NATIONAL MARINE FISHERIES SERVICE
ENDANGERED SPECIES ACT SECTION 7
BIOLOGICAL OPINION

Title:	Biological Opinion on the Issuance of Incidental Take Permit No. 23148 to Exelon Generating Company, LLC, for Operation of Eddystone Generating Station
Consultation Conducted By:	Endangered Species Act Interagency Cooperation Division, Office of Protected Resources, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce
Action Agency:	Endangered Species Conservation Division, Office of Protected Resources, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce
Publisher:	Office of Protected Resources, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce
Approved:	WIETING.DONNA.S.1365710607 Digitally signed by WIETING.DONNA.S.1365710607 Date: 2020.06.24 12:59:06 -04'00' Donna S. Wieting Director, Office of Protected Resources
Date:	June 19, 2020
Consultation Tracking number:	OPR-2019-03367
Digital Object Identifier (DOI):	https://doi.org/10.25923/kh0z-qg97

This page left blank intentionally

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.) establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat they depend on. Section 7(a)(2) of the ESA requires Federal agencies to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Federal agencies must do so in consultation with National Marine Fisheries Service (NMFS) for threatened or endangered species (ESA-listed), or designated critical habitat that may be affected by the action that are under NMFS jurisdiction (50 C.F.R. §402.14(a)). If a Federal action agency determines that an action "may affect, but is not likely to adversely affect" endangered species, threatened species, or designated critical habitat and NMFS concur with that determination for species under NMFS jurisdiction, consultation concludes informally (50 C.F.R. §402.14(b)).

Section 7(b)(3) of the ESA requires that at the conclusion of consultation, NMFS provides a biological opinion stating whether the Federal agency's action is likely to jeopardize ESA-listed species or destroy or adversely modify designated critical habitat. If NMFS determines that the action is likely to jeopardize listed species or destroy or adversely modify critical habitat, NMFS provides a reasonable and prudent alternative that allows the action to proceed in compliance with section 7(a)(2) of the ESA. If an incidental take is expected, section 7(b)(4) requires NMFS to provide an incidental take statement (ITS) that specifies the impact of any incidental taking and includes reasonable and prudent measures to minimize such impacts and terms and conditions to implement the reasonable and prudent measures.

Updates to the regulations governing interagency consultation (50 C.F.R. 402) became effective on October 28, 2019 (84 FR 44976). This consultation was pending at the time the regulations became effective and we are applying the updated regulations to the consultation. As the preamble to the final rule adopting the regulations noted, "This final rule does not lower or raise the bar on section 7 consultations, and it does not alter what is required or analyzed during a consultation. Instead, it improves clarity and consistency, streamlines consultations, and codifies existing practice." We have reviewed the information and analyses relied upon to complete this biological opinion (Opinion) in light of the updated regulations and conclude the Opinion is fully consistent with the updated regulations.

The action agency for this consultation is the NMFS, Office of Protected Resources, Endangered Species Conservation Division (hereafter the Endangered Species Conservation Division). The Endangered Species Conservation Division proposes to issue an Incidental Take Permit (ITP; Permit No. 23148) to Exelon Generation Company, LLC (Exelon) pursuant to section 10(a)(1)(B) of the ESA.

This consultation, biological opinion, and ITS were completed in accordance with section 7(a)(2) of the statute (16 U.S.C. 1536 (a)(2)), associated implementing regulations (50 C.F.R. §§401-16), and agency policy and guidance was conducted by NMFS Office of Protected Resources Endangered Species Act Interagency Cooperation Division (hereafter referred to as "we"). This biological opinion (Opinion) and ITS were prepared by NMFS Office of Protected Resources Endangered Species Act Interagency Cooperation Division in accordance with section 7(b) of the ESA and implementing regulations at 50 C.F.R. §402.

This document represents NMFS' Opinion on the effects of the issuance of Permit No. 23148 on fin whales (*Balaenoptera physalus*), North Atlantic right whales (*Eubalaena glacialis*), green turtle (*Chelonia mydas*) (North Atlantic DPS), Kemp's ridley turtle (*Lepidochelys kempii*), leatherback turtle (*Dermochelys coriacea*), loggerhead turtle (*Caretta caretta*) (Northwest Atlantic Ocean DPS), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) (Gulf of Maine distinct population segment (DPS), New York Bight DPS, Chesapeake Bay DPS, Carolina DPS, and South Atlantic DPS), shortnose sturgeon (*Acipenser brevirostrum*), and designated critical habitat for Atlantic sturgeon (New York Bight DPS). A complete record of this consultation is on file at the NMFS Office of Protected Resources in Silver Spring, Maryland.

1.1 Background

Section 9 of the ESA and Federal regulations prohibit the 'taking' of a species listed as endangered or threatened. The ESA defines ''take'' to mean harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. NMFS may issue permits, under limited circumstances to take listed species incidental to, and not the purpose of, otherwise lawful activities. Section 10(a)(1)(B) of the ESA provides a mechanism for authorizing incidental take of listed species. NMFS regulations governing permits for threatened and endangered species are promulgated at 50 CFR 222.307.

We received a request for consultation under Section 7 of the ESA from the Endangered Species Conservation Division on October 1, 2019. The consultation request package consisted of an ESA Section 7 Initiation Memorandum, draft Environmental Assessment, and Exelon's ITP application/Habitat Conservation Plan. The Endangered Species Conservation Division requested consultation on its proposed action of issuing a section 10(a)(1)(B) permit to Exelon for the take of ESA-listed shortnose sturgeon and Atlantic sturgeon (New York Bight Distinct Population Segment) due to the operation of the cooling water intake structure (CWIS) and vessel activity associated with fuel delivery to the station at the Eddystone Generating Station (Eddystone) on the Delaware River in Eddystone, Pennsylvania.

In the course of their operations, electric power facilities and certain manufacturing facilities use large amounts of water either for cooling purposes or in their manufacturing processes. Such facilities typically remove water from nearby sources using "cooling water intake structures." The structures associated with water removal pose a number of threats to the environment. Principally, aquatic organisms are squashed against intake screens—impingement—or drawn into the cooling system—entrainment. Section 316(b) of the Clean Water Act (CWA) requires the Environmental Protection Agency (EPA) to develop standards for cooling water intake structures.

Eddystone consists of two identical, natural gas/fuel oil-fired electric generating units which run at higher levels of generation capacity during the summer and winter months. The electrical output of each of these units during the summer is 380 megawatts. These generating units became operational in 1974 and 1976. Exelon anticipates these units to be retired in 2033. The operation of a CWIS is the primary aspect of the facility operations under consideration for this ITP for Eddystone due to the potential impacts to ESA-listed sturgeon. Exelon also considered potential threats to listed species from transportation of fuel to the facility as well as thermal stress caused by heated discharge water. Under CWA section 316(b), Exelon conducted entrainment sampling at Eddystone in 2005-2006, 2016, and 2017. One Atlantic sturgeon yolk-sac larva was collected in May 2017. Thus, Exelon determined it was necessary to apply for an ITP in accordance with the requirements under Section 10(a)(1)(B) of the ESA.

1.2 Consultation History

This opinion is based on information provided in the permit application (Exelon 2019), correspondence, and discussions with the Endangered Species Conservation Division and the applicant, biological opinions and annual reports for other similar research activities for which we have conducted ESA section 7 consultations, and the best scientific and commercial data available.

Our communication with the Endangered Species Conservation Division regarding this consultation is summarized as follows:

- On February 28, 2017, Exelon met with NMFS to discuss their application and their proposed methods of analyzing potential incidental takes of Atlantic and shortnose sturgeon.
- On January 25, 2018, Exelon met with NMFS to discuss their revised methods of analyzing incidental take of Atlantic sturgeon after the entrainment of a single larve at Eddystone in May 2017.
- On June 28, 2018, Exelon met with NMFS to discuss its draft application.
- On December 21, 2018, the Endangered Species Conservation Division received an application for an incidental take permit from Exelon, which we received on January 28, 2019.
- On June 21, 2019, the Endangered Species Conservation Division received a revised application from Exelon, which we received on June 25, 2019.
- On October 1, 2019, the Endangered Species Conservation Division sent us a memorandum requesting formal consultation. We determined there was sufficient information to initiate formal consultation.

- On December 4, 2019, we provided the Endangered Species Conservation Division with an initiation memorandum.
- On December 31, 2019, Exelon provided minor revisions to their application.
- On January 7, 2020, Exelon provided additional information regarding oil barge routes.
- On March 23, 2020, we received revised sturgeon take estimates from the Endangered Species Conservation Division calculated by Exelon.
- On April 4, 2020, we received clarification from Exelon regarding the methodology behind the calculations of their updated sturgeon take estimates.
- On May 4, 2020, Exelon provided new sturgeon take estimates based on average actual intakes per day of energy generation.

2 THE ASSESSMENT FRAMEWORK

Section 7(a)(2) of the ESA requires Federal agencies, in consultation with NMFS, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species; or adversely modify or destroy their designated critical habitat.

"Jeopardize the continued existence of" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of an ESA-listed species in the wild by reducing the reproduction, numbers, or distribution of that species." 50 C.F.R. §402.02.

"Destruction or adverse modification" means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR 402.02).

An ESA section 7 assessment involves the following steps:

Description of the Proposed Action (Section 3): We describe the proposed action and those aspects (or stressors) of the proposed action that may have effects on the physical, chemical, and biotic environment.

Action Area (Section 4): We describe the action area with the spatial extent of those stressors.

Potential Stressors (Section 5): We identify the stressors that could occur as a result of the proposed action and affect ESA-listed species and designated critical habitat.

Species and Critical Habitat that may be Affected by the Proposed Action (Section 6): We identify the ESA-listed and designated critical habitat that may be affected by the stressors.

Species Likely to be Adversely Affected by the Proposed Action (Section 7): We identify the ESA-listed species that are likely to co-occur with those stressors in space and time and evaluate the status of those species and habitat.

Status of Species Likely to be Adversely Affected by the Proposed Action (Section 8): We examine the status of each species that would be adversely affected by the proposed action throughout the action area.

*Environmental Baseline (*Section 9): The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, 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 consultations, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

Effects of the Action (Section 10): Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 CFR 402.17). In our analysis, which describes the effects of the proposed action, we considered 50 CFR 402.17(a) and (b). In this section, we identify the number, age (or life stage), and gender of ESA-listed individuals that are likely to be exposed to the stressors and the populations or sub-populations to which those individuals belong. We also consider whether the action "may affect" designated critical habitat. This is our exposure analysis. We then evaluate the available evidence to determine how individuals of those ESA-listed species are likely to respond given their probable exposure. We also consider how the action may affect designated critical habitat. This is our response analyses. We assess the consequences of these responses of individuals that are likely to be exposed to the populations those individuals represent, and the species those populations comprise. This is our risk analysis. The destruction or adverse modification analysis considers the impacts of the proposed action on the essential habitat features and conservation value of designated critical habitat.

Cumulative Effects (Section 11): Cumulative effects are the effects to ESA-listed species and designated critical habitat of future state or private activities that are reasonably certain to occur within the action area (50 C.F.R. §402.02). Effects from future Federal actions that are unrelated to the proposed action are not considered because they require separate ESA section 7 compliance.

Integration and Synthesis (Section 12): The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (Section 10) to the environmental baseline (Section 9) and the cumulative effects (Section 11), taking into account the status of the species (Section 8), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) Reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

Conclusion (Section 13): With full consideration of the status of the species and the designated critical habitat, we consider the effects of the action within the action area on populations or subpopulations and on essential habitat features when added to the environmental baseline and the cumulative effects to determine whether the action could reasonably be expected to jeopardize the continued existence of listed species or destroy or adversely modify its designated critical habitat.

If, in completing the last step in the analysis, we determine that the action under consultation is likely to jeopardize the continued existence of ESA-listed species or destroy or adversely modify designated critical habitat, then we must identify reasonable and prudent alternative(s) to the action, if any, or indicate that to the best of our knowledge there are no reasonable and prudent alternatives (See 50 C.F.R. §402.14).

In addition, we include an *Incidental Take Statement* (Section 14) that specifies the impact of the incidental take, reasonable and prudent measures to minimize the impact of the incidental take, and terms and conditions to implement the reasonable and prudent measures (ESA section 7(b)(4); 50 C.F.R. §402.14(i)). We also provide discretionary conservation recommendations that may be implemented by action agency (Section 15) (50 C.F.R. §402.14(j)). Finally, we identify the circumstances in which reinitiation of consultation is required (Section 16) (50 C.F.R. §402.16).

To comply with our obligation to use the best scientific and commercial data available, we collected information identified through searches of *Google* scholar and literature cited sections of peer reviewed articles, species listing documentation, and reports published by government and private entities. This consultation is based on our review and analysis of various information sources, including:

- Information submitted by the NMFS Permits and Conservation Division and the applicants;
- Government reports (including NMFS opinions, recovery plans, and stock assessment reports);
- National Oceanic and Atmospheric Administration (NOAA) technical memorandums;
- Annual reports; and
- Peer-reviewed scientific literature.

These resources were used to identify information relevant to the potential stressors and responses of ESA-listed species and designated critical habitat under NMFS' jurisdiction that may be affected by the proposed action to draw conclusions on risks the action may pose to the continued existence of these species and the value of designated critical habitat for the conservation of ESA-listed species.

3 DESCRIPTION OF THE PROPOSED ACTION

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies. The proposed action for this consultation is NMFS Endangered Species Conservation Division's issuance of an Incidental Take Permit (ITP) pursuant to the requirements of the ESA to Exelon.

The Endangered Species Conservation Division proposes to issue ITP No. 23148 to Exelon to cover incidental takes of Atlantic and shortnose sturgeon during operation of Eddystone on the Delaware River in Eddystone, Pennsylvania. Operations that may result in takes of sturgeon include the withdrawal of cooling water from the river, the discharge of pollutants into the river, and the transport of fuel oil to Eddystone by barge.

Dredging of the navigation channel is occasionally required to allow the fuel barges to access Eddystone, but these are infrequent, are conducted on an as-needed basis, and no dredging activities are currently scheduled. Any future dredging activities have been previously evaluated under the ESA during consultation on a United States Army Corps of Engineers permit, Weeks Marine Dredging Permit CENAP-OP-R-2013-0695-46. Therefore dredging activities are not addressed in the Habitat Conservation Plan for this consultation.

