to develop the feature over time.

5.1.3.1 Physical and Biological Feature 1

Hard bottom substrate (e.g., rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (i.e., 0.0–0.5 ppt range) for settlement of fertilized eggs, refuge, growth, and development of early life stages

In considering effects to PBF 1, we consider whether the proposed action will have any effects on areas of hard bottom substrate (e.g., rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (i.e., 0.0–0.5 ppt range) for settlement of fertilized eggs, refuge, growth, and development of early life stages. Therefore, we consider how the action may affect hard bottom substrate and salinity and how any effects may change the value of this feature in the action area. We also consider whether the action will have effects on access to this feature, temporarily or permanently and consider the effect of the action on the action area's ability to develop the feature over time.

Because salinity shifts daily, seasonally and annually, it is not possible to identify exactly where the break between PBF 1 and PBF 2 will be at any given time. However, we can use available salinity information to identify the general reaches where salinity is typically at 0.5 ppt or below. The Delaware River Basin Commission (DRBC) defines the salt front as the area in the river where the water registers 250 milligrams per liter (0.25 ppt) chloride concentration. Due to its dynamic nature, the location of the salt front fluctuates depending on several variables, namely the tidal inflows and streamflows, as well as scheduled water releases from five reservoirs used to push back the location of the salt front. These variations can cause a specific salinity value or range to move upstream or downstream by as much as 16 km (~10 mi) in a day due to semi-diurnal tides, and by more than 32 km (~20 miles) over periods ranging from a day to weeks or months due to storm and seasonal effects on freshwater inflows (USACE 2009). DRBC reports the median location of the salt front to be from RKM 107.8 to RKM 122.3 (RM 67 to RM 76) (DRBC 2017). The border between PBF 1 and PBF 2 is where salinity is 0.5 ppt. Given the dynamic nature of salinity near the salt front, the availability of data on salinity levels of 0.25 ppt and not 0.5 ppt and the very small area where there would be a difference in salinity between 0.25 and 0.5 ppt, it is reasonable to use the furthest downstream extent of the median range of the location of the salt front (0.25 ppt) as a proxy for the downstream border of PBF 1 in the Delaware River. For this Opinion, we consider the area upstream of RKM 122.3 (RM 76) to have salinity levels consistent with the requirements of PBF 1. The action area for the Paulsboro RoRo Berth project within PBF 1 includes the project area for the proposed Berth and the Federal Navigation Channel between RKM 122.3 and 214.5 (RM 76 and 133.3).

Within the freshwater reaches of the Delaware River that are designated as critical habitat, PBF 1 occurs where there is hard bottom substrate for settlement of fertilized eggs, refuge, growth, and development of early life stages. Those hard bottom areas are only present in parts of the freshwater reach designated as critical habitat. We estimate the freshwater area of critical habitat in the Delaware River (all of which is in the action area) to be 28,436 acres. From tagging and tracking studies, we know that Atlantic sturgeon spawning may occur upstream of the salt front over hard bottom substrate between Claymont, DE/Marcus Hook, PA (Marcus Hook Bar), approximately RKM 125 (RM 77.7), and the fall line at Trenton, NJ, approximately RKM 212 (RM 131.7) (Breece et al. 2013; Simpson 2008). Within that range, DiJohnson et al. 2015 provided evidence for suitable spawning habitat made of outcrops of bedrock and non-depositional, mixed grained material (i.e., hard but not stationary), occurs both within the navigation channel and along the northern edge of the channel near the Eddystone Range (~RKM 133-138/RM 82.6-85.7).

Activities that occur with the portion of the Delaware River that contains PBF 1 include dredging of 8.9 acres to construct the berthing and mooring for the Berth; and the vessel traffic in the Philadelphia to the Sea Federal Navigation Channel. Here we consider whether those activities may affect PBF 1 and if so, whether those possible effects are insignificant, extremely unlikely, entirely beneficial or adverse.

Dredging will primarily remove soft substrates (silts and fine sands) along with some gravel-sized material. The action area will be dredged to a 10 m (33 ft) depth (including overdredge), or 2.7 m (9 ft) shallower than the depth dredged at the adjoining Paulsboro Marine Terminal wharf slips. Based on sediment sampling conducted in 2010 (Jacobs, 2021) and 2021 (Jacobs, 2021), a distinct layer consisting primarily of sand, but with some gravel, is located at a depth ranging from approximately -6 m (-20 ft) mean lower low water (MLLW) near the shoreline to -8.2 m (-27 ft) MLLW near the Federal Navigation Channel, and extends to depths of -13.7 m (-45 ft) MLLW or deeper. Of the five locations from which a petite ponar grab sampler was used to collect material from the top 0.15 m (0.5 ft) of substrate throughout the dredge footprint, some gravel was present; however, sand sized sediments dominated (62.3 – 87.0 percent) at the three locations sampled within the proposed turning basin and the two locations sampled within the proposed area for mooring dolphin and revetment construction.

While some larger coarse substrate (gravel) is present within the dredge footprint as part of this larger complex of coarse sandy material found in the vicinity of the action area, based on the results from the grab samples, the substrate in this portion of the action area is unlikely to provide suitable hard bottom habitat in low salinity waters for settlement of fertilized eggs, refuge, growth, and development of early life stages because the percentage of sand is so high. In order for hard bottom substrate to be suitable for the settlement of fertilized eggs, refuge, growth, and development of early life stages, it must have interstitial spaces where eggs and/or larvae can settle or hide. The high percentage of sandy sediments within the dredge footprint, however, indicates a low availability of hard surfaces for eggs to adhere to and reduces the availability of interstitial spaces, present in coarser substrates, which are used by larvae as refuge from predators. Thus, we expect the project area to have a low likelihood of supporting spawning activity and successful rearing of early life stages, and therefore, has little conservation value for the species.

This is supported by Simpson (2008), which concluded that although the location of spawning habitat in the Delaware River has not been confirmed, pairing telemetry results with substrate and water quality data indicates that spawning in the river likely occurs between the Marcus Hook Bar (RKM 125/RM 78) and the downstream end of Little Tinicum Island (RKM 138/RM 86), which is 7 km (4.3 mi) downstream from the Berth, and in the river upstream of north Philadelphia (RKM 176/RM 109.3) to Trenton (RKM 211/RM 131.1). Therefore, we do not expect early life stages such as eggs and yolk-sac larvae that are immobile and remain close to their spawning site to be present within the dredging footprint.

The applicant will dredge 8.9 acres of the 350-acre project area (Figure 3) to create the access channel and berth, which will disturb the bottom substrate. Based on this, the proposed project will expose PBF 1 to dredging within 2.5 percent of the project area (located approximately between RKM 139.2 and 144.4 (RM 86.5 and 89.7). We estimate the freshwater area of critical habitat in the Delaware River to be 28,436 acres (NMFS 2019b). Though not all of this area provides hard substrate, the proposed dredging will affect only a small fraction of available hard substrate within the freshwater reach of the Delaware River and, as noted above, the hard substrate in this area is of low conservation value because of the high volume of sand mixed with the gravel and the lack of interstitial spaces for refuge of early life stages.

The dredged substrate at this new depth is expected to be similar in composition to what was removed; medium to dense sand or gravely sand, with interlayered consolidated clay (USACE 2018). This is generally similar to the surface substrates collected during the recent benthic study, which, as summarized above, does not provide suitable spawning substrate. Therefore, we do not anticipate that dredging will measurably increase or decrease the amount of hard bottom habitat available to Atlantic sturgeon in the action area. In addition, we do not expect dredging to impact salinity levels to an extent that would influence the movement or seasonal location of the salt front or the availability of hard bottom substrate in low salinity waters (PBF 1).

During construction, tugs transporting dredge material to upriver disposal sites will use the Federal Navigation Channel within PBF 1. Cargo vessels will also use the Federal Navigation Channel within PBF 1 during the operational lifespan of the Berth. The areas that represent the vast majority of the Federal Navigation Channel from Philadelphia to the Sea are all soft substrates. The vessel propellers can scour the riverbed. As mentioned above, PBF 1 consists of hard substrate such as gravel and bedrock. For the propeller jet to scour the coarse substrate of PBF 1, the vessels need to have very little clearance from the bottom; however, we anticipate that the vessels will remain within the Federal Navigation Channel, which will provide 6 to 7.6 m (19.7 to 25 ft) of clearance between the hull and the bottom. Even when traveling outside of the Federal Navigation Channel, we expect that they will remain in areas with a depth that provides enough clearance to the riverbed to avoid scouring the bottom. Vessels with a clearance of ≥6 m (19.7 ft), which includes most tugs and tow vessels, should have little impact on the riverbed (PIANC 2008). Further, we expect that vessels will travel in the Federal Navigation Channel at a speed of 10 knots or more, and moving vessels at constant speed cause less shear stress on the riverbed than during maneuvering (PIANC 2008, Stoschek et al. 2014). Therefore, we do not anticipate that the propeller jet of the vessels will scour the river bottom during construction and operation of the Paulsboro RoRo Berth.

Given the considerations above, the effects of the project on the value of PBF 1 in the action area will be too small to be meaningfully measured, evaluated, or detected. Therefore, any effects to the value of PBF 1 to the conservation of the species are insignificant.

5.1.3.2 Physical and Biological Feature 2

Transitional salinity zone with soft substrate for juvenile foraging and physiological development

Aquatic habitat with a gradual downstream salinity gradient of 0.5 up to as high as 30 ppt and soft substrate (e.g., sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development can be found within the action area. Therefore, the soft substrate component of PBF 2 is present within the action area.

As described above, there is no clear salinity gradient within the Delaware River estuary. However, the river from RKM 93.9 to RKM 120.54 (RM 58.4 to RM 74.9) is characterized as oligohaline (0.5 to 5 ppt) and from RKM 49.8 to RKM 91.9 (RM 30.9 to RM 57.1) as mesohaline (5 to 18 ppt). A historic salinity transition zone occurs from RKM 91.9 to RKM 93.9 (RM 57.1 to 58.4) and DRBC (2017) identifies RKM 107.8 to RKM 122.3 (RM 67 to RM 76), as the median range for the salt front.

In the Delaware River, for this Opinion, we consider PBF 2 to occur from approximately RKM 78 (RM 48.5) (where the final critical habitat rule describes the mouth of the river) to between RKM 107.8 and RKM 122.3 (RM 67 to RM 76), or the median range of the salt front. As described above, salinity levels in the river are dynamic, and the salt front is defined by a lower concentration (0.25 ppt) than the lower level of PBF 2 (0.5 ppt), but the transitional zone between RKM 107.8 and RKM 122.3 (RM 67 to RM 76) is a reasonable approximation given the lack of real time data. Previous consultations with USACE for construction of the Paulsboro Marine Terminal has described conditions in the river at the Paulsboro Marine Terminal as having low to no salinity. Therefore, PBF 2 is not present within the construction area at the Berth (RKM 145/RM 90); however, the Philadelphia to the Sea Navigation Channel from RKM 78 to RKM 122.3 (RM 48.5 to RM 76) overlaps with the area where PBF 2 occurs. We estimate the total area of critical habitat (bank-to-bank in the mainstem of the river between RKM 78 and 122.3/RM 48.5 and 76) to be 37,362 acres. The action area within PBF 2 consists of the Federal Navigation Channel, which we estimate to be an area of 2,943 acres between the mouth of the river (RKM 78/RM 48.5) and the upstream end of the PBF 2 (RKM 122.3/RM 76). The various acreages are presented below:

Feature	Acreage
River channel between RKM 78 and 122.3 bank to bank	37,362
Navigation Chanel between RKM 78 and 122.3	2,943

Captured sturgeon and subsequent tracking studies have provided evidence that they use soft substrate habitat in the Delaware River with the salinity gradient matching the criteria for PBF 2. Detections of tagged juvenile Atlantic sturgeon have been documented in the lower tidal Delaware River, especially between the middle Liston Range (RKM 70/RM 43.5) to Tinicum Island (RKM 141/RM 87.6)(Calvo *et al.* 2010). Juveniles tracked in this study ranged in size. Older, larger juveniles (average 716 mm, range 505-947 mm) moved towards the Bay but were not detected below Liston Range. The smaller juveniles averaged 524 mm (range 485-566 mm).

Based on the best available information on the distribution of juveniles in the Delaware River, we generally expect that juveniles will occur year round in this area from RKM 78 to RKM 122.3 (RM 48.5 to RM 76). Foraging is expected to occur over soft substrates that support the benthic invertebrates that juvenile Atlantic sturgeon eat. Juveniles are thought to forage year-round with the lightest foraging during the winter. The most active foraging in these areas likely occurs in the spring to fall months. Later in the fall, larger, late-stage juveniles likely move into more saline waters in the lower Delaware River estuary (without leaving the estuary altogether, as that would indicate a transition to the subadult life stage), while the younger juveniles remain and either continue foraging, or move upstream to winter aggregation areas, such as those documented near Marcus Hook (ERC 2016, 2017, 2018, 2019, 2020a, b).

In considering effects to PBF 2, we consider whether the proposed action will have any effect on areas of soft substrate within transitional salinity zones between the river mouth and spawning sites for juvenile foraging and physiological development; therefore, we consider effects of the action on soft substrate and salinity and any change in the value of this feature in the action area. In addition, we consider whether the action will have effects on the access to this feature, temporarily or permanently. We also consider the effects of the action on the action area's ability to develop the feature over time.

In order to successfully complete their physiological development, Atlantic sturgeon must have access to a gradual gradient of salinity from freshwater to saltwater. Atlantic sturgeon move along this gradient as their tolerance to salinity increases with age. They also need enough forage to support their energy demands and growth during their transition. PBF 2 occurs from approximately RKM 78 (RM 48.5) (where the final rule describes the mouth of the river entering Delaware Bay) to approximately RKM 107.8-122.3 (RM 67-76) or the current median salt front location range. The location of the Berth at RKM 145 (RM 90) is above the median range of the salt front; however, the Federal Navigation Channel, which vessels will use to access the

Paulsboro RoRo Berth, is within PBF 2. We estimate the area of bank-to-bank critical habitat from RKM 78-122.3 (RM 48.5-76) is 37,362 acres, of which approximately 2,943 acres are within the action area (i.e. the Federal Navigation Channel between RKM 78 and 122.3 (RM 48.5 and 76)) for the proposed project. If we assume that benthic communities in the action area will be degraded to some degree by propeller wash and dredging and subtract that area from the available PBF 2 in the river, the critical habitat area between RKM 78 and 122.3 (RM 48.5 and 76) when excluding the Federal Navigation Channel amounts to 34,419 acres.

As discussed in section 8.4.1.3, propeller jets can scour several centimeters deep into the substrate. Vessel traffic within PBF 2 during operation of the Berth will be limited to the Federal Navigation Channel below RKM 122.3 (RM 76) and benthic disturbance associated with this vessel traffic could affect prey availability for foraging Atlantic sturgeon within the dredged area. The repeated disturbance that will occur due to vessel traffic during operation of the proposed Berth may permanently disturb the soft substrate and the benthic community, reducing the quality of PBF 2 within the Federal Navigation Channel.

The Philadelphia to the Sea Navigation Channel within PBF 2 consists of soft substrate; however, with thousands of deep draft vessels traveling up and down the Federal Navigation Channel, the channel bottom is also regularly impacted from prop wash. The benthic community in this area includes polychaete worms, isopods, and amphipods, which are common prey items for Atlantic sturgeon. Based on the best available information on the distribution of juveniles in the Delaware River, juveniles will mostly use the area in the spring to fall months. Late-stage juveniles may remain in fall while the younger juveniles may move to winter aggregation areas, such as those documented near Marcus Hook (ERC 2016, 2017). Thus, the Federal Navigation Channel provides PBF 2 that is suitable and valuable for conservation of the species.

It is difficult to determine the effect that this impact on PBF 2 will have for the value of PBF 2 to support the conservation of the species, particularly given that, as we note above, with thousands of deep draft vessels traveling up and down the Federal Navigation Channel, the channel bottom is regularly impacted by prop wash and accordingly, PBF2 within the channel is likely degraded. We have to consider the function of soft substrate and how it supports juvenile foraging and physiological development in relation to the salinity of the reach where these activities occur. The Federal Navigation Channel within PBF 2 provides an area where Atlantic sturgeon juveniles acclimate to increasing salinity before moving into the mesohaline zone, the polyhaline Delaware Bay, and eventually marine waters. This reduction in the amount and quality of soft bottom substrate means that, within the action area, there will be less aquatic habitat available for juvenile foraging and physiological development as juveniles transition to migrant subadults.

The vessel traffic during the operation of the Berth will negatively affect PBF 2, and will contribute to the feature's inability to improve in value in the future, as the repeated degradation of substrates by prop wash will interrupt the establishment and succession of benthic invertebrates in these areas that juvenile Atlantic sturgeon would otherwise feed on. However, the areas of the Federal Navigation Channel represents a small and non-contiguous amount of the available soft bottom substrate within the action area. Not all of these areas will be impacted at any given time. Considering these factors, as well as the naturally dynamic nature of these areas that may limit their ability to support foraging juvenile Atlantic sturgeon even if vessel traffic did not occur, the effects of vessel traffic within this small amount of available habitat on juvenile foraging or physiological development will be too small to be meaningfully measured, evaluated, or detected. Therefore, any effects to the value of PBF 2 to the conservation of the species are insignificant.

5.1.3.3 Physical and Biological Feature 3

Water absent physical barriers to passage between the river mouth and spawning sites

Water of appropriate depth and absent physical barriers to passage between the river mouth and spawning sites necessary to support: (i) Unimpeded movement of adults to and from spawning sites; (ii) Seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary; and (iii) Staging, resting, or holding of subadults or spawning condition adults, are present throughout the extent of critical habitat designated in the Delaware River; therefore, PBF 3 is present within the action area.

Water depths in the main river channels, including the Berth site, are also deep enough (e.g., at least 1.2 m (4 ft)) to ensure continuous flow in the main channel at all times during which any sturgeon life stage is present in the river. Therefore, PBF 3 overlaps with the navigation channel between RKM 78 to RKM 214.5 (RM 48.5 to 133.3) and the Berth site at RKM 145 (RM 90). Physical barriers that may impede sturgeon passage include (but are not limited to) locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc. Sturgeon need to be able to make unimpeded movements up and downstream at all life stages. Adults must be able to stage before spawning and then move to and from the river mouth to spawning sites; subadults need to be able to enter the river for foraging opportunities; and juveniles must be able to move between appropriate salinity zones, foraging areas, and overwintering sites.

While there are some impediments to sturgeon movements (i.e., piers, pilings, etc. that sturgeon maneuver around within the river) there are no permanent barriers to movement within the action area. In addition to navigating around existing structures, sturgeon movements are also impacted by gear set in the river, vessel traffic, and in-water stressors from ongoing construction projects (e.g., turbidity from dredging, sound pressure waves from pile driving, etc.). Studies have shown that even in close proximity to active dredging equipment, sturgeon pass through the area, while showing little to no sign of disturbance (Balazik *et al.* 2021, Moser and Ross 1995, Reine *et al.* 2014).

In considering effects to PBF 3, we consider whether the proposed action will have any effect on water of appropriate depth and absent physical barriers to passage (e.g., locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support: unimpeded movements of adults to and from spawning sites; seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary, and; staging, resting, or holding of subadults or spawning condition adults. We also consider whether the proposed action will affect water depth or water flow because shallow water can be a barrier to sturgeon movements, and an alteration in water flow could similarly affect the movements of sturgeon in the river, particularly early life stages that are dependent on downstream drift. Therefore, we consider effects of the action on water depth and water flow and whether the action results in barriers to passage that impede the movements of Atlantic sturgeon. We also consider whether the action will have effects on access to this feature, temporarily or permanently, and consider the effects of the action on the action area's ability to develop the feature over time.

No portion of the action area that is within critical habitat is dammed, and the movement of sturgeon is unimpeded to and from spawning sites; therefore, PBF 3 is present within the action area. Unlike some southern rivers, given the extent of tidal flow, geomorphology and naturally deep depths of the Delaware River, it is not vulnerable to natural reductions in water flow or water depth that can result in barriers to sturgeon movements. At this time, we are not aware of any anthropogenic impacts that reduce water depth or water flow in a way that impact sturgeon movements. We are not aware of any complete barriers to passage for Atlantic sturgeon in the Delaware River. That is, we do not know of any structures or conditions that prevent sturgeon from moving up- or downstream within the river. There are areas in the Delaware River critical habitat unit where sturgeon movements are affected by water quality (e.g., low DO) and noise (e.g., during pile driving at ongoing in-water construction projects); however, impacts on movements are normally temporary and/or intermittent and we expect there always to be a zone of passage through the affected river reach. Activities that overlap with the portion of the Delaware River that contains PBF 3 include the site of the proposed Berth and vessel transit routes. Here, we consider whether those activities may affect PBF 3 and, if so, whether those effects are adverse, insignificant, extremely unlikely, or entirely beneficial.

The proposed Berth involves construction to expand the existing marine terminal, dredging to create a turning basin and allow berthing, and installation of a revetment. As part of the proposed action, four dolphin structures will be constructed, and are berthing and mooring structures located independently of the existing marine terminal. The proposed dolphins will be constructed at the landward edge of the proposed berthing slip, to guide the vessels in to berth and secure them in position while loading and offloading. The width of the Delaware River at the Berth is approximately 1.03 km (0.64 mi), and the proposed Berth will not create a physical barrier to movement of sturgeon. Project activities, such as dredging and noise from construction, may cause sturgeon to temporarily avoid the active work area, but these activities are temporary and will not prevent sturgeon from accessing areas farther upstream. Dredging and pile driving activities will not occur between March 15 and June 30 in order to minimize disruption during the spawning period and will not affect the movements of mature adults to spawning sites. The width of the Navigation Channel, turning basin, and access channel for the Paulsboro RoRo Berth project will be at most 305 m (1,000 ft), whereas the total river width at the project site is approximately 1.03 km (0.64 mi). Even if a sturgeon was to completely avoid the Navigation Channel and turning basin-access channel when a vessel was maneuvering, approximately 70% of the river width would remain unaffected by such maneuvering. It should also be considered that vessel maneuvering to or from the berth is a temporally very limited (taking approximately 10 to 15 minutes per docking/undocking event) (MITAGS, 2018) and infrequent event. Anchoring of inbound ships calling on the Paulsboro RoRo Berth is not anticipated to occur. Dredging will increase water depths in the access channel and turning basin, but otherwise will not affect water depth within the Delaware River. Based on this information, effects of the proposed action to PBF 3 are too small to be meaningfully measured, detected, or evaluated; and therefore, are insignificant.

5.1.3.4 Physical and Biological Feature 4

Water with the temperature, salinity, and oxygen values that, combined, provide for dissolved oxygen values that support successful reproduction and recruitment and are within the temperature range that supports the habitat function

Water between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that combined support spawning, survival, and larval, juvenile, and subadult development and recruitment may be present throughout the extent of critical habitat designated in the Delaware River (depending on the life stage). Therefore, PBF 4 is present within the action area.

Water quality factors such as temperature, salinity and DO are interrelated environmental variables, and in a river system such as the Delaware, are constantly changing from influences of the tide, weather, season, etc. DO concentrations in water can fluctuate given a number of factors including water temperature (e.g., cold water holds more oxygen than warm water) and salinity (e.g., the amount of oxygen that can dissolve in water decreases as salinity increases). As such, DO levels that support growth and development will be different at different combinations of water temperature and salinity. Similarly, the DO levels that we would expect Atlantic sturgeon to avoid would also vary depending on the particular water temperature, salinity, and life stage. As DO tolerance changes with age, the conditions that support growth and development, including the DO levels that may be avoided, also change (82 FR 39160; August 17, 2017).

On top of natural fluctuations in water quality, a number of human activities directly affect the temperature, salinity, and oxygen values within the Delaware River (also see discussion in section 6.1.2). Water pollution, whether it be urban and rural runoff, combined sewer overflows (CSOs), accidental spills (e.g., Delaware River and Bay Oil Spill Advisory Committee 2010), or thermal plumes from nuclear generating stations (e.g., Salem and Hope Creek, section 6.3.2) impact the water quality parameters in PBF 4. Construction activity also affects water quality. Turbidity from dredging or vessel activity that affects soft substrate may decrease levels of light and impact temperature. Dredging has the potential to increase water depths and cause cooling at the bottom of the water column (i.e., deeper water receives less light). Climate change, the effects of which are discussed in section 7 of this Opinion, will likely lead to an upstream shift in the salt front resulting from rising sea levels. Increases in salinity may shift the distribution of juveniles and subadults. However, at this time, we do not have enough information to predict how climate change would affect juvenile and subadult development and recruitment.

Overall, water quality in the Delaware River has improved dramatically since the mid-20th century. In the late 1800s into the mid-1900s, water pollution still caused much of the lower

Delaware River to be anoxic in the summer and fall months (Environmental Baseline, section 6), which created a barrier for diadromous fish passage. Two major causes of the turnaround in water quality were the passage of the Federal Water Pollution Control Act in 1948 (later amended in 1972 and more commonly called the Clean Water Act) and the creation of the DRBC, a federal-interstate agency created in October 1961. The most recent Delaware River and Bay Water Quality Assessment (DRBC 2020) concluded that the location of the proposed Berth meets DRBC's water quality standard for dissolved oxygen in is a 24-hour average concentration not less than between 4.5 mg/L and 6.0 mg/L.

In considering effects to PBF 4, we consider whether the proposed action will have any effect on water, between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support: spawning; annual and interannual adult, subadult, larval, and juvenile survival; and larval, juvenile, and subadult growth, development, and recruitment. Therefore, we consider effects of the action on temperature, salinity and dissolved oxygen needs for Atlantic sturgeon spawning and recruitment. These water quality conditions are interactive and both temperature and salinity influence the DO saturation for a particular area. We also consider whether the action will have effects on the access to this feature, temporarily or permanently and consider the effects of the action on the action area's ability to develop the feature over time.

Baseline water quality in the action area is described above and in section 6.1.2. Based on this information, PBF 4 exists in the action area from RKM 214.5 (RM 133.3) downstream to RKM 78 (RM 48.5) where the Delaware River empties into the Delaware Bay. Flow, temperature, and DO are likely to be highly spatially and temporally variable throughout the action area. Resuspension of sediment during pile driving may temporarily decrease DO within 91 m (299 ft) from the shoreline but will have no effect on water temperature or salinity. Dredging will result in increased total suspended sediment within the action area, which may also decrease DO; however, the plume will cover very little of the channel and any changes in DO will be short lived because of the large volume of water that is moved during tidal flow. Dredging will not affect salinity or water temperature. The proposed action will increase vessel traffic over baseline conditions, but vessels will not alter the salinity, DO, or temperature of water in the Delaware River. Bottom water temperatures in the dredging area and construction area may decrease slightly because of increased depth, but these changes in water temperatures at the scale of the river channel would be so small they could not be meaningfully measured, detected or evaluated within the temporal and spatial variation in water temperatures of the river channel. Stormwater discharges from the upland marine terminal will be monitored under discharge limits set by the NJDEP. Discharge limits set by the state are expected to be protective of aquatic life stages, including sturgeon. Considering these factors, the effects of the project on the value of PBF 4 in the action will be too small to be meaningfully measured, evaluated, or detected. Therefore, any effects to the value of PBF 4 to the conservation of the species are insignificant.

5.1.3.5 Summary of the Effects of the Proposed Action on Atlantic sturgeon Critical Habitat

We have determined that proposed action will have effects to PBFs 1, 2, 3, and 4 that are either so small that they are not able to be meaningfully measured, detected or evaluated and, therefore, insignificant or extremely unlikely. Thus, the proposed project is not likely to adversely affect critical habitat designated for Atlantic sturgeon.

5.2 Species Likely to be Adversely Affected by the Proposed Action

5.2.1 Shortnose Sturgeon

Shortnose sturgeon are fish that occur in rivers and estuaries along the East Coast of the U.S. and Canada (SSSRT (Shortnose Sturgeon Status Review Team) 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 foraging (SSSRT (Shortnose Sturgeon Status Review Team) 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.

5.2.1.1 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 5 below.

Table 5. 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 (Kynard *et al.* 2016). 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 (Kynard *et al.* 2016, Kynard *et al.* 2012a). Shortnose sturgeon spawn in freshwater reaches of their natal rivers when water temperatures reach 9–15°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 (Dadswell *et al.* 1984, Heidt and Gilbert 1978); with temperatures above 28°C considered to be stressful. Depths used are highly variable, ranging from shallow mudflats while foraging to deep channels up to 30 m (Dadswell *et al.* 1984, Kynard 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 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) freshwater areas with minimal movement and foraging (Buckley and Kynard 1985, Dadswell 1979, Dovel *et al.* 1992, Kynard *et al.* 2016, Kynard *et al.* 2012b). 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).

5.2.1.2 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 the1880s (Kynard *et al.* 2016). 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.

5.2.1.3 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 (Shortnose Sturgeon Status Review Team) 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).

5.2.1.4 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 (Grunwald *et al.* 2008, King *et al.* 2001a, SSSRT (Shortnose Sturgeon Status Review Team) 2010, Waldman *et al.* 2002, 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

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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.

populations (Grunwald *et al.* 2008, King *et al.* 2001b, SSSRT (Shortnose Sturgeon Status Review Team) 2010, Wirgin *et al.* 2005, Wirgin *et al.* 2002). 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.

5.2.1.5 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; Dionne 2010 in Maine DMR 2010).

Kennebec/Androscoggin/Sheepscot

The estimated size of the adult population (>50cm 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) suggesting 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.* (2017b) 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; Piotrowski 2002); currently shortnose sturgeon cannot move past the Essex Dam in Lawrence, MA (RKM 46). 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 (King *et al.* 2013). 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, unpubl. 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.* 2012b). 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 were captured in the CT, 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 (Shortnose Sturgeon Status Review Team) 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, pers. comm. 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 likelyresults 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.

5.2.1.6 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 1999). 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 CT). 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 (King *et al.* 2001) 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 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 YOY and juveniles as compared to adults (Gross *et al.* 2002); that is, increasing the number of YOY 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 (National Marine Fisheries Service) 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.

5.2.1.7 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 condition 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.

5.2.1.8 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 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, the sensitivity of adults to very specific spawning cues which can result in years with no recruitment, and the impact of losses of young of the year and juveniles to population persistence and stability.

5.2.2 Atlantic Sturgeon

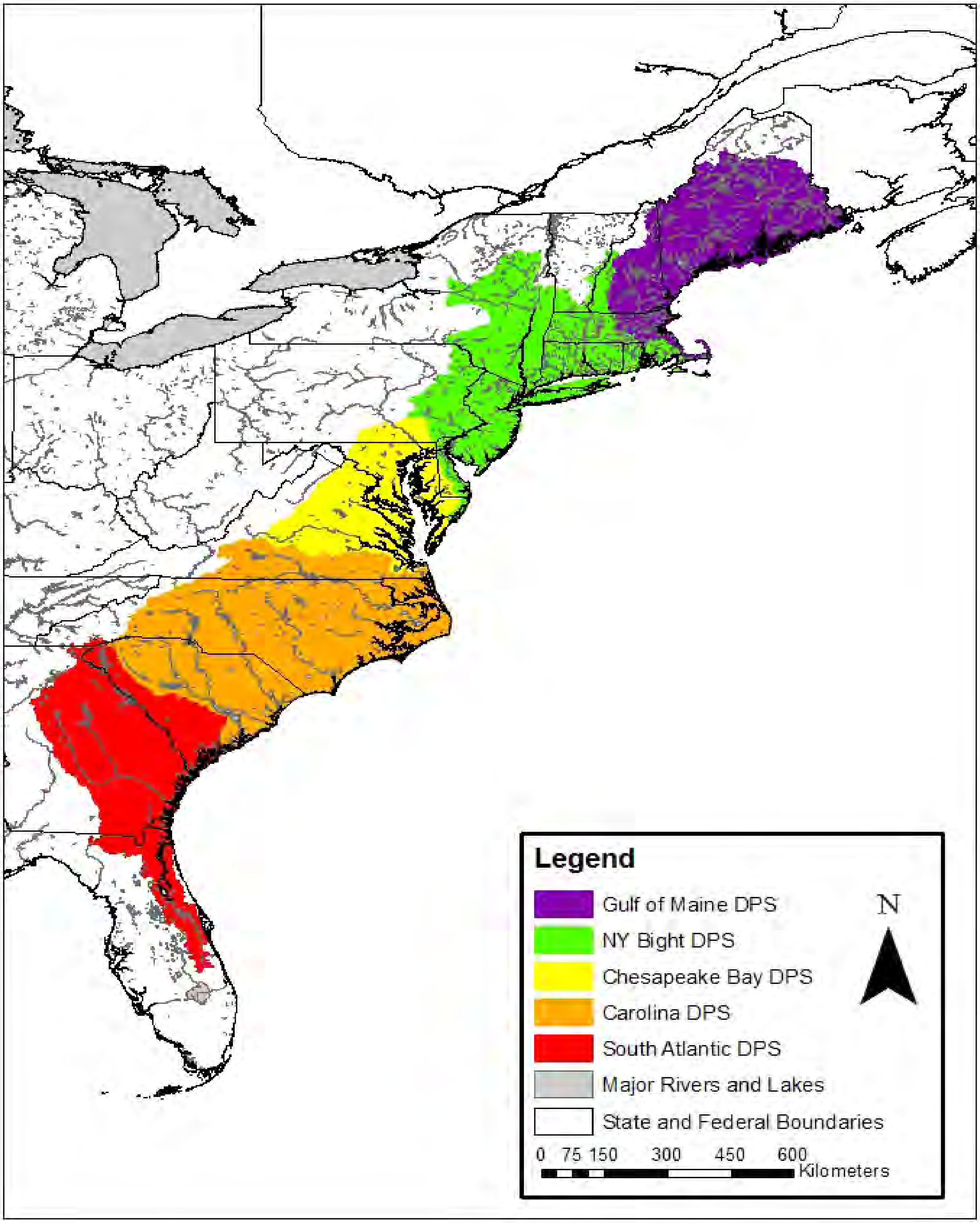
The section below describes the Atlantic sturgeon listing, provides life history information that is relevant to all DPSs of Atlantic sturgeon and then provides information specific to the status of each DPS of Atlantic sturgeon. Below, we also provide a description of which Atlantic sturgeon DPSs likely 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 (ASSRT 2007, Scott *et al.* 1988). 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 4). 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 (Wirgin *et al.* 2015a, 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 in Figure 4 below.