That plan can be accessed on NMFS ITP webpage: **Incidental Take Permit to Eddystone Generating Station**. The permit would expire ten years after the date of issuance. Information regarding the operation of Eddystone, discussed below, was obtained from Exelon's ITP application/Habitat Conservation Plan (Exelon 2019). The various stressors that may be introduced to the river as a result of the proposed action are discussed further in Section 5.

3.1 Eddystone Operations

Eddystone consists of two identical, natural gas/fuel oil-fired electric generating units which run at higher levels of generation capacity during the summer and winter months, especially summer (Table 1). Exelon anticipates these generating units would be retired in 2033.

Dispatch of the generating units is determined by PJM Interconnection, LLC (PJM) based on power system energy needs as well as the cost of generation. PJM operates the electric generation system based on price, with the least cost units being called to generate first, and then additional units are called to operate based on their prices, with the higher-cost, generally older units like Eddystone being called to run less frequently. Eddystone's units also participate in PJM's capacity market and therefore must be available for dispatch whenever called upon by PJM. PJM's capacity market ensures long-term grid reliability by securing generation to meet future energy demand. In recent years, Eddystone has typically generated power on days with high demand, such as during the hottest summer days or coldest winter days, or during times when there are issues with the stability of the grid due to transmission line access, lower cost units being off-line, or disruptions in the fuel supply. When PJM notifies Exelon that power from Eddystone is required, Exelon only has 12.5 hours to bring the systems and pieces of equipment necessary for the generation of electricity from cold stand-by to full operation (four hours if the units are in hot stand-by). Given the number of variables that can impact stable operations of the grid, it is impractical to accurately predict whether Eddystone operations will increase, decrease or stay the same based on the previous year of operation. If PJM were to direct Exelon to operate the Eddystone units at an increased frequency in future years, the actual intake flow for the Station would also increase (Exelon 2020a).

Table 1. Average monthly capacity utilization rate percentages for Eddystone's two currently functioning electric generating units from 2013 to 2017 (Exelon 2019) (Avg = average).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2013	0	0	0	0	0.8	1.7	6.7	2.1	2.0	0	0	0	**1.1**
2014	6.0	0	0	0	1.0	1.8	5.0	1.2	1.5	0	0	0.8	**1.4**
2015	0	8.8	0	0	0	1.6	7.9	15.1	7.5	0	0.4	0	**3.4**
2016	0	0	0	<0.1	1.3	0.3	13.8	11.3	5.2	<0.1	0	0.1	**2.7**
2017	0	0	0	0.2	0.4	0.4	2.8	<0.1	2.3	2.2	0.5	0	**0.7**
Avg	**1.2**	**1.8**	**0**	**<0.1**	**0.7**	**1.1**	**7.2**	**5.9**	**3.7**	**0.4**	**0.2**	**0.2**	**1.9**

3.2 Cooling Water Intake Structure Operations

Cooling water for each generating unit is withdrawn from the Delaware River through a CWIS, located along the western shore of the river, directly in front of Eddystone. Each of the four intake bays (two for each generating unit) is designed to reduce fish impingement mortality and entrainment; curtain walls, multiple screens, and trash racks are used to reduce water intake velocities and an opening to the river is provided for fish behind the trash racks in the intake bays (Dickinson 1974; Exelon et al. 2008). Each trash rack is approximately 3.4 meters (11.2 feet) in height and width with vertical 1.27 centimeter (0.5 inch)-wide bars spaced 9.5 centimeters (3.75 inches) apart, center to center. Each intake bay can be sealed off for maintenance via stop log guides.

Traveling screens are located in wells behind each stop log guide. Each traveling screen is a 14.6- meter (48-foot) vertical, chain-link, four-post-type machine with a 1.0-centimeter (0.4-inch) mesh. This machine consists of 54 screen panels continuously traveling vertically to collect material from the incoming water. Each screen panel is approximately 3.0 meters (10 feet) wide and is made of 304 stainless-steel mesh. The panels are equipped with debris troughs and a high-pressure spray wash system (HDR 2018). Under non-freezing ambient conditions, the screens run on a timer to operate one rotation every eight hours, and continuously as needed during the fall leaf season.

In each intake bay, a circulating water pump with a rated capacity of approximately 750 million liters (198 million gallons) per day provides cooling water to the generating unit. Each intake bay is also equipped with a river water pump that provides cooling water to cool equipment and for miscellaneous uses (Exelon et al. 2008). The river water pumps typically operate when the units are not generating power and when the circulating water pumps are not operating. Each river water pump has a rated capacity of 40.9 million liters (10.8 million gallons) per day. Therefore, each of the two generating units have a design flow of 1.6 billion liters (417.6 million gallons) per day, resulting in a total design intake flow of 3.2 billion liters (835.2 million gallons) per day at Eddystone. However, the actual intake flows for Eddystone from 2013 to 2020 were much lower than the design intake flow (Table 2).

Table 2. Average monthly actual intake flow (million gallons per day) for Eddystone from January 2013 through February 2020 (Exelon 2020b) (Avg = average).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2013	208.8	213.5	208.8	214.0	244.4	279.8	347.5	457.2	438.3	261.6	208.8	86.6	**264.1**
2014	469.5	42.0	53.5	103.2	110.7	152.7	377.0	97.0	192.4	10.8	41.0	217.7	**155.6**
2015	21.6	349.9	87.1	10.8	10.8	263.8	484.6	790.3	621.4	399.1	92.5	205.4	**278.1**
2016	213.2	114.0	169.7	200.2	438.1	423.6	658.3	720.1	553.7	224.1	157.5	333.1	**350.5**
2017	203.1	189.9	173.2	100.4	259.4	380.3	486.4	310.4	462.2	186.0	200.8	224.4	**264.7**
Avg (2013-2017)	**223.2**	**181.9**	**138.5**	**125.7**	**212.7**	**300.0**	**470.8**	**475.0**	**453.6**	**216.3**	**140.1**	**213.5**	**262.6**
2018	217.9	20.6	17.3	51.8	240.8	352.7	454.0	414.1	363.4	170.0	82.4	21.7	**200.6**
2019	21.6	21.6	14.1	83.4	65.3	34.0	173.1	34.3	99.6	64.6	33.9	41.7	**57.3**
2020	23.2	23.0	-	-	-	-	-	-	-	-	-	-	-

3.3 Discharge

The cooling water is withdrawn from the Delaware River through the CWIS on the shoreline, passed through a condenser, and then discharged back into the river through a pipe 3.7 meters (12 feet) in diameter (Outfall 008, Figure 1) extending 300 feet (91.4 meters) into the river along its bottom (Environmental Resources Management 2014). The temperature of this discharged water, which varies depending on the electricity generation rates and efficiencies of the units at Eddystone, is higher than the source water. Water temperatures at the intake and outfall are continuously monitored by Exelon to calculate the increase in temperature at the outfall relative to the intake water temperature (ΔT), as required in Eddystone's NPDES permit.

Eddystone's last hydrothermal assessment was conducted in 2014 using the Delaware River Basin Commission (DRBC) Cornell Mixing Zone Expert System modeling procedure using data from the United States Geological Survey, NOAA, and Exelon. For this simulation, the full capacity effluent discharge of 580,000 gallons (2.2 million liters) per minute was used. To account for seasonal changes, two temperature conditions were used. For the month of February, the ambient water temperature was assumed to be 2.2 degrees Celsius (36 degrees Fahrenheit). For the month of August, the ambient water temperature was assumed to be 27.2 degrees Celsius (81 degrees Fahrenheit). As established as the limit in Eddystone's National Pollutant Discharge Elimination System (NPDES) permit, ΔT was assumed to be 11.7 degrees Celsius (21 degrees Fahrenheit).

In 2018, Exelon requested that the results of the 2014 modeling effort be further examined in order to characterize the bottom characteristics of the plume (Environmental Resources Management 2018). The thermal plume was modeled as the area with a ΔT greater than 2.8 degrees Celsius (5 degrees Fahrenheit), based upon the requirements for heat dissipation areas ("HDAs") established by DRBC. Modeled plume characterizations demonstrated that during the simulation for February, the maximum extent of the 2.8 degrees Celsius (5 degrees Fahrenheit) isotherm extended 21.8 meters (71.5 feet) downstream during ebb tide, 23.4 meters (76.8 feet) upstream during flood tide, and 105.7 meters (346.7 feet) laterally during slack tide. During the August simulation, the extent of the 2.8 degrees Celsius (5 degrees Fahrenheit) isotherm extended 57.9 meters (189.9 feet) downstream during ebb tide, 49.0 meters (160.8 feet) upstream during flood tide, and 81.6 meters (267.8 feet) laterally during ebb tide.

Based upon the hydrothermal assessment, the HDA for Eddystone, defined by the extent of the 2.8 degrees Celsius (5 degrees Fahrenheit) isotherm, extends 69.5 meters (228 feet) upstream, 58.8 meters (193 feet) downstream, and 121.9 meters (400 feet) across the river. Accordingly, NPDES and DRBC permitted an HDA of 64.0 meters (210 feet) upstream and downstream of the outfall and 121.9 meters (400 feet) offshore of the outfall at Eddystone. The bottom contact areas of the modeled thermal plume were small and varied with the tidal cycle, as was observed for the surface extent of the plume. In February, the area of bottom contact ranged from 6.3 to 175.2 square meters (68 to 1886 square feet) with an average of 157.8 square meters (1699 square feet). Generally, the areas of bottom contact were larger in August than in February, ranging from 19.0 to 250.3 square meters (204 to 2694 square feet) with an average of 201.0 square meters (2164 square feet).

Pollutants present in the discharged water include the biocides ChemTreat C2189G, a bromide-based microbial control agent, and ChemTreat CL2005 and ChemTreat A103G, molluscicides used to control Asiatic clams. These are authorized to be added to the circulating water pumps when they are in service (limit of two hours per day per generating unit), in accordance with Eddystone's NPDES permit and (Pennsylvania Department of Environmental Protection 2014)'s list of approved chemical additives for water management systems. Cooling water effluents are monitored for total residual chlorine, total suspended solids, ChemTreat CL2005, ammonia-nitrogen, and bromide.

Along with cooling water, Exelon is authorized to discharge effluents from Eddystone's wastewater treatment plant into the Delaware River and stormwater into Crum Creek, a tributary of the Delaware. Oil from the influents is removed via an oil/water separator. Effluents from the plant may include ethylenediaminetetraacetic acid (EDTA), sodium hydroxide, citric acid, hydrochloric acid, ROClean P111, sodium bisulfite, Kathon, PW 76AS, Versine 100XL, and Hypersperse 772. These chemicals generally occur in small concentrations in the wastewater treatment plant influent, when present. Effluents from the wastewater treatment plant are monitored at Monitoring Point 108 for total suspended solids, total dissolved solids, oil and grease, total copper, total iron, polychlorinated biphenyls (PCBs), and carbonaceous biological oxygen demand. Monitoring Point 108 is located upstream of the location where the effluent empties into the discharge pipe and commingles with the effluent prior to being discharged via Outfall 008. Per the Pollution Minimization Pan rule implemented by the DRBC in 2005, wet weather monitoring of PCBs is required at a subset of Eddystone's additional outfalls.

3.4 Vessel Activity

A waterfront structure with a docking length of 695 feet (211.8 meters) is located in the Delaware River where fuel oil has been unloaded from barges with overall lengths ranging from 287 feet (87.5 meters) to 414 feet (126.2 meters) with drafts of 12 feet (3.7 meters) to 24 feet (7.3 meters). These barges have been maneuvered by tug boats ranging from 75 feet (22.9 meters) to 117 feet (35.7 meters) in length with drafts of 10 feet (3.0 meters) to 16 feet (4.9 meters). Eddystone has received 12 fuel oil deliveries since 2013, with these deliveries occurring at irregular intervals and originating from Philadelphia, Pennsylvania; Perth Amboy; and Linden, New Jersey. In 2018, there was one roundtrip vessel delivery on January 31, 2018. Six deliveries via barges with drafts ranging from approximately 10 feet (3.0 meters) to 25 feet (7.6 meters) were anticipated for 2019. This was an anomalous year because Eddystone's oil tank was taken out of service for a tank inspection; a total of five vessel roundtrips occurred: two on March 5, 2019 and March 10, 2019 associated with emptying the oil tank to allow for the "out of service" tank inspection; and three on May 21, 2019, June 14, 2019, and September 10, 2019 to refill the tank after the inspection. As "out of service" tank inspections occur very infrequently, approximately once every 20 years, the next out of service tank inspection is not due until 2039. Furthermore, only two of the seven vessel trips in 2018 and 2019 occurred within the March 15-July 15 vessel activity avoidance period, and these two trips were associated with the out of service inspection event (Exelon 2020b).

Future barges are anticipated to transit between Eddystone and Croydon, Pennsylvania or between Eddystone and a port between New York Harbor and Philadelphia. The frequency of delivery depends on a variety of factors including the amount of fuel oil already in storage, the amount of time the Station operates, and contractual obligations for the purchase of fuel oil. Variability in these factors makes the frequency of future deliveries beyond 2019 difficult to predict. The majority of past fuel oil deliveries (i.e., 8 of 12) over 2013 to 2017 have occurred between September 1 and March 14. The Station generally runs on natural gas outside the winter months, often eliminating the need to receive oil deliveries between March 15 and July 15, the period when adult sturgeon are likely present in the Delaware River to spawn. However, other factors (e.g., availability, pricing, or reliability) may require Eddystone to schedule fuel oil deliveries between mid-March and mid-July (Exelon 2019).

3.5 Habitat Conservation Plan: Minimization, Monitoring, Mitigation, and Reporting

To minimize the number of takes associated with the facility operation, Exelon prepared a Habitat Conservation Plan (Exelon 2019) that describes measures designed to monitor, minimize, and mitigate, to the maximum extent practicable, the incidental take of shortnose and Atlantic (New York Bight DPS) sturgeon. The goals of the Conservation Plan are to avoid and minimize take, and to aid in the conservation of shortnose and Atlantic (New York Bight DPS) sturgeon in the Delaware River by supporting two initiatives: to build on the existing knowledge of cohorts spawning in the Delaware River; and, to improve knowledge of shortnose and Atlantic sturgeon spatial and temporal use of the freshwater tidal portion of the Delaware River. The ITP, if issued, would require mitigation and monitoring measures to avoid or minimize impacts to sturgeon, as stated in the Habitat Conservation Plan and described below, as contained in Exelon's Conservation Plan.

3.5.1 Circulating Water Pumps

Mitigation procedures (listed below) were implemented at Eddystone in December of 2018 and PJM's energy requirements were anomalously low in 2019 (Exelon 2020b). As a result, the actual intake flows at the CWIS have decreased substantially (see Table 2). The average daily actual intake flow declined from an average of 262.6 million gallons per day over the 2013 through 2017 time period to 57.3 million gallons per day in 2019, a 78.2 percent reduction. During the period of April through July, when Atlantic sturgeon larvae would potentially be present near Eddystone, the average daily actual intake flow declined from an average of 277.9 million gallons per day over that same five-year period to 89.5 million gallons per day in 2019, a

68 percent reduction. These observed reductions were driven largely by PJM requirements not under Exelon's control.

However, the implementation of Exelon's new standard operating procedures alone also led to decreases in actual intake flows (Exelon 2020b). Exelon estimated that the average daily intake flow declined from an average of 7 million gallons per day over the 2013 through 2017 time period to 4.8 million gallons per day in 2019, a 32 percent reduction, due to the implementation of these new procedures. During the period of April through July, when Atlantic sturgeon larvae would potentially be present near Eddystone, the average daily actual intake flow declined from an average of 15 million gallons per day over that same five-year period to 8.9 million gallons per day in 2019, a 41 percent reduction.

Exelon will continue to only operate Eddystone's circulating water pumps:

1) when the Station is generating electricity, which includes two days for ramp-up (which includes 36 hours to address contingencies) and 10 days for ramp-down; and

2) for incidental maintenance or testing (generally once per month) (referred to collectively as "Essential Station Operations"); or as required by a governmental agency or other entity with jurisdiction to require operations.

Exelon will also limit operations to one circulating water pump per unit when possible. In addition, Exelon will rely on the river water pumps to provide cooling water for other critical Station operations outside of Essential Station Operations. These measures will avoid and minimize the incidental take of sturgeon due to entrainment or impingement by eliminating or reducing water withdrawals at times when such withdrawals are not specifically required for Essential Station Operations or for governmental agency-mandated use.

3.5.2 Entrainment Monitoring

Monitoring of the CWIS for the entrainment of Atlantic sturgeon at Eddystone is based on: the established means and methods used during the most recent Clean Water Act 316(b) study sampling completed by Exelon; the best available information on Atlantic sturgeon spawning seasons in the Delaware River (i.e., the period(s) when early life-stage Atlantic sturgeon may be susceptible to entrainment at Eddystone); the established knowledge that Atlantic sturgeon early life-stages prefer demersal habitat and their past occurrence in near-bottom entrainment samples; and a monitoring goal of confirming the rate at which early life stage Atlantic sturgeon may be entrained at Eddystone. Monitoring for incidental take of Atlantic sturgeon due to entrainment will specifically consist of the following:

Eddystone will collect entrainment samples during the 17-week period of potential entrainment of Atlantic sturgeon (April through July). On each day of entrainment sampling, samples will be collected over a 24-hour period. The proposed schedule for entrainment sampling is:

- 2 days per week during each week in which Eddystone runs circulating water pumps for two or more days,
- 1 day per week during each week in which Eddystone runs circulating water pumps for one day only, and
- No sampling during each week in which Eddystone does not run circulating water pumps on any days.

Entrainment sampling will be conducted by an experienced biological consulting firm. On each day of sampling, four entrainment samples will be collected at approximately six-hour intervals, resulting in a collection representative of a full 24-hour day. Samples will be collected behind the traveling screens of the operating unit using a permanently mounted sample pipe. A 4-inch pump will pump water from the sample pipe into a 500-micrometer plankton net suspended in a large tank of water. Target sample volume will be 100 cubic meters. Approximately half of the sample volume will be collected from a depth of 32 feet below mean low water (MLW) (i.e., approximately 3 feet above the bottom of the intake forebay), and approximately half of the sample will be collected from a depth of approximately 22.5 feet below MLW. At the end of each sampling period, the net will be washed down so the contents collect in the cod end. The contents of the cod end will be strained through a 500-micrometer sieve, and the material collected on the sieve will be transferred to a labeled sample jar and preserved with formalin.

Preserved samples will be shipped to the contractor’s ichthyoplankton laboratory under proper Chain of Custody. The field staff will include a Chain of Custody document with each shipment that includes the collection date, collection time, and identification number for each sample in a shipment as well as the total number of samples in the shipment. Upon receipt of the shipment, laboratory staff will verify that all shipped samples were received, and will sign and date the Chain of Custody document. Samples will be sorted by trained technicians and any Atlantic sturgeon larvae will be identified and counted. Exelon will notify NMFS within 24 hours of a confirmed identification of an Atlantic sturgeon larva.

Exelon will prepare and submit monthly monitoring reports for April through July and an annual monitoring report for each year covered under the IITP. Monthly reports will be submitted within one month of the end of the monthly reporting period, and annual reports will be submitted within three months of the end of the annual reporting period.

Monthly reports will include:
1) the volume of cooling water withdrawn on each day of the month;
2) the days on which entrainment sampling was scheduled, any reasons sampling did not occur as scheduled, and the days on which sampling was actually conducted;
3) the volume of water sampled and the number and life stage of Atlantic sturgeon collected (if any) for each entrainment sample; and
4) a narrative describing any issues encountered that interfered with implementation of the Conservation plan.

Annual reports will include:
1) an estimate of annual take of Atlantic sturgeon due to entrainment, with a 95 percent confidence limit, computed using the methods described in Appendix A of the conservation plan;
2) an annual data set compiled from the data provided in the monthly monitoring reports; and
3) a narrative describing any issues encountered during the year that interfered with implementation of the conservation plan including a description of any corrective actions taken or any proposed issue resolution.

Entrainment monitoring will be conducted for three years following issuance of the ITP. If after three years of monitoring Atlantic sturgeon eggs, larvae or juveniles are collected at a rate significantly above that considered in the ITP, annual monitoring will continue and Exelon will work with NMFS to re-evaluate the relevant provisions of the ITP. Sampling protocols will follow those of the prior three years.

3.5.3 Impingement Monitoring

For impingement, Eddystone will collect impingement samples year-round at the Station for an initial period of three years. Impingement of shortnose and Atlantic sturgeon will be recorded on each day of impingement sampling. Each day of impingement sampling will consist of enumeration of all sturgeon collected in the traveling screen wash water collection basket over a 24-hour period. The proposed schedule for impingement sampling is:

- 1 day per week during each week in which Eddystone runs circulating water pumps for one or more days, and
- No sampling during each week in which Eddystone does not run circulating water pumps on any days.

An experienced biological consulting firm will conduct impingement sampling once per week for every week when the circulating water pumps are in operation throughout the year. On each day of sampling, a single 24-hour sample will be collected. Prior to initiation of sampling, the screens, screenhouse, and sluiceways will be flushed of fish and debris by operating the screens continuously for one full rotation. Additionally, contents of the screen-wash dumpster will be flattened and a layer of plastic sheeting will be put down to separate fish collected during the 24-hour sampling period from previously collected fish and debris. At the end of each sampling period, all fish on top of the layer of plastic sheeting will be separated from the debris, and any shortnose or Atlantic sturgeon will be identified and assessed to determine live/dead status.

If a live shortnose or Atlantic sturgeon is collected in an impingement sample, the following handling procedures will be followed:

1. The personnel handling the sturgeon will put on the appropriate protective equipment as expeditiously as possible while ensuring personnel safety.

2. The live sturgeon will be placed in a tub filled with ambient river water of a sufficient depth to cover the fish.
3. The following information will be collected while giving priority to sturgeon survival over data collection: fork length (centimeters); photographs of the dorsal, ventral, and lateral sides of the sturgeon; and documentation of any external tags or markings.
4. The sturgeon will be returned to the river as quickly and gently as possible.

For dead shortnose and Atlantic sturgeon, the following procedures will be followed:

1. The fish will be measured and fork length and total length (centimeters) will be recorded; photographs of the dorsal, ventral, and lateral sides of the sturgeon will be taken; and external tags or markings will be documented.
2. The dead sturgeon will be retained by the monitoring crew and stored frozen until its disposition is discussed with NMFS.

Exelon will notify NMFS within 24 hours of a confirmed identification of a shortnose or Atlantic sturgeon collected in impingement sampling. Additionally, Exelon will include, prepare, and submit monthly monitoring reports and an annual monitoring report for each year covered under the ITP. Exelon will submit monthly reports within one month of the end of the monthly reporting period, and annual reports within three months of the end of the annual reporting period.

Monthly reports will include:

1) the volume of cooling water withdrawn on each day of the month;

2) the days on which impingement sampling was conducted;

3) the volume of water sampled and the number of shortnose or Atlantic sturgeon collected, if any, along with any additional information collected, as described in the handling procedures above;

4) a narrative describing any issues encountered that interfered with implementation of the Conservation plan.

Annual reports will include:

1) an estimate of annual take of shortnose and Atlantic sturgeon due to impingement;

2) an annual data set compiled from the data provided in the monthly monitoring reports; and

3) a narrative describing any issues encountered during that year that interfered with implementation of the Conservation Plan, including a description of any corrective actions taken or any proposed issue resolution.

The monitoring and data that Eddystone will provide through this sampling will benefit the species by filling knowledge gaps, thereby enabling informed and tailored actions to protect and conserve shortnose and Atlantic (NY Bight DPS) sturgeon. Additionally, for encounters during impingement sampling associated with CWIS operations, the impingement sampling plan includes handling procedures focused on reducing stress and quickly releasing sturgeon. The sampling plans for both entrainment and impingement include notification and reporting procedures.

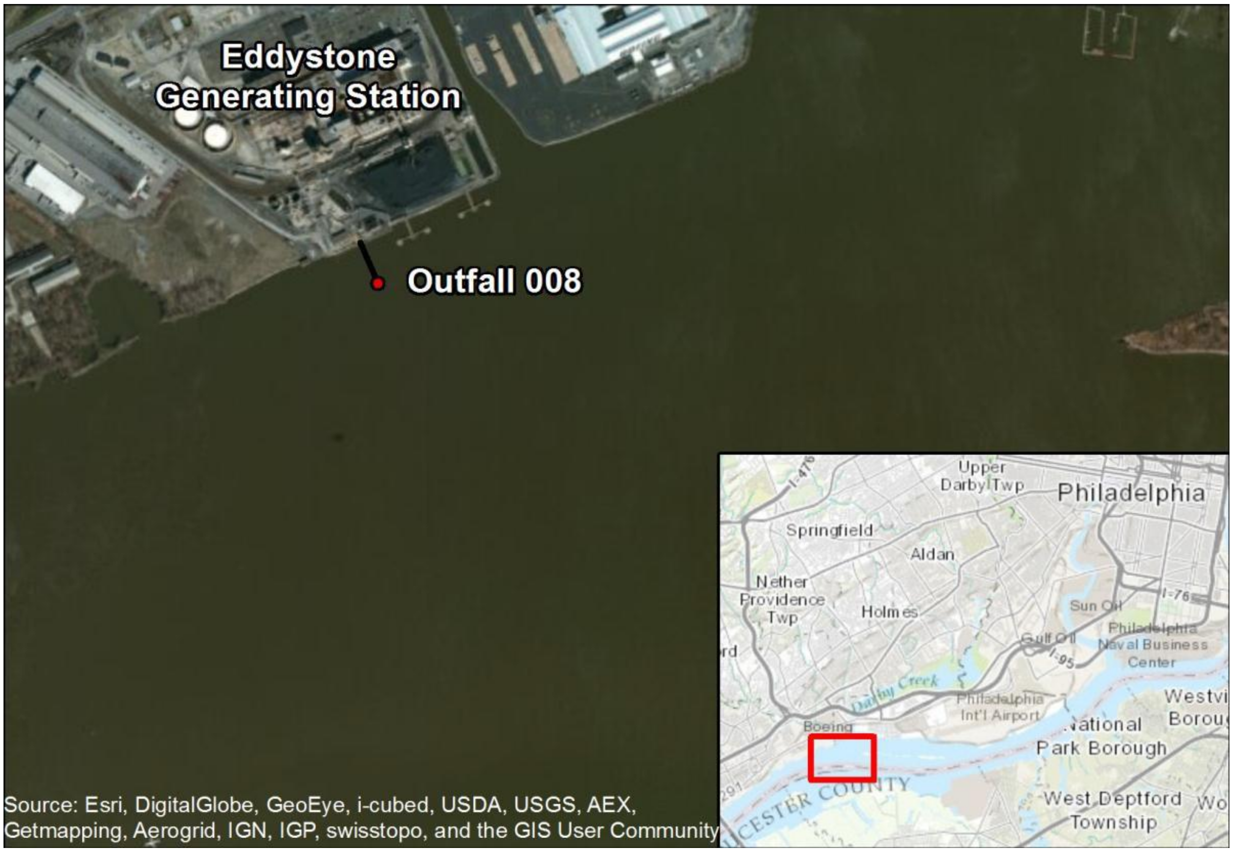
3.5.4 Vessel Deliveries

In order to monitor for take, Exelon will submit an annual report to NMFS documenting the date, duration, and number of one-way vessel trips to and from Eddystone. In the event that the number of vessel trips exceeds the greatest annual number used to estimate take in this application (i.e., ten one-way trips), Exelon would submit the report within 30 days of the completion of the eleventh trip.

Exelon will make all reasonable efforts to schedule fuel oil deliveries outside of the March 15-July 15 time period. For oil deliveries scheduled between March 15 and July 15, the monitoring plan described above will be implemented.