Figure 4. Map depicting the five Atlantic sturgeon DPSs



5.2.2.1 Life History and General Habitat Use

The Atlantic sturgeon is a long-lived (approximately 60 years), late maturing, estuarine dependent, anadromous[3] fish (ASSRT 2007). They are a relatively large fish, even amongst sturgeon species (Pikitch *et al.* 2005). They grow slowly, eventually reaching 1.5 to 1.8 m (5 to 6

[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.

ft) in length at maturity. 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 1953). 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 6 below.

Table 6. 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 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 (NMFS 2019, ASSRT 2007) 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). Based on tagging records, Atlantic sturgeon return to their natal rivers to spawn (ASSRT 2007), with spawning intervals ranging from one to five years in males (Caron *et al.* 2002, Collins *et al.* 2000a, 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 of females range from 400,000 to approximately 8 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 (Smith *et al.*, 1982; Van Eenennaam *et al.*, 1996; Van Eenennaam and Doroshov, 1998; Dadswell, 2006).

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). The eggs Incubation time for the eggs increases as water temperature decreases (Mohler 2003). At temperatures of 20° and 18° C, 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; 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 exhaust the yolk sac and become (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-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.* 2000b, Hilton *et al.* 2016). Atlantic sturgeon remain in the natal estuary for months to years before emigrating to open ocean as subadults (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 1953, 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.* 2007, 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, 2015, Breece *et al.* 2016, Dunton *et al.* 2012, 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 1953, Guilbard *et al.* 2007, Savoy 2007).

5.2.2.2 Population dynamics

A population estimate was derived from the Northeast Area Monitoring and Assessment Program (NEAMAP) trawl surveys (Kocik *et al.* 2013).[4] For this Opinion, we are relying 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 is 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 7). 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 (YOY) 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

[4] 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.

captured in a portion of the action 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 action area, and therefore a portion of the Atlantic sturgeon's range.

Table 7. 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 DPSs of Atlantic sturgeon due to a lack of long-term abundance data. The ASMFC (2017a) 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 2017a).

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. 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.

The range of all five listed DPSs extends from Canada through Cape Canaveral, Florida. All five DPSs use the action area. While a new study reflects an improvement in genetic approaches, we decided not to use the most recent published mixed stock analysis from (Kazyak *et al.* 2021), because the percentages were based on genetic sampling of Atlantic sturgeon that were encountered across the U.S. Atlantic coast and the Delaware samples are only from river-resident juveniles. Instead, we use the percentages from (Damon-Randall *et al.* 2013) for subadults and adults because their analysis is more consistent in habitat and geography to the action area defined in this biological opinion.

The proposed action takes place in 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, and thereby, in the action area, will have originated from the Delaware River and belong to the NYB DPS. Subadult and adult Atlantic sturgeon can be found throughout the range of the species; therefore, subadult and adult Atlantic sturgeon in the Delaware River and estuary would not be limited to just individuals originating from the NYB DPS. Based on mixed-stock analysis, 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; NYB 42 percent; Chesapeake Bay 24 percent; South Atlantic 20 percent; and Carolina 1 percent. These 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). This is the closest sampling effort (geographically) to the action area for which mixed stock analysis results are available. Because the genetic composition of the mixed stock changes with distance from the rivers of origin, it is appropriate to use mixed stock analysis results from the nearest sampling location. Therefore, this represents the best available information on the likely genetic makeup of individuals occurring in the action area.

We also considered information on the genetic makeup of subadults and adults captured within the Delaware River. However, we only have information on the assignment of these individuals to the river of origin and do not have a mixed stock analysis for these samples. The river assignments are very similar to the mixed stock analysis results for the Delaware Coastal sampling, with the Hudson/Delaware accounting for 55-61 percent of the fish, James River accounting for 17-18 percent, Savannah/Ogeechee/Altamaha 17-18 percent, and Kennebec 9-11 percent. The range in assignments considers the slightly different percentages calculated by treating each sample individually versus treating each fish individually (some fish were captured in more than one of the years during the three-year study). Carolina DPS origin fish have rarely been detected in samples taken in the Northeast and are not detected in either the Delaware Coast or the in-river samples noted above. However, 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, 4 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. 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 0.5 percent of the Atlantic sturgeon captured in the action area could originate from the Carolina DPS. The genetic assignments have a plus/minus 5 percent confidence interval; however, for purposes of Section 7 consultation, we have selected the reported values above, which approximate the mid-point of the range, as a reasonable indication of the likely genetic makeup of Atlantic sturgeon in the action area. These assignments and the data from which they are derived are described in detail in Damon-Randall *et al.* (2013).

Depending on life stage, sturgeon may be present in freshwater, marine and estuarine ecosystems. The action area for this biological opinion ranges from freshwater at the Berth site to marine at the mouth of the Bay. Juvenile, subadult and adult Atlantic sturgeon are tolerant of all of these conditions; however, early life stages of Atlantic sturgeon (eggs, larvae,) occur in exclusively freshwater ecosystems. As discussed below, based on telemetered movements of spawning adults, spawning occurs from April through July, from RKM 125-212 (RM 77.7-131.7). Therefore, eggs and yolk-sac larvae (YSL) could be present in appropriate spawning habitat from April through August. Post-yolk sac larvae (PYSL) could be present throughout from May through September. For information on Atlantic sturgeon distribution in freshwater ecosystems, refer to: (ASSRT 2007); 77 FR 5880 (February 6, 2012); 77 FR 5914 (February 6, 2012); (NMFS 2017d); and (ASMFC 2017a).

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, although the Hudson River population from the New York Bight DPS dominates (ASMFC 2017b, 2019, ASSRT 2007, Dadswell 2006, Dovel and Berggren 1983, Dunton *et al.* 2012, Dunton *et al.* 2015, Dunton *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.* 2015b, Wirgin *et al.* 2012).

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, Wirgin *et al.* 2015a, 2015b). However, they are not restricted to these depths and excursions into deeper (e.g., 75 m) 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 *et al.* 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).

Water temperature plays a 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 2017c, 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.* 2012b, Breece *et al.* 2013, Dovel and Berggren 1983, Greene *et al.* 2009, Hatin *et al.* 2002, Ingram *et al.* 2019, Smith 1985, Smith *et al.* 1982).

5.2.2.3 Status

In 2022, pursuant to Section 4(c)(2)(A) of the ESA, we released the 5-year review for the NYB DPS, CB DPS, and GOM DPS of Atlantic sturgeon. As part of the 5-year review, we are required to consider new information that became available since the New York Bight DPS of Atlantic sturgeon was listed as endangered in February 2012. We reviewed and considered new information for the New York Bight DPS, specifically, as well as other new information for Atlantic sturgeon generally because there is still a relatively limited amount of DPS-specific information. In addition to previously available information, this Opinion includes updates from new information that has become available since the ESA-listing and critical habitat designation for the NYB DPS, and is considered the best available scientific information. The complete 5-year review for the NYB DPS, is 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.

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 specific occupied areas designated as critical habitat for Atlantic sturgeon (NMFS 2017a, NMFS (National Marine Fisheries Service) 2017). 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 placed a 20-40 year moratorium on a coastwide basis to allow 20 consecutive cohorts of females to reach sexual maturity and spawn, which will facilitate restoration of the age structure. The 20 to 40-year moratorium was put in place 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. A first-of-its-kind climate vulnerability assessment, conducted on 82 fish and invertebrate species in the Northeast U.S. Shelf, concluded that Atlantic sturgeon from all five DPSs were among the most vulnerable species to global climate change (Hare *et al.* 2016b).

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 (Table 7). 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).

5.2.2.4 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.

5.2.2.5 Recovery Goals

Recovery Plans have not been drafted for any of the Atlantic sturgeon 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.

5.2.2.6 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 the Cocheco and Salmon Falls rivers) rivers. Spawning has been documented in the Kennebec River. During the study period of 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 (NMFS 2018).

Studies are on-going to determine whether Atlantic sturgeon are spawning in these rivers. Atlantic sturgeons that spawn elsewhere continue to use habitats within all of these rivers as part of their overall marine range (ASSRT 2007). 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).

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 (Atlantic States Marine Fisheries Commission) 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, ME (ASMFC (Atlantic States Marine Fisheries Commission) 2007, NMFS (National Marine Fisheries Service) and U.S. FWS (U.S. Fish and Wildlife Service) 1998); and (4) 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.

Several 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 17^{th} 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. Nevertheless, mortalities associated with bycatch in fisheries occurring in state and federal waters still occurs. 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). Subadults and adults are killed as a result of bycatch in fisheries authorized under Northeast Fishery Management Plans (FMPs). At this time, we are not able to quantify the impacts from this and other threats or estimate the number of individuals killed as a result of anthropogenic threats. Habitat disturbance and direct mortality from anthropogenic sources are the primary concerns.

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 effects to habitat.

Connectivity is disrupted by the presence of dams on some rivers in the Gulf of Maine region, including the Penobscot and Merrimack Rivers. While there are also dams on the Kennebec, Androscoggin, and Saco 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 effects 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 *et al.* (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[5], which measures how many adults contributed to producing the next generation based on genetic determinations of parentage from the offspring. Effective

[5] 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.

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 occur in Kennebec and may occur Androscoggin. Spawning may be occurring 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. Detections of acoustically-tagged sturgeon indicate that both adult and subadult Atlantic sturgeon use the area for foraging and come back to the area year after year (Little 2013, Novak *et al.* 2017). Some sturgeon also overwinter in Saco Bay (Hylton *et al.* 2018, Little 2013) 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 2013), 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).

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 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). Thus, a significant number of the GOM 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).

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.

5.2.2.7 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, MA to the Delaware-Maryland border on Fenwick Island. Within this range, Atlantic sturgeon historically spawned in the Connecticut, Delaware, Hudson, and Taunton Rivers (ASSRT 2007, Murawski and Pacheco 1977, Secor and Niklitschek 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). 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).

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. 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.

There are no abundance estimates for the entire NYB DPS or for the entirety of either the Hudson or Delaware River spawning populations. There are, however, some abundance estimates for specific life stages (e.g., natal juvenile abundance, spawning run abundance, and effective population size). 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 percent CRI = 310-745). White *et al.* (in press) recently estimated the number of adults (Ns) 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.* (in press) 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.* (in press) concluded, 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.

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 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 percent CI=171.7-230.7; (O'Leary *et al.* 2014)) and 156 (95 percent 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 percent CI=74.7-186.1) (O'Leary *et al.* 2014) and 40 (95 percent CI=34.7-46.2), respectively (Waldman *et al.* 2019).

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 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 (Wirgin *et al.* 2015a, 2015b). The Waldman *et al.* (2019) calculations of maximum effective population size, and comparison of these to four other spawning populations outside of the NYB 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.

As described above, the CT DEEP determined that very few adults contributed to the juveniles found in the Connecticut River in 2014. Based on the genetic analysis of 45 of the captured juveniles, the effective population size for the Connecticut River was estimated to be 2.4 sturgeon (Savoy *et al.* 2017). As noted above, the CT DEEP is further investigating the presence of and origins for a spawning population in the Connecticut River.

For 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 because we do not have subadult and adult mixed stock analysis for in river. Therefore, we concluded that subadult and adult abundance of the New York Bight DPS was 34,566 sturgeon (NMFS 2013). 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.

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). However, as noted above, the Commission noted considerable uncertainty related to trend data. 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 abundance of the New York Bight DPS or otherwise quantify the trend in abundance because of the limited available information

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. In the Hudson River, sources of potential mortality include vessel strikes and entrainment in dredges. Individuals are also exposed to effects of bridge construction (including the replacement of the Tappan Zee Bridge). Impingement at water intakes, including the Danskammer, Roseton and Indian Point power plants also occurs. Recent information from surveys of juveniles indicates that the number of young Atlantic sturgeon in the Hudson River is increasing compared to recent years, but is still low compared to the 1970s. There is currently not enough information regarding any life stage to establish a trend for the entire Hudson River population.

Several 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. A dredged navigation channel extends from Trenton seaward through the tidal river (Brundage and O'Herron 2009), and the river receives significant shipping traffic. Vessel strikes have been identified as a threat in the Hudson and Delaware Rivers. Similar to the Hudson River, there is currently not enough information to determine a population trend for the Delaware River population.

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 (2018, Dunton *et al.* 2012, 2019, Waldman *et al.* 2013, Wirgin *et al.* 2015a). 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 1 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[6] before its tag popped up, about 7 months after being tagged. Collectively, all of the tagged sturgeon occurred in marine and estuarine

[6] 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.

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 York Bight DPS Atlantic sturgeon, particularly in the spring through early fall; and, (3) information to better assess effects 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, the available information suggests that the straying rate is high between these rivers. There is uncertainty related to trends in abundance for the New York Bight DPS (ASMFC 2017b). Some of the impact 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 effects 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. 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. As evidenced by the studies of Hare *et al.* (2016a) 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.* 2004b). Currently available estimates indicate that at least 4 percent of adults may be killed as a result of bycatch in fisheries authorized under Northeast FMPs. Based on mixed stock analysis results presented by Wirgin and King (2011). 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. 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 effects 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). 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 exposure to contaminants.

Vessel strikes occur in the Delaware River and Bay. One-hundred and one mortalities believed to be the result of vessel strikes were documented in the Delaware River from 2005 to 2019, and at least 64 of these fish were large adults and subadults. 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, 138 sturgeon carcasses were observed on the Hudson River and reported to the NYSDEC between 2007 and 2015. Of these, 69 are suspected of having been killed by vessel strike. 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.

Studies have shown that to rebuild, Atlantic sturgeon can only sustain low levels of anthropogenic mortality (ASMFC 2007, Boreman 1997, Brown *et al.* 2012, Kahnle *et al.* 2007). There are no empirical abundance estimates of the number of Atlantic sturgeon in the New York Bight DPS. We determined that the New York Bight 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.

5.2.2.8 Chesapeake Bay DPS of Atlantic sturgeon

The Chesapeake Bay (CB) 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 CB DPS extends from Hamilton Inlet, Labrador, Canada, to Cape Canaveral, Florida. The riverine range of the CB DPS and the adjacent portion of the marine range are shown in Figure 4. 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, 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.* 2017, Balazik *et al.*

2012b, 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 CB 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). Therefore, age at maturity for Atlantic sturgeon of the CB DPS likely falls within these values.

Several threats play a role in shaping the current status of CB 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 *et al.* 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 CB DPS, especially since the Chesapeake Bay system is vulnerable to the effects 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 the some areas of the Bay's health, the ecosystem remains in poor condition. In 2020, 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). 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 modest gain in the health score was due to a relatively stable adult blue crab population, promising results from oyster reef restoration, less nitrogen and phosphorous in the water, a smaller dead zone, and improvements in water clarity as highlighted below:

- Monitoring data indicated that the 2020 dead zone was the seventh smallest in the past 35 years;
- Three decades of data recently reviewed by scientists at the Chesapeake Bay Program revealed that, although waters in the Bay may still look cloudy to the human eye, light attenuation trends are improving—in other words, more light is penetrating through the water due to changes in the types of particles in the water that block sunlight;
- Nitrogen and phosphorus pollution from the Susquehanna and Potomac Rivers was well below the 10-year average, partially a reflection of below-average precipitation, From 2019-2020, Maryland and Virginia completed 343 and 21 acres of oyster reef restoration projects in the Little Choptank River and the Eastern Branch of the Elizabeth River, respectively; and
- Although the most recent population estimate for blue crab declined slightly, it remained within the bounds fishery scientists consider healthy(Chesapeake Bay Foundation 2020).

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 have 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 CB 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 abundance estimates for the entire Chesapeake Bay DPS or for the spawning populations in the James River or the Nanticoke River system. Spawning for the CB DPS is known to occur in only the James and Pamunkey Rivers and in Nanticoke River system. Spawning may be occurring in other rivers, such as the York, and 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). 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.

There are 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 2017b); 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.* 2017). 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).

Some of the impact from the threats that facilitated the decline of the CB 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 CB DPS of Atlantic sturgeon. Of the 35 percent of Atlantic sturgeon incidentally caught in the Bay of Fundy, about one percent were CB 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 CB 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.

5.2.2.9 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 4. 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 YOY 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. 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 8. Major rivers, tributaries, and sounds within the range 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.

5.2.2.10 South Atlantic DPS of Atlantic sturgeon

The South Atlantic (SA) 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 SA DPS extends from the Hamilton Inlet, Labrador, Canada, to Cape Canaveral, Florida. The riverine range of the SA DPS and the adjacent portion of the marine range are shown in Figure 4.

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 YOY were observed, or mature adults were present, in freshwater portions of a system (Table 9). 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 SA DPS likely use other river systems than those listed here for their specific life functions.

Table 9. Major river, tributaries, and sounds within the range of the SA 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 SA DPSs, it is likely that some of the historical 8,000 fish would be attributed to both the Carolina DPS and SA 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 SA 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 SA 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 SA 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 SA 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 SA 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 SA DPS, particularly during times of high water temperatures, which increase the detrimental effects on Atlantic sturgeon habitat. Interbasin water transfers and climate change threaten to exacerbate existing water quality issues. Bycatch also contributes to the SA 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 SA 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 SA 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 Water Quality

6.1.2.1 Salinity

Salinity affects the fitness and distribution of sturgeon age classes within the Delaware Bay and the tidal Delaware River. Sturgeon 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.

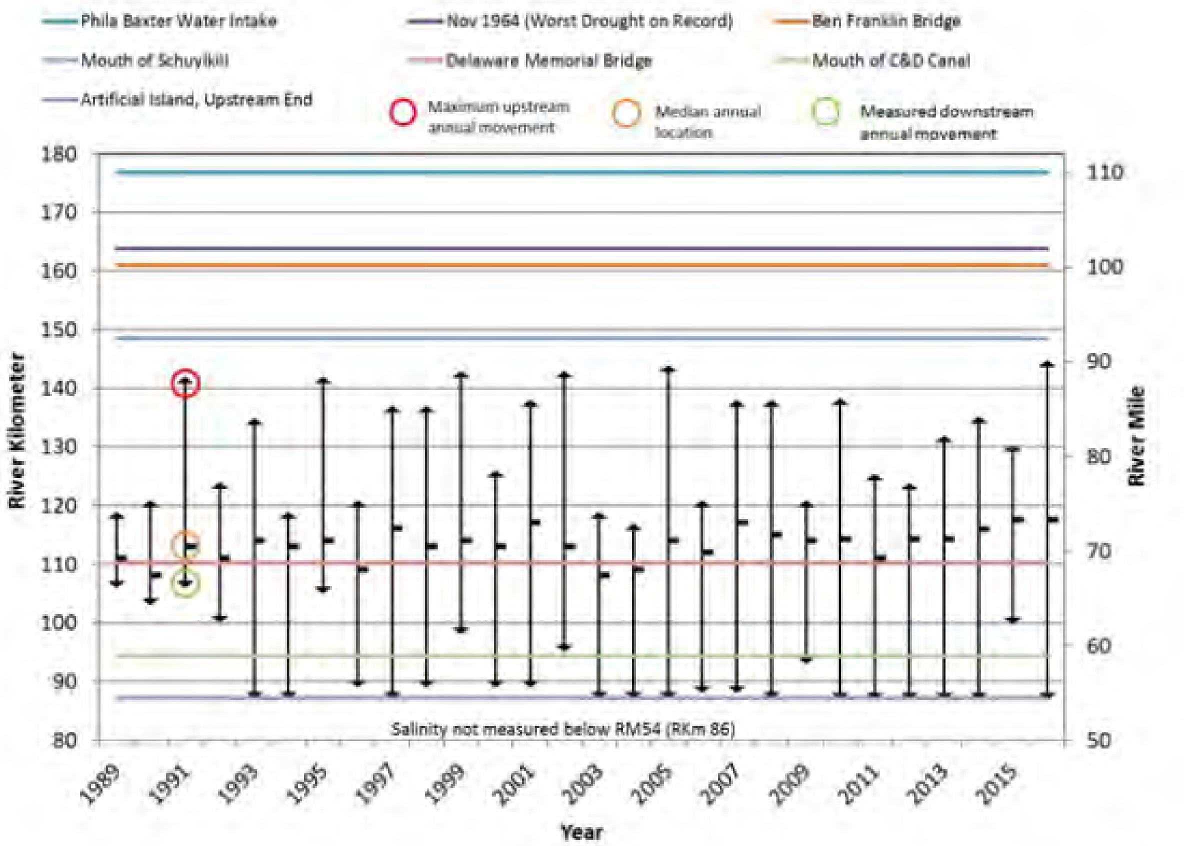
The distribution of salinity in the Delaware estuary exhibits significant variability on both spatial and temporal scales. At any given time, the salinity levels reflect the opposing influences of freshwater inflow from upstream non-tidal portion of the Delaware River, tributaries, and precipitation 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, but calculations show that current median salt front location range from RKM 107.8 and 122.3 (RM 67 and 76) (DRBC https://www.nj.gov/drbc/programs/flow/salt-front.html). The Delaware River Basin Commission calculated the 2021 median monthly salt front location between RKM 122 (RM 76) (September) and RKM 108 (RM 67) (April) just below the Delaware Memorial Bridge (2022). Seasonal and annual differences are much less pronounced today than they were before 1969 when the salt front was further downstream during spring and farther upstream during fall (DRBC 2019). Flow management releases 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. Therefore, since 1970, low-flow values that once occurred 10% of the time now occur only 1% of the time.

The salt front shifts seasonally with its locations usually being further downstream during spring months and farther upstream during fall months (DRBC 2019). 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 2019). 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 2019).

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. However, older life stages of Atlantic sturgeon are more likely to be present in the action area. A study by Breece *et al.* (2013) demonstrates that adult Atlantic sturgeon are most likely to be within ±30 km of the salt front.

Figure 5. 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)



6.1.2.2 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) in the Delaware Estuary and are most likely to occur during summer months. The Delaware Estuary has historically been plagued by hypoxic conditions (severe depression of DO) that results from the discharge of raw and poorly treated wastewater. 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 10). 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 10. Mean monthy 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., shortnose sturgeon eggs and yolk-sac larvae are not likely to occur there because spawning occurs at and upstream of Trenton, NJ, which is more than 70 km upstream of the Berth) (NMFS 2014).

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 (Dadswell *et al.* 1984). 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 Deepwater Point, New Jersey, (approximately 30.6 km (19 mi) below the Berth 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 salinity and the best available information on spawning locations, eggs are not likely to be at the Berth site. Distribution of adult, juvenile, and shortnose sturgeon larvae 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. Thus, spawning does not occur within the action area.

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, although sturgeon have been reported on the spawning grounds at water temperatures as high as 18ºC.

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 sack 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, 2015). There are only two records of shortnose sturgeon larvae being collected in the upper tidal Delaware River, between RKM 204-212, 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. However, 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 to 76), which is below the project site for the Berth. Based on the information above, shortnose sturgeon early life stages may be present as far downstream as the project site.

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 finding 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 2017). 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 (Error! Reference source not found.), juvenile shortnose sturgeon were detected throughout the year with fewer detections in August through September and January.

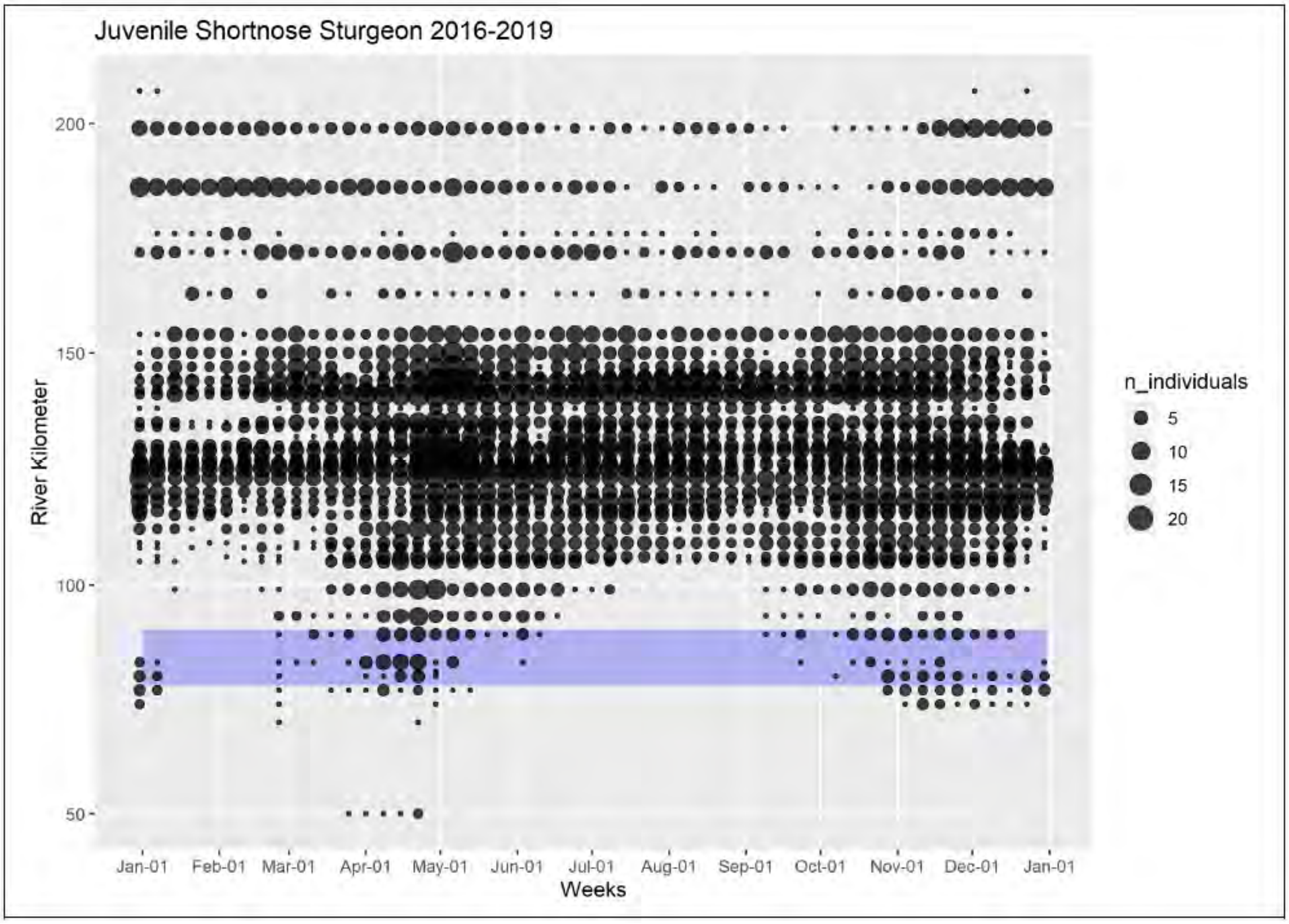


Figure 5. Distribution of Juvenile Shortnose Sturgeon in the tidal Delaware River, by week, all years combined

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 site.

By the time water temperatures have reached 10°C, typically by mid-November[7], most adult sturgeon have returned to the overwintering grounds around Duck Island and Newbold Island.

[7] 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).

These patterns are generally supported by the movement of radio-tagged fish in the region 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 Aberdeen (1994) 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 (Error! Reference source not found.).

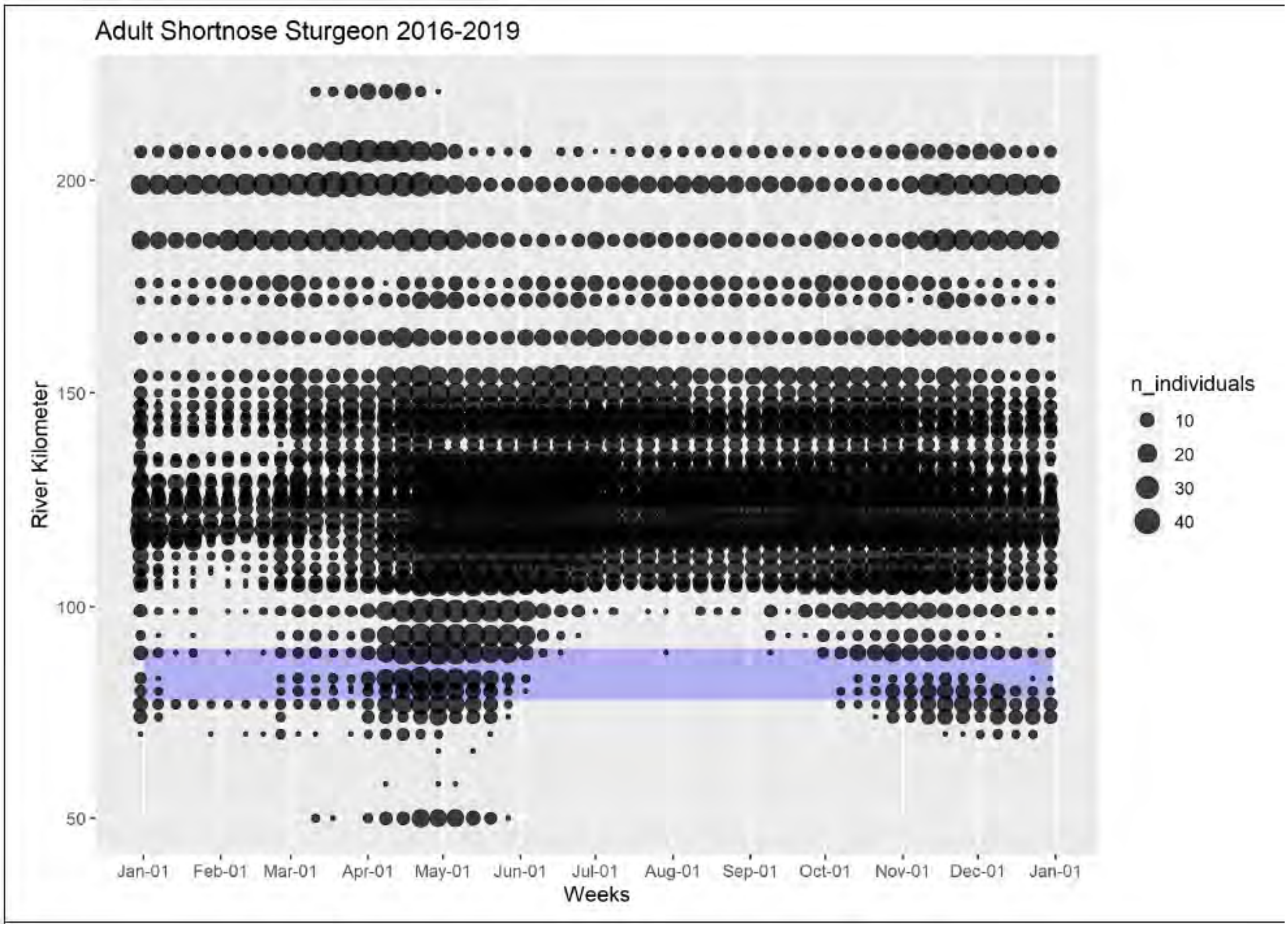


Figure 6. Distribution of Adult Shortnose Sturgeon in the tidal Delaware River, by week, all years combined

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 just 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, NJ, a distance of almost 220 km (136.7 mi) (Hilton *et al.* 2016, Simpson 2008). 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, PA). However, based on tagging and tracking studies, current Atlantic sturgeon spawning may occur upstream of the salt front over hard bottom substrate between Claymont, DE/Marcus Hook, PA (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.