4 ACTION AREA

Action area means all areas affected directly, or indirectly, by the Federal action, and not just the immediate area involved in the action (50 C.F.R. §402.02). The action area for this consultation is the Delaware River from 64 meters upriver from Eddystone downriver to the mouth, its tributary Crum Creek, and marine waters from the mouth of the Delaware River to New York Harbor. Eddystone is located on the western shore of the Delaware River (Figure 1), approximately 12 miles downstream of Philadelphia, Pennsylvania at river kilometer (RKM) 136 (river mile (RM) 84.5). This is the region of the river that may be affected by the operation of Eddystone, which includes the operation of the CWIS, the discharge of cooling water, effluents, and stormwater, and vessel activity. Cumulatively, these activities would be conducted year-round but Eddystone operations are expected to peak during the summer and winter months. Vessels delivering oil to Eddystone are expected to originate from New York Harbor and enter the mouth of the Delaware River from Delaware Bay and coastal waters off of New Jersey (Figure 2).



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 1. Location of Eddystone on the western shore of the Delaware River (Exelon 2019).

Figure 2. Map showing the location of New York Harbor (red pin) and Delaware Bay (yellow star) in relation to Philadelphia, the location of Eddystone.

5 POTENTIAL STRESSORS

Stressors are any physical, chemical, or biological entity that may directly or indirectly induce an adverse response either in an ESA-listed species or their designated critical habitat. During consultation, we identify stressors that are reasonably certain to result from the proposed action. There are several potential stressors that we expect to occur because of the proposed actions resulting from the issuance of ITP No. 23148. These potential stressors include interactions with the CWIS (entrainment, impingement, and intake forebay entrapment), interactions with the thermal plume discharged into the Delaware River, interactions with chemical discharges, and interactions with vessels delivering oil to Eddystone (vessel strike, pollution). These stressors were evaluated independently to assess the effect each may have on the ESA-listed species and their designated critical habitat (see Section 10).

Entrainment presents stressors associated with organisms passing through the power plant, including but not limited to thermal stress. Impingement presents the stressor of direct physical contact with the traveling screens. Entrapment in the intake forebay would result in sturgeon having limited mobility and may result in impingement on the traveling screens. Interactions with the thermal plume would result in thermal stress. Interactions with chemical discharges would result in exposure to contaminants. Vessel strikes present stressors of direct physical contact and trauma. Pollution from oil spills would result in exposure to contaminants.

6 SPECIES AND CRITICAL HABITAT THAT MAY BE AFFECTED BY THE PROPOSED ACTION

Below, we evaluate effects to ESA-listed species and designated critical habitat that may be affected by the proposed action. We also discuss the condition and current function of designated critical habitat, including the essential physical and biological features that contribute to that conservation value of the critical habitat. All of the species potentially occurring within the action area and may be affected by the proposed action are listed in Table 3 along with their regulatory status and critical habitat designation, although the only designated critical habitat within the action area is that of the New York Bight DPS of Atlantic sturgeon. Table 4 provides a summary of the effects of each stressor on each ESA-listed species and the Atlantic sturgeon New York Bight DPS designated critical habitat.

Table 3. Endangered Species Act-listed endangered species that may be affected by the Endangered Species Conservation Division's proposed action of issuance of incidental take permit No. 23148 to Exelon (* indicates critical habitat occurring outside the action area and therefore will not be affected by the proposed action).

Marine Mammals – Cetaceans			
Species	**ESA Status**	**Critical Habitat**	**Recovery Plan**
Fin Whale (*Balaenoptera physalus)*	E – 35 FR 18319	-- --	75 FR 47538 07/2010
North Atlantic Right Whale (*Eubalaena glacialis*)	E – 73 FR 12024	81 FR 4837	70 FR 32293 08/2004
Marine Reptiles			
Species	**ESA Status**	**Critical Habitat**	**Recovery Plan**
Green Turtle (*Chelonia mydas*) – North Atlantic DPS	T – 81 FR 20057	63 FR 46693*	FR Not Available 10/1991 – U.S. Atlantic
Kemp's Ridley Turtle (*Lepidochelys kempii*)	E – 35 FR 18319	-- --	03/2010 – U.S. Caribbean, Atlantic, and Gulf of Mexico 09/2011

Leatherback Turtle (*Dermochelys coriacea*)	E – 35 FR 8491	44 FR 17710* and 77 FR 4170*	10/1991 – U.S. Caribbean, Atlantic, and Gulf of Mexico 63 FR 28359 05/1998 – U.S. Pacific
Loggerhead Turtle (*Caretta caretta*) – Northwest Atlantic Ocean DPS	T – 76 FR 58868	79 FR 39855*	74 FR 2995 10/1991 – U.S. Caribbean, Atlantic, and Gulf of Mexico 05/1998 – U.S. Pacific 01/2009 – Northwest Atlantic

Fish		
Species	**ESA Status**	**Critical Habitat**
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – Carolina DPS	E – 77 FR 5913	82 FR 39160*
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – Chesapeake DPS	E – 77 FR 5879	82 FR 39160*
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – Gulf of Maine DPS	T – 77 FR 5879	82 FR 39160*
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – New York Bight DPS	E – 77 FR 5879	-- --
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – New York Bight DPS Critical Habitat	-- --	82 FR 39160
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – South Atlantic DPS	E – 77 FR 5913	82 FR 39160*
Shortnose Sturgeon (*Acipenser brevirostrum*)	E – 32 FR 4001	63 FR 69613 12/1998

Table 4. Summary table of stressor effects on ESA-listed species and designated critical habitat in the action area (AS - Atlantic sturgeon, LAA - likely to adversely affect, NE – no effect, NLAA - not likely to adversely affect).

Species	Entrainment	Imping-ement (Trash Racks)	Imping-ement (Traveling Screens)	Entrapm-ent (Intake Forebay)	Thermal Plume	Chemical Discharge	Vessel Strike	Oil Spill	Loss of Food Resources from CWIS
Fin whale	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NE

Species	**Entrainment**	**Imping-ement (Trash Racks)**	**Imping-ement (Traveling Screens)**	**Entrapm-ent (Intake Forebay)**	**Thermal Plume**	**Chemical Discharge**	**Vessel Strike**	**Oil Spill**	**Loss of Food Resources from CWIS**
North Atlantic right whale	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NE
Green turtle (North Atlantic DPS)	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NE
Kemp's ridely turtle	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NE
Leatherback turtle	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NE
Loggerhead turtle (Northwest Atlantic Ocean DPS)	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NE
AS (Carolina DPS)	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NE
AS (Chesapeake DPS)	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NE
AS (Gulf of Maine DPS)	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NE
AS (New York Bight DPS)	LAA	NLAA	LAA	NLAA	NLAA	NLAA	LAA	NLAA	NE
AS (South Atlantic DPS)	NE	NE	NE	NE	NE	NE	NLAA	NLAA	NLAA
Shortnose sturgeon	NLAA	NLAA	LAA	NLAA	NLAA	NLAA	NLAA	NLAA	NE
AS New York Bight DPS Critical Habitat	NE	NE	NE	NE	NLAA	NLAA	NE	NLAA	NE

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

NMFS uses two criteria to identify the ESA-listed or critical habitat that are not likely to be adversely affected by the proposed action, as well as the effects of activities that are consequences of the Federal agency's proposed action. The first criterion is exposure, or some reasonable expectation of a co-occurrence, between one or more potential stressors associated with the proposed activities and ESA-listed species or designated critical habitat. If we conclude that an ESA-listed species or designated critical habitat is not likely to be exposed to the proposed activities, we must also conclude that the species or critical habitat is not likely to be adversely affected by those activities.

The second criterion is the probability of a response given exposure. ESA-listed species or designated critical habitat that is exposed to a potential stressor but is likely to be unaffected by the exposure is also not likely to be adversely affected by the proposed action. We applied these criteria to the species ESA-listed in Table 3 (see Table 4) and we summarize our results below.

An action warrants a "may affect, not likely to be adversely affected" finding when its effects are wholly beneficial, insignificant or when effects are extremely unlikely to occur. Beneficial effects have an immediate positive effect without any adverse effects to the species or habitat. Beneficial effects are usually discussed when the project has a clear link to the ESA-listed species or its specific habitat needs and consultation is required because the species may be affected. Insignificant effects relate to the size or severity of the impact and include those effects that are undetectable, not measurable, or so minor that they cannot be meaningfully evaluated. Insignificant is the appropriate effect conclusion when plausible effects are going to happen, but will not rise to the level of constituting an adverse effect. That means the ESA-listed species may be expected to be affected, but not harmed or harassed.

If the effects of an action are determined to be wholly beneficial, insignificant, or when effects are extremely unlikely to occur, we conclude that the action is not likely to adversely affect ESA-listed species or designated critical habitat. This same decision model applies to individual stressors associated with the proposed action, such that some stressors may be determined to be not likely to adversely affect ESA-listed species or critical habitat because any effects associated with the stressors will not rise to the level of take under the ESA. All of the species potentially occurring within the action area and are not likely to be adversely affected by the proposed action are listed in Table 5 along with their regulatory status.

Table 5. Endangered Species Act-listed endangered species and critical habitat that are not likely to be adversely affected by the Endangered Species Conservation Division's proposed action of issuance of incidental take permit No. 23148 to Exelon.

Marine Mammals – Cetaceans			
Species	**ESA Status**	**Critical Habitat**	**Recovery Plan**
Fin Whale (*Balaenoptera physalus)*	E – 35 FR 18319	-- --	75 FR 47538 07/2010
North Atlantic Right Whale (*Eubalaena glacialis*)	E – 73 FR 12024	81 FR 4837	70 FR 32293 08/2004
Marine Reptiles			
Species	**ESA Status**	**Critical Habitat**	**Recovery Plan**

Green Turtle (*Chelonia mydas*) – North Atlantic DPS	T – 81 FR 20057	63 FR 46693*	FR Not Available 10/1991 – U.S. Atlantic
Kemp's Ridley Turtle (*Lepidochelys kempii*)	E – 35 FR 18319	-- --	03/2010 – U.S. Caribbean, Atlantic, and Gulf of Mexico 09/2011
Leatherback Turtle (*Dermochelys coriacea*)	E – 35 FR 8491	44 FR 17710* and 77 FR 4170*	10/1991 – U.S. Caribbean, Atlantic, and Gulf of Mexico 63 FR 28359 05/1998 – U.S. Pacific
Loggerhead Turtle (*Caretta caretta*) – Northwest Atlantic Ocean DPS	T – 76 FR 58868	79 FR 39855*	74 FR 2995 10/1991 – U.S. Caribbean, Atlantic, and Gulf of Mexico 05/1998 – U.S. Pacific 01/2009 – Northwest Atlantic

Fish		
Species/Critical Habitat	**ESA Status**	**Critical Habitat**
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – Carolina DPS	E – 77 FR 5913	82 FR 39160*
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – Chesapeake DPS	E – 77 FR 5879	82 FR 39160*
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – Gulf of Maine DPS	T – 77 FR 5879	82 FR 39160*
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – South Atlantic DPS	E – 77 FR 5913	82 FR 39160*
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – New York Bight DPS Critical Habitat	-- --	82 FR 39160

6.1.1 Endangered Species Act-Listed Marine Mammals

Vessels delivering oil to Eddystone will be traversing marine waters that spatially overlap with ESA-listed fin whales and North Atlantic right whales. Fin and North Atlantic right whales occur throughout the continental shelf and slopes of the mid-Atlantic (NMFS 2017d). In addition, right whale sightings have been documented at the mouth of the Delaware Bay and in a few rare occasions within the bay. 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 2020). Adult and juvenile fin whales could be present within the action area in the Delaware Bay or at its mouth and have been observed off the coast of Cape May, New Jersey (Beans and Niles 2003). Given the lower salinity and shallower depths than marine waters, right and fin whales are not present in the lower Delaware River.

Whales are most likely to be hit by vessels traveling at speeds of 10 knots or more (Laist et al. 2001; Pace and Silber 2005; Vanderlaan and Taggart 2007). Therefore, NMFS established Seasonal Management Areas (SMAs) 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). A mid-Atlantic SMA is located at the mouth of the Delaware River and is active from November 1 through April 30 of any given year. Vessels 65 feet or longer are required to operate at speeds of 10 knots or less when traveling through the SMA. In addition, federal regulations, as specified in 50 CFR 222.32, requires 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 500 yards (460 meters) of the vessel. Thus, measures to avoid vessel strikes are already in place. Fin whales may be present when the SMA is not active (May through October), but the majority of past oil deliveries to Eddystone have occurred between September and March and this schedule is not anticipated to change. Fin whales are uncommon in the action area, federal regulations to avoid vessel strike are in place seasonally, and the number of planned roundtrips to deliver oil to Eddystone is small. North Atlantic right whales would be present within the action area only seasonally if at all, the SMA is active seasonally, and oil deliveries to Eddystone would be infrequent. Given this information, we believe the possibility of an oil vessel striking a fin whale or North Atlantic right whale is extremely unlikely.

Discharge from vessels in the form of leakages of fuel or oil is possible, though spills and discharges are rare. Five round trips are antipated over the ten-year duration of this ITP. Because vessel trips are infrequent and spills and discharges during each trip are rare, it is unlikely they will occur. Therefore, the likelihood of effects to fin whales and North Atlantic right whales from fuel or oil spills is extremely unlikly to occur. We conclude that the proposed action is not likely to adversely affect the ESA-listed fin whale and North Atlantic right whale.

6.1.2 Endangered Species Act-Listed Marine Reptiles

Vessels delivering oil to Eddystone will be traversing marine waters that spatially overlap with several ESA-listed turtles, including the North Atlantic DPS of green turtle, Kemp’s ridley turtle, leatherback turtle, and Northwest Atlantic Ocean DPS of loggerhead turtle. These species occur within the Atlantic Ocean, the Delaware Bay, and the Delaware River estuary (Stetzar 2002). The upper range within the Delaware River estuary is considered Artificial Island at RKM 87

(RM 54) due to low salinity above this point; however, sea turtles occasionally occur as far up as the mouth of the Chesapeake & Delaware Canal (C&D Canal) at RKM 94.3 (RM 58.6).

Sea turtles arrive in the mid-Atlantic from southern overwintering areas in May and typically begin migrating southward by mid-November.

Interactions between vessels and sea turtles are poorly 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, since the animal has more time to maneuver and avoid the vessel (Sapp 2010). Stetzar (2002) reports that 33 of 109 sea turtles stranded along the Delaware Estuary from 1994 to 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). Approximately 3,000 deep-draft vessels enter the Delaware River each year (DRBC 2017b, cited in NMFS 2018). Even if only commercial vessels were to be considered as the cause of sea turtle mortality and assuming that they are evenly distributed throughout the year such that half of the vessel trips occur during turtle season, the likelihood of an interaction between a sea turtle and any one of the commercial vessels transiting the Federal navigation channel is extremely low. In general, 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 (NMFS 2013b). We believe the possibility of an oil vessel striking a North Atlantic DPS of green turtle, Kemp's ridley turtle, leatherback turtle, and Northwest Atlantic Ocean DPS of loggerhead turtle is extremely unlikely.