Based on previous studies, 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. Therefore, mobile early life stages, such as PYSL, may occur at the Berth location because they are free-swimming and supplementary habitat is present immediately upriver and downriver of the closest known spawning area is approximately 7 km (4.3 mi) downstream.

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). Post yolk-sac larvae (stage when the larva has exhausted the yolk-sac and is free moving) initiated downstream movement in the simulated river drift that lasted for 6-12 days, which, in the Hudson River, would be sufficient to transport the larvae from spawning to rearing areas without entering salt water (Kynard and Horgan, 2002).

There is no information about post yolk-sac larvae distribution and presence in the Delaware River; however, post yolk-sac larvae are believed to drift with currents downstream to areas immediately above the salt front where they settle to feed and grow (Kynard and Horgan 2002), but they are also free-swimming and capable of accessing habitat upstream. Thus, post yolk sac larvae may occur in the river by the project site if Atlantic sturgeon spawn in reaches upstream of the Paulsboro Port. Based on this information, as well as what is known about post yolk-sac larvae, Atlantic sturgeon early life stages, may be present in the river near Paulsboro where the Berth will be located.

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, NJ. 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. 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, it is likely that YOY occur within the action area.

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 (Simpson, 2008; Calvo *et al.*, 2010) as well as near Artificial Island (Simpson 2008). Brundage *et al*. (2014), 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 young of the year (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 (where pile driving and dredging will occur) throughout the year, based on acoustic detections at receivers in the tidal portion of the Delaware River (Figure 8).

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; Brundage et al., 2014; Hale et al., 2016).

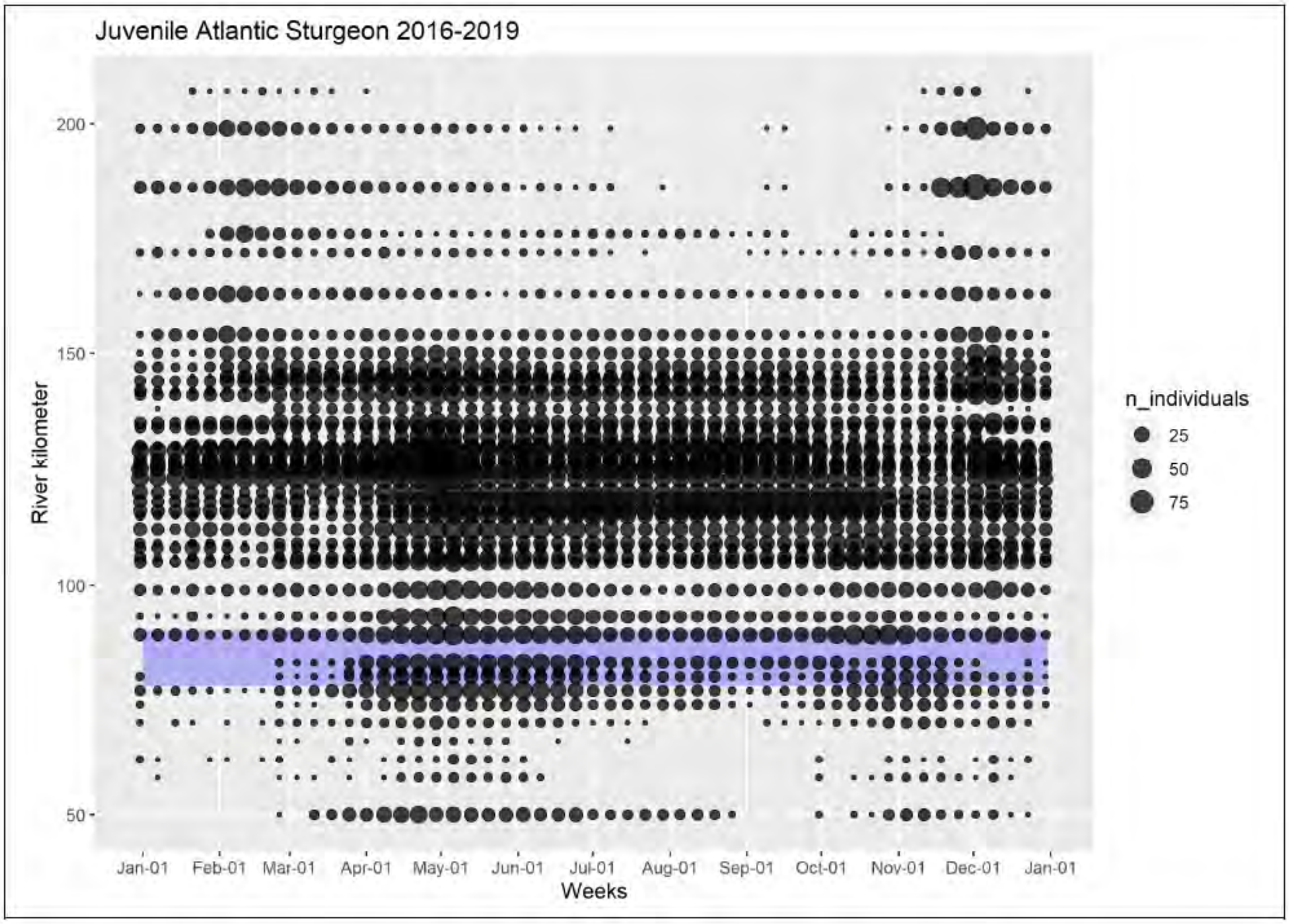


Figure 7. Distribution of Juvenile Atlantic Sturgeon in the tidal Delaware River, by week, all years combined

Adults and Subadults

Adult and subadult (non-natal late stage juveniles) 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 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) and Bay are used by sturgeon from multiple DPSs. Genetic studies show that the majority of sturgeon are assigned to the Delaware River (NYB DPS) population; however, samples were only taken from river-resident juvenile fish, which could result in an overestimate of Delaware River fish (Kazyak *et al.* 2021). Kazyak (2021) notes that expanded genetic sampling that include additional populations that are not currently represented will improve inferences from mixed-stock analyses. However, characterizing these populations is not likely to change the broad patterns observed in the Kayzak (2021) study, because individuals from under represented populations would be assigned to the most similar population in the baseline, which are likely in close proximity and part of the same DPS.

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.*, 1997; 1999; Brundage and O'Herron, 2009; Brundage and O'Herron in Calvo *et al.*, 2010).

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).

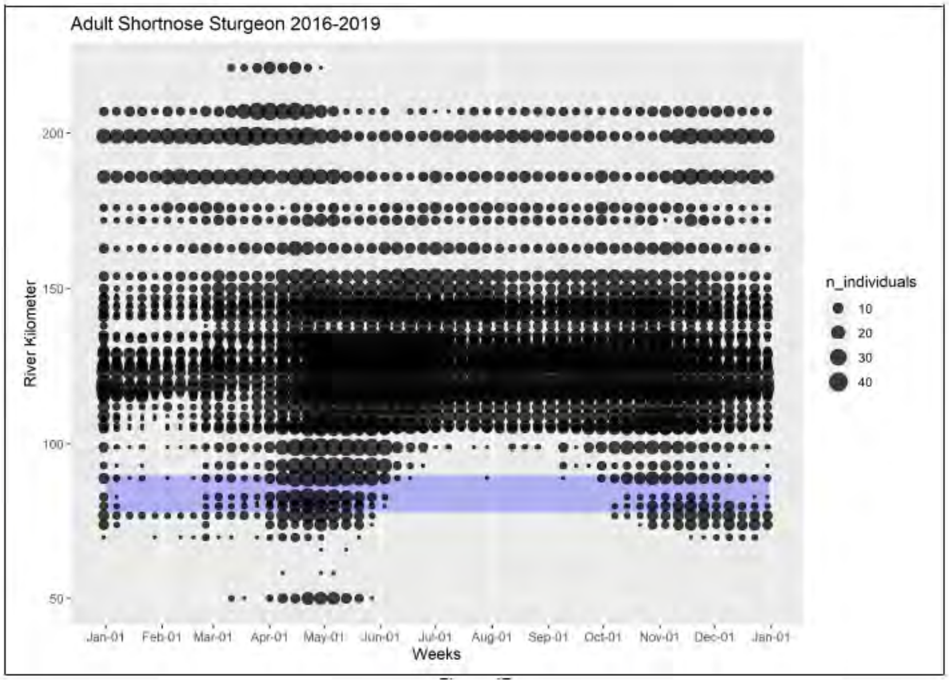


Figure 8. Distribution of Adult Atlantic Sturgeon in the tidal Delaware River, by week, all years combined

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 uses 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).

6.2.2.2 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; however, adults and subadults are present year round with lower occurrences during winter months. Migrating adults belong to the New York Bight DPS, but subadults and non-mature adults may belong to multiple DPSs.

6.3 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.

6.3.1 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.

6.3.1.1 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.

6.3.1.2 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 10).

Figure 10. Delaware River main channel deepening project

6.3.1.3 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).

6.3.1.4 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). Tables 11 and 12 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 11. 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 Marine Terminal)	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 – December 31 (Cutterhead)

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	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 12. 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

6.3.1.5 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).

6.3.2 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 (NMFS 2015).

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, and the consultation is ongoing. Therefore, we rely on the ITS of the 2014 biological opinion.

As described in Table 13 through Table 16 below, the ITS of the Salem and Hope Creek Generation Stations 2014 biological opinion exempts take (injured, killed, capture or collected) of 26 shortnose sturgeon, 500 Atlantic sturgeon, and 5 loggerhead, 1 green, and 2 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 (NMFS 2014).

As explained in the 2014 biological opinion, we also determined that the IBMWP, required by the NJPDES permit issued to PSEG for the operation of Salem 1 and 2, including the bay-wide trawl survey and beach seine sampling, is an interrelated activity (another activity that is caused by the proposed action). Thus, in the Effects of the Action section, we considered the effects of the IBMWP. We estimated that the continuation of the bottom trawl survey will result in the non-lethal capture of 9 shortnose sturgeon, 11 Atlantic sturgeon (6 NYB, 2 CB, and 3 SA, GOM or Carolina DPS) and 5 sea turtles (4 loggerheads and 1 Kemp's ridley or green). We also expect the beach seine survey to result in the non-lethal capture of one Atlantic sturgeon (likely NYB DPS origin) and one shortnose sturgeon. 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 13. Salem and HCGS - Impingement or Collection of Shortnose Sturgeon at the Trash Bars.

Salem Unit 1	**Salem Unit 2**	**Total Unit 1 and 2**
12 (10 dead, 5 due to impingement)	14 (12 dead, 6 due to impingement)	26 (22 dead, 11 due to impingement)

Table 14. Salem and HCGS - Impingement or Collection of Atlantic Sturgeon at the Trash Bars.

Age Class and DPS	**Salem Unit 1**	**Salem Unit 2**	**Total Unit 1 and 2**
All age classes and DPSs combined	92 (28 dead, 8 due to impingement)	108 (33 dead, 10 due to impingement)	200 (61 dead, 18 due to impingement)
Juveniles (NYB DPS)	88 (27 dead, 7 due to impingement)	104 (32 dead, 9 due to impingement)	192 (59 dead, 16 due to impingement)
Subadult or adult TOTAL:	4 (1 dead due to impingement)	4 (1 dead due to impingement)	8 (2 dead due to impingement)
Sub adult or adult NYB DPS	3 (1 dead due to impingement)	3 (1 due to impingement)	6 (2 dead due to impingement)
Sub adult or adult CB DPS Subadult or adult SA DPS Subadult or adult GOM DPS Subadult or adult Carolina DPS	1 dead or alive from either the CB, SA, GOM or Carolina DPS	1 dead or alive from either the CB, SA, GOM and/or Carolina DPS	Total of 2 from the CB, SA, GOM and/or Carolina DPS

Table 15. Salem and HCGS - Impingement/Collection of Atlantic Sturgeon at the Traveling Screens.

DPS	**Salem Unit 1**	**Salem Unit 2**	**Total Units 1 and 2**
NYB DPS	138 (12 injury or mortality)	162 (14 injury or mortality)	300 (26 injury or mortality)

Table 16. Salem and HCGS - Impingement/Collection of Sea Turtles at the Trash Bars.

Sea Turtle Species	**Salem Unit 1**	**Salem Unit 2**
Loggerhead	4 (1 dead)	5 (1 dead)
Green	One at Unit 1 or Unit 2 (alive or dead)	
Kemp's Ridley	2 (1 dead)	2 (dead)

6.3.3 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 2017b). 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) [8]. Four of these are likely to belong to the NYB DPS, one to CB DPS, and one from either SA DPS or GOM DPS[9]. 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 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

[8] 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.

[9] 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).

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 USACD NLAA determination.

6.3.4 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.[10] 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 (Figure 11), located 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.

[10] 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). Consultation is currently ongoing.

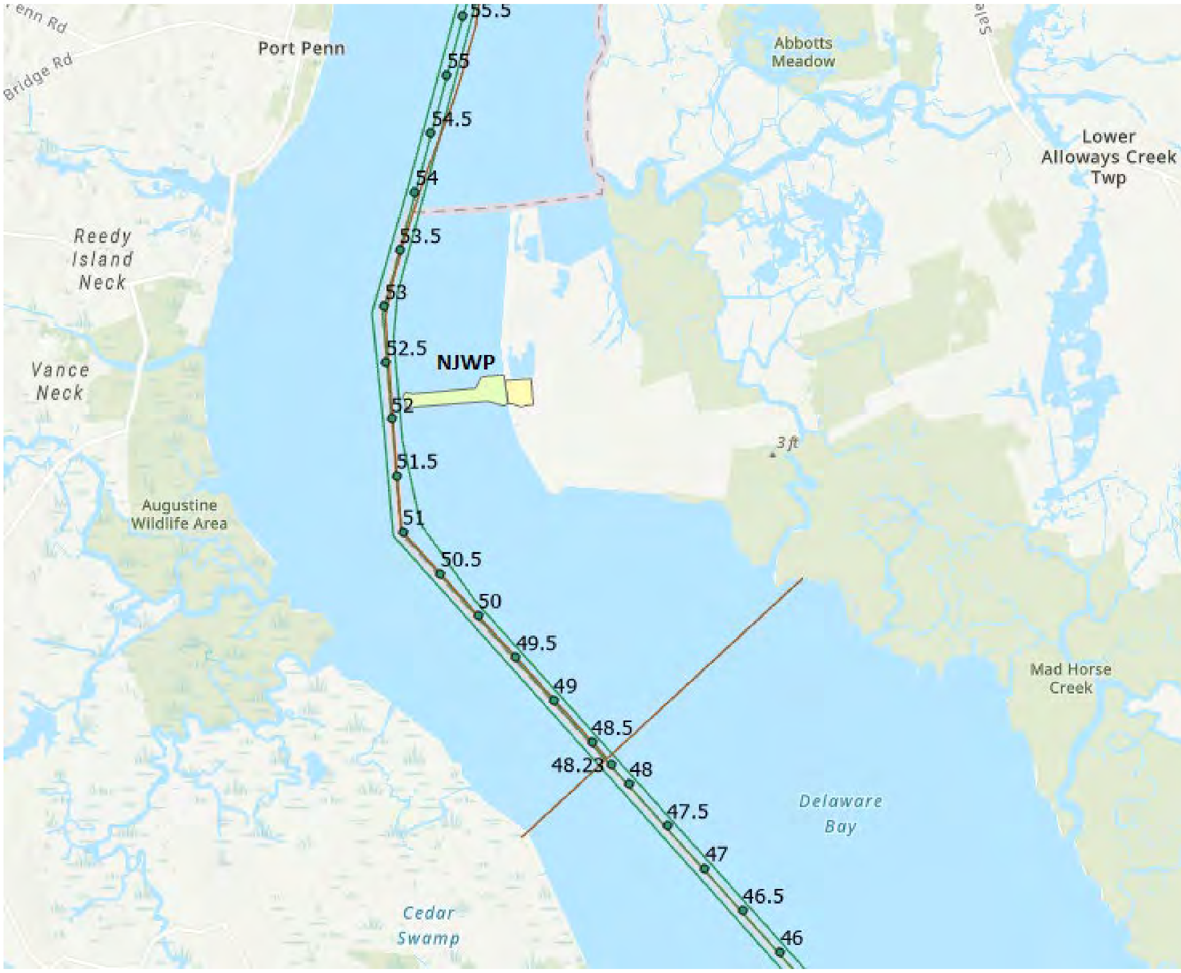


Figure 11. New Jersey Wind Port Development Boundary. The line across the channel is the location of the Delaware River mouth.

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[11]. 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[12]

6.3.5 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).

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

[11] 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.

[12] 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).

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 one (1) shortnose sturgeon and two (2) Atlantic sturgeon. The shortnose sturgeon may be a juvenile or an adult. The Atlantic sturgeon will be either juveniles or adults or one of each of the NYB DPS. Finally, we expect up to 54 lethal vessel strikes during operation of the Port[13]. Of these:

- Up to 4 shortnose sturgeon juveniles, adults, or mix of the two
- Up to 10 juvenile Atlantic sturgeon from NYB DPS
- Up to 23 adult Atlantic sturgeon from NYB DPS
- Up to 7 adult Atlantic sturgeon from CB DPS
- Up to 7 adult Atlantic sturgeon from SA DPS
- Up to 3 adult Atlantic sturgeon from GOM DPS[14]

Table 17. Comparison of Atlantic Sturgeon Takes from Hope Creek, Edgemoor, and DRP

Project	Life	Trips	Project Life Takes (Fox)	Project Life Takes (Balazik)	Annual Takes (Fox)	Annual Takes (Balazik)
Hope Creek	25	32,000	249.60	38.4 *	9.98	1.54
Edgemoor	50	35,400	276.12	42.48 *	5.52	0.85
DRP	30	5,460	42.59	6.55 *	1.42	0.22

[13] 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 276 takes of Atlantic sturgeon over 50 years or 5.5 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.

[14] 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).

6.4 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.

6.4.1 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 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[15] 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 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. 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 project may affect but is not likely to adversely affect Atlantic sturgeon or Atlantic sturgeon critical habitat.

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15 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.

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. The effects of vessels (private and commercial) in the action area are further considered in section 6.7.3.1.

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.

6.5 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[16]. 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 18 and Table 19). However, many research activities include a larger area of the Atlantic Ocean, and the requested take did not always specify the waters where take would occur. Thus, some of the requested 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 18. 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[17] - 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

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

[17] 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.

Permittee	File #	Project	Area	Shortnose Sturgeon Takes	Research Timeframe
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) Incidental mortality - 1 adult/sub-adult[18] Non-lethal (annually) - 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.		Lethal Incidental mortality - 1 adult (no more than 2 for 10 yr permit period) - 1 juvenile (no more than 2 for 10 yr permit period) Non-lethal - 10 adult - 65 juvenile	10 Years, 01/28/2021 to 01/31/2031

Table 19. 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 Massachusetts south to the North Carolina-South Carolina border. Part B: U.S. Atlantic waters off North Carolina, south to the border of Georgia and Florida	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 New York, New Jersey, Delaware, and Connecticut 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	10 years, 02/27/2016 to 03/31/2027

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

Permittee	File #	Project	Area	Atlantic Sturgeon Takes	Research Timeframe
				- 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	
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 endangered 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

6.5.1 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. We issued a biological opinion for the permit on June 19, 2020 (NMFS 2020).

Table 20. 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

6.6 State or Private Actions in the Action Area

6.6.1 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[19]. 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.

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-

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[19] 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.

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.[20] 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 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

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

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 (Atlantic States Marine Fisheries Commission) 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.

6.7 Other Impacts of Human Activities in the Action Area

6.7.1 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. Routine discharges and fuel leaks from commercial and recreational vessels release hydrocarbon-based pollutants into the waters of the Delaware River and Bay.

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 (Varanasi 1992). 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.

6.7.2 Private and Commercial Vessel Operations

The Delaware River Basin port system is one of the largest in the US (Altiok *et al.* 2012). We have identified 11 major ports with over 39 terminals within the Delaware River. 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 supporting 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). Further, high volume of vessel traffic increases the risk of oil spills and leakage (Delaware River and Bay Oil Spill Advisory Committee 2010), which may detrimentally impact Atlantic sturgeon critical habitat as well as individual sturgeon.

6.7.3 Vessel Activity

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 risk of vessel strike to shortnose and Atlantic sturgeon.

6.7.3.1 Vessel Activity in the Project Area

The area between the proposed Berth and the Federal Navigation Channel does not currently have a maintained navigation channel and very little, if any, vessel disturbance occurs within the proposed dredging footprint. Thus, the river between the Federal Navigation Channel and the Berth provides a foraging area and a passageway for spawning migrations where movement is uninterrupted by maintained vessel infrastructure. However, the proposed Berth will be integrated with the existing Paulsboro Marine Terminal, which was recently constructed. The access channel to the existing deep-water berths at the Paulsboro Marine Terminal is present just upstream of and adjacent to the Project Area. This portion of 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 12). 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).

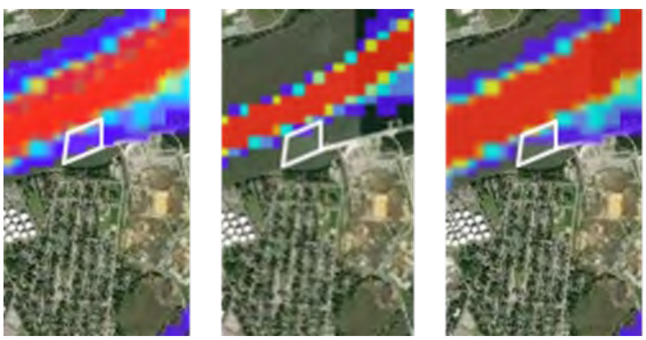

Figure 12. Vessel density in the area (outlined) where project vessels will operate during construction and operation of the proposed Paulsboro Berth. Vessel activity is represented as a number of vessels transecting each 100 x 100 square meter cell in a grid. Blue shades represent fewer vessels while shades of yellow and red represent areas of increased vessel density. The highest density of vessels occurs in the navigation channel.

6.7.3.2 Vessel Activity within 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 publishes data on waterborne traffic movements involving the transport of goods on navigable waters of the U.S. (https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center-2/WCSC-Waterborne-Commerce/). The data includes both self-propelled and non-self-propelled vessels but 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., 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 Philadelphia to the Sea Federal Navigation Channel in the Delaware River.

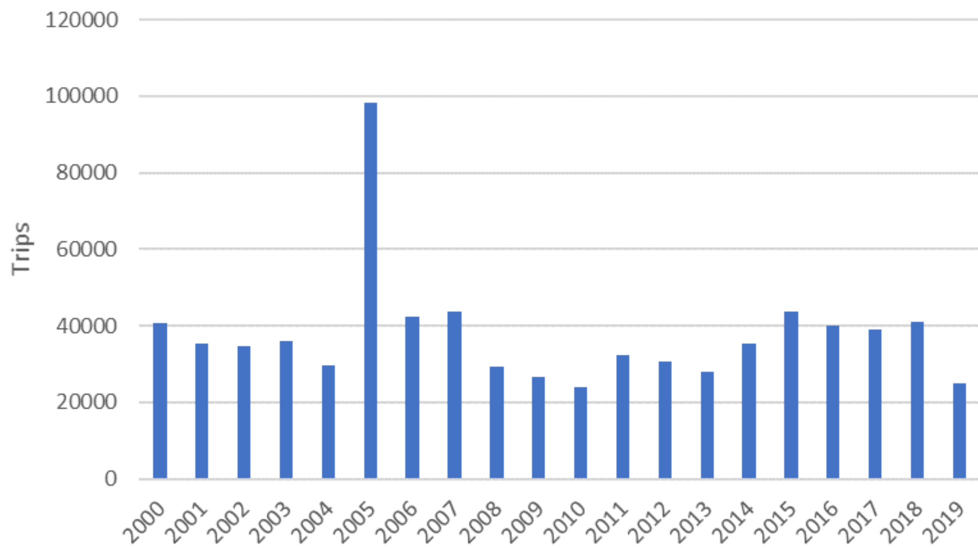

Figure 13. Annual number of trips by self-propelled vessels in the Trenton to the Sea Federal Navigation Channel.

The Waterborne Commerce data available to us includes data from 2000 to 2019. Vessel activity during this period in the Trenton to the Sea Federal Navigation Channel has varied with significant economic trends visible in the number of vessel trips (Figure 13). A substantially higher number of vessel trips occur in the Philadelphia to the Sea Federal Navigation Channel compared to the Philadelphia to Trenton Federal Navigation Channel. For instance, over the years from 2000 to 2019 an annual median of 46,282 (max=111,119; min=30,418) occurred in Philadelphia to the Sea while an annual median of 5,970 (max=10,013; min=3,086) occurred in the Philadelphia to Trenton. For this analysis, we used data from 2010 to 2019 to characterize the baseline vessel trips in the Trenton to the Sea Federal Navigation Channel (Figure 14). 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 21). Based on the observations of vessel strikes and examination of carcasses, 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 22). 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 ten-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 23). Figure 14 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).

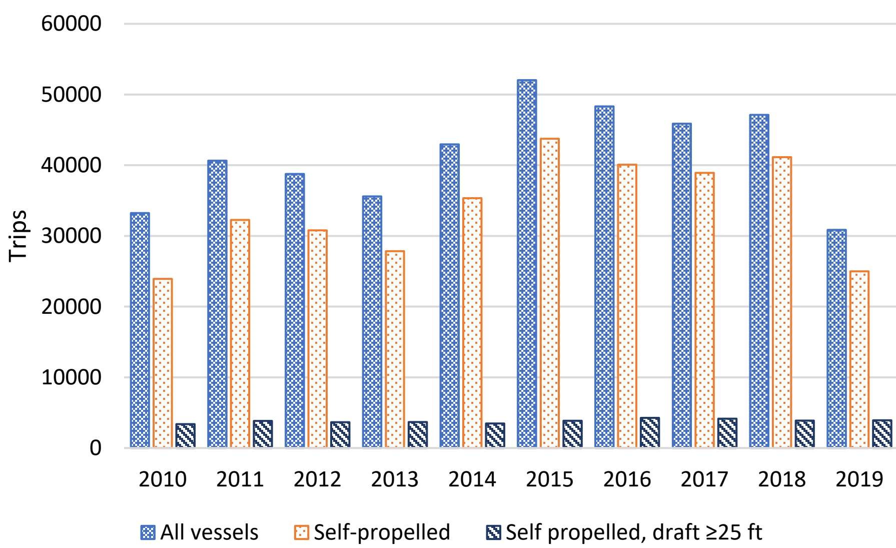

Figure 14. Annual number of Philadelphia to Sea vessel trips by vessel category (USACE Waterborne Commerce Data 2021)

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 (USCG 2012 as cited in NMFS 2017e).

Table 21. Annual number of vessel trips, Philadelphia 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 22. Annual number of vessel trips, Philadelphia 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 23. Annual number of vessel trips, Philadelphia 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**

6.7.3.3 Information on Sturgeon Mortality Resulting from Vessel Strike

As detailed above, the impacts of vessel strikes on sturgeon is a concern, and, specifically, concern lies with the lethal strikes resulting in mortality, which have been documented. 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 where 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% of the mortalities reported being juveniles. The majority (71%) of sturgeon carcasses showed sign 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).

The Delaware 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/). 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, DENRC, 2017). Thus, while it represents the best available data, it cannot be used 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[21], public and state employees reported 237 sturgeon carcasses (data provided by Ian Park, DNREC, 2017). Of these, 217 were identified as Atlantic sturgeon, 13 were identified as shortnose sturgeon, and seven were not identified to species.

Of all sturgeon carcasses reported, 126 showed sign of interaction with boat propellers and 18 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 93 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.

Atlantic sturgeon vessel mortalities

Of the 217 carcasses that DNREC biologists identified as Atlantic sturgeon, 23 were observed outside the Delaware River and Bay and are excluded from the calculations below. Vessel strike was identified as the likely cause of death for 101 of the 194 Atlantic sturgeon carcasses reported in the Delaware River and Bay over the period from 2005 to 2019. Over the 15-year period, the annual number of Atlantic sturgeon vessel mortalities in the Delaware River and Bay ranged from two to 15 (median =5) per year. If the carcasses with undetermined causes of death are included, then the total number of reported carcasses equaled 176 with a range from five to 22 (median = 11) per year. Of the 176 Atlantic sturgeon whose cause of death were reported either as vessel strikes or unknown, 89 (50.6 %) were adults, 2 (1.1%) were sub-adults, 37 (21%) were juveniles, and 48 (27.3%) had no reported life stage.

The majority of Atlantic sturgeon mortalities in the Delaware River and Delaware Bay occurred during spring and early summer (Table 24). Fifty-eight (58%) percent of the Atlantic sturgeon vessel strike and unknown mortalities were reported during May and June. Ninety percent (90.3%) 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.

Including only those reported as vessel mortalities, the majority (73%) of adult carcasses were reported during May and June while juvenile vessel strike mortalities were more evenly distributed across months (Table 24). The number of reported adult carcasses has the same distribution (69.7% reported in May and June) when both vessel strike mortalities and unknown mortalities are included (Table 25). The highest number (21) of reported carcasses (vessel strike and undetermined mortalities) of undetermined life stages was reported in May with 73 percent

[21] 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).

reported during May through August (Table 24 and Table 25). Since some carcasses were mutilated and size was estimated on remains, it is possible that some sturgeon reported as adults were sub-adults. Still, despite seasonal bias in reporting rates and possible mischaracterization of life stage, the results agree with findings by others that most 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 24. Total number and percentage of adults, sub-adults, juveniles, and unknown life-stage vessel strike mortalities reported for each month over the years 2005 to 2019.

Month	**Adult**	**%**	**Juvenile**	**%**	**Subadult**		**Unknown**	**%**	**All**	**%**
January	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
February	0	0.0%	1	5.6%	0	0.0%	0	0.0%	1	1.0%
March	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
April	2	3.2%	1	5.6%	0	0.0%	0	0.0%	3	3.0%
May	26	41.3%	0	0.0%	0	0.0%	8	44.4%	34	33.7%
June	20	31.7%	4	22.2%	0	0.0%	2	11.1%	26	25.7%
July	3	4.8%	4	22.2%	0	0.0%	4	22.2%	11	10.9%
August	4	6.3%	2	11.1%	1	50.0%	2	11.1%	9	8.9%
September	2	3.2%	2	11.1%	0	0.0%	1	5.6%	5	5.0%
October	5	7.9%	3	16.7%	1	50.0%	1	5.6%	10	9.9%
November	1	1.6%	0	0.0%	0	0.0%	0	0.0%	1	1.0%

December	0	0.0%	1	5.6%	0	0.0%	0	0.0%	1	1.0%
All Months	63	100.0%	18	100.0%	2	100.0%	18	100.0%	101	100.0%

Table 25. Total number and percentage of adults, sub-adults, juveniles, and unknown life-stage vessel strike and unknown mortalities reported for each month over the years 2005 to 2019.