Discharge from vessels in the form of leakages of fuel or oil is possible, though spills and discharges are rare. Five round trips are antipated over the ten-year duration of this ITP. Because vessel trips are infrequent and spills and discharges during each trip are rare, it is unlikely they will occur. Therefore, the likelihood of effects to North Atlantic DPS of green turtle, Kemp's ridley turtle, leatherback turtle, and Northwest Atlantic Ocean DPS of loggerhead turtle from fuel or oil spills is extremely unlikly to occur. We conclude that the proposed action is not likely to adversely affect the ESA-listed North Atlantic DPS of green turtle, Kemp's ridley turtle, leatherback turtle, and Northwest Atlantic Ocean DPS of loggerhead turtle.

6.1.3 Endangered Species Act-Listed Fish

Atlantic and shortnose sturgeon are present all year in the action area. Most of the year, shortnose and New York Bight DPS Atlantic sturgeon in the Delaware River are under 2 years old, however, when adult New York Bight DPS Atlantic sturgeon return to spawn, it is possible the proposed action could affect them as well. Additionally, non-spawning adult and sub-adult Atlantic sturgeon from the entire Atlantic Coast may spend time in Delaware Bay and the lower Delaware River up to the saltwater interface.

Atlantic sturgeon in the Delaware River spawn in flowing water with temperatures ranging from 13.3 to 17.8 degrees Celsius (56 to 64 degrees Fahrenheit) (ASMFC 2012; ASSRT 2007a), while shortnose sturgeon spawn in water temperatures of 7 to 9.7 degrees Celsius (45 to 49.5 degrees Fahrenheit) on days with about 13 hours of daylight and lasts until temperatures reach between 12 and 15 degrees Celsius (54 and 59 degrees Fahrenheit) (Kynard 1997; Kynard et al. 2012). Based on the dimensions calculated from the assessment, NPDES and DRBC permitted an HDA of 64.0 meters (210 feet) upstream and downstream of the outfall and 121.9 meters (400 feet) offshore of the outfall at Eddystone. The average size of the bottom contact areas ranged from 157.8 square meters (1699 square feet) in February to 201.0 square meters (2164 square feet) in August. The size of this HDA is upstream of the primary juvenile rearing area and downstream of the primary spawning areas.

Adult sturgeon are able to move approximately 2 body lengths, or approximately 4 meters (12 feet) per second. Therefore the worst case scenario of adult exposure is approximately 30 seconds to a minute depending on the rate of movement. Larval sturgeon (shortnose and Atlantic) would slowly drift past Eddystone in the spring when the station produces minimal power, minimizing exposure. Juvenile sturgeon could move upriver into the thermal plume, but would do so by choice. Exposure to a thermal plume is likely to occur to both adult and juvenile shortnose and New York Bight DPS Atlantic sturgeon, but the effects of that exposure are likely to be so minimal as to not be measureable. Therefore, thermal discharges from the operation of Eddystone may effect, but are not likely to adversely affect endangered shortnose or New York Bight DPS Atlantic sturgeon and will not be discussed further with regard to these species.

Chemical discharge from the Eddystone plant could also affect shortnose and New York Bight DPS Atlantic sturgeon in the Delaware River. Effluent monitoring from January 2011 to December 2017 has shown that Eddystone’s effluents have been in compliance with permitted levels for potential contaminants with the exception of July 2015, when permit limits of daily maximum total suspended solids and instantaneous maximum total residual chlorine were exceeded. Eddystone’s Pollution Minimization Plan was completed in 2006 and high-PCB oils in transformers and circuit breakers have been replaced with low- or non-PCB oils. Eddystone is also required to submit an annual report that includes data for its required annual PCB sampling (Exelon 2019). Eddystone continues to be in compliance with contaminant levels. Therefore, we believe exposure is possible but any response from shortnose and New York Bight DPS Atlantic sturgeon to chemical discharges is extremely unlikly to occur. Therefore, we conclude that pollution by chemical discharge is not likely to adversely affect shortnose and New York Bight DPS Atlantic sturgeon, and will not be carried forward in this consultation.

Vessels delivering oil to Eddystone will be traversing marine waters that spatially overlap with the ESA-listed Carolina, Chesapeake, New York Bight, Gulf of Maine, and South Atlantic Atlantic sturgeon DPSs. Sturgeon from all five DPSs have been collected south of the entrance to Delaware Bay near Bethany Beach, Delaware, near the action area (Wirgin et al. 2015a). There are thousands of vessels operating in New York Harbor and around New Jersey every year.

NMFS (2017a) estimated that one Atlantic sturgeon is killed by vessel strike for approximately every 883 trips undertaken by vessels in the Delaware River. Given the high amount of vessel traffic in this area, the increase in vessel traffic due to vessel deliveries to Eddystone is extremely small. Therefore, the corresponding increase in risk of strike is very small. Additionally, vessel strikes are thought to predominantly occur between May through July and likely affect adults migrating through the river to spawning grounds (Brown and Murphy 2010). Exelon proposes to make all reasonable efforts to schedule fuel oil deliveries outside this timeframe. Over the 10-year period for the ITP, the number of vessel-related sturgeon mortalities is estimated to be 0.30 sturgeon (i.e., 0.03 sturgeon per year for 10 years). Stated another way, there is a 30 percent chance one adult Atlantic Sturgeon will be struck by a vessel delivering fuel to Eddystrone during the ten year period covered by the ITP. Based on this risk, NMFS has proposed to authorize one lethal take of an adult Atlantic Sturgeon by vessel strike. This is a sufficient risk to carry vessel activity associated with Eddystone forward in the consultation.

From 1975 to 2005, Eddystone has had 23 incidents related to spills of coal ash or oil from either vessels or shore, which were cleaned up to the extent possible and no environmental damage was observed. Eddystone has best management practices for spill control plans, emergency response, and Integrated Contingency Plans, which are submitted to regulators (Exelon 2019). Given the infrequent number of incidents and mitigation measures in place to quickly respond, the likelihood of effects to shortnose sturgeon and New York Bight DPS Atlantic sturgeon from fuel or oil spills is extremely unlikly to occur. Therefore, we conclude that pollution by oil or fuel leakage is not likely to adversely affect ESA-listed species, and will not be carried forward in this consultation.

Shortnose sturgeon spawning occurs between Trenton and Lambertville (RKM 214-238 (RM 133-148)), and eggs and larvae rear above RKM 214 (RM 133) (NMFS 2017f), well upstream of Eddystone. Early life stages would not be expected to occur in the vicinity of the Station and we therefore believe shortnose sturgeon are not likely to be susceptible to entrainment at Eddystone. We conclude that effects of entrainment of shortnose sturgeon is extremely unlikly to occur and entrainment is therefore not likely to adversely effect shortnose sturgeon. Entrainment of shortnose sturgeon will not be carried forward in this consultation.

The intake forebay is the area between the trash racks and the traveling screens. Each intake forebay has an opening through which sturgeon can return to the river. Sturgeon unable to return to the river through the trash racks or forebay openings would likely become impinged on the traveling screens. Traveling screen impingement for juvenile sturgeon is discussed in Section 10.1.3. Since adult Atlantic sturgeon should be able to avoid impingement at velocities up to 3 feet per second, velocities well in excess of those experienced at the Station’s CWIS (NMFS 2013a), we believe adult shortnose sturgeon should also be able to avoid impingement at the Station. Therefore, the effects to adult ESA-listed species from traveling screen impingement and all life stages of ESA-listed species from intake forebay entrapment are insignificant. Traveling screen impingement is therefore not likely to adversely affect adult shortnose and New York

Bight DPS Atlantis sturgeon and intake forebay entrapment is not likely to adversely affect shortnose and New York Bight DPS Atlantic sturgeon. Effects from these stressors on the aforementioned life stages of shortnose and New York Bight DPS Atlantic sturgeon will not be carried forward in this consultation.

6.1.4 Designated Critical Habitat - New York Bight Distinct Population Segment Atlantic Sturgeon

Eddystone lies within designated critical habitat for Atlantic sturgeon (NMFS 2017c). As noted above, critical habitat includes those physical or biological features essential to the conservation of the species which may require special management considerations or protection. Physical or biological features are defined as, "the features that support the life-history needs of the species, including water characteristics, soil type, geological features, sites, prey, vegetation, symbiotic species, or other features" (NMFS 2017c). The physical or biological features identified in the critical habitat designation for the New York Bight DPS of Atlantic sturgeon include: hard bottom substrate in low salinity waters; aquatic habitat with a gradual downstream salinity gradient and soft bottom substrate; waters that allow unimpeded movement, staging, and resting; and water with appropriate temperature, salinity, and oxygen for critical life history functions.

The operation of Eddystone is not expected to affect salinity within the Delaware and or have an appreciable effect on dissolved oxygen. All dissolved oxygen observations between October 1, 2010 and September 30, 2015 in a region in the Delaware River extending from RKM 152.9 (RM 95.0) near Philadelphia to RKM 126.8 (RM 78.8) met both the daily mean water quality criteria and seasonal water quality criteria established by DRBC (DRBC 2016). Eddystone's operations are not expected to have a significant effect on bottom substrate. Eddystone's thermal discharge could affect water temperature in the immediate vicinity of the Station. However, Eddystone's HDA is small and is not expected to impede sturgeon movement or have a significant impact on critical life history functions. Therefore, the operation of Eddystone is not expected to significantly affect any of the physical or biological features identified in the critical habitat designation; therefore, Station operations may effect, but are not likely to adversely affect designated critical habitat for the New York Bight DPS Atlantic sturgeon. Effects from thermal discharge will not be discussed further.

The proposed action will not likely affect the physical aspects of New York Bight DPS Atlantic sturgeon designated critical habitat. Eddystone's intake and discharge pipes do not obstruct the passage of sturgeon through the Delaware River; these pipes extend around 300 feet into the river where the river is approximately 6,000 feet wide (Exelon 2019). However, the operation of the Eddystone's CWIS could potentially influence available prey for Atlantic sturgeon. Exelon evaluated the potential effects of the CWIS on prey availability in their Conservation Plan, the following of which is an excerpt.

> NMFS's critical habitat designation determined that a key conservation objective for the New York Bight DPS of Atlantic sturgeon is to increase abundance by

> facilitating increased reproduction and recruitment to the marine environment. The final rule specifically recognized that, "the ability of subadults to find and access food is necessary for continued survival, growth, and physiological development to the adult lifestage" (NMFS 2017c). *Gammarus* spp. are among the most abundant macroinvertebrates in the Delaware, and this taxon has been identified as an important component of age- 0 Atlantic sturgeon diets in the St. Lawrence Estuary (Guilbard et al. 2007; Nellis and Munro 2007). *Gammarus* spp. are entrained at Eddystone, and this taxon was enumerated in entrainment samples collected during 2017. To evaluate the potential for entrainment of prey species to affect critical habitat for Atlantic sturgeon, entrainment densities of *Gammarus* spp. were compared to *Gammarus* spp. densities in the Delaware in the vicinity of Eddystone. Abundance of *Gammarus* spp. was evaluated from 2002 to 2004 as part of Public Service Enterprise Group's Biological Monitoring Program, the most recent study on *Gammarus* spp. in the Delaware. Ichthyoplankton trawls were conducted between April and July, and densities of target taxa, including *Gammarus* spp., were reported for each sampling zone. In the zone closest to the Station, mean monthly densities (n/1,000 m^3) of *Gammarus* spp. ranged from 4,945 to 367,535 between April and July with a mean seasonal density of 143,794 (Table VI-1) (Public Service Enterprise Group 2002; Public Service Enterprise Group 2003; Public Service Enterprise Group 2004). Monthly mean entrainment densities (n/1,000 m^3) at Eddystone between April and July during 2017 ranged from 734 to 6,148 with a seasonal mean density of 3,349 (Normandeau Associates 2018), approximately 97.7% lower than the mean density in the River in the vicinity of the Station over the period when the ichthyoplankton trawl was conducted (Table VI-1).

The mean discharge rate of the Delaware River from April through July was 13,559.28 cfs (8,763.59 MGD) over the period from 1970 to 2016 (United States Geological Survey 2018). Average actual intake flows at the Station from 2013 to 2017 for the same seasonal period was 277.3 MGD (Table II-2), approximately 3.16 percent of the River's discharge. Therefore, only a small fraction of the total *Gammarus* spp. present around Eddystone would likely become entrained and potentially unavailable for consumption by ESA-listed sturgeon in the area. Given this information, we conclude that entrainment via the CWIS is not likely to adversely affect prey availability for New York Bight DPS Atlantic sturgeon and will not be carried forward in this consultation.

7 SPECIES LIKELY TO BE ADVERSELY AFFECTED BY THE PROPOSED ACTION

This section identifies the ESA-listed species that occur within the action area (see Section 4) that may be affected by Eddystone operations. All of the species potentially occurring within the action area and are likely to be adversely affected by the proposed action are listed in Table 6 along with their regulatory status.

Table 6. Endangered Species Act-listed endangered species that may be affected and are likely to be adversely affected by the Endangered Species Conservation Division's proposed action of issuance of incidental take permit No. 23148 to Exelon.

Species	ESA Status	Recovery Plan
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) – New York Bight DPS	E – 77 FR 5879	-- --
Shortnose Sturgeon (*Acipenser brevirostrum*)	E – 32 FR 4001	63 FR 69613 12/1998

8 STATUS OF SPECIES LIKELY TO BE ADVERSELY AFFECTED BY THE PROPOSED ACTION

This section examines the status of each species that would be affected by the proposed action. The status includes the existing level of risk that the ESA-listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. The species status section helps to inform the description of the species' current "reproduction, numbers, or distribution," which is part of the jeopardy determination as described in 50 C.F.R. §402.02. More detailed information on the status and trends of these ESA-listed species, and their biology and ecology can be found in the listing regulations and critical habitat designations published in the Federal Register, status reviews, recovery plans, and on this NMFS website: https://www.fisheries.noaa.gov/species-directory/threatened-endangered, among others. This section begins with a general description of Atlantic sturgeon followed by a description specifically for the New York Bight DPS of Atlantic sturgeon.