Month	Adult	%	Juvenile	%	Subadult		Unknown	%	All	%
January	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
February	1	1.12%	1	2.70%	0	0.00%	0	0.00%	2	1.14%
March	0	0.00%	2	5.41%	0	0.00%	0	0.00%	2	1.14%
April	2	2.25%	3	8.11%	0	0.00%	3	6.25%	8	4.55%
May	34	38.20%	4	10.81%	0	0.00%	22	45.83%	60	34.09%
June	28	31.46%	9	24.32%	0	0.00%	5	10.42%	42	23.86%
July	4	4.49%	5	13.51%	0	0.00%	9	18.75%	18	10.23%
August	6	6.74%	3	8.11%	1	50.00%	2	4.17%	12	6.82%
September	4	4.49%	3	8.11%	0	0.00%	4	8.33%	11	6.25%
October	8	8.99%	5	13.51%	1	50.00%	3	6.25%	17	9.66%
November	2	2.25%	1	2.70%	0	0.00%	0	0.00%	3	1.70%
December	0	0.00%	1	2.70%	0	0.00%	0	0.00%	1	0.57%
All Months	89	100.00%	37	100.00%	2	100.00%	48	100.00%	176	100.00%

Adjusting 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, the actual number of sturgeon mortalities is probably greater than the 176 reported. Studies are ongoing to provide accurate reporting estimates and interaction rates of Atlantic sturgeon with vessel traffic. 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, other studies such as from the Delaware State University in partnership with the US Fish and Wildlife Service and DNREC estimate reporting rates varied from 2.0 (spring 2018) to 12.5 (summer and fall 2018) percent with a reporting rate of about 5 percent when they combined the data for all seasons over the two years (2018 and 2019) of the study. Because there is substantial uncertainty regarding the precise rate of interactions, carcass observations, as well as other factors such as, seasonality, annual fluctuations in number and type of vessels, and the distribution and abundance of sturgeon, we asked the Northeast Fisheries Science Center to review our analytical approach to determine mortality rates associated with vessel strikes and the best available data. In May 2022, after careful review of the vessel strike take calculations used in past Opinions developed by staff at the Greater Atlantic Regional Fisheries Office, Protected Resources Division, we received guidance from the Northeast Fisheries Science Center that, although our general analytical approach for vessel traffic analysis 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. This approach will be applied in this Opinion and may continue to evolve as new research becomes available, which may modify the methodology for future ESA consultations. For this Opinion, we estimate the range of Atlantic sturgeon vessel strike mortalities (juvenile, sub-adult, and adult) within the Delaware River during the 2005 to 2019 period to be between a minimum of 187 fish and a maximum of 767.

Baseline Vessel Strike Risk

Records of observed sturgeon mortalities are maintained by the Sturgeon Vessel Strike Database at the State of Delaware's Division of Fish and Wildlife. The database is based on a public reporting program by the state to enable the general public to directly notify state biologists of observed sturgeon carcasses. The public reporting program was initiated in 2005 and data from 2005 to 2019 was available to us at time of the New Jersey Wind Port and the Edgemoor Terminal consultations. 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 available. These data represent the best available information for calculating sturgeon mortalities per vessel trip. During the 2012-2019 period, 123 Atlantic sturgeon carcasses were reported. Of the dead Atlantic sturgeon reported, 60 (47.3%) died from apparent vessel strikes and 18 (14.3%) died from apparent non-vessel related injuries. A cause of death could not be determined for the remaining 45 (38.5%) carcasses. For purposes of this biological opinion, it is conservatively assumed that those 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). Accordingly, over the 8-year period (2012 through 2019), there was an average of 12 vessel strike mortalities of Atlantic sturgeon in the Delaware River per year reported.

We obtained the number of vessel trips between Trenton and the mouth of the Delaware Bay from Waterborne Commerce data for the years 2012 through 2019. The Waterborne Commerce 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 severed sturgeon carcasses have been observed suggesting that most vessel strike mortalities occur when sturgeon are entrained in the water going through the propellers of large vessels (Balazik *et al.* 2012b, 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.

The number of self-propelled vessel trips between Philadelphia and the mouth of the Delaware Bay during the period from 2012 to 2019 was 282,891 (Table 22). The NEFSC suggested two different approaches to derive the observed mortality rate:

1. Median Values. Using the median values for sturgeon mortalities and vessel trips from 2012 - 2019.

2. Time Series Totals. Using the total number of sturgeon mortalities and vessel trips from 2012 - 2019.

In general, the median value of a data set is the preferred metric for central tendency, especially in situations with outliers or skewed data. However, this begins to break down when there are fewer than 25 data points. In this situation, we are dealing with 8 data points, which requires additional thought on the appropriate metric.

	Min	Max	Mean	Median	Total
Sturgeon Mortalities	7	22	13.1	11.5	105
Vessel Trips	24,992	43,754	35,361.4	37,132.5	282,891

Looking at the distribution of the sturgeon mortalities by year, we observed a small difference between the mean and median values of the data set, providing an initial indication that either approach is appropriate.

Following Method 1 (time series median), the median values were 11.5 reported sturgeon mortalities and 37,132.5 vessel trips, resulting in an observed mortality rate (Mo) of 0.000310.

Following Method 2 (time series totals), the total counts of the time series were 105 sturgeon mortalities and 282,891 vessel trips, resulting in an observed mortality rate (Mo) of 0.000371.

While the difference between the two methods is 0.000061, or 20%, scientists at our NEFSC believe it is more appropriate to use Method 2 (time series totals) due to the short time series; therefore, we have chosen to apply that value forward in the rest of this Opinion (J. Boucher, NEFSC, pers. comm.).

Given this scenario, we estimate the number of sturgeon killed per vessel trip by dividing the estimated number of Atlantic sturgeon vessel mortalities (105) by the number of vessel trips (282,891) over the same period. Thus, each vessel trip killed 0.000371 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. In this Opinion, this is referred to as the adjusted annual mortality rate and is calculated by dividing the observed annual mortality rate (M_o) by an externally derived carcass reporting rate. 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.

In previous biological opinions, the carcass reporting rate was informed by the only available estimate from the Balazik *et al*. (2012) study of Atlantic sturgeon on the James River in Virginia. That study estimated that 31% (5 out of 16) deceased sturgeon that were released in the river were eventually reported. This study was not designed to estimate a robust reporting rate. The study only occurred during a short time period (approximately 4 weeks) in a single year, the sample size was extremely small (16 deployments with some fish deployed more than once), and the researchers were actively searching for the carcasses. By actively searching for the carcasses, the researchers biased the reporting rate higher than would be experienced in a natural setting. Acknowledging these deficiencies should not take away from the quality science performed by Balazik *et al*. (2012), only to illustrate that the use of a carcass reporting rate from this study likely underestimated the number of unobserved mortalities in the Delaware River as it was not intended to estimate the efficiency of public reporting of sturgeon carcasses. However, as the only available peer-reviewed estimate, it was the best available scientific data until recently.

In May 2022, we received guidance from the Northeast Fisheries Science Center that, although our general analytical approach for vessel traffic analysis was sound, certain improvements should be made, including incorporating the findings of a recent study into the vessel strike rate analysis used to inform the amount of anticipated take of Atlantic sturgeon. A new study by 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. A total of 168 carcasses were deployed seasonally over two years, providing a greater sample size and temporal distribution than Balazik *et al*. (2012). Additionally, Fox *et al*. (2020) relied on multiple sources of reporting and was not based on researchers actively searching for the carcasses. The Fox *et al*. (2020) study is also more appropriate for Delaware River biological opinions as it accounts for the hydrology of the Delaware River. Although the Fox *et al*. (2020) study provides reporting rates by season, the Northeast Fisheries Science Center recommended using the reporting rate combined across both years and all seasons because this number leverages the strength of reports from the entire time series (8 out of 168). The new rate of 4.76% is substantially smaller than the 31% rate used in prior biological opinions, but, as noted above, this new rate is the best available information.

From the adjusted mortality rate (M_a), we are now able to estimate the number of sturgeon killed in a given year by vessel strikes. The annual mortality (M_A) of Atlantic sturgeon is calculated by applying the adjusted annual mortality rate to the number of vessel trips in a year. This is represented as:

$$M_A = V_t * M_a$$

where M_a is the adjusted annual mortality rate and V_t is the number of vessel trips in a given year.

Substituting the equation for M_a we get:

$$M_A = \frac{V_t * M_o}{R}$$

where the estimate for the annual number Atlantic sturgeon killed by vessel strikes in the Delaware River and Estuary is obtained by multiplying the number of trips in a year by the observed mortality rate and dividing the carcass reporting rate.

For carcass reporting rate (R), we estimate that the annual mortality of Delaware River Atlantic sturgeon from vessel strikes between 2005 and 2019 ranged from a minimum of 187 fish to a maximum of 767 following Fox *et al*. (2020).

Shortnose sturgeon

Early reports of potential vessel strikes of shortnose sturgeon include one incident in 2007 and one in 2008. On June 8, 2008, a 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%) were adults, three (23%) were juveniles, and no life stage was reported for seven (54%) of the carcasses.

Of the 13 reported carcasses, ten were reported between 2012 and 2019. If we assume that mortalities of unknown cause were vessel strike mortalities and that only about one of three carcasses are reported, then there were approximately 30 shortnose sturgeon vessel strike mortalities in the Delaware River during that eight-year period. With 282,891 vessel trips during the same period, approximately 0.00011 shortnose sturgeon are killed per vessel trip. This equates to one shortnose sturgeon vessel strike mortality occur for every 9,430 vessel trips.

The low number of shortnose sturgeon carcasses reported from the Delaware River basin may be related to a several factors: 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.

6.7.3.4 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.

7 CLIMATE CHANGE

The discussion below presents background information on global climate change and information on past and predicted future effects of global climate change throughout the range of the listed species considered here. Additionally, we present the available information about predicted effects 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*, *Effects of the Action*, and *Cumulative Effects* sections of this 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 were 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 2021, 2021).

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 under the low GHG emissions scenario, 0.44-0.76 m under the intermediate GHG emissions scenario, and 0.63-1.01 m 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 effects of climate change globally, it is more difficult to assess the potential effects of climate change on smaller geographic scales, such as in the action area. The effects 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 wide-ranging effects 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 effects 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 effects 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 effects 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 effects 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 2017a). 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 in the action area 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 one degree 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 has improved, areas with critical low DO still occur occasionally depending on flow and water temperatures. Thus, we expect similar effects as in the Chesapeake Bay if summer water temperatures in the Delaware River should increase with one degree.

As discussed above in the effects to critical habitat section, the substrate within the action area does contain gravel, but is unlikely to support spawning for shortnose and Atlantic sturgeon; however, shortnose sturgeon are migrating through the action area to reach their natal river spawning habitat and Atlantic sturgeon spawning is likely to occur between the Marcus Hook Bar (RKM 125/RM 78) and the downstream end of Little Tinicum Island (RKM 138/RM 86). 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 the action area. This may cause an increase or decrease in the number of sturgeon present in the action area. 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 through the action area.

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.* (2016b) 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 comprehensive assessment, Hare *et al.* (2016a) 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 effects 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 effects is difficult to assess (Hare *et al.* 2016a). 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% (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 Effects 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 construction and operation of the Berth**.** The current tenant's plan for the monopile production facility is to use the proposed Ro/Ro berth discussed in this Opinion for 10 years, therefore, here, we consider the likely effects of climate change from now through 2032.

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 critical habitat). 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, NJ, (~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 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 and >30°C 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. Additionally, these predictions do not take into account the adaptive capacity of these species, which may allow them to deal with change better than predicted. When we designated the Delaware River as critical habitat for the New York Bight DPS of Atlantic sturgeon, we did not extend any areas upstream because of anticipated impacts of climate change. Rather, we determined that the areas designated would accommodate any changes in distribution of the PBFs that may result from climate change over the anticipated 10-year life span of the Berth.

As mentioned earlier, the overall vulnerability of Atlantic sturgeon to climate change has been found to be very high (Hare *et al.* 2016a). 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 2017) 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 to 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 EFFECTS OF THE ACTION ON SPECIES

Construction of the RoRo Berth, including dredging and pile driving is anticipated to take approximately three months. The exact dates for these activities depends on many factors and, at this time, our analysis considers that they may commence any time after July 1 2022, with no in-water work between March 15 and June 30.

Table 26. Atlantic sturgeon and shornose sturgeon life stages present during construction and operation

Species/Life Stage Presence in Action Area	Proposed Action Component			
	Dredging (July - March)	**Pile Driving (July - March)**	**Revetment Placement (July - March)**	**Operations – Vessel Transits (year-round)**
Atlantic sturgeon				
Eggs: present April - July				X
Larvae: present May - September	X	X	X	X
Juveniles: present year-round	X	X	X	X
Adults: present April - November	X	X	X	X
Shortnose sturgeon				
Eggs: not present				
Larvae: present May - September	X	X	X	X
Juvenile: present year-round	X	X	X	X
Adults: present year-round	X	X	X	X

X = present in action area and during proposed action schedule

8.1 Sound Energy from Pile Driving

The driving and removal of piles generates sound waves that travel through the water body and may affect listed sturgeon species. Exposure to human generated sounds may potentially affect communication with conspecifics (members of the same species), effects on stress levels and the immune system, temporary or permanent loss of hearing, damage to body tissues, mortality, and mortality or damage to eggs and larvae. Moreover, exposure to high sound levels can result in potential long-term effects that might show up hours, days, or even weeks after exposure to sounds.

Sound is an important source of environmental information for most vertebrates (Buhler *et al*. 2015, Halvorsen *et al*. 2011). Fish use sound to learn about their general environment, the presence of predators and prey, and, for some species, for acoustic communication. Therefore, sound is important for fish survival, and anything that impedes the ability of fish to detect a biologically relevant sound (e.g., anthropogenic sound sources) could affect individual fish. Further, studies and observations show that underwater sound pressure waves can directly injure or kill fish (Reyff 2003, Abbott and Bing-Sawyer 2002, Caltrans 2001, Longmuir and Lively 2001, Stotz and Colby 2001).

The applicant proposes to use cushioned impact pile driving equipment from a barge-mounted crane with tug support to install twelve 48-in steel piles for the four dolphin structures and three 30-in steel piles for construction of the catwalk structure.

Table 27. Pile supported structures at Paulsboro RoRo Berth

Structure Component*	No of Piles	Diameter (inches)	Total Length (feet)	Mud Depth (feet)
Mooring Dolphin 1 (MD-1)	3	48	140	110
Mooring Dolphin 2 (MD-2)	3	48	140	110
Berthing Dolphin 1 (BD-1)	3	48	140	110
Berthing Dolphin 2 (BD-2)	3	48	140	110
Platform Catwalk Supports	3	30	75	45
*Includes piles for the permitted activities. Does not include piles installed under existing or previous permits				

Driving of piles generates sound pressure waves that travels through surrounding water bodies. The frequency and intensity of these pressure waves depends on a variety of factors including the size and material of the piles, installation methods, substrate type where the piles are driven, depth, in-water obstructions, and other factors (Buehler *et al.* 2015). Pile driving may expose aquatic species to sound pressure traveling through the water body resulting in effects ranging from startle response to physiological injury and death. Factors that contribute to the likelihood of an adverse effects include size, species, condition of individuals, distance to the source, and behavioral response to exposure (Buehler *et al.* 2015).

In this section, we present background information on acoustics with an analysis of exposure; a summary of available information on sturgeon hearing; a summary of available information on the physiological and behavioral effects of exposure to underwater noise; and the established thresholds and criteria to consider when assessing impacts of underwater noise. We also present the results of the Fish and Hydroacoustics Working Group' review of hydroacoustic pressure levels and effects on fish to help inform the analysis[22.] We then present empirical data and modeling provided to establish the noise associated with pile installation and consider the effects of exposure of individual sturgeon to these noise sources.

8.1.1 Basic Background on Acoustics and Fish Bioacoustics

Frequency (i.e., number of cycles per unit of time, with hertz (Hz) as the unit of measurement) and amplitude (loudness, measured in decibels, or dB) are the measures typically used to describe sound. The hearing range for most fish ranges from a low of 20 Hz to 800 to 1,000 Hz.

[22] http://www.dot.ca.gov/hq/env/bio/fisheries_bioacoustics.htm

Most fish in the Delaware River fit into this hearing range, although catfish may hear to about 3,000 or 4,000 Hz and some of the herring-like fishes can hear sounds to about 4,000 Hz, while a few, and specifically the American shad, can hear to over 100,000 Hz (Popper *et al.* 2003; Bass and Ladich 2008; Popper and Schilt 2008).

An acoustic field from any source consists of a propagating pressure wave, generated from particle motions in the medium that causes compression and rarefaction. This sound wave consists of both pressure and particle motion components that propagate from the source. All fishes have sensory systems to detect the particle motion component of a sound field, while fishes with a swim bladder (a chamber of air in the abdominal cavity) may also be able to detect the pressure component. Pressure detection is primarily found in fishes where the swim bladder (or other air chamber) lies very close to the ear, whereas fishes in which there is no air chamber near the ear primarily detect particle motion (Popper *et al.* 2003; Popper and Schilt 2009; Popper and Fay 2010). Sturgeon have swim bladders, but they are not located very close to the ear; thus, sturgeon are assumed to detect primarily particle motion rather than pressure.

The level of a sound in water can be expressed in several different ways, but always in terms of dB relative to 1 micro-Pascal (μPa). Decibels are a log scale; each 10 dB increase is a ten-fold increase in sound pressure. Accordingly, a 10 dB increase is a factor of 10 increase in sound pressure, and a 20 dB increase is a 100-fold increase in sound pressure.

The following are commonly used measures of sound:

- Peak sound pressure level (SPL): the maximum sound pressure level (highest level of sound) in a signal measured in dB re 1 μPa.
- Sound exposure level (SEL): the integral of the squared sound pressure over the duration of the pulse (*e.g.*, a full pile driving strike.) SEL is the integration over time of the square of the acoustic pressure in the signal and is thus an indication of the total acoustic energy received by an organism from a particular source (such as pile strikes). Measured in dB re 1μPa2-s.
- Single Strike SEL (ssSEL): the amount of energy in one strike of a pile.
- Cumulative SEL (cSEL): the energy accumulated over multiple strikes. cSEL indicates the full energy to which an animal is exposed during any kind of signal. The rapidity with which the cSEL accumulates depends on the level of the single strike SEL. The actual level of accumulated energy (cSEL) is the logarithmic sum of the total number of single strike SELs. Thus, cSEL (dB) = Single-strike SEL + 10log10(N); where N is the number of strikes.
- Root Mean Square (RMS): the average level of a sound signal over a specific period of time.

8.1.2 Criteria for Assessing the Potential for Physiological Effects

There is limited data from other projects to demonstrate the circumstances under which immediate mortality occurs: mortality appears to occur when fish are close (within a few feet to 30 ft) to driving of relatively large diameter piles. Studies conducted by the California

Department of Transportation (Caltrans) showed some mortality for several different species of wild fish exposed to the driving of steel pipe piles 8 ft in diameter, whereas Ruggerone *et al.* (2008) found no mortality to caged yearling coho salmon (*Oncorhynchus kisutch*) placed as close as two feet from a 1.5 ft diameter pile and exposed to over 1,600 strikes. As noted above, the data indicates that species have different tolerances to noise and may exhibit different responses to the same noise source.

Potential physiological effects are highly diverse. Sound exposure that may result in mortality-inducing physiological effects could in one species result in physiological effects that would have no effect on fish survival in another. Potential effects range from very small ruptures of capillaries in fins (which are not likely to have any effect on survival) to severe hemorrhaging of major organ systems such as the liver, kidney, or brain (Stephenson *et al.* 2010). Other potential effects include rupture of the swim bladder (the bubble of air in the abdominal cavity of most fish species that is involved in maintenance of buoyancy). See Halvorsen *et al.* 2011 for a review of potential injuries from pile driving.

Effects on body tissues may result from barotrauma or result from rapid oscillations of air bubbles. Barotrauma occurs when there is a rapid change in pressure that directly affects the body gasses. Gas in the swim bladder, blood, and tissue of fish can experience a change in state, expand and contract during rapid pressure changes, which can lead to tissue damage and organ failure (Stephenson *et al.* 2010).

Related to this are changes that result from very rapid and substantial excursions (oscillations) of the walls of air-filled chambers, such as the swim bladder, striking nearby structures. Under normal circumstances the walls of the swim bladder do not move very far during changes in depth or when exposed to normal sounds. However, very intense noise, and particularly those with very sharp onset (also called “rise time”) will cause the swim bladder walls to move a much greater distance and thereby strike nearby tissues such as the kidney or liver. Rapid and frequent striking (as can occur during one or more sound exposures) may result in bruising, and ultimately in damage, to the nearby tissues.

The Fisheries Hydroacoustic Working Group (FHWG) was formed in 2004 and consists of biologists from NMFS, U.S. Fish and Wildlife Service (USFWS), U.S. Federal Highway Administration (FHWA), California Department of Fish and Game, USACE, and the California, Washington, and Oregon DOTs, supported by national experts on sound propagation activities that affect fish and wildlife species of concern. In June 2008, the NMFS, USFWS, FHWA, and the state agencies signed an MOA documenting criteria for assessing physiological effects of pile driving on fish (Molnar *et al.* 2020). The criteria were developed for the acoustic levels at which physiological effects to fish could be expected. It should be noted, that these are onset of physiological effects (Molnar *et al.* 2020), and not levels at which fish are necessarily mortally damaged. These criteria were developed to apply to all fish species, including listed green sturgeon, which are biologically similar to shortnose and Atlantic sturgeon and for these purposes can be considered a surrogate. The interim criteria are:

- Peak SPL: 206 decibels relative to 1 micro-Pascal (dB re 1 µPa).
- cSEL: 187 decibels relative to 1 micro-Pascal-squared second (dB re 1µPa^2-s) for fishes above 2 grams (0.07 ounces).
- cSEL: 183 dB re 1µPa^2-s for fishes below 2 grams (0.07 ounces).

The FHWG developed the interim criteria because resource agencies needed immediate thresholds to guide the evaluation of the effects of pile driving in order to ensure conservative protection of threatened and endangered fish. However, at the time when the FHWG developed the interim criteria, the FHWG recognized that more data and research was necessary to further consider and refine the thresholds. Studies of noise effects on fish do demonstrate that individual species possess different "tolerances" to varying noise sources and that for some species and in unique situations, fish can be exposed to noise levels greater than the FHWG criteria and exhibit little or no negative effects. For instance, recent research summarized in Popper *et al.* (2014) suggests that $SEL_{CUMULATIVE}$ thresholds for injury may be well above 200 dB. Molnar *et al.* (2020) noted that "during the time that has passed since the interim injury thresholds were first established in 2008, there has not been a single documented (in the field or lab studies) instance of even minor injury to fish that have been exposed to sound pressure levels in excess of the $SEL_{CUMULATIVE}$ threshold." However, for different reasons, the FHWG discussions related to modifications of the interim thresholds, though warranted, have not proceeded and the 2008 criteria remain in place. Given this, at this time, we consider the FHWG criteria to represent the best available information on the thresholds at which physiological effects to sturgeon are likely to occur. Thus, for the purposes of this Opinion, we consider the potential for physiological effects upon exposure to 206dB re 1 µPa peak and 187 dB re 1 µPa^2-s cSEL. It is important to note that physiological effects may range from minor injuries that individuals are anticipated to completely recover from with no impact to overall fitness to significant injuries that will lead to death. The severity of injury is related to the distance from the pile being installed and the duration of exposure. The closer to the source and the greater the duration of the exposure, the higher likelihood of significant injury.

8.1.3 Available Information for Assessing Behavioral Effects

Empirical studies on the hearing of fishes, amphibians, birds, and mammals (including humans), in general, show that behavioral responses vary substantially. Even within a single species, depending on a wide range of factors (e.g., the motivation of an animal at a particular time, the nature of other activities that the animal is engaged in when it detects a new stimulus, the hearing capabilities of an animal or species) responses demonstrate variability (Brumm and Slabbekoorn 2005). Thus, it may be difficult to assign a single criterion above which behavioral responses to noise would occur.

For purposes of assessing behavioral effects of pile driving at several West Coast projects, NMFS has employed a 150dB re 1 µPa RMS SPL criterion at several sites including the San Francisco-Oakland Bay Bridge and the Columbia River Crossings. For the purposes of this consultation, we will use 150 dB re 1 µPa RMS as a conservative indicator of the noise level at which there is the potential for behavioral effects. That is not to say that exposure to noise levels of 150 dB re 1 μPa RMS will always result in behavioral modifications or that any behavioral modifications will rise to the level of take (i.e., harm or harassment) but that there is the potential, upon exposure to noise at this level, to experience some behavioral response. Behavioral responses could range from a temporary startle to avoidance of an ensonified area.

As hearing generalists, sturgeon rely primarily on particle motion to detect sounds (Lovell *et al.* 2005), which does not propagate as far from the sound source as does pressure. However, a clear threshold for particle motion was not provided in the Lovell study. In addition, flanking[23] of the sounds through the substrate may result in higher levels of particle motion at greater distances than would be expected from the non-flanking sounds. Unfortunately, data on particle motion from pile driving is not available at this time, and we must rely on sound pressure level criteria. Although we agree that more research is needed, the studies noted above support the 150 dB re 1 μPa RMS criterion as an indication for when behavioral effects could be expected. With the exception of studies carried out during the Tappan Zee Pile Installation Demonstration Project in the Hudson River, NY, (Krebs *et al.* 2012, 2016), we are not aware of any studies that have considered the behavior of shortnose or Atlantic sturgeon in response to pile driving noise. However, given the available information from studies on other fish species, we consider 150 dB re 1 μPa RMS to be a reasonable estimate of the noise level at which exposure may result in behavioral modifications.

8.1.4 Exposure to Increased Underwater Noise

In water, sound follows the same physical principles as in air. The major difference is that due to the density of water, sound travels about 4.5 times faster in water than in air (approx. 4900ft./s vs. 1100 ft./s), and it attenuates much less rapidly than in air. As a result of the greater speed, the wavelength of a particular sound frequency is about 4.5 times longer in water than in air (Rogers and Cox 1988; Bass and Clarke 2003).

Pile installation for the Berth is expected to take approximately 15 work days spread over one month to complete, with no in-water work between March 15 and June 30. Based on this schedule, pile driving will occur outside of the sturgeon spawning period, and adult Atlantic sturgeon will not be exposed to sound from pile driving during spawning migrations; however, adults, especially males, may move downstream near pile driving activities as late as October. Therefore, pile driving can expose adult Atlantic sturgeon to elevated noise. Shortnose sturgeon move upstream to spawning sites in spring before in-water construction activities will take place and they spawn outside (i.e., upstream) of the action area. Thus, adult spawners will not be exposed to noise generated by pile driving. However, non-spawning shortnose sturgeon adults may be present in this reach of the river, opportunistically foraging, resting, or migrating, and installation of piles may expose the adults to elevated noise levels. Juvenile shortnose and

[23] Flanking sound (or flanking noise) is sound that transmits between spaces indirectly, going over or around, rather than directly through the main separating element.

Atlantic sturgeon are present within the action area year-round and may be exposed to noise from pile driving.

To estimate pile driving sound levels at different distances during construction, we primarily rely on data compiled for the California Department of Transportation from tests conducted by others under similar conditions to estimate attenuation rates and the distance at which sound levels could affect sturgeon (Molnar *et al.* 2020).

We used the acoustic tool developed by our office (GARFO Acoustic Tool) that uses proxy projects to assist in estimating the ensonified area for piles of different types and sizes, driven with different hammers, and with different attenuations[24]. The GARFO tool also provides a Simplified Attenuation Formula (SAF) that was developed in order to estimate the ensonification area of pile driving projects in shallow, confined areas, such as rivers. SAF was needed as the Practical Spreading Loss Model (PSLM) is the most accurate for projects in deeper, open water scenarios (e.g., pile driving for wind farms), and tends to greatly overestimate the ensonfication area of pile driving projects in shallower, confined spaces. PSLM also requires an estimate of the number of strikes needed to install a pile (or the number of seconds with a vibratory hammer), and this information is not always available. SAF assumes a constant sound attenuation rate (depending on the type of pile). Attenuation rates were estimated using measurements reported in the "Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish" (Technical Guidance) prepared for Caltrans in 2009 (last amended in 2020) (Molnar *et al.* 2020). If Caltrans did not include a clear attenuation estimate, the GARFO Acoustic Tool uses 5dB/10m attenuation rate, which we believe to be a conservative estimate because of the likely absorption of sound into the riverbed/seafloor, as well as greater rate at which sound waves attenuate as they get further from the source and cover a wider area (5dB/10m is also representative of the most commonly seen range of attenuation rates in the data presented by Caltrans). For this Opinion, we use the GARFO acoustic tool and the SAF to estimate intensity and spatial extent of sound levels to analyze the effects of the proposed pile driving because of the location of the Berth (summarized in Tables below).

To attenuate noise levels from pile driving by impact hammer, a cushion block consisting of multiple layers of plywood approximately 30.5 cm (12 in) thick will be used. WSDOT (2006) demonstrated that wood cushion blocks can reduce underwater sound levels by 11 to 26 dB compared to an unattenuated impact hammer if functioning properly. However, Buehler *et al.* (2015) recommended that a specific sound level reduction credit not be taken for the use of cushion blocks because of the limited nature of the WSDOT study, their ability to attenuate noise was highly variable, and because they can splinter or break. Because the effects of a wood cushion caps varies, the GARFO acoustic tool uses the lower end (-11 dB) of measured attenuation in estimating the potential for pile driving exceeding injurious peak noise levels.

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[24] The spreadsheet is available at https://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/consultation/index.html.

Based on the use wood caps to attenuate noise, we conclude that driving of any of the diameter piles as proposed will not exceed 206 dB re 1 µPa.

Table 28 and Table 29 provide estimated sound levels and distance from piles where injury and behavioral effects would occur for the 48-in diameter steel piles and 30-in steel piles, respectively.

Table 28. Estimated intensity and extent of underwater noise for a 48-inch steel pipe pile based on proxy projects. a) Proxy projects and piles for estimating underwater noise. b) Proxy-based estimates for underwater noise. c) Estimated distances to sturgeon injury and behavioral thresholds.

a. Proxy Project

Proxy	**Project Location**	**Water Depth (m)**	**Pile Size (in)**	**Pile Type**	**Hammer Type**	**Attenuation rate (dB/10m)**
A	Russian River, CA	0	48	Steel Pipe	Impact	2
B	Russian River, CA	0	48	Steel Pipe	Cushioned Impact	2

b. Underwater Noise

Proxy	**Type of Pile**	**Estimated Peak Noise Level (dB_{Peak})**	**Estimated Pressure Level (dB_{RMS})**	**Estimated Single Strike Sound Exposure Level (dB_{sSEL})**
A	48-inch Steel Pipe	198	185	175
B	48-inch Steel Pipe	187	174	164

c. Distance to Injury and Behavioral Threshold

Proxy	**Distance (m) to 206dBPeak (injury)**	**Distance (m) to 150 dBsSEL (surrogate for 187 dBcSEL injury)**	**Distance (m) to Behavioral Disturbance Threshold (150 dBRMS)**
A	NA	135	185
B	NA	80	130

Table 29. Estimated intensity and extent of underwater noise for a 30-in steel piles. a) Proxy projects and piles for estimating underwater noise. b) Proxy-based estimates for underwater noise. c) Estimated distances to sturgeon injury and behavioral thresholds.

a. Proxy Project

Proxy	**Project Location**	**Water Depth (m)**	**Pile Size (in)**	**Pile Type**	**Hammer Type**	**Attenuation rate (dB/10m)**
A	Florence, OR	3	30	Steel	Impact	5
B	Florence, OR	3	30	Steel	Cushioned Impact	5

b. Underwater Noise

Proxy	**Type of Pile**	**Estimated Peak Noise Level (dB_{Peak})**	**Estimated Pressure Level (dB_{RMS})**	**Estimated Single Strike Sound Exposure Level (dB_{sSEL})**
A	30-inch Steel	210	190	177

B	30-in Steel	199	179	166

c. Distance to Injury and Behavioral Threshold

Proxy	Distance (m) to 206dBPeak (injury)	Distance (m) to 150 dBsSEL (surrogate for 187 dBcSEL injury)	Distance (m) to Behavioral Disturbance Threshold (150 dBRMS)
A	18	64	90
B	NA	42	68

Based on the data above, driving (with the proposed cushion) steel pipe piles will only result in peak sound levels above 206 dB during installation of the 30-in steel piles. Thus, there is no potential for physiological effects due to exposure to peak noise levels during construction of the 48-in pile dolphin structures. Based on sound measured at a 10 m (33 ft) distance from the pile (with the proposed cushion), fish within 18 m (59 ft) of a 30-in steel pile will be exposed to peak sound at levels known to cause injury (Table 29c).