8.1 Atlantic Sturgeon

This section provides general information on the Atlantic sturgeon coast-wide population including information about the species life history, population dynamics, and status. We then provide a subsection with information and characteristics specific to the New York Bight DPS of Atlantic sturgeon.

8.1.1 Life History

The general life history pattern of Atlantic sturgeon is that of a long lived, late maturing, iteroparous, anadromous species. Atlantic sturgeon spawn in freshwater, but spend most of their subadult and adult life in the marine environment. While few specific spawning locations have been identified, between 20 and 27 rivers are thought to support reproducing populations (ASMFC 2017; ASSRT 2007a; Hilton et al. 2016; Kahn et al. 2019). Smith (1985) reported that the timing of the arrival of mature adults into estuaries was temperature dependent and varied with latitude: February in Florida, Georgia, and South Carolina; April in the Delaware and Chesapeake Bay systems; and May-June in the Gulf of Maine (GOM) and Gulf of St. Lawrence systems. Traditionally, it was believed that spawning within all populations occurred during the spring and early summer months. More recent studies, however, suggest that spawning occurs from late summer to early autumn in two tributaries of the Chesapeake Bay (James River and York River, Virginia) the Altamaha River, the Edisto River, and the Roanoke River (Balazik et al. 2012; Collins et al. 2000; Hager et al. 2014; Ingram and Peterson 2016; Smith et al. 2015). A recent study indicates that two races of Atlantic sturgeon repeatedly spawn during two different times (spring and fall) and places in the James River, and possibly the groups have become genetically distinct from each other (Balazik et al. 2017). Farrae et al. (2017) found genetically distinct fall- and spring-spawned Atlantic sturgeon in the Edisto River.

Sturgeon eggs are highly adhesive and are deposited on the bottom substrate, usually on hard surfaces (e.g., cobble) (Smith and Clugston 1997). Hatching occurs approximately 94 to 140 hours after egg deposition, and larvae assume a demersal existence (Smith et al. 1980). The yolksac larval stage is completed in about 8 to 12 days, during which time the larvae move downstream to rearing grounds over a 6 to 12-day period (Kynard and Horgan 2002). During the first half of their migration downstream, movement is limited to nighttime. During the day, larvae use benthic structure (e.g., gravel matrix) as refugia (Kynard and Horgan 2002). During the latter half of migration when larvae are more fully developed, movement to rearing grounds occurs both day and night. The larvae grow rapidly and are 4 inches (10.2 centimeters) to 5.5 inches (14.0 centimeters) long at a month old (MSPO 1993). At this size, the young sturgeon bear teeth and have sharp, closely spaced spine-tipped scutes. As growth continues, they lose their teeth, the scutes separate and lose their sharpness.

Juvenile Atlantic sturgeon continue to move downstream into brackish waters, and eventually become residents in estuarine waters. Juvenile Atlantic sturgeon are resident within their natal estuaries for two to six years, depending on their natal river of origin, after which they emigrate as subadults to coastal waters (Dovel 1983) or to other estuaries seasonally (Waldman et al. 2013). Atlantic sturgeon undertake long marine migrations and utilize habitats up and down the East Coast for rearing, feeding, and migrating (Bain 1997; Dovel 1983; Stevenson 1997). Migratory subadults and adults are normally located in shallow (10 to 50 meters) nearshore areas dominated by gravel and sand substrate (Stein et al. 2004a). Tagging and genetic data indicate that subadult and adult Atlantic sturgeon may travel widely once they emigrate from rivers (Bartron 2007; Wirgin et al. 2015b). Once in marine waters, subadults undergo rapid growth (Dovel 1983; Stevenson 1997). Despite extensive mixing in coastal waters, Atlantic sturgeon display high site fidelity to their natal streams. In one study by Grunwald et al. (2008), straying between rivers within a DPS would sometimes exceed five migrants per generation, but between DPSs was usually less than one migrant per generation, with the exception of fish from the Delaware River straying more frequently to southern rivers (Grunwald et al. 2008).

Atlantic sturgeon have been aged to 60 years (Mangin 1964) but this should be taken as an approximation because the age validation studies conducted to date show ages cannot be reliably estimated after 15 to 20 years (Stevenson and Secor 2000). Vital parameters of sturgeon populations generally show clinal variation with faster growth, earlier age at maturation, and shorter life span in more southern systems. Spawning intervals range from one to five years for male Atlantic sturgeon (Collins et al. 2000; Smith 1985) and three to five years for females (Schueller and Peterson 2010; Stevenson and Secor 2000). Fecundity of Atlantic sturgeon is correlated with age and body size, ranging from approximately 400,000 to 1.5 million eggs (Dadswell 2006; Smith et al. 1982; Van Eenennaam and Doroshov 1998). Dadswell et al. (2017) found that caviar weight was equal to approximately ten percent of dressed weight. The average age at which 50 percent of Atlantic sturgeon maximum lifetime egg production is achieved is estimated to be 29 years, approximately 3 to 10 times longer than for other bony fish species examined (Boreman 1997).

Atlantic sturgeon feed on molluscs, polychaeta worms, gastropods, shrimps, pea crabs, decapods, amphipods, isopods, and small fishes in the marine environment (Collins et al. 2006; Guilbard et al. 2007; Savoy 2007). The sturgeon "roots" in the sand or mud with its snout, like a pig, to dislodge worms and molluscs that it sucks into its protrusible mouth, along with considerable amounts of mud. The Atlantic sturgeon has a stomach with very thick, muscular walls that resemble the gizzard of a bird. This gizzard enables it to grind such food items as molluscs and gastropods (MSPO 1993).

8.1.2 Population Dynamics

Atlantic sturgeon throughout their range exhibit ecological separation during spawning that has resulted in multiple, genetically distinct, interbreeding population segments. Studies have consistently found populations to be genetically diverse and indicate that there are between seven and ten out of 11 populations examined that can be statistically differentiated (Grunwald et al. 2008; King et al. 2001; Waldman et al. 2002; Wirgin et al. 2007). However, there is some disagreement among studies, and results do not include samples from all rivers inhabited by Atlantic sturgeon. Overall, the genetic markers used for mixed stock classification resulted in an average accuracy of 85 percent for determining a sturgeon’s natal river origin, but an average accuracy of 96 percent for correctly classifying it to one of the five ESA-listed DPSs (Tim King, USGS, unpublished data collected in 2014).

8.1.3 Status

The 1998 Atlantic sturgeon status review determined that the species did not warrant listing at that time since direct fishing pressure was essentially removed by a coast-wide moratorium on the fishery and water quality had improved substantially since the early 1900s (NMFS and USFWS 1998). The 1998 status review team, also determined that bycatch of Atlantic sturgeon in other fisheries was unsubstantial and did not pose a threat to the viability of species. The 2007 status review concluded that only a few subpopulations seem to be increasing or stabilizing since 1998, with the majority of subpopulations showing no signs of recovery (ASSRT 2007). New information also suggested that stressors such as bycatch, ship strikes, and water quality were resulting in substantial impacts on subpopulations. The Atlantic Sturgeon Status Review Team (ASSRT) also noted that subpopulation estimates of Atlantic sturgeon remained low, with the lack of recovery attributed to habitat degradation, ship strikes, bycatch and dams.

In 2012 NMFS listed the New York Bight and Chesapeake Bay DPSs as endangered and the GOM DPS as threatened on the basis of low population size and the level of impacts and number of threats such as continued degraded water quality, habitat impacts from dredging, continued bycatch in state and federally-managed fisheries, and vessel strikes to each DPS. Historically, each of these DPSs likely supported more than 10,000 spawning adults (ASSRT 2007a; MSPO 1993; Secor 2002). The best available data indicate that current numbers of spawning adults for each DPS are one to two orders of magnitude smaller (e.g., hundreds to low thousands) than historical levels (ASSRT 2007a; Kahnle et al. 2007). The Carolina and South Atlantic DPSs were estimated to have declined to less than three and six percent of their historical population sizes, respectively (ASSRT 2007a). Both of these DPSs were listed as endangered due to a combination of habitat curtailment and alteration, bycatch in commercial fisheries, and inadequacy of regulatory mechanisms in ameliorating these impacts and threats.

Information needed to fully assess population status is lacking for many individual Atlantic sturgeon spawning stocks. Population trend estimates are only available for two spawning stocks: York River 0 percent; and Penobscot River 0 percent. Estimated adult survival rate, available for five river populations, ranges from 78 percent (Cape Fear) to 98 percent (York). Some of the rivers where spawning is known to occur include one GOM DPS river system (Kennebec), three New York Bight DPS river systems (Hudson, Delaware, and Connecticut), three Chesapeake Bay DPS rivers (Rappahannock, James, and York), six Carolina DPS river system (Roanoke, Tar/Pamlico, Neuse, Waccamaw, Santee, and Cooper) and six south Atlantic river systems (ACE [Ashepoo, the Combahee, and Edisto] Basin, Savannah, Ogeechee, Altamaha, Satilla, and St. Mary’s).

Major threats to Atlantic sturgeon, defined as threats that if altered could lead to recovery, are currently identified for three river systems: competition and predation from invasive species in the York and James rivers (J. Kahn, NMFS HQ, pers. comm. to R. Salz, NMFS HQ, December 22, 2016); and commercial fisheries bycatch in the Roanoke river. One or more minor threats, defined as threats that likely result in a low level of mortality, have been identified for several other river populations. The most prevalent minor threats to Atlantic sturgeon are water quality (12 river systems), bycatch (8 river systems), and impingement/entrainment (7 river systems). Effective adult population size is estimated for 11 out of the 21 identified Atlantic sturgeon spawning stocks.

A ratio of 10:1 (census:effective population) based on Frankham (1995) was used to derive census population estimates. Relatively large estimated adult Atlantic sturgeon populations are found in the Hudson (3,000), Altamaha (1,325), Delaware (1,305), Kennebec (865), Savannah (745), and James (705). Estimating the number of Atlantic sturgeon spawning adults relies on the assumptions that (1) all adults that migrate into the freshwater portion of a river are native to that river and (2) all adults are making that upstream migration with the intention of spawning. Juvenile Atlantic sturgeon abundance may be a more precise way to measure the status of Atlantic sturgeon populations because it is believed that all age-1 and age-2 juveniles are restricted to their natal rivers (Bain et al. 1999; Dovel 1983), avoiding the assumptions noted above. Published estimates of Atlantic sturgeon juvenile abundance are available in the following river systems: Hudson - 4,314 age 1 fish in 1995 (Peterson et al. 2000); Delaware - 3,656 age 0-1 fish in 2014 (Hale et al. 2016); Altamaha - 1,072 to 2,033 age 1-2 fish, 2004-2007 average (Schueller and Peterson 2010); and Satilla – 154 age 1 fish in 2010 (Fritts et al. 2016).

8.1.3.1 Atlantic Sturgeon – New York Bight Distinct Population Segment

The New York Bight DPS was listed as endangered under the ESA on February 6, 2012. The New York Bight, ranging from Cape Cod to the Delmarva Peninsula, historically supported four or more spawning subpopulations, but currently this DPS only supports two known spawning subpopulations: Delaware and Hudson River. The ASSRT found that the Delaware River subpopulation had a moderately high risk (greater than a 50 percent chance) of becoming endangered in the next 20 years, due to the loss of adults from ship strikes. Other stressors contributing to this conclusion that were ranked as moderate risk were dredging, water quality, and commercial bycatch (ASSRT 2007a).

Hale et al. (2016) suggests that a spawning population of Atlantic Sturgeon exists in the Delaware River and that some level of early juvenile recruitment is continuing to persist despite current depressed population levels. They estimated that 3,656 (95 percent confidence interval from 1,935 to 33,041) juveniles (ages 0–1) used the Delaware River estuary as a nursery in 2014. These findings suggest that the Delaware River spawning subpopulation contributes more to the New York Bight DPS than was formerly considered. Based on manual tracking of telemetered juvenile and adult Atlantic sturgeon, upstream and downstream migration within the Delaware commonly occurs within the shipping channel (Shirey et al. 1998; Simpson and Fox 2007).

Spawning adults migrate from the Atlantic Ocean upriver to freshwater sites in the spring and early summer (April-May) in mid-Atlantic estuaries when water temperatures reach 18 degrees Celsius (64.4 degrees Fahrenheit) (Able and Fahay 2010; ASSRT 2007a); spawning may occur as late as mid to late June in the Delaware River (Simpson and Fox 2007). Spawning habitat, identified based on the location of tagged adult Atlantic sturgeon during the presumed spawning season combined with substrate material and location of the salt front, generally occurs in the River between Stoney Creek (RKM 120 [RM 74]) and Trenton, New Jersey (RKM 211 [RM 131]), with areas of high sturgeon concentration near Claymont, Delaware (RKM 125 [RM 78]) and Chester, Pennsylvania (RKM 130 [RM 81]) (Breece et al. 2013; NMFS 2014a; Simpson and Fox 2007). Females typically migrate back to coastal waters immediately after spawning (J. Kahn, NMFS HQ, pers. comm. to S. Thornton, NMFS HQ, February 6 2020), while males may remain in the River or lower estuary until the fall (Able and Fahay 2010). When present in the Delaware, the majority of adults were detected within 30 kilometers [18.6 miles]) of the salt front, typically between New Castle, Delaware (RKM 99 [RM 61]) and the Schuylkill River (RKM 148 [RM 92]) (Breece et al. 2013).

Studies have found that movements of juveniles within the Delaware are seasonally driven (Breece et al. 2013; Hale et al. 2016). Sturgeon move into brackish and tidal freshwater regions in the spring and summer; they move downstream to overwintering areas in the lower estuary or nearshore ocean waters in the fall and winter (Brundage and Meadows 1982; Brundage and O'Harron 2009; Lazzari et al. 1986; Shirey et al. 1998). Burton et al. (2005) found that some juvenile Atlantic sturgeon in the River may also overwinter in tidal fresh water near Marcus Hook (RKM 126 [RM 78]).