In addition to the peak exposure criteria that relate to the energy received from a single pile strike, the potential for injury exists for multiple exposures to noise over a period of time. The cSEL threshold accounts for multiple exposures. The cSEL is a measure of the accumulated energy over a specific period of time (e.g., the period of time it takes to install a pile), rather than an instantaneous maximum noise threshold (Buehler *et al.* 2015). When it is not possible to accurately calculate the distance to the 186 dB cSEL isopleth, we used a calculation of the distance to the 150 dB sSEL isopleth.[25] The greater the distance between the fish and the pile being driven, the greater the number of strikes it must be exposed to in order to be injurious. The threshold distance from the pile indicates that the fish is far enough away that, regardless of the number of strikes it is exposed to, the energy accumulated is not sufficient to cause injury. This distance is where the 150 dB sSEL isopleth occurs (Stadler and Woodbury 2009). A fish located outside of this isopleth has no risk of injury, regardless of the number of pile strikes.

Using the information from proxy projects and reducing the sSELwith an 11dB attenuation from use of cushion block, we estimated distances of sSEL of 150 dB during impact driving. The distance for the proxy projects was 80 m (262.5 ft) for the 48-in steel pipe piles. Sturgeon that remain within a distance up to 80 m (262.5 ft) of the steel pipe piles during construction of the dolphin structures will be exposed to injurious levels of noise during installation of the piles. During installation of the 30-in steel piles, sturgeon that remain within a distance up to 42 m (137.8 ft) of a 30-in steel pile driven with a cushioned impact hammer will be exposed to injurious levels of noise during installation of the piles. It should be noted that the risk of injury

[25] The GARFO developed the Simplified Attenuation Formula (SAF) in order to estimate the ensonification area of pile driving projects in shallow, confined areas, such as rivers. SAF assumes a constant sound attenuation rate (depending on the type of pile). We estimated the distance to the 150 dB re 1uPa sSEL isopleth, using SAF.

decreases with distance from the pile and a sturgeon farther from a pile receive less energy over a given time period than a fish close to a pile.

8.1.5 Sturgeon Response to Proposed Pile Driving

It is reasonable to assume that sturgeon, on hearing pile driving, will either not approach the source or will move around it. Sturgeon in the area are expected to leave the area when pile driving begins facilitated by the use of a “soft start” or system of “warning strikes” where the pile driving will begin at only 40% of its total energy. These “warning strikes” are designed to cause fish to leave the area before the pile driving begins at full energy.

Studies on sturgeon behavior towards noise from pile driving in relationship to the construction of the Tappen Zee Bridge over Hudson River found that sturgeon avoid or move out of the ensonified area (NMFS 2017e). Thus, we expect the sturgeon to avoid an ensonified area upon exposure to underwater noise levels of 150 dB_{RMS}, if fish do not completely leave after the warning strikes. Behavioral modification (avoidance) is expected 130 m (426.5 ft) from the piles being driven. Even if a sturgeon is within the ensonified area of 150 dB sSEL when pile driving begins, injury is unlikely because the cSEL injury threshold is cumulative (requiring prolonged exposure to the noise at that level) and sturgeon are expected to leave the area upon the start of pile driving.

We have considered whether a sturgeon is likely to be able to swim far enough away from the pile being installed in time to avoid exposure to the full duration of pile installation. The furthest distances required would be for the 48-in steel pipe piles. Assuming pile driving times of approximately fifteen minutes; a sturgeon would need to swim at least 80 m (262.5 ft) before the fifteen minute pile driving time was completed, requiring a swim speed of approximately 0.09 m (0.29 ft) per second to leave the ensonified area. Deslauriers and Kieffer (2012b) measured sustained swimming speed (swimming against a current for 200 minutes) for YOY shortnose sturgeon to 18 cm/s (0.18 m/s). Further, shortnose sturgeon YOY could sustain swimming at velocities of 0.35 m/s for up to 30 to 50 minutes depending on water temperature (Deslauriers and Kieffer 2012a).

Assuming that the sturgeon in the action area have a swimming ability equal to those above, we expect all juvenile shortnose sturgeon and Atlantic sturgeon in the action area to have a prolonged swim speed of at least 0.35 m/s and a sustained speed of 0.18 m/s. Therefore, we expect all sturgeon in the action area to be able to readily swim away from any ensonified area in time to avoid injury.

The cSEL 187 dB re $1\mu Pa^2$-s area never occupies the entire width of the river; therefore, fish will always be able to move away from an area while pile driving is ongoing. As such, we do not expect sturgeon to remain close enough to a pile during installation for long enough to accumulate enough energy to be injured. Further, the use of a reduced energy "soft start"[26] technique would help ensure that sturgeon are exposed to reduced noise levels for several minutes before the maximum noise levels are reached. We expect this to cause sturgeon close to active pile driving to move further away, thereby reducing the potential for exposure to noise levels that may be injurious or fatal. Thus, any sturgeon present in the area during the start of pile driving are expected to leave the area and not be close to any pile driving activity for a long enough to experience injuries or mortality. While sturgeon in the action area will be temporarily exposed to noise levels before moving out of the ensonfied area, the short-term exposure is not likely to result in injuries. Atlantic sturgeon are known to avoid areas with conditions that cause physiological effects (e.g., low DO, high temperature, unsuitable salinity); thus, it is reasonable to anticipate that sturgeon will also avoid any areas with noise levels that could result in physiological stress or injury. The only way that a sturgeon could be exposed to injurious or fatal noise levels is if a fish is within 18 m (59 ft) to the 30-in steel pile while full strength pile driving was ongoing. Because of soft start techniques and cushion blocks the expected behavioral response of fish is to move away from the piles being installed, it is extremely unlikely that sturgeon will be exposed to high noise levels long enough to cause injury.

8.1.6 Summary of physiological effects

As described above, the driving of 30-in steel pipe piles will produce injurious peak sound levels (≥206 dBpeak) within 18 m (59 ft) of the pile. Thus, construction of the catwalk support structures may expose sturgeon to injurious peak dB levels; however, the impact hammer would need to be operating at full power for sturgeon to be exposed to injurious peak dB levels and the implementation of a “soft start” is expected to clear fish from the immediate area. Based on our analysis, we do not expect that the driving of 48-in steel piles with a cushioned impact hammer will result in injurious peak sound levels. Exposures to pile driving noise below 206 dBpeak can cause injury if the sturgeon is exposed to the noise over a long enough period of time. However, based on the above analysis, we expect that any sturgeon present during the start of pile driving will move out of the ensonified area before the short-term exposure is likely to result in injuries. We also expect that sturgeon will not enter the ensonified area once pile driving has begun. Given the previously stated information, we have determined that pile driving is extremely unlikely to cause injury to shortsnose sturgeon or Atlantic sturgeon.

8.1.7 Effects of Behavioral Modifications

As noted above, since the pile driving sounds are very loud, it is very likely that any sturgeon in the action area will hear the sound, and respond behaviorally by moving out of or avoiding the ensonified area. Available information suggests that the potential for behavioral shifts may begin upon exposure to noise at levels of 150 dB re 1 µPa RMS.

When considering the potential for behavioral effects, we need to consider the geographic and temporal scope of any impacted area. For this analysis, we consider the area within the river

[26] The Soft Start for impact drivers will be to provide an initial set of strikes at reduced energy, followed by a thirty-second waiting period, then two subsequent reduced energy strike sets. Soft Start will be implemented at the start of each day's pile driving and at any time following cessation of pile driving for a period of one hour or longer.

where noise levels greater than 150 dB re 1 µPa RMS will be experienced and the duration of time that those underwater noise levels could occur.

Depending on the pile size, the 150 dB re 1 µPa RMS isopleth (radius) would extend from 68 to 130 m (223 to 426.6 ft) from the piles being driven. Shortnose sturgeon and Atlantic sturgeon are likely to be foraging (where forage is present), resting, or migrating up or downstream in the area where piles are being installed. We consider two scenarios here; (1) sturgeon near the pile being installed must swim away from the pile to move out of the area where noise is greater than 150 dB re 1µPa RMS; and, (2) sturgeon outside of the area where noise is greater than 150 dB re 1µPa RMS at the onset of pile driving would need to avoid this area when pile driving was ongoing.

In the first scenario, sturgeon exposed to noise greater than 150 dB re 1µPa RMS are expected to move away from the ensonified area and have their foraging, resting or migrating behaviors disrupted. Even at a slow sustained speed of 0.18 m (0.6 ft) per second (mps), all sturgeon would be able to swim out of the area where noise is 150 dB re 1uPa RMS within 12 minutes. Thus, we expect any disruption to normal behaviors to last for no longer than 12 minutes. Foraging is expected to resume as soon as sturgeon leave the area. Resting and migration can also continue as soon as the individual had moved away from the disturbing level of noise. It is unlikely that a short-term (in the worst-case scenario of no more than 12 minutes, and generally much shorter) disruption of foraging, resting or migrating will have any impact on the health of an individual sturgeon. In addition, because we expect these movements to occur at normal sustained swim speeds, we do not expect there to be any decrease in fitness or other negative effects.

Pile driving may occur for up to 12 hours a day, and in the worst-case scenario, fish are expected avoid the ensonified area for the entirety of the pile driving period, as previously detailed. The Delaware River at the Berth location is approximately 1.03 km (0.64 mi) wide from the Delaware bank to the New Jersey bank. The dolphin structures will be installed close to the shoreline. Thus, the behavioral disturbance at the ensonified area will extend a maximum of 130 m (426.6 ft) into the channel. At all times, there will be at least 900 m (~2,953 ft) of the river width free of pile driving generated noise levels greater than 150 dB re 1uPa RMS. Therefore, it is likely that any sturgeon not near the piles at the beginning of installation will be able to completely avoid the area where noise levels exceed 150 dB re 1uPa RMS. Assuming the worst case scenario behaviorally, where sturgeon need to avoid areas with underwater noise greater than 150 dB re 1 µPa during active pile driving, there will still always be enough space for fish to pass unimpeded in the waterway.

Pile driving activities may cause sturgeon near the construction activities to move into the Federal Navigation Channel, where there is an increased risk of interaction with vessels. The proposed pile driving activities are located approximately 152 m (500 ft) from the Federal Navigation Channel. With noise levels not expected to extend into the channel, there is ample clearance to avoid areas with elevated noise without entering the Navigation Channel. Further, time of year restrictions for in-water work ensures that adult sturgeon will not be migrating through the construction area to the spawning grounds during pile-driving.

Based on this analysis, we have determined that any minor changes in behavior resulting from exposure to increased underwater noise associated with pile installation will not preclude any shortnose or Atlantic sturgeon from completing any essential behaviors such as resting, opportunistic foraging or migrating and/or affect the fitness of any individuals. Additionally, we do not expect any increase in energy expenditure that has any detectable effects to the physiology of any individuals or any future effects to growth, reproduction, or general health. Thus, effects are too small to be meaningfully measured, detected, or evaluated and, therefore, effects are insignificant.

8.2 Dredging Entrapment

The applicant proposes to deepen portions of the Delaware River adjacent to the Federal Navigation Channel to create a turning basin and mooring approach that will serve the proposed berth construction at the Paulsboro Site. Dredging is expected to take 30 to 50 days to complete, with no in-water work between March 15 and June 30. The applicant plans to dredge approximately 140,900 cy of material from approximately 8.9 acres within the Delaware River.

Dredging will be performed primarily with a clamshell bucket to mechanically dredge fine-grained materials that generally encompass the top several feet of the dredge area. It is estimated that 10,300 cy of fine-grained material will be dredged in the action area at the construction site at a rate of 1,500 to 2,000 cy per day for approximately 5 to 8 days. In addition, sandy and more coarsely grained materials may be dredged using a mechanical dredge (clamshell or excavator), or cutterhead hydraulic dredge. Approximately 2,000 cy of coarse-grained dredge material per day will be removed if mechanically dredged, and 2,500 to 5,000 cy will be removed per day if a cutterhead is used. Coarse-grained material dredging will last between 20 and 50 days depending on the dredge used. Dredging is anticipated to commence after July 1, 2022, and take place for 30 to 50 days, with no in-water work between March 15 and June 30.

8.2.1 Mechanical Dredge Entrapment of Non-Larval Sturgeon

Mechanical dredging entails lowering the open bucket or clamshell through the water column, closing the bucket after impact on the bottom, lifting the bucket up through the water column, and emptying the bucket into a barge. The bucket operates without suction or hydraulic intake, moves relatively slowly through the water column and affects only a small area of the aquatic bottom at any time. In order to be captured in a dredge bucket, an animal must be on the bottom directly below the dredge bucket as it contacts the substrate and remain stationary as the bucket closes. Species captured in dredge buckets can be injured or killed if entrapped in the bucket or buried in sediment during dredging and/or when sediment is deposited into the dredge scow. Species captured and emptied out of the bucket can suffer stress or injury, which can lead to mortality.

8.2.1.1 Mechanical Dredging Effects on Sturgeon

In 2012, the USACE provided us with a list of all documented interactions between dredges and sturgeon reported along the U.S. East Coast; reports dated as far back as 1990. The list includes five incidents of sturgeon captured in dredge buckets. These include the capture of a decomposed Atlantic sturgeon in Wilmington Harbor in 2001. The condition of this fish indicated it was not killed during the dredging operation and was likely dead on the bottom or in the water column and merely scooped up by the dredge bucket. Another record was the reported lethal capture of an Atlantic sturgeon in Wilmington Harbor in 1998; however, this record was never verified. An Atlantic sturgeon was captured in a clamshell bucket, deposited in the dredge scow, and released apparently unharmed during dredging operations at Bath Iron Works (BIW) in 2001. On April 30, 2003, a shortnose sturgeon was captured in a clam-shell bucket dredge operating in the BIW sinking basin; the fish was nearly cut in half. This fish was killed during the last hour of a 24-hour a day dredging operation that had been ongoing for approximately six weeks. One shortnose sturgeon was captured in a clamshell bucket and detected in the dredge scow on June 1, 2009, during dredging operations at BIW. Observer coverage at dredging operations at the BIW facility has been 100 percent for approximately 20 years, with dredging occurring every one to two years.

Monitoring has been ongoing at dredging projects associated with the Tappan Zee Bridge replacement project on the Hudson River. The first stage of dredging occurred in 2013. Two dredges were used between August 2 and October 30, 2013, and a total of 844,120 cy of material were removed using a bucket dredge. NMFS-approved observers were present to monitor 100 percent of all dredging. All dredge observer forms were submitted to us on December 31, 2013. While fish and other biological materials were observed in 279 loads (out of approximately 1,500), no shortnose or Atlantic sturgeon were observed. Dredging occurred again in 2015 with approximately 150,000 cy of material removed; observer coverage was 100 percent and no shortnose or Atlantic sturgeon were observed. The area where dredging occurred is a high use area for shortnose and Atlantic sturgeon.

We expect the risk of interactions between sturgeon and mechanical dredges to be highest in areas where large numbers of sturgeon are known to aggregate. The behavior of sturgeon in the area may also affect the risk of capture. While foraging, sturgeon are at the bottom of the river interacting with the sediment. This behavior may increase the susceptibility of capture with a dredge bucket. We also expect the risk of capture to be higher in areas where sturgeon are overwintering in dense aggregations as overwintering sturgeon may be less responsive to stimuli which could reduce the potential for a sturgeon to avoid an oncoming dredge bucket. The 8.9-acre area to be mechanically dredged is not a known overwintering aggregation site for sturgeon; however, sturgeon may opportunistically use the area for foraging, resting, or migrating. Habitat suitable for overwintering may be available outside of the dredging site in other parts of the action area.

Most mobile organisms, including adult and subadult Atlantic sturgeon, are able to avoid mechanical dredge buckets. For a bucket dredge to capture a sturgeon, the sturgeon has to be immediately below the bucket and remain stationary as the bucket jaw closes. The slow movement of the dredge bucket through the water column and the relatively small area of bottom impacted by each pass of the bucket makes the likelihood of interaction between a dredge bucket and an individual fish unlikely. Based on all available evidence, the risk that a mechanical dredge will capture a subadult or adult sturgeon is low. Thus, entrapment from a mechanical dredge is extremely unlikely to occur.

8.2.2 Cutterhead Dredge Entrapment of Non-Larval Sturgeon

8.2.2.1 Available Information on the Risk of Entrainment of Sturgeon in Cutterhead Dredge

A cutterhead dredge operates with the dredge head buried in the sediment; however, a flow field is produced by the suction of the operating dredge head. The amount of suction produced is dependent on linear flow rates inside the pipe and the pipe diameter (Clausner and Jones 2004). High flow rates and larger pipes create greater suction velocities and wider flow fields. The suction produced decreases exponentially with distance from the dredge head (Boysen and Hoover 2009). With a cutterhead dredge, material is pumped directly from the dredged area to a disposal site. As such, there is no opportunity to monitor for biological material on board the dredge; rather, observers work at the disposal site to inspect material.

It is generally assumed that sturgeon are mobile enough to avoid the suction of an oncoming cutterhead dredge and that any sturgeon (with the exception of eggs and immobile larvae) in the vicinity of such an operation would be able to avoid the intake and escape. However, in mid-March 1996, two shortnose sturgeon were found in a dredge discharge pool on Money Island, near Newbold Island in the upper Delaware River. The dead sturgeon were found on the side of the spoil area into which the hydraulic pipeline dredge was pumping. An assessment of the condition of the fish indicated that the fish were likely alive and in good condition prior to entrainment and that they were both adult females. The area where dredging was occurring was a known overwintering area for shortnose sturgeon and large numbers of shortnose sturgeon were known to be concentrated in the general area. A total of 509,946 cy were dredged between Florence and the upper end of Newbold Island during this dredge cycle. Since that time, dredging occurring in the winter months in the Newbold – Kinkora range of the Delaware River required that inspectors conduct daily inspections of the dredge spoil area in an attempt to detect the presence of any sturgeon. In January 1998, three shortnose sturgeon carcasses were discovered in the Money Island Disposal Area. The sturgeon were found on three separate dates: January 6, January 12, and January 13. Dredging was being conducted in the Kinkora and Florence ranges at that time, which also overlaps with the shortnose sturgeon overwintering area. A total of 512,923 cy of material was dredged between Florence and upper Newbold Island during that dredge cycle. While it is possible that not all shortnose sturgeon killed during dredging operations were observed at the dredge disposal pool, USACE has indicated that due to flow patterns in the pool, it is expected that all large material (i.e., sturgeon, logs etc.) will move towards the edges of the pool and be readily observable. Monitoring of dredge disposal areas used for deepening of the Delaware River with a cutterhead dredge has occurred. Dredging in Reach C occurred from March – August 2010 with 3,594,963 cy of material removed with a cutterhead dredge. Dredging in Reach B occurred in November and December 2011, with 1,100,000 cy of material removed with a cutterhead dredge. In both cases, the dredge disposal area was inspected daily for the presence of sturgeon. No sturgeon were detected.

Several studies have been conducted to understand the behaviors of Atlantic sturgeon and shortnose sturgeon. The USACE worked with sturgeon researchers to track the movements of tagged juvenile Atlantic and shortnose sturgeon to understand their behavior while cutterhead dredge operations were ongoing in Reach B of the Delaware River Philadelphia to the Sea Federal Navigation Channel. The movements of 19 acoustically tagged sturgeon were monitored using both passive and active methods (ERC 2012). Three of the juvenile sturgeon detected during this study (two Atlantic sturgeons and one shortnose sturgeon) appeared to have moved through Reach B when the dredge was working. The patterns and rates of movement of these fish indicated nothing to suggest that their behaviors were affected by dredge operation. The other sturgeon that were detected in the lower portion of the study area either moved through the area before or after the dredging period (two Atlantic sturgeon), moved through Reach B when the dredge was shut down (three Atlantic sturgeon), or moved through the channel on the east side of Cherry Island Flats (one shortnose sturgeon and one Atlantic sturgeon 2091) opposite the Federal Navigation Channel. It is unknown whether some of these fish chose behaviors (routes or timing of movement) that kept them from the immediate vicinity of the operating dredge. In the report, ERC (2012) concluded that this could either be to avoid the noisy area near the dredge or that the movements of the sturgeon relative to dredge operation could simply have been coincidence.

Reine *et al.* (2014) concluded that sturgeon do not modify their behavior in presence of active cutterhead dredges based on studies they carried out in the James River (Virginia). Reine *et al.* (2014) implanted five subadult Atlantic sturgeon (TL = 77.5- 100 cm) with both active and passive transmitters, released the fish in the immediate vicinity of the dredge, and tracked them continuously for several days. Reine *et al.* (2014) concluded that: tagged fish showed no signs of impeded up- or downriver movement due to the physical presence of the dredge; fish were actively tracked freely moving past the dredge during full production mode; fish showed no signs of avoidance response (e.g., due to noise generated by the dredge) as indicated by the amount of time spent in close proximity to the dredge after release (3.5 – 21.5 hours); and, tagged fish showed no evidence of attraction to the dredge.

(Balazik *et al.* 2020) also studied the movement of Atlantic sturgeon near an operating cutterhead dredge in the James River in Virginia. The analysis showed that dredging in the lower James River does not create a barrier for adult Atlantic sturgeon migrating to spawning habitat or cause adults to significantly modify swim behavior. The results showed that adult and subadult Atlantic sturgeon were are able to and freely swim past the operating dredge during their estuarine migrations and no incidents of entrainment occurred (Balazik *et al.* 2020).

Additional scientific studies have been undertaken to understand the ability of sturgeon to avoid being entrained in the intake of cutterhead dredges. Hoover *et al.* (2011) demonstrated the swimming performance of juvenile lake sturgeon and pallid sturgeon (12 – 17.3 cm FL) in laboratory evaluations. The authors compared swimming behaviors and abilities in water velocities ranging from 10 to 90 cm/second (0.33-3.0 fps). Based on the known intake velocities of several sizes of cutterhead dredges. At distances more than 1.5 m (5 ft) from the dredges, water velocities were negligible (10 cm/s). The authors concluded that in order for a sturgeon to be entrained in a dredge, the fish would need to be almost on top of the drag head and be unaffected by associated disturbance (e.g., turbidity and noise). The authors also concluded that juvenile sturgeon are only at risk of entrainment in a cutterhead dredge if they are in close proximity, less than 1.0 m (3.3 ft), to the cutterhead.

Boysen and Hoover (2009) assessed the probability of entrainment of juvenile white sturgeon by evaluating swimming performance of young of the year fish (8-10 cm (3.1-4 in) TL). The authors determined that within 1.0 m (3.3 ft) of an operating dredge head, all fish would escape when the pipe was 61 cm (2 ft) or smaller. Fish larger than 9.3 cm (about 4 in) would be able to avoid the intake when the pipe was as large as 66 cm (2.2 ft). The authors concluded that regardless of fish size or pipe size, fish are only at risk of entrainment within a radius of 1.5-2 m (5-6.5 ft) of the dredge head; beyond that distance, velocities decrease to less than 0.3 mps (1 fps).

Clarke (2011) reports that a cutterhead dredge with a suction pipe diameter of 36-in (larger than the one to be used for this project) has an intake velocity of approximately 95 cm/s at a distance of 1.0 m (3.3 ft) from the dredge head and that the velocity reduces to approximately 40cm/s at a distance of 1.5 m (5 ft), 25cm/s at a distance of 2 m (6.6 ft) and less than 10cm/s at a distance of 3 m (9.8 ft). Clarke also reports on swim tunnel performance tests conducted on juvenile and subadult Atlantic, white and lake sturgeon. He concludes that there is a risk of sturgeon entrainment only within one meter of a cutterhead dredge head with a 36-in pipe diameter and suction of 4.6 mps.

8.2.2.2 Predicted Entrainment of sturgeon in a cutterhead dredge

Adult and sub-adult sturgeon are at low risk of entrainment in cutterhead dredges because a dredge head needs to be within one meter of them in order to potentially affect their ability to swim away. As studies in the Delaware and James Rivers has shown, sturgeon do not typically react to cutterhead dredge presence. Juvenile and adult shortnose sturgeon, and juvenile Atlantic sturgeon occur in the general vicinity of the Berth year-round. Adult Atlantic sturgeon are present between April and July; however, due to their larger size and seasonal occurrence, for the purposes of this Opinion, we do not expect that adult Atlantic sturgeon will be entrained.

During dredging at the Paulsboro site, the smaller size of juveniles makes them more likely than large adult sturgeon to be at risk of entrainment. However, there are several factors that may generally increase the risk of entrainment in upper Delaware River that are not present where cutterhead dredging will occur for this action. The behavior of the fish at overwintering grounds (overwintering in dense aggregations where they rest on the bottom and exhibit little movement and may be slow to respond to stimuli such as an oncoming dredge), and the location (fairly narrow and constricted portion of the Delaware River), may all play a role in limiting the ability of sturgeon to avoid an oncoming dredge. However, the dredging at the Berth is within a reach of the Delaware River that is 1.03 km (0.64 mi) wide (the upper Delaware at Newbold Island is approximately 400 m wide), and cutterhead dredging will not occur where fish may be in dense aggregations (overwintering is not known to occur in the dredging footprint, but they do overwinter in the lower tidal river in the vicinity of Marcus Hook and Chester, PA, which is approximately 11.3 km (7 mi) downstream). Although we expect that sturgeon will be present, tracking studies in the James and Delaware Rivers demonstrate that sturgeon are not attracted to the dredging equipment. These studies also show that dredging operations do not affect sturgeon behavior[27]. Therefore, it is likely that nearly all sturgeon in the action area will never encounter the dredge as they would not occur within 1.0 m (3.3. ft) of the dredge and movement is not confined to a narrow stretch of the river. Information from the tracking studies in the James and Delaware River supports this risk assessment.

While the risk of entrainment is low, it cannot be completely discounted when sturgeon are present during dredging operations. The entrainment of five sturgeon in the upper Delaware River indicates that entrainment of sturgeon in cutterhead dredges is possible. However, there were no reported takes of juvenile, subadult or adult sturgeon from the use of a cutterhead dredge for maintenance dredging of the 45-ft Philadelphia to the Sea Navigation Channel during the period from March 2010 through June 2019, which illustrates the rarity of these interactions. Deepening occurred in Reach C, Reach B and Reach A. Dredging in Reach C occurred from March – September 2010 with 3,594,963 cy of material removed with a cutterhead dredge. Dredging in Reach B, which overlaps with the Federal Navigation Channel portion of the action area in this Opinion, occurred in November and December 2011, with 1,100,000 cy of material removed with a cutterhead dredge. Dredging in Reach A occurred from September – February 2013 with the removal of approximately 1.2 million cy of material with a cutterhead dredge. In all cases, the dredge disposal area was inspected daily for the presence of sturgeon. We received no reports that sturgeon were detected. Based on the available information presented here, entrainment in a cutterhead dredge is likely to be rare, and would only occur if a juvenile sturgeon is within one meter of the dredge head.

Our previous Biological Opinions for dredge projects with cutterheads removing large quantities of material in areas where multiple life stages of sturgeon are present have quantified the mortality of juvenile sturgeon. In 2019, the Biological Opinion for the James River Federal Navigation Project estimated take based on similar factors as noted above, and concluded that no more than one sub-adult or juvenile Atlantic sturgeon would be entrained per 1.5 million cy (no more than 1 per year) by the cutterhead dredge used for maintenance dredging in the action area. In 2022, our Biological Opinion for the New Jersey Wind Port concluded that the cutterhead dredging of 4,290,000 cy of material in an 82 acre area of the Delaware River would kill two

[27] The studies analyzed behavior (change in direction of migrating fish or changes in distribution in response to the presence of an operating dredge) of sturgeon in the general vicinity of cutterhead dredges and not the fine scale response of sturgeon when a dredge head is approaching within a few meters of the fish.

sturgeon – either a juvenile or adult shortnose sturgeon, juvenile Atlantic sturgeon, or one of each. Our recent Biological Opinion for the Edgemoor Container Port concluded that the cutterhead dredging of 3,300,000 cy of material in an 87 acre area of the Delaware River would 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.

Our analysis for this Opinion similarly reflects an understanding of the likely risks to sturgeon from the ongoing use of cutterhead dredges within this reach of the Delaware River. The dredging for the Paulsboro RoRo terminal includes a substantially smaller dredge volume (approximately 140,900 cy), over a substantially smaller area (8.9 acres), and for fewer days (30 to 50 days) than for the sites referenced above. In addition, several studies, as well as relocation trawling during deepening of the Delaware River Federal Navigation Channel, demonstrate that the lower estuary (below Little Tinicum Island to the mouth of the river, where the Edgemoor and New Jersey Wind Port projects are located) is an important year-round rearing area with high densities of juveniles of both sturgeon species (sections 6.2.1 and 6.2.2). Aggregations of Atlantic sturgeon subadults and adults, as well as adult shortnose sturgeon, also occur in portions of the lower estuary. However, the Berth is located in the freshwater reach of the Delaware River, well upstream of the salt front and upstream of the Little Tinicum Island; although tracking studies by Stetzar *et al.* (2015) suggest that some juvenile Atlantic sturgeon rearing occurs at the Mifflin (Mantua Creek) anchorage located in the channel off of the Paulsboro Marine Terminal. Several studies, however, show that sturgeon are mostly found at depths of 6 m and deeper (Shirey *et al.* 1997, Stetzar *et al.* 2015). Because of this, based on available information, we do not expect the shallower channel shoreline at the Paulsboro Marine Terminal location to support high densities of Atlantic sturgeon and shortnose sturgeon juveniles or adults. This is because young juvenile sturgeon commonly rear downstream in freshwater reaches just above the salt front and older Atlantic sturgeon move downstream into increasingly higher salinity with age.

Based on the observed rarity of entrainment events, the expected low presence of sturgeon in the vicinity of the Berth, the timing and duration of the dredge cycle, and the low dredge volume together with studies showing that sturgeon need to be within one meter of the dredge head to be entrained, it is extremely unlikely that a juvenile, subadult or adult sturgeon would interact with a dredge.

8.2.3 Entrapment of Early Life Stages

Sturgeon spawn over hard substrate in freshwater reaches of the Delaware River, and eggs and larvae may be present in the Delaware River including the larger action area from late-April into September. As we noted in our discussion of PBF 1 of critical habitat (section 5.1.3.1), while there are some areas of gravel in the predominantly sandy substrate of the Berth area, the area is not suitable for sturgeon spawning and thus has low conservation value. As such, Atlantic sturgeon eggs and yolk-sac larvae are unlikely to be present due to the lack of suitable hard bottom substrate for deposition of eggs and interstitial spaces for refuge for early life stages.

Shortnose sturgeon spawning occurs upstream of the action area from Trenton rapids (about RKM 214/RM 133) to the Lambertville rapids and therefore, eggs and YSL will not be affected by dredging activities. Atlantic sturgeon spawn over suitable habitat from RKM 125 (RM 78) and upstream to approximately RKM 212 (RM 132), however, as discussed above, we do not expect Atlantic sturgeon to spawn in the area where dredging is proposed.

The applicant took sediment samples from five locations throughout the dredge footprint, with two replicates at each location, using a petite ponar grab sampler to collect material from the top 0.15 m (0.5 ft) of substrate (Jacobs, 2021). While some gravel was present, sand sized sediments dominated (62.3 – 87.0 percent) the three samples taken within the proposed turning basin and the two samples taken within the proposed area for mooring dolphin and revetment construction. Based on these results, the substrate within the dredge footprint is unlikely to provide suitable habitat for spawning, refuge, growth, and development of early life stages. The high percentage of sandy sediments within the dredge footprint indicates a low availability of adequate hard surfaces for eggs to adhere to and reduces the availability of interstitial spaces, present in coarser substrates, used by larvae for refuge from predators. Further, pairing telemetry results with substrate and water quality data indicates that spawning in the river likely occurs between the Marcus Hook Bar (RKM 125/RM 78) and the downstream end of Little Tinicum Island (RKM 138/RM 86), which is 7 km (4.3 mi) downstream from the Berth, and in the river upstream of north Philadelphia (RKM 176/RM 109.4) to Trenton (RKM 211/RM 131.1)(Simpson 2008). Because of the lack of suitable habitat in this portion of the action area, which is required to support early life stages, dredging is extremely unlikely to expose Atlantic and shortnose sturgeon eggs and YSL to entrainment or capture in dredge equipment. Therefore, effects to eggs and YSL are extremely unlikely to occur. After the YSL deplete their yolk-sac, free swimming post-yolk sac larvae (PYSL) drift with currents to downstream rearing areas where they settle. Atlantic sturgeon seem to drift to downstream rearing areas just above the salt front while shortnose sturgeon may drift only short distances before settling in rearing areas just downstream of spawning sites.(Kynard and Horgan 2002, Kynard 2007). Both species may also seek refuge in the interstitial spaces of hard bottom habitat while drifting. Based on the proposed timing for dredging, PYSL may be at risk for entrainment. Similar to eggs and YSL, sturgeon PYSL may be present in the Delaware River between April and September, depending on the year. Shortnose sturgeon may spawn as late as mid-May and development to PYSL takes from 25 to 50 days. Thus, shortnose sturgeon PYSL may occur into July. Shortnose sturgeon PYSL have been collected downstream of Trenton, NJ, and likely settle in areas of the upper tidal river, and could (though unlikely) drift downstream to the Paulsboro Marine Terminal. Atlantic sturgeon are believed to spawn at locations upstream (above RKM 176/RM 109.4) as well as downstream of the Paulsboro Marine Terminal, and PYSL are expected to drift in the river past the Berth site downstream to rearing areas upstream of the salt front but below Little Tinicum Island. Atlantic sturgeon PYSL may be present into September.