In the Delaware, young-of-the-year Atlantic sturgeon have been collected in close proximity to potential spawning grounds near RKM 125 and RKM 130 (RM 78 and RM 81) (Breece et al. 2013). Juvenile Atlantic sturgeon have been found to concentrate in three main areas: Artificial Island (RKM 89 [RM 55]), Cherry Island Flats (RKM 110 [RM 68]), and Marcus Hook (RKM 126 [RM 78]). Juveniles tracked during 2012-2014 spent most of their time downstream of RKM 150 (RM 92.2), although several fish were detected intermittently as far upstream as RKM 200 (RM 124.2) (ERC 2015).

8.2 Shortnose Sturgeon

Shortnose sturgeon were initially listed as endangered on March 11, 1967 under the Endangered Species Preservation Act of 1966. In 1994, the species was listed as endangered throughout its range under the ESA (38 FR 41370). Critical habitat has not been designated for shortnose sturgeon. Shortnose sturgeon occur along the Atlantic Coast of North America, from the St. John River in Canada to the St. Johns River in Florida.

8.2.1 Life History

Shortnose sturgeon are amphidromous, inhabiting large coastal rivers or nearshore estuaries within river systems (Buckley and Kynard 1985; Kieffer and Kynard 1993). Sturgeon spawn in upper, freshwater areas, and feed and overwinter in both fresh and saline habitats. Adult shortnose sturgeon typically prefer deep downstream areas with vegetated bottoms and soft substrates. During the summer and winter months, adults occur primarily in freshwater tidally influenced river reaches; therefore, they often occupy only a few short reaches of a river’s entire length (Buckley and Kynard 1985). In the southern end of their range, during the summer adult and juvenile shortnose sturgeon congregate in cool, deep areas of rivers to seek refuge from high temperatures (Flournoy et al. 1992; Rogers and Weber 1995; Weber 1996). Older juveniles or subadults tend to move downstream in the fall and winter as water temperatures decline and the salt wedge recedes. In the spring and summer, they move upstream and feed mostly in freshwater reaches; however, these movements usually occur above the saltwater/freshwater river interface (Dadswell et al. 1984; Hall et al. 1991). Young-of-the-year shortnose sturgeon are believed to move downstream after hatching (Dovel 1983) but remain within freshwater habitats.

Shortnose sturgeon have been found in waters with temperatures as low as 2 to 3 degrees Celsius (35.6 to 37.4 degrees Fahrenheit) (Dadswell et al. 1984) and as high as 34 degrees Celsius (93.2 degrees Fahrenheit) (Heidt and Gilbert 1979). However, temperatures above 28 degrees Celsius (82.4 degrees Fahrenheit) are thought to adversely affect shortnose sturgeon (Kynard 1997; Ziegeweid et al. 2008). In the Altamaha River, temperatures of 28 to 30 degrees Celsius (82.4 to 86.0 degrees Fahrenheit) during summer months create unsuitable conditions and shortnose sturgeon are found in deep cool water refuges. DO also plays a role in temperature tolerance; i.e., increased stress levels and lower temperature tolerance in waters with low DO (Kahn and Mohead 2010; Niklitschek 2001).

Adult shortnose sturgeon can occur throughout the Delaware River from the lower bay as far upstream as Lambertville, New Jersey (RKM 239 [RM 149]). They may occasionally enter the nearshore ocean off Delaware Bay but likely spend protracted periods of time at specific resting, aggregation, and/or feeding sites within the River (Hastings et al. 1987; SSSRT 2010). Adults typically spend summer days in deeper areas with little or no current and move into shallower water or exhibit upstream or downstream movement at night (Able and Fahay 2010). A large portion of the adult population may overwinter in freshwater areas near potential spawning sites in preparation for spawning in the spring (Dadswell 1979).

In the Delaware River, spawning begins in late March or early April, reaching its peak by mid-April. Spawning activity is concentrated in non-tidal waters between Trenton (RKM 214 [RM 133]) and Scudders Falls (RKM 225 [RM 140]), but eggs have been found as far upstream as Lambertville (RKM 239 [RM 149]) (Environmental Research and Consulting 2008; Environmental Research and Consulting 2015; NMFS 2014a; SSSRT 2010). Females leave the spawning grounds relatively soon after spawning, while males tend to remain in the River for a longer period of time (O'Herron et al. 1993). After spawning, adults migrate downstream to brackish waters near Burlington Island (RKM 190 [RM 118]), moving at least as far downstream as Philadelphia (RKM 165 [RM 102]) before moving back upstream to areas of the River between Fieldsboro, New Jersey (RKM 205 [RM 127]) and Assunpink Creek (RKM 215 [RM 133]) (O'Herron et al. 1993).

In early to mid-winter, shortnose sturgeon migrate to overwintering areas where they congregate in sedentary groups between Burlington Island (RKM 190 [RM 118]) and Duck Island (RKM 210 [RM 130]), especially in the channel off Duck Island (O'Herron et al. 1993). A substantial portion of the overwintering population reaches its destination by November and remains there through late March or early April before beginning the upstream spawning migration when temperatures approach 7 to 10 degrees Celsius (44.6 to 50 degrees Fahrenheit) (Kynard et al. 2012; O'Herron et al. 1993; SSSRT 2010). In general, spawning activity for shortnose sturgeon occurs in the River when water temperatures range between 6 and 18 degrees Celsius (42.8 and 64.4 degrees Fahrenheit), with peak spawning activity at about 13 degrees Celsius (55.4 degrees Fahrenheit) (Environmental Research and Consulting 2015).

Juvenile shortnose sturgeon are thought to remain in deeper channels within freshwater environments upstream of the salt front for the first year (Dadswell et al. 1984; Kynard 1997). (Brundage and O'Harron 2009) collected juvenile shortnose sturgeon from deep waters (greater than 6.1 meters (20 feet)) in the lower tidal reach of the River spanning from Wilmington (RKM 110 [RM 68]) to Marcus Hook (RKM 130 [RM 81]) during all months except February, March, and April. Juveniles were found to remain upstream of Wilmington, where DO concentrations are higher, in the spring and summer, distribute widely throughout the River in fall, and congregate in the lower tidal reaches during the winter (Brundage and O'Harron 2009). Overwintering occurs between Philadelphia (RKM 165 [RM 102]) and Artificial Island (RKM 80 [RM 49]); juveniles do not overwinter in the same areas as adults (Brundage and O'Harron 2009; O'Herron et al. 1993).

8.2.2 Population Dynamics

Historically, shortnose sturgeon are believed to have inhabited nearly all major rivers and estuaries along the entire east coast of North America. NMFS's Shortnose Sturgeon Recovery Plan identifies 19 populations based on the fish's strong fidelity to natal rivers and the premise that populations in adjacent river systems did not interbreed with any regularity (NMFS 1998). The Plan recommended that each population be managed separately until further evidence and information allowed for the consideration of potential DPS delineations for shortnose sturgeon. Since the Plan was published in 1998, additional information on straying rates and genetic analysis have been made available. Both mitochondrial deoxyribonucleic acid (DNA) and nuclear DNA analyses indicate effective (with spawning) coastal migrations are occurring between adjacent rivers in some areas, particularly within the GOM and the Southeast (King et al. 2014). The currently available genetic information suggests that shortnose sturgeon can be separated into smaller groupings that form regional clusters across their geographic range (SSSRT 2010). Differences in life history and ecology further support these genetic groupings or clusters. Both regional population and metapopulation structures may exist according to genetic analyses and dispersal and migration patterns (King et al. 2014; Wirgin et al. 2010). The Shortnose Sturgeon Status Review Team (SSSRT) concluded shortnose sturgeon across their geographic range include five genetically distinct groupings each of which have geographic ecological adaptations: 1) GOM; 2) Connecticut and Housatonic Rivers; 3) Hudson River; 4) Delaware River and Chesapeake Bay; and 5) Southeast (SSSRT 2010).

Three of these regional groups appear to be functioning as a metapopulation: GOM, Delaware/Chesapeake Bay, and Southeast. Very few shortnose sturgeon have been captured in the Chesapeake Bay since the species was listed (40 in the Potomac, 1 at mouth of the Rappahonock and 1 in the James river), and those fish moved back and forth to the Delaware estuary, which is why it is grouped with the Delaware population. The other two groups (Connecticut/Housatonic and the Hudson River) are thought to be evolutionarily significant. Two additional geographically separate populations occur behind dams in the Connecticut River (above the Holyoke Dam) and in Lake Marion on the Santee-Cooper River system in South Carolina (above the Wilson and Pinopolis Dams). Although these populations are geographically isolated, genetic analyses suggest individual shortnose sturgeon move between some of these populations each generation (Quattro et al. 2002; Wirgin et al. 2005; Wirgin et al. 2010). The SSSRT also recommended that each riverine population be considered as a separate management/recovery unit (SSSRT 2010).

The distribution of shortnose sturgeon is disjointed across their range, with northern populations separated from southern populations by a distance of about 400 kilometers near their geographic center in Virginia. There are no spawning areas in the northern part of North Carolina, and a very small population in the Cape Fear estuary. At the northern end of the species’ distribution, the highest rate of gene flow (which suggests migration) occurs between the Kennebec, Penobscot, and Androscoggin Rivers. At the southern end of the species’ distribution, populations south of the Pee Dee River appear to exchange between one to ten individuals per generation, with the highest rates of exchange occurring between the Ogeechee and Altamaha Rivers (Wirgin et al. 2005).

Additionally, these researchers concluded that genetic components of sturgeon in rivers separated by more than 400 kilometers were connected by very little migration, while rivers separated by less than 20 kilometers (such as the rivers flowing into coastal South Carolina) would experience high migration rates (Wirgin et al. 2005). Shortnose sturgeon are known to occur in the Chesapeake Bay, but these fish may be transients from the Delaware River via the Chesapeake and Delaware Canal (Welsh et al. 2002; Wirgin et al. 2010) or remnants of a population in the Potomac River. Shortnose sturgeon were thought to be extirpated from three southern rivers (St. Johns, St. Mary’s, and Satilla) (Collins et al. 2000; Rogers and Weber 1995). However, in 2002 one shortnose sturgeon was captured in the St. Johns River (FFWCC 2007), and from 2008-2011 researchers captured and tagged 11 shortnose sturgeon from the Satilla River and one from the St. Mary’s River (Fritts and Peterson 2011). These studies suggest either a small remnant population exists or emigration from other populations. Fritts and Peterson (2011) concluded that growth and survival of juvenile shortnose sturgeon were likely hindered during summer months by hypoxic conditions in critical nursery habitats in these rivers occupying the southern range of this species.

8.2.3 Status

The 2010 shortnose sturgeon SRT conducted a three-step risk assessment for shortnose sturgeon at a riverine scale: (1) assess population health, (2) populate a "matrix of stressors" by ranking threats, and (3) review assessment by comparing population health scores to stressor scores. The Hudson River had the highest estimated adult abundance (30,000 to 61,000), followed by the Delaware (12,000), Kennebec Complex (9,000), and Altamaha (6,000) (SSSRT 2010). The SSSRT found evidence of an increasing abundance trend for the Kennebec Complex and ACE Basin populations; a stable trend for the Merrimack, Connecticut, Hudson, Delaware, Winyah Bay Complex, Cooper, Savannah, Ogeechee, and Altamaha populations; and a declining trend only for the Cape Fear population (all other populations had an unknown trend) (SSSRT 2010).

The SSSRT summarized continuing threats to the species in each of the 29 identified populations (SSSRT 2010). Dams represent a major threat to seven shortnose sturgeon populations and a moderate threat to seven additional populations. Dredging represents a major threat to one shortnose sturgeon population (Savannah River), a moderately high threat to three populations, and a moderate threat to seven populations. Fisheries bycatch represents a major threat to one shortnose sturgeon population (Lakes Marion and Moultrie in Santee-Cooper Reservoir System), a moderately high threat to four populations, and a moderate threat to ten populations (SSSRT 2010). Water quality represents a major threat to one shortnose sturgeon population (Potomac River), a moderately high threat to six populations, a moderate threat to 13 populations, and a moderately low threat to one population. Specific sources of water quality degradation affecting shortnose sturgeon include coal tar, wastewater treatment plants, fish hatcheries, industrial waste, pulp mills, sewage outflows, industrial farms, water withdrawals, and non-point sources. These sources contribute to the following conditions that may have adverse effects on shortnose sturgeon: nutrient loading, low DO, algal blooms, increased sedimentation, elevated contaminant levels (mercury, polychlorinated biphenyl [PCBs], dioxin, polycyclic aromatic hydrocarbons [PAHs], endocrine disrupting chemicals, cadmium), and low pH levels (SSSRT 2010). Impingement/entrainment at power plants and treatment plants was rated as a moderate threat to two shortnose sturgeon populations (Delaware and Potomac).

The SSSRT examined the relationship between population health scores and associated stressors/threats for each shortnose sturgeon riverine population (Figure 3) and concluded the following: 1) despite relatively high stressor scores, the Hudson and Kennebec River populations appear relatively healthy; 2) shortnose sturgeon in the Savannah River appear moderately healthy, but their status is perilous; 3) shortnose in the ACE system are of moderate health with low stress and may be most able to recover (SSSRT 2010). Climate warming has the potential to reduce abundance or eliminate shortnose sturgeon in many rivers, particularly in the South (Kynard et al. 2016).