Once settled in rearing areas, PYSL are expected to be near the bottom of the river, either foraging over soft substrate or resting/seeking refuge within hard substrate with big enough interstitial spaces to provide cover. A mechanical dredge lowers the clamshell bucket at slow speeds (approximately 2 m/s) and the area covered by the bucket is small. While PYSL are not fully developed, we do expect them to sense the bucket as it is lowered on the substrate and be able to escape. Thus, the probability that a clamshell bucket will capture a PYSL is low. However, given the small size of PYSL (14-37 mm for Atlantic sturgeon), and the intake velocity of cutterhead dredges (~4.6m/second), it is unlikely that a PYSL that is over or within substrates being removed by the dredge could avoid entrainment. Additionally, the possible size of openings in the cutterhead suction pipe (~15-24 in) would not provide any screening or protection from entrainment. Given the limited mobility of PYSL, we expect that a cutterhead dredge could entrain PYSL if they are present in the dredge footprint (i.e. exposed to the dredge head). As proposed, if a cutterhead dredge is used to dredge the harder, lower layers of the sediment, then the access channel and Berth dredging will take about 30 days. Thus, cutterhead dredging will occur over a short period of time, which may or may not coincide with presence of PYSL, depending on a given year and the timing of spawning.

Overall, we expect that the risk of dredge entrainment for Atlantic or shortnose sturgeon PYSL to be extremely low. We lack information about PYSL presence, distribution, and behavior in the Delaware River, but based on a study by Kynard and Horgan (2002), we expect that shortnose sturgeon PYSL will remain near spawning areas until they fully develop. Further, we expect Atlantic sturgeon PYSL to drift to and settle in rearing areas just above the salt front, which is typically several miles downstream of the Paulsboro Marine Terminal. Studies also demonstrate that YOY Atlantic sturgeon reside and concentrate in the Marcus Hook range below Little Tinicum Island (section 6.2.2) (Hale *et al.* 2016). This supports the assumption that PYSL do not settle into suitable habitat until they drift past Little Tinicum Island to the Marcus Hook area, which is located several miles downstream of the Berth. Additionally, sturgeon larvae seem to drift near the bottom of the deepest parts of the river when drifting to rearing areas (Bain 1997, Bath *et al.* 1981, Braaten *et al.* 2010, Smith and King 2005). Thus, we anticipate Atlantic sturgeon PYSL to use the channel near the Paulsboro Marine Terminal mainly as a conduit for drifting to rearing areas downstream of the terminal without settling to rear in this reach of the river, and not the shallow areas along the shore where dredging will take place. Based on the expected behavior of PYSL, the fact that the proposed dredging area does not contain suitable hard bottom resting or rearing habitat (interstitial spaces for resting and cover between hard bottom), we expect it is extremely unlikely that dredging with a hydraulic cutterhead dredge will expose PYSL to entrainment by the dredgehead. Thus, effects are extremely unlikely to occur.

8.2.4 Summary of Effects

- Effects to juvenile, subadult, and adult Atlantic sturgeon from mechanical and cutterhead dredging are extremely unlikely.
- Effects to juvenile and adult shortnose sturgeon from mechanical and cutterhead dredging are extremely unlikely.
- Effects to early life stages of sturgeon are extremely unlikely.

8.3 Interaction with Suspended Sediment

Dredging suspend sediment into the water column. Resuspension of sediment may increase total suspended sediment (TSS) load and turbidity above ambient baseline levels. Turbidity relates to the optical quality of light transmission through a fluid containing sediment particles (most often measured as nephelometric turbidity units) and TSS concentration is the gravimetric measure of particles in suspension (generally measured as milligrams per liter).

High concentration of suspended sediment or turbidity may affect fish through many pathways (Johnson 2018, Kjelland *et al.* 2015). Sediment and turbidity can affect fish directly by reducing the gill's ability to take up oxygen, causing acute toxic reactions, resulting in physiological stress, and reducing foraging efficiency and/or predator avoidance. Resuspension of fine sediment with high organic content can affect fish indirectly by reducing dissolved oxygen levels. For all fish species in which effects to early life stages have been measured, it is clear that eggs and larvae are the most sensitive to suspended sediments and sediment deposition. The deposition of sediment from dredging or other human activities can be harmful to eggs and larvae through burial or encasement of eggs in fine particles occupying interstitial spaces, and these earlier stages are unable to avoid this stressor because of their limited mobility.

Effects of dredging will vary based on site-specific conditions (Wilber and Clarke 2001). Site-specific conditions (e.g., bathymetry, currents) and material (e.g., sand versus silt) should be taken into consideration as it may influence turbidity and re-suspended sediment at a site. Assessing exposure of listed species to elevated levels of turbidity or TSS concentration requires an understanding of the sources (e.g., dredge type), factors that influence the duration and intensity of exposure (e.g., sediment type and/or current), as well as the individual species tolerance to the anticipated level of exposure at a given life stage. In our analysis, we consider information from earlier studies of sediment resuspension and turbidity to understand the intensity and extent of turbidity impacts. However, we also consider site-specific information to understand how local conditions influence turbidity and re-suspended sediment.

8.3.1 Thresholds for Total Suspended Sediment (TSS) and Turbidity

Literature reviews of the effects of suspended sediment on fish show that effects varies greatly among species and suggest that concentrations of suspended solids can reach thousands of milligrams per liter before an acute toxic reaction is expected (Burton 1993, Kjelland *et al.* 2015, Wilber and Clarke 2001). Burton (1993) evaluated effects of bucket dredging in the Delaware River and determined that lethal effects on fish due to turbid waters can occur at levels between 580 mg/L to 700,000 mg/L, depending on the species. The studies reviewed by Kjelland *et al.* (2015) found that, depending on species, reported mortality ranged from 10 to 100 percent when exposed to TSS levels ranging from 300 to 300,000 mg/L after exposure periods ranging from 24 to 48 hours. Wilber and Clarke (2001) found that for adult estuarine species, TSS effects ranged from "no effect" when exposed to 14,000 mg/L for a duration of three days for two species to the lowest observed concentration that caused mortality at 580 mg/L after one day of exposure for Atlantic silverside. The concentration of suspended sediment is not the only factor determining effects but also the duration at which a fish is exposed. Most studies report response after exposure ranging from 24 to 48 hours.

There have been no directed studies on the physiological effects of TSS on shortnose or Atlantic sturgeon. However, Kjelland *et al.* (2015) noted that benthic species in general are more tolerant to suspended sediment than pelagic species. Shortnose and Atlantic sturgeon juveniles and adults are often documented in turbid water and Dadswell *et al.* (1984) reports that shortnose sturgeon are more active under lowered light conditions, such as those found in turbid waters. As such, shortnose and Atlantic sturgeon are assumed to be at least as tolerant to suspended sediment as other estuarine fish. Therefore, we regard sublethal and lethal effects on juvenile and adult Atlantic sturgeon and shortnose sturgeon to occur when exposed to 24 hours of concentrations at or above 580 mg/L.

High TSS levels can cause a reduction in DO levels, which can cause both Atlantic and shortnose sturgeon to become stressed when DO falls below 3.5 mg/L (Secor and Niklitschek 2001). Jenkins *et al.* (1993) observed that younger shortnose sturgeon experienced high levels of mortality at low dissolved oxygen levels while older individuals tolerated those reduced levels for short time periods. Tolerances may decline if chronic exposure to low dissolved oxygen levels occurs. Johnson (2018) recommends that sturgeon should not be exposed to TSS levels of 1,000 mg/L above ambient for longer than 14 days at a time to avoid behavioral and physiological effects.

As is the case with physiological effects, behavioral response to increased turbidity and turbidity plumes varies among species and depends on their specific biology such as sensory capabilities and adaptive strategies. Studies of how fish respond to suspended sediment have detected behavioral effects of turbidity on feeding and vulnerability to predation (Kjelland *et al.* 2015, Wilber and Clarke 2001). High turbidity may affect feeding efficiency for species using visual detection during foraging, which again can result in reduced growth, fecundity or increase stress and susceptibility to disease and parasites. However, turbidity, at least at TSS levels below what would cause physiological effects, is not likely to substantially affect Atlantic sturgeon or shortnose sturgeon foraging. Sturgeon typically occur in turbid waters and Atlantic sturgeon and shortnose sturgeon forage by rooting along the bottom with their snout in search for benthic prey that they grasp with their protruberant mouth (Gilbert 1983, Kynard *et al.* 2016). During foraging, they use their barbels as sensory organs to detect prey (Hilton *et al.* 2016, Kynard *et al.* 2016). Both species also actively forage during night (Dadswell *et al.* 1984). Based on foraging method, tolerance to high turbidity and foraging during night it is unlikely that visual detection of prey is of major importance for Atlantic sturgeon and shortnose sturgeon foraging success. Elevated TSS levels resulting in physiological effects may elicit avoidance behavior and movement away from turbidity plumes. Studies on another an anadromous species, striped bass, showed that pre-spawners did not avoid TSS concentrations of 954 mg/L to 1920 mg/L to reach spawning sites (Summerfelt and Moiser 1976, Combs 1979 in Burton 1993).

8.3.2 Extent and intensity of water quality changes

8.3.2.1 Dredging

Mechanical Dredge

Mechanical dredges include many different bucket designs (e.g., clamshell, closed versus open bucket, level-cut bucket) and backhoe dredges, representing a wide range of bucket sizes. TSS concentrations associated with mechanical clamshell bucket dredging operations have been shown to range from 105 mg/L in the middle of the water column to 445 mg/L near the bottom (210 mg/L, depth-averaged) (ACOE 2001). Furthermore, a study by Burton (1993) measured TSS concentrations at distances of 152, 305, 610, and 1006 m (500, 1,000, 2,000, and 3,300 ft) from dredge sites in the Delaware River and were able to detect concentrations between 15 mg/L and 191 mg/L up to 610 m (2,000 ft) from the dredge site. In support of the New York/New Jersey Harbor Deepening Project, the U.S. Army Corps of Engineers conducted extensive monitoring of mechanical dredge plumes (ACOE 2015a). The dredge sites included Arthur Kill, Kill Van Kull, Newark Bay, and Upper New York Bay. Although briefly addressed in the report, the effect of currents and tides on the dispersal of suspended sediment were not thoroughly examined or documented. Independent of bucket type or size, plumes dissipated to background levels within 183 m (600 ft) of the source in the upper water column and 732 m (2,400 ft) in the lower water column. Based on these studies, elevated suspended sediment concentrations at several hundreds of mg/L above background may be present in the immediate vicinity of the bucket, but settle rapidly within a 732 m (2,400 ft) radius of the dredge location. A turbidity curtain would reduce the extent of the turbidity plume; however, because the practicality of deploying a turbidity curtain is unknown, we assume the worst-case scenario that a turbidity curtain will not be practicable and that turbidity will extend 732 m (2,400 ft) from the dredge.

Hydraulic Cutterhead Dredge

Cutterhead dredges use suction to entrain sediment for pumping through a pipeline to a designated discharge site. Production rates vary greatly based on pump capacities and the type (size and rotational speed) of cutter used, as well as distance between the cutterhead and the substrate. Sediments are resuspended during lateral swinging of the cutterhead as the dredge progresses forward. Modeling results of cutterhead dredging indicated that TSS concentrations above background levels would be present throughout the bottom 1.8 m (6 ft) of the water column for a distance of approximately 305 m (1,000 ft) (ACOE 1983). Elevated suspended sediment levels are expected to be present only within a 300-500 m (984.3 to 1,640.4 ft) radius of the cutterhead dredge (ACOE 1983; LaSalle 1990; Hayes et al. 2000, as reported in Wilber and Clarke 2001). TSS concentrations associated with cutterhead dredge sediment plumes typically range from 11.5 to 282.0 mg/L with the highest levels (550.0 mg/L) detected adjacent to the cutterhead dredge and concentrations decreasing with greater distance from the dredge (Nightingale and Simenstad 2001; ACOE 2005, 2010, 2015b).

8.3.2.2 Pile driving

The installation of piles will disturb bottom sediments and may cause a temporary increase in suspended sediment in the action area. Using available information collected from a project in the Hudson River, we expect pile driving activities to produce total suspended sediment (TSS) concentrations of approximately 5.0 to 10.0 mg/L above background levels within approximately 91 m (300 ft) of the pile being driven (FHWA 2012). The small resulting sediment plume is expected to settle out of the water column within a few hours. Studies of the effects of turbid water on fish suggest that concentrations of suspended sediment can reach thousands of milligrams per liter before an acute toxic reaction is expected (Burton 1993). The TSS levels expected for pile driving or removal (5.0 to 10.0 mg/L) are below those shown to have adverse effects on fish (typically up to 1,000.0 mg/L; see summary of scientific literature in Burton 1993; Wilber and Clarke 2001) and benthic communities (390.0 mg/L (EPA 1986)).

8.3.2.3 Erosion and stormwater runoff

The release of stormwater during construction of the Berth may temporarily increase suspended sediment concentration, thus elevating turbidity in the receiving waterbody. Erosion and stormwater runoff associated with adjacent upland activities during construction of the proposed Berth could affect water quality for aquatic species, including sturgeon. However, upland construction activities will be conducted in compliance with an approved Stormwater, Erosion, and Sedimentation Control (SESC) plan to minimize water quality impacts. By discharging effluent through a fabric filter, hay bales, or a vegetated buffer strip prior to the effluent entering the receiving waterbody any remaining sediment in the effluent will be trapped or be allowed to settle out of suspension.

8.3.3 Exposure to suspended sediment

Eggs and yolk-sac larvae are not likely to be present at or adjacent to the Berth project area, and, therefore, will not be exposed to suspended sediment and elevated turbidity caused by project activities. Erosion and stormwater runoff from upland construction activities could occur any time of the year. However, we expect the implementation of a SESC plan to eliminating listed species exposure to elevated concentrations of suspended sediment. Dredging and pile driving will occur after July 1, 2022, with no in-water work between March 15 and June 30. During this period, PSYL Atlantic sturgeon, juvenile shortnose sturgeon and Atlantic sturgeon, adult shortnose sturgeon and Atlantic sturgeon, and subadult Atlantic sturgeon occur within the project area. Thus, these activities may expose all these life stages to elevated sediment concentration and turbidity.

8.3.4 Response to exposure

Juvenile and adult sturgeon are frequently found in turbid water and would be capable of avoiding any sediment plume by swimming higher in the water column. Laboratory studies (Niklitschek 2001, Secor and Niklitschek 2002) have demonstrated shortnose sturgeon are able to actively avoid areas with unfavorable water quality conditions and that they will seek out more favorable conditions when available. Additionally, the highest TSS levels expected for any of the dredging is up to 550 mg/L (cutterhead dredging), which is below those shown to have lethal and sublethal effects on estuarine fish (typically up to 1,000.0 mg/L; see summary of scientific literature in Burton 1993, and Wilber and Clarke 2001).

TSS is most likely to affect PYSL, juvenile and adult sturgeon if a plume causes a barrier to normal behaviors. However, the increase in TSS levels expected are below those shown to have adverse effects on fish, so we expect sturgeon to either swim through the plumes or make small evasive movements to avoid them.

Even if sturgeon avoid the turbidity plume, this will not be a barrier to migration. Elevated suspended sediment levels at the Berth site that may cause avoidance will be due to the sediment plumes generated by pile driving, mechanical, and hydraulic dredging, with radii of 91 m (298.5 ft), 732 m (2,400 ft), and 500 m (1,640.4 ft), respectively. Given the river width in the vicinity of the Berth (approximately 1.03 km (0.64 mi)), the plumes would affect 8.8 to 71% of the River's cross-section. The sediment suspended during dredging will quickly decrease to low concentrations as the distance increases from the dredging area and the sediment falls out of the water column. Any TSS levels that may cause avoidance will be closer to the dredge than the full extent of the sediment plume. Thus, any avoidance of the plume will not hinder upstream or downstream movements of sturgeon.

Avoidance of turbidity plumes may cause adult Atlantic sturgeon to move into the shipping channel and increase their exposure to vessel strike during the spawning migration; however, dredging will not occur during Atlantic sturgeon spawning migrations.

Energy expenditure to avoid turbidity plumes could reduce growth of sturgeon, delaying ocean migration and, eventually, expected lifetime fecundity. Sturgeon will use extra energy if they want to avoid the turbidity plumes. However, sturgeon feed on a large range of prey and actively move over the riverbed in search of forage when foraging. The small evasive movements that would be necessary to avoid high TSS concentrations would be within their normal range of movements and we do not expect this to increase substantially normal energy use. Thus, it is unlikely that these movements will result in a measurable effects on growth or fecundity of sturgeon.

8.3.5 Effects of Interaction with Suspended Sediment

Construction of the Berth may expose Atlantic sturgeon PSYL, juveniles and adults of both shortnose sturgeon and Atlantic sturgeon to TSS concentration and turbidity above baseline conditions. However, TSS concentrations will be below concentrations that would cause physiological effects and the increased turbidity is unlikely to affect foraging. Thus, no injury or mortality will occur to juvenile and older sturgeon. Sturgeon may avoid turbidity plumes, but this will not be a barrier to migration. Sturgeon may make small evasive movements to avoid turbidity plumes, but these small adjustments are unlikely to affect growth, survival, or fecundity. Based on these considerations, effects to juvenile and older sturgeon are too small to be meaningfully measured, detected, or evaluated. Therefore, effects are insignificant. Eggs and yolk-sac larvae are not expected to be present within the portion of the action area where dredging and elevated turbidity could occur. Thus, effects to eggs and YSL are extremely unlikely to occur, but PYSL may be exposed to elevated turbidity because the turbidity plume may extend into deeper portions of the river where the channel is located. If PYSL drift through that area, they may be exposed to the plume. We have no information about larval tolerance to elevated turbidity. However, the Delaware River normally has high TSS background levels and we expect that the dredging will have minimal impact on TSS levels within the main channel as turbidity is expected to be reduced with distance from the dredge, which will only be operating within the shallower Berth dredging footprint. Therefore, we do not anticipate that the dredging will result in TSS levels substantially higher than background levels. Based on this, effects are too small to be meaningfully measured, detected, or evaluated and, therefore, are insignificant.

8.4 Benthic Habitat Modification and Loss of Forage

The proposed project will remove and disturb the riverbed through dredging and scour from the propeller jet of vessels.

Soft substrate support a variety of benthic invertebrates that are important prey for sturgeon. Therefore, removal and disturbance of the bottom sediment or conversion of the riverbed from soft to hard substrate can eliminate or reduce forage for sturgeon. This can again limit forage available to sturgeon and reduce the numbers that an area can support. Widespread habitat loss and deterioration decreases the carrying capacity of the river habitat and/or can impact the fitness of individuals.

In this section, we present background information on the existing habitat and the proposed project's impacts; the established thresholds and criteria to consider when assessing habitat impact; an analysis of exposure; and a summary of available information on sturgeon habitat use and available information on sturgeon responses to loss of habitat and forage. We then consider the effects of exposure of individual sturgeon to habitat loss and degradation.

8.4.1 Intensity and Extent of Habitat and Forage Impacts

The Project Area consists primarily of soft substrate, which supports a variety of benthic invertebrates that are important prey for sturgeon. Analysis of benthic community samples taken at the site were dominated by the species in the taxa freshwater worms (order Tubificidae), Amphipoda crustaceans, Asiatic clams (Bivales: Corbicula), and midges (Dipetera), which are common taxa in sandy substrates of freshwater and estuarine environments. These organisms provide food sources for juvenile and adult Atlantic and shortnose sturgeon foraging within the project area. Recent benthic sampling indicates that sand was the dominant substrate type with fine (silt) depositional materials less prevalent and constituting a lesser percentage of the dredge surface area within the proposed areas of dredging and revetment (Jacobs, 2021).

8.4.1.1 Dredging

Dredging for the proposed action is expected to commence after July 1, 2022, and take 30 to 50 days to complete, with no in-water work between March 15 and June 30. The total dredge footprint occupies approximately 8.9 acres of the existing riverbed. Dredging will temporarily remove all benthic invertebrates within the dredge footprint. We expect that this activity is more likely to disturb or displace non-mobile organisms that occur at the surface of the sediment and is less likely to impact mobile invertebrates (such as crabs). Dredging is likely to entrain and kill at least some of mobile invertebrates. Further, turbidity and suspended sediments from dredging activities may affect benthic resources in those areas. Some of the TSS levels expected for the proposed activities (ranging from 445 mg/L to 550 mg/L) exceed the levels shown to have adverse effects on benthic communities (390 mg/L (EPA 1986).

Studies done by Wilber and Clarke (2001) demonstrate that benthic communities in temperate regions occupying shallow waters with substrate of sand, silt, or clay reported recovery times between one and 11 months after dredging. Therefore, if a dredge site remains undisturbed after dredging, the benthic invertebrate fauna within the dredged areas could recover to pre-project conditions within one year following completion of the initial dredging. However, we do not know how the change in depth may affect composition and density of the invertebrate fauna.

8.4.1.2 Revetment

After dredging is completed, approximately 2,000 cy of armor stone will be placed around the dolphin piles to form the revetment, which will provide shoreline protection. The revetment will be constructed within the 8.9-acre dredge footprint. A clamshell bucket from a barge-mounted crane, and rock scow similar in size and draft to the dredge scows, will deposit the armor stone. A 0.6 m (2 ft) layer of armor stone (15.2 to 38.1 cm (6 to 15 in) diameter stones) will be placed on the graded revetment slope from the existing sediment surface at an approximate depth of -2.0 m (-7 ft) MLLW to -10 m (-33 ft) MLLW to meet the dredged area depth. The constructed revetment will have a slope of 1 vertical: 1.5 horizontal.

The installation of the revetment and additional armor stone along the shoreline will create permanent hard substrate, replacing the existing soft sediments. The grading of the area to a 1:1.5 slope will be accomplished by dredging and is discussed in the dredging section of the proposed action. As a result of this change in habitat from soft sediment to hard substrate, a different assemblage of benthic organisms, particularly epifaunal communities, will colonize the area. This shift would not support viable foraging habitat for juvenile and adult sturgeon, which prefer soft sediment forage items. Dredged and disturbed areas where the revetment will be placed are not likely to support early life stages of sturgeon, therefore no effects to early life stage habitat are expected. The placement of armor stone is also not likely impact any juvenile or adult sturgeon directly through impingement. There would be no effect from noise created during revetment installation on any sturgeon species or life stages, as sound levels would not reach any effect thresholds. The magnitude of the impact from the installation of the revetment is considered small compared to the available unimpacted aquatic habitats within the action area; therefore, the effects of the installation of the revetment on sturgeon forage habitat are too small to be meaningfully detected.

8.4.1.3 Vessel Traffic

Vessels maneuvering in shallow waters can result in major erosion of the riverbed and suspension of sediment (Breedveld *et al.* 2018a, PIANC 2008, Stoschek *et al.* 2014). Erosion of the riverbed and resuspension of sediment will affect the composition, density, and availability of benthic invertebrates (Gabel 2012). The strong swirling jet flow induced by a rotating ship propeller causes shear stress that can cause considerable scour to the riverbed (Breedveld *et al.* 2018a, Hong *et al.* 2013, Hong *et al.* 2016, Karaki and van Hoften 1975). Because the propeller-induced bed shear stress is a main stirring force, sediment erosion, resuspension and deposition are all expected to be closely related to vessels maneuvering in narrow channels and while docking (Karaki and van Hoften 1975, PIANC 2008).

Several theoretical models and empirical methods have been developed to calculate the amount of scour and sediment transport caused by propeller shear stress and jet propulsion (Breedveld *et al.* 2018b, Hong *et al.* 2016, PIANC 2008, Stoschek *et al.* 2014). However, the USACE has not provided any analysis of effects from the operation of Azipods at the Berth and we cannot quantify the amount of bed erosion and sediment resuspension, expected TSS by a single vessel docking at the proposed Berth, or the direction and extent of the sediment plume given that it depends on a variety of factors, including but not limited to tidal fluctuations, turbulence dynamics of the river reach, salinity layers, and the density of vessel traffic. Nevertheless, studies of berthing areas and docks show that vessels maneuvering at docks commonly result in substantial scouring of the riverbed and increased total suspended sediment in the water column (Breedveld *et al.* 2018a, PIANC 2008, Stoschek *et al.* 2014). Because the propeller-induced bed velocity and shear stress is strongest when vessels start from a still position, are repositioning, or are increasing its use of horsepower, resuspension and deposition are expected to be highest during a vessel's maneuvering and docking operations, i.e. situations where vessels start, stop, accelerate, and decelerate (Karaki and van Hoften 1975, PIANC 2008). We expect the propeller jets from large vessels to hit the bottom in the access channel, turning basin, and berths. Vessels approaching, docking at, and departing from the Berth will use Azipods to maneuver and maintain position in the turning basin and berthing areas. The water jet from Dynamic Positioning thrusters – another type of propulsion used to maneuver vessels - have been shown to cause erosion (PIANC 2008). We expect that the use of Azipods will have similar effects. Thus, the Azipods, as well as more conventional vessel propellers and hulls, have the potential to disturb the river bottom and associated benthic invertebrate community in the access channel, turning basin, and berth.

The vessels docking at the proposed Berth will have Azipods or large sized propellers, and have a draft clearance of less than 3 m (9.8 ft) in the access channel and the docking site. Therefore, we expect the operation of the Berth will result in continuous disturbance of sediment and the density and composition of benthic invertebrates. Further, vessel activity and propeller motion when vessels are arriving and leaving the berth are likely to disturb sturgeon or cause vessel strike of sturgeon that are present within or adjacent to the berthing area. Based on these considerations, we conclude that the operation of the terminal will cause a permanent degradation of sturgeon foraging habitat within the project area.

8.4.2 Exposure to changes in habitat and forage

As previously described, juvenile and adult shortnose sturgeon and Atlantic sturgeon as well as PYSL Atlantic sturgeon occur within the action area. Both Atlantic sturgeon and shortnose sturgeon commonly use depths of 6 m (19.7 ft) or deeper in the Delaware River. The depths in the area between the Philadelphia to the Sea Navigation Channel and the Berth generally range from 0-13.7 m (0-45 ft). Thus, the depths at portions of the Berth site (those between 6 m (19.7 ft) and 13.7 m (45 ft)), are within the depth range where sturgeon are found.

Sturgeon will be exposed to the temporary loss and permanent reductions of benthic prey within 8.9 acres of the 350-acre Berth area (Figure 3). Based on this, the proposed project will expose Atlantic and shortnose sturgeon to reduced foraging opportunities within 2.5 percent of the project area (located approximately between RKM 139.2 and 144.4 (RM 86.5 and 89.7)) over a 10-year period. The action area also includes the Federal Navigation Channel between RKM 214.5 (RM 133.3) and the mouth of the Bay at RKM 5 (RM 3.1) and is 11,568 acres; however, it is uncertain what percentage of the channel supports benthic prey because maintenance dredging and regular vessel disturbance can create a suboptimal environment.

8.4.3 Response to changes in habitat and forage

Juveniles and adults of both species likely forage on benthic invertebrates that are present within the action area. The temporary loss of invertebrates and long-term disturbance of invertebrate habitat will limit sturgeon ability to forage within the proposed access channel and Berth for at least a 10-year period. The project area still contains approximately 341.1 acres of soft bottom substrate but the quality of the habitat at the Paulsboro Marine Terminal and in the Federal Navigation Channel is impacted by regular maintenance dredging and vessel traffic. However, the Federal Navigation Channel plus the dredge footprint constitutes only a small percentage of the river between RKM 5 and 214.5 (RM 3.1 to 133.3). Within this entire reach, the proposed project will expose sturgeon to an extremely small reduction in forage habitat. Younger Atlantic and shortnose sturgeon move seasonally between the lower estuary at the mouth of the river and the Berth area. We assume they use this whole area for foraging. Thus, the reduction in forage within the dredge footprint and the Federal Navigation Channel from dredging and scour from vessel traffic represents a very small percentage of foraging habitat used by the sturgeon. Therefore, when added to baseline, we do not expect the proposed project will limit forage for Atlantic sturgeon and shortnose sturgeon of any life stage to such extent that essential behaviors are modified and the fitness of individuals is reduced.

8.4.4 Effects of Habitat Modification and Loss of Forage

When added to baseline bottom disturbances, the proposed project will affect a relatively small portion of river bottom and reduce the availability of benthic invertebrate prey. This will affect sturgeon distribution and foraging within the Berth area. However, the action area still provides ample available bottom habitat, and the temporary loss of benthic invertebrates within the 8.9-

acre dredge footprint is small relative to the amount of soft bottom habitat present in the action area and in the Delaware River. Therefore, we do not expect the proposed project to limit forage for juvenile Atlantic sturgeon or shortnose sturgeon. We similarly expect that the action area and lower estuary will provide ample forage for adult Atlantic sturgeon as they move through the area during the spawning migration. As such, we do not expect this impact to available foraging habitat caused by the proposed project to limit forage to an extent that would significantly impair essential behavioral patterns. Based on this, we have determined that the consequence to sturgeon habitat and forage from dredging and vessel use of the Port access channel and turning basin is too small to be meaningfully measured, detected, or evaluated. Therefore, effects are insignificant.

8.5 Vessel Strike

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 within the Delaware River.

Construction and operation of the Berth will cause an increase in vessels operating within the Delaware River and the Delaware Bay. Vessels supporting construction and dredging will operate within the Philadelphia to the Sea Navigation Channel after July 1, 2022, with no in-water work between March 15 and June 30. 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.

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 vessels strikes killing sturgeon have also been reported (e.g., Park 2017, personal communication).

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).

The construction and operation of the proposed Berth is expected to increase vessel traffic at the site and within the Federal Navigational Channel. Both construction and 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.

8.5.1 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. moving away) 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, and are not able to evade the propeller(s) even if they do attempt to move when approached by a 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 personal communication, 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). 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 them 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 occurs 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 ft) or greater were not drawn into the 2.4-m (7.8-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, personal communication). We do not have calculations of the approach velocity of water in front of the Azipods or propellers of the inbound and outbound 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% for a 12.5 cm (5 in) fish to 5% for a 35 cm (13.8 in) long fish, and from 50% for a 72 cm (28.3 in) long fish to 80% 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 (8.2 ft), a draft of up to 2.7 m (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 (Ian Park, DENRC, personal communication, June 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.* (2012b) 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 Environmental 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 increase their exposure to vessels (Balazik *et al.* 2017a, Brown and Murphy 2010, Fisher 2011).

8.5.2 Effects of Vessel Activity during Construction

During Berth construction, tugboats, crew vessels, and barges will operate in the channel between the Berth site and the Federal Navigation Channel in the Delaware River. Further, barges pushed by tugboats will transport dredged material to disposal facilities. Thus, construction activities will temporarily increase vessel traffic in the action area, which in turn could increase the risk of sturgeon interactions with vessels. While most sturgeon vessel mortalities have been attributed to large commercial vessels, tugboats, barges, and towboats have been observed striking and killing sturgeon (Balazik 2012; Brown and Murphy 2010; Gutreuter et al. 2003). If the construction of the Berth results in a substantial increase in sturgeon exposure to vessels in addition to baseline conditions, then we can expect an increase in vessel strike mortalities.

8.5.2.1 Extent of Vessel Traffic

Pile Driving

Vessels used during pile driving activities will include a single barge-mounted crane anchored with spuds, a tugboat (20 to 40 ft long, 8-ft draft), and a crewboat (20 to 30 ft long, 5-ft draft). These vessels will berth at the Paulsboro Marine Terminal minimizing the distance of transits and the use of the Federal Navigation Channel. Pile construction is scheduled to occur before dredging. The movement of pile driving construction vessels will be slow (<10 knots) and will be limited to repositioning, as needed. Pile driving is estimated to take place over 15 to 20 days spread across a 1-month period, with overwater construction taking a further 6 to 8 weeks. Piles will be loaded onto barges at the Paulsboro Marine Terminal Berth. Thus, we expect that all vessel traffic during pile driving will be restricted to the movement of vessels to and from the adjacent existing wharf of the Paulsboro Marine Terminal site and along the shore where the new dolphins will be constructed. We do not have information regarding the homeport of the tug, barge, and crew boat, at this time. However, we assume that pile driving will result in two vessel trips (one tug pushing the barge and one crew boat) on the Delaware River from the homeport to the construction site at the start of construction and two return trips at the end of construction for a total of four vessel trips.

Dredging

For this analysis, we assume that dredging will commence in the beginning of the proposed work window (i.e. July) and will have a duration of 30 to 50 days depending on dredge equipment used. Vessels used during dredging activities will include up to two dredge barge/scows, one crewboat (6.1 to 9.1 m (20 to 30 ft) long, 1.5 m (5 ft) draft), and up to two tugboats (6.1 to 12.2 m (20 to 40 ft) long, 2.4 m (8 ft) draft) for assisting with barge transport and dredge maneuvers.

In the first phase of dredging, sediments may be mechanically unloaded from scows to the Paulsboro Marine Terminal wharf for disposal or reuse. However, if not disposed of onsite, barges pushed by tugboats will transport dredge material to either Biles Island, Pennsylvania, 68 RKM (42 RM) upstream of the project area, or Whites Basin, New Jersey, located approximately 10 RKM (6 RM) downstream of the project area. For the purpose of this analysis, we will assume that dredge materials will be transported to either the Biles Island or the Whites Basin facilities as the worst-case scenario, in the event it is not reused onsite. Under this scenario, approximately 10,300 cy of dredged material will be transported to Biles Island or Whites Basin. Scows have a loaded transport capacity for this type of dredged material of 2,000 cy, which translates to six tug excursions, but the USACE and the applicant estimate as many as eight excursions (16 vessel trips) may be needed.

During the second phase of dredging, the deeper layers of sand and gravel will be dredged with a backhoe excavator dredge mounted to a barge (9.1 m (30 ft) wide by 30.5 m (100 ft) long by 1.8

m (6 ft) draft), with dredged material placed and dewatered in scows (45.7 (150 ft) long, 11.4 m (37.5 ft) wide, and 1.8 m (6 ft) draft; similar to the first round of dredging), prior to offloading at the wharf. Alternatively, a hydraulic cutterhead dredge will dredge the coarser-grained, deeper sediments and the material will be piped directly to the upland disposal areas for onsite reuse.

For both phases, dredging will be ongoing once construction begins and dredges will operate 24 hours per day, 7 days per week. Vessels will berth at the existing Paulsboro Marine Terminal facility and vessel activity during dredging will consist of stockpiling and decanting dredged sediments immediately adjacent to the construction area. Daily travel by crew vessels will also be limited to movements between the existing wharf of the Paulsboro Marine Terminal and the dredge vessels.

As with pile driving, we assume that all vessels (two tugs, two barges and one crew boat) have homeports located within the Delaware River basin. Thus, the transport of these vessels to the project site at the beginning of dredging and transport to the homeport (or another work assignment) once dredging is finished will result in six vessel trips (two tugs with barges and one crew boat) on the Delaware River.

<u>Summary of Vessel Activity</u>

Tug and crew boat activity supporting pile driving and dredging will be confined to the area between the edge of the Federal Navigation Channel and the existing Paulsboro Marine Terminal.

All construction activities will occur after July 1, with no in-water work between March 15 and June 30. Therefore, we expect all vessel trips associated with pile driving and dredging to occur during this period. As discussed above, we anticipate that the proposed construction of the Berth will result in a total of 6 vessel trips for dredging, 4 vessel trips for pile driving and 16 trips for disposal of dredged material for a total of 26 trips.

8.5.2.2 Exposure to Vessels

Potential exposure to vessels (tugs, crew vessels, and barges) during construction will occur within the 8.9-acre dredging footprint and at the existing berths at the Paulsboro Marine Terminal. Some overlap between vessel movements and sturgeon presence may also occur outside of, but adjacent, to this area. In addition, vessels traveling to Biles Island or Whites Basin will overlap with sturgeon presence in the Federal Navigation Channel.

The area between the proposed Berth and the Federal Navigation Channel currently does not have an access channel. Tow or tug vessels occasionally transit along the shore outside of the Navigation Channel, and other vessels, such as recreational and fishing vessels, also travel outside the Navigation Channel and occasionally within the footprint of the proposed access channel. However, the majority of vessel traffic in the area occurs in the deeper portions of the Project Area closer to the Federal Navigation Channel. Thus, the proposed project will result in an increase in vessel activity relative to baseline conditions within the dredge footprint and along the shoreline where the dolphins will be installed.

Project vessel activity will occur for up to 50 days during dredging and up to three months for construction of the dolphins and catwalk. However, dredging and overwater work on the dolphins and catwalk will overlap in time. Thus, we expect that construction will add vessel activity to the baseline vessel traffic for a period of three months and that this activity will occur sometime after July 1, 2022, with no in water work between March 15 and June 30.

We anticipate that juvenile Atlantic sturgeon and juvenile and adult shortnose sturgeon may be present in the Delaware River at and near the project site year round. We also anticipate that adult Atlantic sturgeon may be present at or near the project site during July and potentially through September. However, we expect that adult and subadult Atlantic sturgeon will use this reach of the river as a migration corridor with no residency within the project area. The work will occur in a section of the waterway that is approximately 1.03 km (0.64 mi) wide. Based on the area of impact, adequate space exists to allow for pile driving and dredging activities at the berth as well as the passage of sturgeon in the waterway without a pathway for effects of vessel interaction.

We also do not expect the project dredging footprint and the Paulsboro Marine Terminal access channel and Berth to be a rearing area for juvenile sturgeon or to support any overwintering aggregations. Any sturgeon presence along the shoreline will be by sturgeon opportunistically foraging within the area. Thus, presence of project vessels within the project area may overlap in time and space with the presence of opportunistically foraging juvenile and adult shortnose sturgeon any time during the work window, with opportunistically foraging juvenile Atlantic sturgeon any time during the work window, and opportunistically foraging adult and subadult Atlantic sturgeon from July through September.

Water depth within the Project Area varies but is generally 2.1-13.7 m (7-45 ft) MLLW. Shallowest depths in the construction area are 2.1 m (7 ft) MLLW and grade deeper towards the Federal Navigation Channel to the north. The average tidal range in this region is 1.7 m (5.5 ft). Tug vessels are expected to have the deepest draft with a maximum draft of 2.4 m (8 ft). Thus, the construction vessels will have 0 to 11.3 m (0-37 ft) clearance of the river bottom during MLLW. Based on this, we expect the propeller's zone of influence (as defined in section 8.5.1) to include the water column down to the bottom of the channel during low tide within the shallow portion of the Project Area (i.e., close to shore). Thus, a tugboat may expose sturgeon to entrainment when water flows through the propellers, especially in the nearshore shallower areas. However, during high tide, the clearance will range from 1.4 to 13 m (4.5 to 42.5 ft) and most sturgeon at the river bottom will be able to avoid exposure to the propeller approach current. We expect that tugs operating with a clearance of 6 m (19.7 ft) or more will not expose sturgeon on the river bottom to the water drawn through the propeller, and will not be at risk of entrainment. However, even though we do not have any calculations on expected velocities of water drawn through the propellers at varying depths, we do not expect sturgeon to be present in shallow waters where they could be at risk of entrainment.

During pile driving, we expect that sturgeon will avoid an ensonified area extending 130 m (426.5 ft) into the river channel from the piles. Most vessel traffic associated with construction of the dolphins will occur during pile driving and will occur within the ensonfied area. Thus, we do not expect a spatial and/or temporal overlap between vessel activity and the presence of sturgeon during pile driving (15 to 20 days during a one-month period).

Vessels traveling between the project area and a dredged material disposal facility are expected to travel within the Federal Navigation Channel. This activity will occur during the 30 to 50 days of dredging of the Berth and access channel. It is not clear at this time when dredging will take place but we anticipate that all dredging will occur after July 1, 2022, with no in-water work between March 15 and June 30.

The transit of vessels to and from the project site as well as the transport of dredged material to disposal facilities is likely to overlap in space and time with presence of sturgeon. We expect juveniles of both sturgeon species to be present year round within the reach of the river from Whites Basin to Biles Island. We also expect adult shortnose sturgeon to be present year round within this reach of the river. Thus, irrespective of what disposal facility is used or the time of year when the activity will occur, the movement of tugs transporting dredged material will overlap with the presence of juvenile sturgeon and adult shortnose sturgeon. Adult Atlantic sturgeon spawning migrations may occur as late as July, and adults, especially males, may remain in the river until October. Subadult Atlantic sturgeon may also be present in the tidal freshwater reaches of the Delaware River. Thus, project vessel activity in the Federal Navigation Channel will overlap with the presence of subadult and adult Atlantic sturgeon if vessels transit between July 1 and October.

During winter, shortnose sturgeon (especially adults) overwinter between Roebling and Trenton, approximately 56 km (35 mi) upriver of the project construction area. This includes approximately 11 km (7 mi) of the upper action area, and transport of dredged materials to Biles Island in Fairless Hills, Pennsylvania, will overlap with shortnose sturgeon overwintering areas. Thus, if dredging occurs in late fall or winter, then this activity may overlap in time with the presence of shortnose overwintering aggregations. However, during overwintering, shortnose sturgeon rest on the river bottom and exhibit little movement. If vessels transport dredged material to Biles Island during winter, then vessel traffic would transit a relatively small area, with a short duration, of shortnose sturgeon overwintering habitat within the action area, while they remain at deeper depths. This will minimize any potential interaction with the sturgeon species that are in the waterway.

The Federal Navigation Channel (Philadelphia to the Sea FNP) from the Paulsboro Marine Terminal downstream to the Whites Basin is maintained at -14 m (-45 ft). From the Paulsboro Marine Terminal to Biles Island, the Federal Navigation Channel (Philadelphia to Trenton FNP) is maintained from -12.2 m (-40 ft) up to RKM 203 and at -7.6 m (-25 ft) to Biles Island.

Sturgeon feed on invertebrates in and on the bottom sediment and remain on the riverbed during foraging and resting. The project vessels will have substantial clearance to the bottom when traveling in the Federal Navigation Channel. Thus, the tugs will have enough clearance to avoid exposing demersal sturgeon or any life stage to the propeller blades or to the water drawn through the propellers. However, actively moving sturgeon, e.g., during spawning migrations, may swim closer to the water surface even in deep waters (see section 8.5.1) and be exposed to the propellers of tugboats.

8.5.2.3 Response to Exposure

As discussed in section 8.5.1, sturgeon do not seem to react to approaching vessels by moving away from them. It is unclear if the velocity of the water drawn through the propeller is so strong that it could entrain a sturgeon (i.e. not be able to escape the water current). However, Steen (2021) believed that even large sturgeon exposed to water currents drawn through propellers may not be able to avoid entrainment if near the propeller. Nevertheless, it is clear that the strength of the current drawn through the propeller will diminish rapidly with increasing distance from the vessel's hull and propeller. The most likely cause of injury if entrained through the propeller is physical contact with a propeller blade rather than the exposure to turbulent water and shear stress, although exposure to shear stress and turbulence may kill smaller sturgeon (Killgore *et al.* 2001). The probability of a sturgeon being struck by a propeller may depend on the size of the fish and smaller sturgeon entrained by the propeller may not actually be struck by a propeller blade while most adult shortnose sturgeon and subadult and adult Atlantic sturgeon are likely to be injured and/or killed because their larger size makes contact with the blade more likely.

8.5.2.4 Risk of Vessel Strike

The proposed Berth and access channel is about 8.9 acres in close proximity to the shoreline. Neither sturgeon species are expected to be present in high numbers, as this shallow nearshore habitat is inconsistent with the type of habitat previous studies indicate the fish use for various behaviors (Stetzar *et al.* 2015). Construction-related vessel activity at the Berth during dredging and pile driving will be temporary and restricted to a small portion (i.e. Project Area) of the overall action area on any given day and to an even smaller portion of the Delaware River channel. Noise from pile driving is likely to deter sturgeon from entering the area where vessels will move during pile driving; and dredging will occur only over 50 days or 14 percent of the year. Sturgeon residing on the bottom are also likely to have enough clearance to avoid being struck by a propeller or being entrained in water drawn through a propeller of any of the vessels used during construction. A propeller blade striking a sturgeon is highly likely to injure or kill the sturgeon. However, given the low probability that sturgeon would be present in the shallow, nearshore waters and the high probability that sturgeon would be on or near the bottom in deeper waters (i.e. depth clearances great enough to avoid interaction), tug and crew vessels within the Project Area will not expose a sturgeon to a propeller, and any increase in the risk of a vessel strike is extremely unlikely and, therefore, discountable.

Significant vessel traffic occurs within the overall action area (i.e., project area and Federal Navigation Channel), and vessel strikes are one of the primary known sources of direct anthropogenic mortality to sturgeon within the Delaware River and Bay. However, vessel strikes are generally rare and stochastic events for any one vessel (see section 6.7.3). Dredging and pile driving will add 26 vessel trips during a three-month period to the baseline of 33,799 annual vessel trips (section 6.7.3.2), and this represents a 0.07 percent increase in vessel trips in the Trenton to the Sea Navigation Channel during construction. Thus, adding project vessels to the existing baseline will not increase the risk of a sturgeon interacting with a vessel to an extent that the effect of the action (i.e., any increase in risk of a strike caused by the project) is extremely unlikely and, therefore, discountable.

8.5.3 Effects of Vessel Activity during Port Operation

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 vessels would not occur but for the proposed Berth. Despite their relatively small number, such vessels will add to the existing vessel activity in the Delaware River and Delaware Bay. As described previously, interaction between vessels and sturgeon have caused vessel strike mortalities in the Delaware River and Bay. Thus, an increase in vessel traffic caused by the proposed project will result in an increase in vessel strikes to Atlantic and shortnose sturgeon.

8.5.3.1 Vessel Interactions

The Proposed Action will result in a minimum of 540 to a maximum of 880 vessel river trips through 2032. These vessel trips are new and entirely associated with the operation of the proposed Paulsboro Marine Terminal Ro/Ro Berth and will not result from traffic redistributed from other ports. 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 Ro/Ro 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. Cargo vessels will use the Philadelphia to the Sea Federal Navigation Channel to travel between the Berth and the mouth of Delaware Bay.

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.

Vessels calling at the proposed Paulsboro RoRo Berth will travel through several areas where sturgeon occur in high densities. Monopile delivery and installation vessels will travel through the Delaware Bay mouth during all times of the year. During summer and early fall months, subadult and adult Atlantic sturgeon aggregate and reside in areas at the mouth of the bay (section 6.2.2.2). 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 do surface and surfacing will expose the fish to the vessels. Surfacing represents a small fraction of an individual's total behavior, but aggregations of sturgeon increase the chance that a vessel may interact with an individual. Because the Bay mouth is an area where higher densities of Atlantic sturgeon occur, the chance of a vessel interacting with a surfacing Atlantic sturgeon is relatively high (Breece *et al.* 2018).

During early spring, mature adults migrate through the narrow bay mouth during the spawning migration and 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). We expect that Atlantic sturgeon will move in a relatively straight line during migration across the Delaware Bay. Such a path across the bay would largely correspond 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 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 migration, they may use the Federal Navigation Channel for up and downstream migration. Atlantic sturgeon swim closer to the surface during spawning migration and other directed movements (Balazik *et al.* 2012d, Fisher 2011, Reine *et al.* 2014). Consequently, sturgeon are substantially more exposed to medium draft vessels (e.g. tugs) as well as deep draft vessels (e.g., cargo vessels) during periods when active movements occur such as spawning migrations or seasonal movements between habitats. Fish attracted to channelized pathways that coincide with shipping routes may be injured or killed as a result of exposure to the propellers of tugs as well as deep draft vessels. This is exemplified by a tug observed striking and decapitating a gravid female Atlantic sturgeon in the Navigation Channel of the Delaware River in 2016 (Park 2017, personal communication).

There are neither quantitative scientific surveys regarding vessel mortalities nor an annual index survey that provides a time series of the relative number of vessel strikes between years. This complicates any evaluation of the relationship between vessel densities and sturgeon mortalities. The biological assessment assumed that the increase in vessel traffic above 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 similarly assume that the risk of a vessel striking and killing a sturgeon is proportional to the volume of traffic in the river. Based on data from the Waterborne Commerce Statistics Center, during the period from 2010 to 2019, the annual median vessel trips by self-propelled vessels of all drafts between Philadelphia and the mouth of Delaware Bay was 33,440 (section 6.7.3.2). We use only the activity of self-propelled vessels to calculate risk of vessel strike as tugs transport non-self-propelled vessels (e.g., barges). Given the high baseline vessel traffic within the Federal Navigation Channel, an annual increase of 100 trips would correspond to an approximate 0.3% increase in vessel traffic over baseline conditions.

This section considers the effects of vessel traffic associated with operation of the Paulsboro RoRo Berth on sturgeon over the approximate 10-year lifetime of the project. First, we evaluate the factors determining the risk of vessel strikes by project-related vessels. We then use the calculated number of sturgeon mortalities relative to vessel activity (annual vessel trips) in the action area from section 6.7.3.2 to calculate an estimate of sturgeon killed.

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, these life stages of Atlantic sturgeon could interact with the increased vessel traffic associated with the proposed Berth. Vessel traffic, consisting of commercial cargo ships, tankers, and tug boats have been identified as a significant source of 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 and entrain sturgeon.

We expect that the data for waterborne commerce vessel trips adequately represents the potential for sturgeon to be exposed to vessel strike within the Delaware River. As we discussed in section 6.7.3.2, 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 yearly 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.

The BA provided by the USACE used data from our 2017 Biological Opinion for the Gibbstown Marine Terminal Project. At the time, we used available data from the Waterborne Commerce Statistics Center to assess the number of vessel trips (all vessel types) in the Philadelphia to the Sea Navigation Channel during the years from 2012 to 2016. We also used carcass-reporting data from the DNREC to calculate number of sturgeon vessel strike mortalities between 2012 and 2016. Then, we multiplied number of observed carcasses by three to account for mortalities not being observed or reported in accordance with Balazik *et al.* (2012d). Based on this, we estimated an adjusted sturgeon vessel strike mortality rate of 0.0012, which the USACE used in their BA for this project. However, in the BA, the USACE also used preliminary data from a new study conducted by the Delaware State University to estimate the carcass-reporting rate for the Delaware River. Based on personal communication with the principal investigator, Professor Dewayne Fox, the USACE used a reporting rate of 0.053 (i.e., 5.3% of carcasses found on the shores of the Delaware River and Bay are reported by the public). With this rate, the USACE estimated that between 1.1 to 7 Atlantic sturgeon vessel strike mortalities would occur as a result of the operation of the proposed RoRo Berth at the Paulsboro Marine Terminal (i.e. these mortalities would not occur but for the proposed project).

For this Opinion, we have used data for the period of 2012 to 2019, which includes DNREC data from 2017 through 2019, to represent vessel-induced mortalities within the action area. Since the DNREC 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 (2012 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 6.7.3.2). 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 6.7.3.3, 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 conservative estimate of vessel mortalities.

Last, our analysis has to account for the fact that most sturgeon mortalities are likely never found and/or reported. Balazik *et al.* (2012b) estimated that approximately one third of vessel mortalities are reported in the James River. The BA included recent studies by Delaware State University, which suggest that only 5.3 percent of sturgeon mortalities are actually reported (Dr. Dewayne Fox personal communication, 2021). However, the Delaware State University released a final report in 2020 with an overall recovery rate of 4.76 percent reporting success (Fox *et al.* 2020). A recent review by the NEFSC concluded that the Delaware State University study and report constitutes the best available information (see section 6.7.3.3). Thus, 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. Based on the above, we calculated that the adjusted annual mortality rate (or sturgeon killed per vessel trip on average) is 0.0078[28] (see section 6.7.3.3 for calculations). This also equates to approximately 128 vessel trips per one vessel strike.

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. Thus, the additional vessel trips will result in the vessel strike mortality of seven Atlantic sturgeon over the 10-year life span of the Berth. Sturgeon entrained in the propeller of vessels could also be injured but survive. This would most likely occur if interacting with a smaller propeller than those expected on the monopile installation and delivery vessels. The vessels calling at the proposed Berth have large propellers

[28] Mo = 105/282,891 = 0.000371, Ma = 0.00037/0.0476 = 0.007773. For description of calculations, see section 6.7.3.3

that rotate with considerable force; therefore, we find it unlikely that a sturgeon struck by propellers of this size will survive and consider all sturgeon interactions with the vessels analyzed in this Opinion to be fatal.

Size was reported for about 70 percent of the carcasses reported since 2005. Of the 101 Atlantic sturgeon in the DNREC data that were assumed to be struck and killed by vessels from 2005 through 2019, 18 (17.8%) were characterized as juveniles and 63 (62.4%) were characterized as adults (life stage was not determined for 18 (17.8%) of the fish and two (2.0%) were characterized as subadults). Murphy and Brown (2010) found that juveniles comprise 39% of Atlantic sturgeon vessel strike mortalities in the Delaware River. 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 juvenile mortality based on reporting bias or carcass persistence time. If we assume, to be conservative, that all mortalities with no life stage information were subadult or adult fish, then these two life stages made up 80.2 percent of the vessel strikes reported to DNREC. We therefore consider one anticipated vessel mortality to be a juvenile and the remaining six to be subadult and/or adult Atlantic sturgeon.

Effects of Vessel Activity on Atlantic Sturgeon by DPS

Above, we concluded that the operation of the RoRo Berth is likely to result in seven vessel strike mortalities that would not occur but for the proposed project. We expect six of these to be subadults, adults, or a mix of the two. We have considered the best available information to determine the likely DPS origin of subadult and adult individuals. We previously used the Damon-Randall *et al.* (2013) mixed stock analysis of Atlantic sturgeon in the Delaware River to determine the percentage of takes from each DPS. However, the NEFSC recently reviewed the data used by Damon-Randall *et al.* (2013) and recommended that we use the the Estuary/Coastal rates presented in Damon-Randall *et al.* (2013) report. The NEFSC also recommended that if analyses can split trips between the Estuary and River portions, we apply the Hudson River rates to the “the upper and middle portions of each river” and the Estuary/Coastal rates to the “lower river and coastal” portions. Approximately 55 percent of the carcasses reported to DNREC were found in the Delaware River and the remaining were found in the bay. However, we cannot relate the number of vessel strike mortalities in the river to number of vessel trips in the river as the Waterborne Commerce Data does not allow for partitioning trips between the river and bay. Thus, we will apply the Estuary/Coastal rates to all of the six (the juvenile will be of NYB origin) vessel strikes to estimate how many are expected to belong to each DPS.

Using the Estuary/Coastal mixed stock analysis, Atlantic sturgeon exposed to commercial vessel traffic of the proposed action originate from the five DPSs at the following frequencies: NYB 42%; Chesapeake Bay 24%; South Atlantic 20%; Gulf of Maine 13%; and Carolina 1% (Damon-Randall *et al.* 2013). Based on these percentages, we have estimated that three (2.52 rounded up) vessel caused mortalities will belong to the NYB DPS, one (1.44 rounded down) will belong to

CB DPS, one (1.2 rounded down) to SA DPS, and one (0.78 rounded down) to GOM DPS. We expect that it is unlikely that any of the vessel strikes are of the Carolina DPS given that these fish were only rarely documented in any of the data sets reviewed by Damon-Randall *et al.* (2013).

Sex ratio data specific to the Delaware River population of Atlantic sturgeon are not available. A skewed sex ratio in the river during spawning might suggest that the likelihood of a vessel striking and killing a male is greater than that for a female during certain times of the year. Males usually begin their spawning migration early and leave after the spawning season, while females make rapid spawning migrations upstream and quickly depart following spawning (Bain 1997 as cited in ASSRT 2007). Assuming that the length of time that sturgeon spend within the river is correlated with an increased risk of vessel strike, this information suggests that male sturgeon are more likely than females to be struck and killed by a vessel in the action area. The DNREC data report the sex for only five adult mortalities (all mortality causes) in the Delaware River (all years). Of these, two were determined to be female and three male. In the absence of additional information, we assume the ratio of male to female Atlantic sturgeon in the Delaware River is even (1:1) and that male sturgeon are equally as likely to be struck and killed by a vessel as female sturgeon. Therefore, the three adult/subadult vessel strike mortalities estimated for the NYB DPS over 10 years could be either male or female.

Shortnose sturgeon

Vessel strikes on shortnose sturgeon are not well documented. Shortnose sturgeon utilize the Federal Navigation Channel when migrating to and from Delaware Bay and offshore habitats, thus there is potential for vessel interactions during operation of the facility. Juvenile and adult shortnose sturgeon are expected to be present year-round from the project site downstream to the mouth of the Delaware River. Adult shortnose sturgeon can occasionally be present within Delaware Bay.

The DNREC data (2005 through 2019) identifies 13 shortnose sturgeon mortalities. Of these, eight were the result of vessel interactions. For the period 2012 through 2019, six shortnose sturgeon carcasses were reported. The cause of death was considered vessel strike for four of the six while the cause of death was not determined for two. Again, assuming that vessel strike caused all mortalities and that only 4.76 percent of all vessel mortalities are reported, we calculate that 126 vessel mortalities occurred during the eight years. Thus, one shortnose sturgeon is killed per 2,245 vessel trips or an adjusted mortality rate of 0.0005[29]. Using the same calculation as above (adjusted mortality rate multiplied with number of vessel trips during operation of the Berth), we expect that over the 10 years of operation of the Berth, 0.39 shortnose sturgeon killed by vessel activity related to the operation of the Berth. Given that a vessel strike cannot kill a fraction of a fish, we anticipate that vessel traffic associated with the proposed Berth will kill one shortnose sturgeon over the course of 10 years of operation. We do not have

[29] Mo = 6/282,891 = 0.00002, Ma = 0.00002/0.0476 = 0.000446. For description of calculations, see section 6.7.3.3

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.

8.5.4 Summary of Effects of Vessel Traffic

Based on information in the biological assessment, the construction of the Berth will add up to 880 vessel trips over a 10-year period (from 2022 to 2032) to the number of baseline vessel trips. We expect the additional vessel traffic in the action area due to the construction and 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 the number of shortnose sturgeon and Atlantic sturgeon that will be killed as a consequence of construction and operation of the proposed Berth. 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
Atlantic sturgeon	NYB	1	3	
	CB	0	1	
	SA	0	1	
	GOM	0	1	
	Carolina	0	0	
Shortnose sturgeon	N/A			1

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 database 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 database 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 made reasonable conservative assumptions, in favor of the species 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.

8.6 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[30].

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

[30] 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."

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 the *Effects of the Action* section, we considered potential effects from the construction (including dredging, pile driving, and revetment installation) and operation of the Berth. These effects include interactions with dredges, and the associated turbidity and noise effects on these species from pile driving. In addition to these effects, we considered the potential for interactions between ESA-listed species and vessels during construction and operation of the Berth and impacts to their habitats and prey.

We concluded that the proposed project may affect but is not likely to adversely affect listed sea turtles and whales (section 5.1), and no take is anticipated or exempted for these species. We also concluded that the proposed project may affect but is not likely to adversely affect critical habitat designated for Atlantic sturgeon.

We concluded that vessel traffic during operation of the facility will result in the mortality of seven Atlantic sturgeon and one shortnose sturgeon. As explained in the *Effects of the Action* section, all other effects to shortnose sturgeon and Atlantic sturgeon from the proposed project, including effects to their prey and habitat will be insignificant and/or extremely unlikely.

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 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. 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 Inc. 2006). 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 Delaware's Department of Natural Resources and Environmental Control (DNREC), indicate that from 2005 through 2017, 8 sturgeon mortalities were attributable to vessel strikes (an additional 3 had an unknown 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 effects 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 utilized. 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, which 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. In high water years, facilities with intakes in the upper river have impinged and entrained larvae, but documented instances are rare and have involved only small numbers of larvae. 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 by climate change modeling, the range of juvenile shortnose sturgeon is likely to be reduced as 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, and 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.

The number of shortnose sturgeon that are 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 activities 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.

A 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% 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 ten-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. While the action is likely to displace sturgeon within the dredge footprint and the area of the turbidity plume (up to 732 m (2,402 ft) from the dredge) will temporarily affect the distribution of individual sturgeon, any change in distribution will be temporary and limited to movements to relatively nearby areas. 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 number shortnose sturgeon likely to be killed as a result of the action as a whole is extremely small (0.008% 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 likely to occur only 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: given that: (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 only a minor and temporary consequence on the distribution of shortnose sturgeon in the action area (related to movements around the working dredge) and 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 shortnose sturgeon 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 impact to forage will be limited to loss of prey in areas being dredged, which together constitutes approximately only 0.3 percent of soft bottom substrate within the freshwater portion of the tidal Delaware River. Impacts to habitat will be limited to the temporary loss of forage within the dredge footprint, continued degradation of forage within the dredge footprint by propeller jet scour and revetment installation, the increases in suspended sediment during dredging and 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.

Atlantic Sturgeon

As explained above, the proposed action is likely to result in the incidental take of up to seven Atlantic sturgeon during the 10-year of operation of the RoRo 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 from. Of the seven sturgeon, four may be of NYB DPS, one of CB DPS, one of SA DPS, and one of GOM DPS (Table 31). Other effects to Atlantic sturgeon, including effects from impacts to habitat and prey because of dredging, installation of revetment, turbidity caused by in-water activities, and noise from pile driving will be insignificant or extremely unlikely.

Given the above, we estimate the following lethal take from each Atlantic sturgeon DPS:

Table 31. Estimated total lethal take for Atlantic sturgeon from the proposed Port

DPS	Juvenile	Subadult/Adult
New York Bight	Up to 1	Up to 3
Chesapeake	0	Up to 1
South Atlantic	0	Up to 1

Gulf of Maine	0	Up to 1
Carolina	0	0

Gulf of Maine DPS

The GOM 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. 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 GOM 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 effects of the loss of up to one Atlantic sturgeon as a result of the proposed action over a 10-year period from the GOM DPS (take is only anticipated during the 10 years of operation of the Port). The reproductive potential of the GOM DPS will not be affected in any way other than through a reduction in numbers of individuals. The loss of up to one individual over a 10-year period will have the consequence of reducing reproduction potential within the DPS because any dead GOM 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 GOM 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 GOM DPS fish for the same reasons.

Because we do not have a population estimate for the GOM DPS, it is difficult to evaluate the effects 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 effects on the numbers and population trend of the GOM DPS.

The proposed action is not likely to reduce distribution because the action will not impede Atlantic sturgeon from accessing any seasonal concentration areas, and will have insignificant effects on the foraging grounds within the action area that may be used by GOM DPS Atlantic sturgeon. Any effects to distribution will be minor and temporary and limited to the avoidance of the area where impacts of the action will occur.

Based on the information provided above, the death of up to one GOM DPS Atlantic sturgeon as a result of the proposed action over a 10-year period will not reduce appreciably the likelihood of survival of the GOM 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 GOM 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 effects 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 GOM DPS Atlantic sturgeon in any year will not change the status or trends of the species as a whole; (2) the loss of the one GOM DPS Atlantic sturgeon is not likely to have effects on the levels of genetic heterogeneity in the population; (3) the action will have only a minor and temporary consequence on the distribution of GOM 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 GOM DPS Atlantic sturgeon to shelter with only an insignificant consequence on any foraging GOM DPS Atlantic sturgeon.

In certain 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 the GOM 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 GOM DPS can rebuild to a point where listing is no longer appropriate. No Recovery Plan for the GOM 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 GOM DPS Atlantic sturgeon. Any effects 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 GOM DPS of Atlantic sturgeon. The action will not change the status or trend of the GOM 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 effects of the proposed action will not delay the recovery timeline or otherwise decrease the likelihood of recovery. The effects 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 reduce appreciably the likelihood that the GOM 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 reduce appreciably the survival and recovery of this species.

Despite the threats faced by individual GOM 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 effects related to the proposed action. We have 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 GOM DPS Atlantic sturgeon over a 10-year period, is not likely to reduce appreciably the survival and recovery of the species.

New York Bight DPS

The NYB DPS is listed as endangered, and 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 SA 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 DPSs spawning rivers. Based on existing data, we expect any NYB DPS Atlantic sturgeon in the action area to originate from the Hudson or Delaware River.

There are no abundance estimates for the entire NYB DPS or for the entirety of either the Hudson or Delaware River spawning populations. There are, however, some abundance estimates for specific life stages (e.g., natal juvenile abundance, spawning run abundance, and effective population size). 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 percent CRI = 310-745). White *et al.* (in press) recently estimated the number of adults (N_S) 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 but because N_S 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.* (in press) concluded, when considering bias in the data when sample size of offspring is small may result in the *Ns* being underestimated, that the N_S for Delaware River Atlantic sturgeon is likely between 125 and 250.

The effective population size (*Ne*) measures the genetic behavior (inbreeding and genetic drift) of a population and is used in conservation biology as a measure of the population's short- or long-term viability. While, the *Ne* is not an estimate of the census population, there is a general relationship between the size of the census population and the size of *Ne*. This is reflected by the Hudson River having one of the largest estimates of *Ne* of Atlantic sturgeon populations while Delaware River has one of the smallest estimates of *Ne* (White *et al.* 2021). 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 percent CI=171.7-230.7; (O'Leary *et al.* 2014)) and 156 (95 percent CI=138.3-176.1) (Waldman *et al.* 2019) respectively, while estimates for the Delaware River spawning population from the same studies are 108.7 (95 percent CI=74.7-186.1) (O'Leary *et al.* 2014) and 40 (95 percent CI=34.7-46.2) (Waldman *et al.* 2019).

The differences in estimated population size for the Hudson and Delaware River spawning populations and differences in *Ne* support the notion that the Hudson River spawning population is the more robust of the two spawning groups. 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 (Wirgin *et al.* 2015a, 2015b). The Waldman *et al.* (2019) calculations of maximum effective population size, and comparison of these to four other spawning populations outside of the NYB 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.

For this Opinion, we have used an estimate of adult and sub-adult abundance of the NYB 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 concluded that sub-adult and adult abundance of the NYB DPS was 34,566 sturgeon based upon the NEAMAP data. This number encompasses many age classes since sub-adults can be as young as two years old when they first enter the marine environment, and adults can live as long as 60 years (Hilton *et al.* 2016). For example, a study of Atlantic sturgeon captured in the geographic NYB 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 (Dunton *et al.* 2016). The 2017 ASMFC stock assessment determined that abundance of the NYB DPS is "depleted" relative to historical levels (ASMFC 2017b). The assessment also determined there is a relatively high probability (75 percent) that the NYB DPS abundance has increased since the implementation of the 1998 fishing moratorium, and a 31 percent probability that mortality for the NYB DPS exceeds the mortality threshold used for the assessment (ASMFC 2017b). As discussed above, however, the Commission noted significant uncertainty in relation to the trend data. Moreover, new information suggests that the Commission's conclusions primarily reflect the status and trend of only the DPS's Hudson River spawning population.

NYB 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. The largest single source of mortality appears to be capture as bycatch in commercial fisheries operating in the marine environment. Because early life stages and juveniles do not leave the river, they are not impacted by fisheries occurring in federal waters. Bycatch and mortality also occur in state fisheries; however, the primary fishery that impacted juvenile sturgeon (the shad fishery) has now been closed and there is no indication that it will reopen soon. NYB DPS Atlantic sturgeon are killed as a result of other anthropogenic activities in the Hudson, Delaware, and other rivers within the NYB as well; sources of potential mortality include vessel strikes and entrainment in dredges.

We anticipate the mortality of up to three adult or subadult NYB DPS Atlantic sturgeon as a result of vessel interaction during the 10-year of operation of the Berth. We also anticipate up to one juvenile sturgeon vessel strike mortality over the ten years of operation of the Berth.

Here, we consider the effects of the loss of up to three adult or subadult and one juvenile NYB DPS Atlantic sturgeon (male or female) as a result of vessel interaction during the 10-year operational period of the RoRo Berth. The reproductive potential of the NYB DPS will not be affected in any way other than through a reduction in numbers of individuals. Assuming the worst case scenario that all sturgeon are female, the loss of four female sturgeon over a 10year period will have the effects of reducing reproduction potential, as any dead NYB DPS Atlantic sturgeon has no potential for future reproduction. However, this small reduction in potential future female 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 effects on the strength of subsequent year classes. Even considering the potential future spawners that would be produced by these individuals that will be killed as a result of the proposed action, any effects 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 NYB DPS fish spawn, as the Berth Area where dredging will occur is not inclusive of suitable spawning habitat and the vessel operation within the Federal Navigation Channel part of the action area will not affect spawning grounds. The action will also not create any barrier to pre-spawning sturgeon accessing the overwintering sites or the spawning grounds used by NYB DPS fish.

Because we do not have a total population estimate for the NYB DPS, it is difficult to evaluate the effects of mortality on the species caused by this action. However, because the proposed action will result in the loss of four individuals over a 10-year period, or an average of less than one per year, it is unlikely that these deaths will have detectable effects on the abundance and population trend of the NYB DPS.

The proposed action is not likely to reduce distribution because the action will not impede Atlantic sturgeon from accessing any seasonal concentration areas, and will have insignificant effects on the foraging grounds within the action area that may be used by NYB DPS Atlantic sturgeon. Any effects to distribution will be minor and temporary and limited to the avoidance of the area where impacts of the action will occur.

Based on the information provided above, the death of up to four individual NYB DPS Atlantic sturgeon as a result of the proposed action over a 10-year period will not reduce appreciably the likelihood of survival of the NYB 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 NYB 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 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 NYB DPS Atlantic sturgeon over a 10-year period represents an extremely small percentage of the species as a whole; (2) the death of these NYB DPS Atlantic sturgeon will not change the status or trends of the species as a whole; (3) the loss of these NYB DPS Atlantic sturgeon is not likely to have effects on the levels of genetic heterogeneity in the population; (4) the loss of these NYB 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 NYB 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 NYB DPS Atlantic sturgeon to shelter with only an insignificant consequence on individual foraging NYB DPS Atlantic sturgeon when considering that the footprint of the dredging site is small relative to available forage within the action area and the lower estuary.

In certain 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 the NYB 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 NYB DPS can rebuild to a point where listing is no longer appropriate. No Recovery Plan for the NYB 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 NYB DPS Atlantic sturgeon and will not affect the overall distribution of NYB DPS Atlantic sturgeon. Any effects 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 number of 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 NYB DPS of Atlantic sturgeon. Additionally, the action will not change the status or population trend of the NYB 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 NYB DPS of Atlantic sturgeon. The effects of the proposed action will not delay the recovery timeline or otherwise decrease the likelihood of recovery. The effects 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 reduce appreciably the likelihood that the NYB 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 reduce appreciably the survival and recovery of this species.

Despite the threats faced by individual NYB 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 effects related to the proposed action. We have 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 four individual NYB DPS Atlantic sturgeon over a 10-year period, is not likely to reduce appreciably the survival and recovery of this species.

Chesapeake Bay DPS

The CB 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 2017).

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 CB DPS Atlantic sturgeon is 8,811 sub-adult and adult individuals. The ASMFC (2017b) stock assessment determined that abundance of the CB 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 CB DPS has increased since the implementation of the 1998 fishing moratorium, and a 30 percent probability that mortality for the CB DPS exceeds the mortality threshold used for the assessment (ASMFC 2017b).

We anticipate the mortality of up to one adult or subadult (male or female) CB DPS Atlantic sturgeon as a result of vessel interactions during the 10 years of operations at the Port. Thus, here, we consider the effects of the loss of up to one Atlantic sturgeon over a 10-year period from the CB DPS. The reproductive potential of the CB DPS will not be affected in any way other than through a reduction in numbers of individuals. The loss of up to one individual over a ten-year period will have the consequence of reducing the amount of reproduction potential as any dead CB 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 effects on the strength of subsequent year classes. Even considering the potential future spawners that would be produced by one CB 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 CB 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 CB DPS fish for the same reasons.

Because we do not have a population estimate for the CB DPS, it is difficult to evaluate the effects 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 sturgeon over the ten years of Berth operation, it is unlikely that this deaths will have a detectable consequence on the abundance and population trend of the CB DPS.

The proposed action is not likely to reduce distribution because the action will not impede Atlantic sturgeon from accessing any seasonal concentration areas, and will have insignificant effects on the foraging grounds within the action area that may be used by CB DPS Atlantic sturgeon. Any effects to distribution will be minor and temporary and limited to the avoidance of the area where impacts of the action will occur.

Based on the information provided above, the death of up to one CB DPS Atlantic sturgeon over 10 years of Port operations will not reduce appreciably the likelihood of survival of the CB 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 CB 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 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 up to one CB DPS Atlantic sturgeon will not change the status or trends of the species as a whole; (2) the loss of the one CB DPS Atlantic sturgeon is not likely to have effects on the levels of genetic heterogeneity in the population; (3) the action will have only a minor and temporary consequence on the distribution of CB 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 CB DPS Atlantic sturgeon to shelter with only an insignificant consequence on any foraging CB DPS Atlantic sturgeon.

In certain instances, an action that does not reduce appreciably the likelihood of a species' survival might reduce appreciably 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 the CB 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 CB DPS can rebuild to a point where listing is no longer appropriate. No Recovery Plan for the CB 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 CB DPS Atlantic sturgeon and it will not affect the overall distribution of CB DPS Atlantic sturgeon. Any effects 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 CB DPS of Atlantic sturgeon. This action will not change the status or trend of the CB 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 CB DPS of Atlantic sturgeon. The effects of the proposed action will not delay the recovery timeline or otherwise decrease the likelihood of recovery. The effects 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 reduce appreciably the likelihood that the CB 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 reduce appreciably the survival and recovery of this species.

Despite the threats faced by individual CB 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 effects related to the proposed action. We have considered the effects 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 one CB DPS Atlantic sturgeon over a 10-year period, is not likely to reduce appreciably the survival and recovery of this species.

South Atlantic DPS

The SA DPS is listed as endangered and Atlantic sturgeon originate from at least six rivers where spawning potentially still occurs. Secor *et al.* (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 *et al.* (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 SA 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 SA 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 SA DPS Atlantic sturgeon sub-adults and adults is 14,911 individuals.

The 2017 ASMFC stock assessment determined that abundance of the SA 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 SA 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 SA DPS exceeds the mortality threshold used for the assessment (ASMFC 2017b).

We anticipate the mortality of up to one (male or female) SA DPS adult or subadult Atlantic sturgeon as a result of the proposed project. Take of SA DPS is only anticipated during the 10 years of operation of the RoRo Berth. Thus, here, we consider the effects of the loss of up to one Atlantic sturgeon over a ten-year period from the SA DPS. The reproductive potential of the SA 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 a dead SA 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 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 SA 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 SA DPS fish for the same reasons.

Because we do not have a population estimate for the SA DPS, it is difficult to evaluate the effects 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 individuals over a 10-year period, it is unlikely that this death will have a detectable consequence on the numbers and population trend of the SA DPS.

The proposed action is not likely to reduce distribution because the action will not impede Atlantic sturgeon from accessing any seasonal concentration areas, and will have insignificant effects on the foraging grounds within the action area that may be used by SA DPS Atlantic sturgeon. Any effects to distribution will be minor and temporary and limited to the avoidance of the area where impacts of the action will occur.

Based on the information provided above, the death of up to one SA DPS Atlantic sturgeon over a 10-year period will not reduce appreciably the likelihood of survival of the SA 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 SA 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 effects to the environment which would prevent SA 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 SA DPS Atlantic sturgeon will not change the status or trends of the species as a whole; (2) the loss of the one SA DPS Atlantic sturgeon is not likely to have effects on the levels of genetic heterogeneity in the population; (3) the loss of the SA 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 SA 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 SA DPS Atlantic sturgeon to shelter with only an insignificant consequence on any foraging SA DPS Atlantic sturgeon.

In certain 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 the SA 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 SA 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 SA DPS Atlantic sturgeon and it will not affect the overall distribution of SA DPS Atlantic sturgeon. Any effects 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 SA DPS of Atlantic sturgeon. This action will not change the status or trend of the SA 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 SA DPS of Atlantic sturgeon. The effects of the proposed action will not delay the recovery timeline or otherwise decrease the likelihood of recovery. The effects 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 reduce appreciably the likelihood that the SA 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 reduce appreciably the survival and recovery of this species.

Despite the threats faced by individual SA 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 effects related to the proposed action. We have 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 SA DPS Atlantic sturgeon over a 10-year period, is not likely to reduce appreciably 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 the shortnose sturgeon, the GOM, NYB, CB, and SA DPSs 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 is proposing to issue a 10-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 and under-development Paulsboro Marine Terminal deep-water import-export marine terminal. The USACE will permit the in-water construction components of the Berth's facilities as well as the dredging of the Berth's turning basing and mooring approach. The USACE has authority to ensure compliance with RPMs and Terms and Conditions related to the dredging and pile driving during construction of the Berth.

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[31].

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 after it has been constructed, 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

[31] 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.

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 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.

Sturgeon Take Incidental from Vessel Traffic During Operation

We expect up to 8 lethal vessel strikes during operation of the Berth. Of these:

Up to 1 shortnose sturgeon juvenile or adult

Up to 1 juvenile Atlantic sturgeon from NYB DPS

Up to 3 adult and/or subadult Atlantic sturgeon from NYB DPS

Up to 1 adult or subadult Atlantic sturgeon from CB DPS

Up to 1 adult 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 (up to 1 shortnose sturgeon and up to 7 Atlantic sturgeon) is expected to occur over the entire period that comprises the operational lifespan of the Paulsboro RoRo Berth (e.g., from 2022 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 seven 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 128 vessel trips and a shortnose sturgeon for every 2,245 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 (e.g., if the total was 8 Atlantic sturgeon: 8 takes via surrogate or two observed in the dredge spoil and 6 via surrogate, etc.),

- 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 32 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 32, 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 32. 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 studies that provide information on effects to Atlantic sturgeon rearing and foraging habitat from dredging and follow up studies to assess if Atlantic sturgeon use of those areas have changed.
(2) USACE should continue to support studies of Atlantic and shortnose sturgeon spawning locations in the Delaware River, behavior and spatial occurrence of early life stages, life stage duration, and other information that may allow refinement of dredging activities and timeframes. This information could be used to explore the possibility of developing measures to avoid and minimize effects to spawning, eggs, yolk-sac larvae, and post yolk-sac larvae.
(3) Population estimates are lacking for Atlantic sturgeon. USACE should continue to support studies to assist in gathering the necessary information to develop a population estimate for the NYB DPS.
(4) USACE should contact us prior to the commencement of dredging and again upon completion of the dredging activity. This correspondence will serve both to alert us of the commencement and cessation of dredging activities and to give us an opportunity to provide USACE with any updated contact information or reporting forms.
(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.
(7) USACE should support efforts to report and keep track of sturgeon carcasses in the Delaware River. These reporting efforts provide important information to evaluate causes of sturgeon mortalities within the Delaware River basin and along the New Jersey coast. Support could include the development, in cooperation with state agencies, of a central reporting database that standardize the procedures for reporting and keeping track of observations of sturgeon carcasses.

14 REINITIATION OF CONSULTATION

This concludes formal consultation on your proposal to issue a 10-year 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

Aberdeen, M. L. 1994. Minimising the Interaction of Cultured and Wildfish: A Comprehensive Evaluation of the Use of Sterile, Triploid, Atlantic Salmon. Dated 1994. Final Report No. AIR 3 CT94 2216.

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. 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. Amendment 1 to the interstate fishery management plan for Atlantic sturgeon. Atlantic States Marine Fisheries Commission, Arlington, Virginia. Fishery Management Report No. 31 No. NOAA Award Nos. NA87FG0025 and NA77FG0029.

ASMFC (Atlantic States Marine Fisheries Commission). 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 2007. Special Report to the ASMFC Atlantic Sturgeon Management Board.

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.

ASPRT, (Atlantic Sturgeon Plan Review Team). 2019. Review of the Atlantic States Marine Fisheries Commission fishery management plan for Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). 2017 fishing year. Atlantic States Marine Fisheries Commission. Dated May.

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., S. Altman, K. J. Reine, and A. W. Katzenmeyer. 2021. Atlantic sturgeon movements in relation to a cutterhead dredge in the James River, Virginia. Dated September 2021 No. ERDC/TN DOER-R31.

Balazik, M. T., D. J. Farrae, T. L. Darden, and G. C. Garman. 2017. 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.

Bath, D. W., J. M. O'Connor, J. B. Alber, and L. G. Arvidson. 1981. Development and identification of larval Atlantic sturgeon (*Acipenser oxyrinchus*) and shortnose sturgeon (*A. brevirostrum*) from the Hudson River estuary, New York. Copeia **3**: 711-717.

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.

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. 1953. 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. 2002 (revised). Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service 53.

Bisack, K. D., D. Squires, D. W. Lipton, J. R. Hilger, II, D. S. Holland, D. H. Johnson, M.-Y. A. Lee, R. J. Lent, D. K. Lew, G. M. Magnusson, M. Pan, L. E. Queirolo, S. M. Stohs, C. L. Speir, K. Wallmo, L. T. Ballance, and S. L. Mesnick. 2015. Proceedings of the 2014 NOAA economics of protected resources workshop, September 9-11, 2014, La Jolla, California. National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts. NOAA Tech Memo. NMFS-NE-233. DOI: http://doi.org/10.7289/V5QR4V3D.

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.
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.

Boysen, K. A. and J. J. Hoover. 2009. Swimming performance of juvenile white sturgeon *(Acipenser transmontanus*): training and the probability of entrainment due to dredging. Journal of Applied Ichthyology **25**: 54-59.

Braaten, P. J., D. B. Fuller, R. D. Lott, M. P. Ruggles, and R. J. Holm. 2010. Spatial distribution of drifting Pallid Sturgeon larvae in the Missouri River inferred from two net designs and multiple sampling locations. North American Journal of Fisheries Management **30**(4): 1062-1074.

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.

Breedveld, G., A. Ruus, T. Bakke, A. Kibsgaard, and H. P. Arp. 2018a. Appendix IX - Transport because of ship-induced resuspension. *Guidelines for risk assessment of contaminated sediments*. Guidance Notes M-1132: 91-113. Norwegian Environment Agency.

Breedveld, G., A. Ruus, T. Bakke, A. Kibsgaard, and H. P. Arp. 2018b. Guidelines for risk assessment of contaminated sediments. Norwegian Environment Agency. Guidance Notes M-1132.

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.

Brown, R. S., T. J. Carlson, A. J. Gingerich, J. R. Stephenson, B. D. Pflugrath, A. E. Welch, M. J. Langeslay, M. L. Ahmann, R. L. Johnson, J. R. Skalski, A. G. Seaburg, and R. L. Townsend. 2012. Quantifying mortal injury of juvenile Chinook Salmon exposed to simulated hydro-turbine passage. Transactions of the American Fisheries Society **141**(1): 147-157.

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 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.

Buehler, D., R. Oestman, J. Reyff, K. Pommerenck, and B. Mitchell. 2015. Technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on fish. Prepared for California Department of Transportation. Illingworth and Rodkin, Inc. and ICF International. Dated November 2015. Contract No. No. 43A0306. Report No. CTHWANP-RT-15-306.01.01.

Burton, W. H. 1993. Effects of bucket dredging on water quality in the Delaware River and the potential for effects on fisheries resources. Versar, Inc., Columbia, Maryland. Dated June 1993. Prepared for Delaware Basin Fish and Wildlife Management Cooperative.

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.

Carretta, J. V., E. M. Oleson, K. A. Forney, A. e. R. Lang, D. W. Weller, J. D. Baker, M. Muto, B. Hanson, A. J. Orr, H. R. Huber, M. S. Lowry, J. Barlow, J. E. Moore, D. Lynch, L. Carswell, and R. L. Brownell. 2018. U.S. Pacific marine mammal stock assessments: 2017. National Marine Fisheries Service, La Jolla, CA. NOAA Technical Memorandum NMFS-SWFSC-602. DOI: https://doi.org/10.7289/v5/tm-swfsc-602.

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

Clarke, D. 2011. Sturgeon protection. (PowerPoint). Presented at the Dredged Material Assessment and Management Seminar, Jacksonville, Florida, 24-26 May, 2011.

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., S. G. Rogers, T. I. J. Smith, and M. L. Moser. 2000a. Primary factors affecting sturgeon populations in the southeastern United States: Fishing mortality and degradation of essential habitats. Bulletin of Marine Science **66**(3): 917-928.

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. 2000b. 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.

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., 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. and T. 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. 2017. Salt Line [Website]. Delaware River Basin Commission. Retrived September 14, 2017, from http://www.state.nj.us/drbc/hydrological/river/salt-line.html.

DRBC. 2020. 2020 Delaware River and Bay Water Quality Assessment. Delaware River Basin Commission, Trenton, New Jersey. Dated December.

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 (Environmental Protection Agency). 1986. Quality Criteria for Water. Environmental Protection Agency, Office of Water Regulations and Standards, Washington D.C. Report No. 440/5-86-001.

EPA (Environmental Protection Agency). 2008. National coastal condition report III. (EPA/842-R-08-002): 329.

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. 2012. Acoustic telemetry study of the movements of juvenile sturgeons in Reach B of the Delaware River during dredging operations. Prepared for the U.S. Army Corps of Engineers. Environmental Research and Consulting, ,Inc., Kennett Square, Pensylvania. Dated March 6, 2012. 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., 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.

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.

Gabel, F. 2012. Impacts of ship-induced waves on benthic macroinvertebrates. Unpublished Ph.D., Landwirtschaftlich-Gärtnerischen Fakultät, Humboldt-Universität zu Berlin: Berling, Germany.

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.

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.

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., D. L. Borggaard, K. D. Friedland, J. Anderson, P. Burns, K. Chu, P. M. Clay, M. J. Collins, P. Cooper, P. S. Fratantoni, M. R. Johnson, J. F. Manderson, L. Milke, T. J. Miller, C.

D. Orphanides, and V. S. Saba. 2016a. Northeast Regional Action Plan - NOAA Fisheries Climate Science Strategy. NMFS, Woods Hole, Masachusetts NMFS-NE -39.

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. 2016b. 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., J. Munro, F. Caron, and R. D. Simons. 2007. 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.

Hayes, S. A. 2019. Draft U.S. Atlantic and Gulf of Mexico marine mammal stock assessment reports - 2019. National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts.

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.

Hong, J.-H., Y.-M. Chiew, and N.-S. Cheng. 2013. Scour caused by a propeller jet. Journal of Hydraulic Engineering **139**(9): 1003-1012.

Hong, J.-H., Y.-M. Chiew, S.-C. Hsieh, N.-S. Cheng, and P.-H. Yeh. 2016. Propeller jet–induced suspended-sediment concentration. Journal of Hydraulic Engineering **142**(4): 04015064.

Hoover, J. J., K. A. Boysen, J. A. Beard, and H. Smith. 2011. Assessing the risk of entrainment by cutterhead dredges to juvenile lake sturgeon (Acipenser fulvescens) and juvenile pallid sturgeon (Scaphirhynchus albus). Journal of Applied Ichthyology **27**(2): 369-375.

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). 2007. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. 976 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*.

J., B. M., F. M., F. T., M. A., and K. Olsen. 2021. Risk assessment to model encounter rates between large whales and vessel traffic from offshore wind energy on the Atlantic OCS. Bureau of Ocean Energy Management, Sterling, Virginia. OCS Study BOEM 2021-034.

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.

Jensen, A. and G. K. Silber. 2003. Large whale ship strike database. National Marine Fisheries Service, Office Protected Resources, Silver Spring, Maryland. Dated January. NOAA Technical Memorandum NMFS-OPR-25.

Johnson, A. 2018. The effects of turbidity and suspended sediments on ESA-listed species from projects occurring in the Greater Atlantic Region. Greater Atlantic Region Policy Series 18-02: 106. NOAA Fisheries, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts.

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.

Karaki, S. and J. van Hoften. 1975. Resuspension of bed material and wave effect on the Illinoise and Upper Mississippi Rivers caused by boat traffic. Colorado State University, Fort Collins, Colorado. Dated February 1975. Contract No. No. LMSSD 75-881.

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., 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., S. T. Maynord, M. D. Chan, and R. P. Morgan. 2001. Evaluation of propeller-induced mortality on early life stages of selected fish species. North American Journal of Fisheries Management **21**(4): 947-955.

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.

King, T. L., S. T. Kalinowski, W. B. Schill, S. A. P., and B. A. Lubinski. 2001a. Population structure of Atlantic salmon (*Salmo salar L.*): a range-wide perspective from microsatellite DNA variation. Molecular Ecology(10): 807-821.

King, T. L., B. A. Lubinski, and A. P. Spidle. 2001b. Microsatellite DNA variation in Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and cross-species amplification in the Acipenseridae. Conservation Genetics **2**(2): 103-119.

Kjelland, M. E., C. M. Woodley, T. M. Swannack, and D. L. Smith. 2015. A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. Environment Systems and Decisions **35**(3): 334-350.

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.

Krebs, J., F. Jacobs, and A. N. Popper. 2012. Presence of acoustic-tagged Atlantic sturgeon and potential avoidance of pile-driving activities during the pile installation demonstration project (PIDP) for the Tappan Zee Hudson River Crossing Project. AKRF, Inc., Hanover, Maryland. Dated August 2012.

Krebs, J., F. Jacobs, and A. N. Popper. 2016. Avoidance of pile-driving noise by Hudson River sturgeon during construction of the new NY Bridge at Tappan Zee. In Popper, A.N. and Hawkins, A. (Eds.), *The Effects of Noise on Aquatic Life II* (pp. 555-563). Springer New York, New York, NY.

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.). 2012a. *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.

Kynard, B., M. Breece, M. Atcheson, M. Mangold and M. Kieffer. 2007. Status of the shortnose sturgeon in the Potomac River. **USGS Natural Resources Preservation Project E 2002-7**.

Kynard, B., D. Pough, T. Parker, and M. C. Kieffer. 2012b. Spawning of Connecticut River shortnose sturgeon in an artificial stream: Adult behavior and early life history. In Kynard, B., Bronzi, P. and Rosenthal, H. (Eds.), *Life history and behavior of Connecticut River shortnose sturgeon and other sturgeons* (pp. 165-195). Books on Demand GmbH, Norderstedt, Germany.

Laist, D. W., A. R. Knowlton, J. G. Mead, A. S. Collet, and M. Podesta. 2001. Collisions between ships and whales. Marine Mammal Science **17**(1): 35-75.

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.

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.

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. 2013. 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.

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.

Lovell, J. M., M. M. Findlay, R. M. Moate, J. R. Nedwell, and M. A. Pegg. 2005. The inner ear morphology and hearing abilities of the Paddlefish (*Polyodon spathula*) and the Lake Sturgeon (*Acipenser fulvescens*). Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology **142**(3): 286-296.

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.

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.

Molnar, M., D. Buehler, R. Oestman, J. Reyff, K. Pommerenck, and B. Mitchell. 2020. Technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on fish. Prepared for California Department of Transportation (Updated). ICF International, Illingworth and Rodkin, Inc., Sacramento, California. Dated October. Report No. CTHWANP-RT-20-365.01.04.

Moser, M. L. and S. W. Ross. 1995. Habitat use and movements of Shortnose and Atlantic Sturgeons in the Lower Cape Fear River, North Carolina. Transactions of the American Fisheries Society **124**(2): 225-234.

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.

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). 2021. 2021 State of the ecosystem: Mid-Atlantic.

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. 2013. Maintenance of the 40-foot Delaware River Federal Navigation Channel. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. Dated August 1. Biological Opinion No. NER-2013-9804.

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. Biological and conference opinion on the proposed implementation of a program for the issuance of permits for research and enhancement activities on the Atlantic and shortnose sturgeon pursuant to Section 10(a) of the Endangered Species Act. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, Maryland. Dated March 20. Biological Opinion No. FPR-2016-9176.

NMFS. 2017b. 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. 2017c. Deepening and maintenance of the Delaware River federal navigation channel. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. Dated November 17, 2017. Biological Opinion No. NER-2016-13823.

NMFS. 2017d. GARFO master ESA species table - Atlantic sturgeon [Portable Document Format (.pdf)]. National Marine Fisheries Service, Greater Atlantic Region Fisheries Office.

Retrived October 25, 2017, from https://www.greateratlantic.fisheries.noaa.gov/protected/section7/listing/index.html.

NMFS. 2017e. Tappen Zee Bridge replacement. National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. Dated November 1. Biological Opinion NER-2017-14375.

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 (National Marine Fisheries Service). 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 (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). 2017. 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 (National Marine Fisheries Service). 2018. Endangered Species Act section 7 consultation biological opinion: Maine Department of Transportation (Maine DOT) replacement of the Frank J. Wood Bridge, NER-2017-14574. Dated March 30, 2018.

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 Johnsen, P.B.]. NOAA Fisheries, Gloucester, Massachusetts, 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.

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.

Popper, A. N., A. D. Hawkins, R. R. Fay, D. A. Mann, S. M. Bartol, T. J. Carlson, S. Coombs, W. T. Ellison, R. L. Gentry, M. B. Halvorsen, S. Løkkebork, P. H. Rogers, B. L. Southall, D. G. Zeddies, and W. N. Tavolga. 2014. Sound exposure guidelines for fishes and sea turtles: A technical report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Springer International Publishing and ASA Press, Cham, Switzerland.

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.

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., 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.

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.

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, K. M. and D. K. King. 2005. Dynamics and extent of larval lake sturgeon *Acipenser fulvescens* drift in the Upper Black River, Michigan. Journal of Applied Ichthyology **21**(3): 161-168.

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.

Southall, B. L. and A. Scholik-Schlomer. 2008. Final Report of the National Oceanic and Atmospheric Administration (NOAA) International Symposium: Potential application of vessel-quieting technology on large commercial vessels. Silver Spring, Maryland, 1-2 May, 2007.

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., Jr. 2003. Completion Report Kennebec River Sturgeon Studies 2000-2001.

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.

SSSRT (Shortnose Sturgeon Status Review Team). 2010. A biological assessment of shortnose sturgeon (*Acipenser brevirostrum*). Dated November 1, 2010. 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.

Stephenson, J. K., A. Gingerich, and R. S. Brown. 2010. Assessing barotrauma in neutrally and negatively buoyant juvenile salmonids exposed to simulated hydro-turbine passage using a mobile aquatic barotrauma laboratory. Fisheries Research **106**(2010): 271-278.

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.

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.

U.S. FWS (U.S. Fish and Wildlife Service) and NMFS (National Marine Fisheries Service). 1998. Endangered Species Act consultation handbook. Procedures for conducting section 7 consultations and conferences. Dated March 1998.

USACE. 2009. Delaware River main stem and channel deepening project. Essential Fish Habitat evaluation. U.S. Army Corps of Engineers, Philadelphia, Pennsylvania. Dated February.

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., C. Grunwald, J. Stabile, and I. I. Wirgin. 2002. Impacts of life history and biogeography on the genetic stock structure of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus*, Gulf sturgeon *A. oxyrinchus desotoi*, and shortnose sturgeon *A. brevirostrum*. Journal of Applied Ichthyology **18**(4-6): 509-518.

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., K. Nolan, and J. Hart. 1996. Genetic differentiation of three key anadromous fish populations of the Hudson River. Estuaries **19**(4): 759-768.

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.

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., S. M. Eyler, M. F. Mangold, and A. J. Spells. 2002. Capture locations and growth rates of Atlantic sturgeon in the Chesapeake Bay. 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: 183-194. American Fisheries Society, Bethesda, Maryland.

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. in press. Evaluating sources of bias in pedigree-based estimates of breeding population size. Ecological Applications.

Wilber, D. H. and D. G. Clarke. 2001. Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management **21**(4): 855-875.

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. 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.

Wippelhauser, G. S., G. B. Zydlewski, M. Kieffer, J. Sulikowski, and M. T. Kinnison. 2015. Shortnose Sturgeon in the Gulf of Maine: Use of Spawning Habitat in the Kennebec System and Response to Dam Removal. Transactions of the American Fisheries Society **144**(4): 742-752.

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. 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, and D. L. Peterson. 2008. Thermal maxima for juvenile shortnose sturgeon acclimated to different temperatures. Environmental Biology of Fishes **82**(3): 299-307.

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.