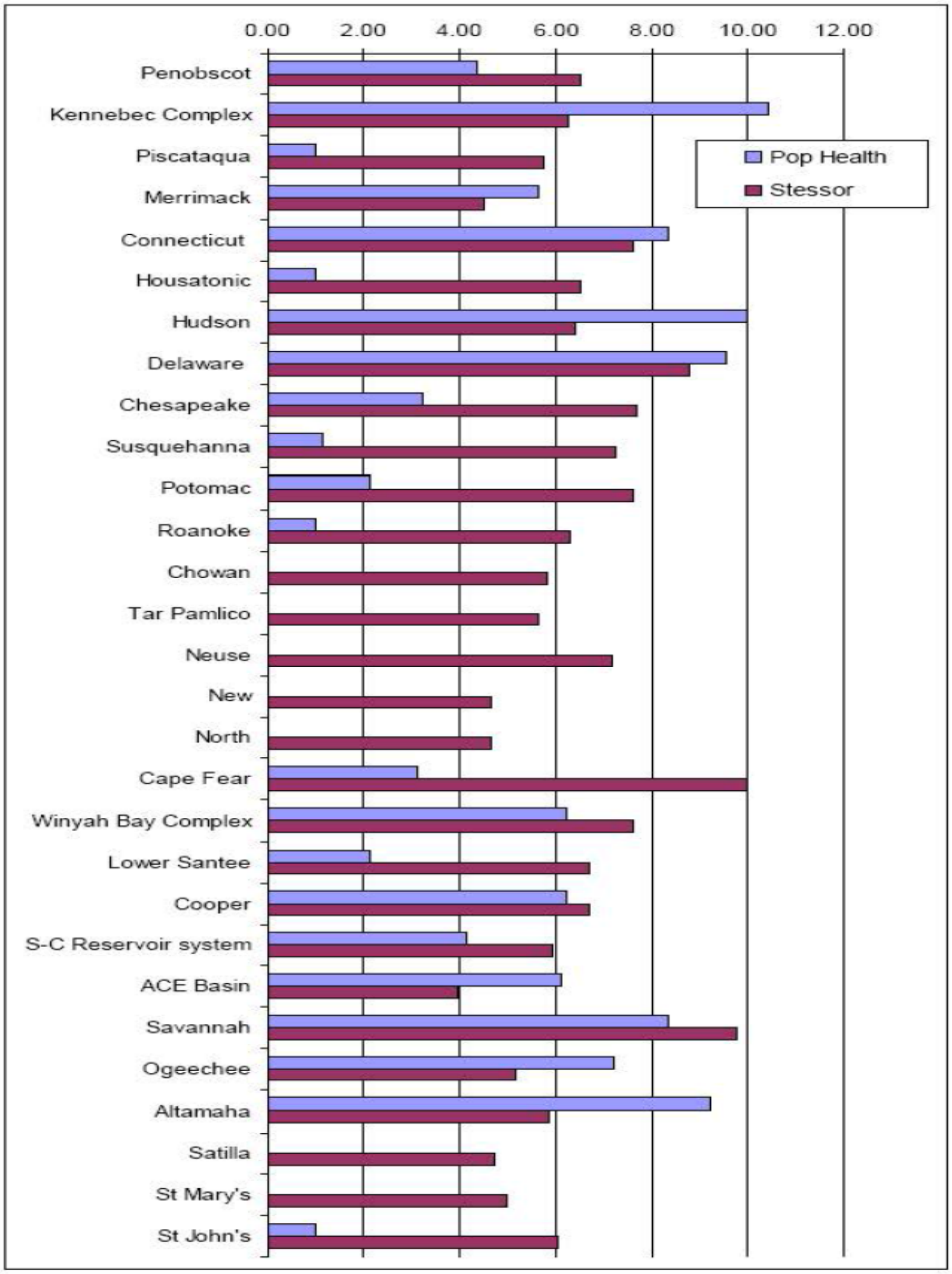


Figure 3. The relationship between population health scores and associated stressors for each shortnose sturgeon river population (SSSRT 2010).

The SSSRT reported results of an age-structured population model using the RAMAS software (Akçakaya and Root 2007) to estimate shortnose sturgeon extinction probabilities for three river systems: Hudson, Cooper, and Altamaha. The estimated probability of extinction was zero for all three populations under the default assumptions, despite the long (100-year) horizon and the relatively high year-to-year variability in fertility and survival rates. The estimated probability of a 50 percent decline was relatively high (Hudson 0.65, Cooper 0.32, Altamaha 0.73), whereas the probability of an 80 percent decline was low (Hudson 0.09, Cooper 0.01, Altamaha 0.23) (SSSRT 2010).

Information needed to fully assess population status is lacking for many individual shortnose sturgeon spawning stocks. The largest shortnose sturgeon adult populations are found in the Northeastern rivers: Hudson 56,708 adults (Bain et al. 2007); Delaware 12,047 (ERC 2006); and Saint Johns over 18,000 adults (Dadswell 1979). Shortnose sturgeon populations in southern rivers are considerably smaller by comparison. Peterson and Bednarski (2013) documented a three-fold variation in adult abundance (707 to 2,122 individuals) over a 7-year period in the Altamaha River. Bahr and Peterson (2017) estimated the adult shortnose population in the Savannah River was 1,865 in 2013, 1,564 in 2014, and 940 in 2015. Their estimates of juvenile shortnose sturgeon ranged from 81-270 age 1 fish and 123-486 age 2 and over fish over the course of the three-year (2013-2015) study period. This study suggests that the Savannah River population is likely the second largest within the South Atlantic (Bahr and Peterson 2017).

Population trend estimates are available for six shortnose sturgeon spawning stocks: St John, Kennebec, Hudson, and Satilla are all decreasing slightly (-1 percent); Delaware and Ogeechee are stable (0 percent). Estimated adult survival rates for shortnose sturgeon are only available for two river populations: Satilla 84 percent and ACE Basin 89 percent. Regular spawning is known to occur in 12 spawning stocks, with intermittent spawning observed in three other river systems. Major threats to shortnose sturgeon, defined as threats that if altered could lead to recovery, are currently identified for four river systems: dams in the Connecticut, Santee, and Cooper Rivers and water quality in the St. Mary’s River. One or more minor threats, defined as threats that likely result in a low level of mortality, have been identified for several other river populations. The most prevalent minor threats to shortnose sturgeon are water quality (ten populations), bycatch (eight populations), and impingement/entrainment (six populations).

8.2.4 Recovery Goals

The Shortnose Sturgeon Recovery Plan was developed in 1998. The long-term recovery objective, as stated in the Plan, is to recover all 19 discrete populations to levels of abundance at which they no longer require protection under the ESA (NMFS 1998). To achieve and preserve minimum population sizes for each population segment, essential habitats must be identified and maintained, and mortality must be monitored and minimized. Accordingly, other key recovery tasks discussed in the Plan are to define essential habitat characteristics, assess mortality factors, and protect shortnose sturgeon through applicable federal and state regulations.

8.3 Threats to Atlantic and Shortnose Sturgeon

The following subsections discuss threats that Atlantic and shortnose sturgeon are exposed to throughout their ranges. Threats that these species experience specifically within the action area are discussed below in the *Environmental Baseline* (Section 9).

8.3.1 Climate Change

There is a large and growing body of literature on past, present, and future impacts of global climate change, exacerbated and accelerated by human activities. Effects of climate change include sea level rise, increased frequency and magnitude of severe weather events, changes in air and water temperatures, and changes in precipitation patterns, all of which are likely to impact ESA resources. NOAA's climate information portal provides basic background information on these and other measured or anticipated climate change effects (see https://climate.gov).

In order to evaluate the implications of different climate outcomes and associated impacts throughout the 21st century, many factors have to be considered. The amount of future greenhouse gas emissions is a key variable. Developments in technology, changes in energy generation and land use, global and regional economic circumstances, and population growth must also be considered.

A set of four scenarios was developed by the Intergovernmental Panel on Climate Change (IPCC) to ensure that starting conditions, historical data, and projections are employed consistently across the various branches of climate science. The scenarios are referred to as representative concentration pathways (RCPs), which capture a range of potential greenhouse gas emissions pathways and associated atmospheric concentration levels through 2100 (IPCC 2014). The RCP scenarios drive climate model projections for temperature, precipitation, sea level, and other variables: RCP2.6 is a stringent mitigation scenario; RCP2.5 and RCP6.0 are intermediate scenarios; and RCP8.5 is a scenario with no mitigation or reduction in the use of fossil fuels. The IPCC future global climate predictions (2014 and 2018) and national and regional climate predictions included in the Fourth National Climate Assessment for U.S. states and territories (2018) use the RCP scenarios.

The increase of global mean surface temperature change by 2100 is projected to be 0.3 to 1.7 degrees Celsius under RCP2.6, 1.1 to 2.6 degrees Celsius under RCP4.5, 1.4 to 3.1 degrees Celsius under RCP6.0, and 2.6 to 4.8 degrees Celsius under RCP8.5 with the Arctic region warming more rapidly than the global mean under all scenarios (IPCC 2014). The Paris Agreement aims to limit the future rise in global average temperature to 2 degrees Celsius, but the observed acceleration in carbon emissions over the last 15 to 20 years, even with a lower trend in 2016, has been consistent with higher future scenarios such as RCP8.5 (Hayhoe et al. 2018).

The globally-averaged combined land and ocean surface temperature data, as calculated by a linear trend, show a warming of approximately 1 degree Celsius from 1901 through 2016 (Hayhoe et al. 2018). The *IPCC Special Report on the Impacts of Global Warming* (2018) (IPCC 2018) noted that human-induced warming reached temperatures between 0.8 and 1.2 degrees Celsius above pre-industrial levels in 2017, likely increasing between 0.1 and 0.3 degrees Celsius per decade. Warming greater than the global average has already been experienced in many regions and seasons, with most land regions experiencing greater warming than over the ocean

(IPCC 2018). Annual average temperatures have increased by 1.8 degrees Celsius across the contiguous U.S. since the beginning of the 20th century with Alaska warming faster than any other state and twice as fast as the global average since the mid-20th century (Jay et al. 2018). Global warming has led to more frequent heatwaves in most land regions and an increase in the frequency and duration of marine heatwaves (IPCC 2018). Average global warming up to 1.5 degrees Celsius as compared to pre-industrial levels is expected to lead to regional changes in extreme temperatures, and increases in the frequency and intensity of precipitation and drought (IPCC 2018).

Several of the most important threats contributing to the extinction risk of ESA-listed species, particularly those with a calcium carbonate skeleton such as corals and mollusks as well as species for which these animals serve as prey or habitat, are related to global climate change. The main concerns regarding impacts of global climate change on coral reefs and other calcium carbonate habitats generally, and on ESA-listed corals and mollusks in particular, are the magnitude and the rapid pace of change in greenhouse gas concentrations (e.g., carbon dioxide and methane) and atmospheric warming since the Industrial Revolution in the mid-19th century. These changes are increasing the warming of the global climate system and altering the carbonate chemistry of the ocean (ocean acidification (IPCC 2014)). As carbon dioxide concentrations increase in the atmosphere, more carbon dioxide is absorbed by the oceans, causing lower pH and reduced availability of calcium carbonate. Because of the increase in carbon dioxide and other greenhouse gases in the atmosphere since the Industrial Revolution, ocean acidification has already occurred throughout the world's oceans, including in the Caribbean Sea, and is predicted to increase considerably between now and 2100 (IPCC 2014).

The Atlantic Ocean appears to be warming faster than all other ocean basins except perhaps the southern oceans (Cheng et al. 2017). In the western North Atlantic Ocean surface temperatures have been unusually warm in recent years (Blunden and Arndt 2016). A study by Polyakov et al. (2009) suggests that the North Atlantic Ocean overall has been experiencing a general warming trend over the last 80 years of 0.031±0.0006 degrees Celsius per decade in the upper 2,000 meters (6,561.7 feet) of the ocean. Additional consequences of climate change include increased ocean stratification, decreased sea-ice extent, altered patterns of ocean circulation, and decreased ocean oxygen levels (Doney et al. 2012). Since the early 1980s, the annual minimum sea ice extent (observed in September each year) in the Arctic ocean has decreased at a rate of 11 to 16 percent per decade (Jay et al. 2018). Further, ocean acidity has increased by 26 percent since the beginning of the industrial era (IPCC 2014) and this rise has been linked to climate change. Climate change is also expected to increase the frequency of extreme weather and climate events including, but not limited to, cyclones, tropical storms, heat waves, and droughts (IPCC 2014).

Climate change has the potential to impact species abundance, geographic distribution, migration patterns, and susceptibility to disease and contaminants, as well as the timing of seasonal activities and community composition and structure (Evans and Bjørge 2013; IPCC 2014; Kintisch 2006; Learmonth et al. 2006; MacLeod et al. 2005; McMahon and Hays 2006;

Robinson et al. 2005). Though predicting the precise consequences of climate change on highly mobile marine species is difficult (Simmonds and Isaac 2007), recent research has indicated a range of consequences already occurring. For example, in sea turtles, sex is determined by the ambient sand temperature (during the middle third of incubation) with female offspring produced at higher temperatures and males at lower temperatures within a thermal tolerance range of 25 to 35 degrees Celsius (Ackerman 1997). Increases in global temperature could skew future sex ratios toward higher numbers of females (NMFS and USFWS 2007a; NMFS and USFWS 2007b; NMFS and USFWS 2013a; NMFS and USFWS 2013b; NMFS and USFWS 2015). These impacts will be exacerbated by sea level rise. This loss of habitat because of climate change could be accelerated due to a combination of other environmental and oceanographic changes such as an increase in the frequency of storms and/or changes in prevailing currents, both of which could lead to increased beach loss via erosion (Antonelis et al. 2006; Baker et al. 2006).

Changes in the marine ecosystem caused by global climate change (e.g., ocean acidification, salinity, oceanic currents, dissolved oxygen levels, nutrient distribution) could influence the distribution and abundance of lower trophic levels (e.g., phytoplankton, zooplankton, submerged aquatic vegetation, crustaceans, mollusks, forage fish), ultimately affecting primary foraging areas of ESA-listed species including marine mammals, sea turtles, and fish. Marine species ranges are expected to shift as they align their distributions to match their physiological tolerances under changing environmental conditions (Doney et al. 2012). Hazen et al. (2012) examined top predator distribution and diversity in the Pacific Ocean in light of rising sea surface temperatures using a database of electronic tags and output from a global climate model. They predicted up to a 35 percent change in core habitat area for some key marine predators in the Pacific Ocean, with some species predicted to experience gains in available core habitat and some predicted to experience losses. Notably, leatherback turtles were predicted to gain core habitat area, whereas loggerhead turtles and blue whales were predicted to experience losses in available core habitat. McMahon and Hays (2006) predicted increased ocean temperatures will expand the distribution of leatherback turtles into more northern latitudes. The authors noted this is already occurring in the Atlantic Ocean. MacLeod (2009) estimated, based upon expected shifts in water temperature, 88 percent of cetaceans will be affected by climate change; with 47 percent predicted to experience unfavorable conditions (e.g., range contraction). Willis-Norton et al. (2015) acknowledged there will be both habitat loss and gain, but overall climate change could result in a 15 percent loss of core pelagic habitat for leatherback turtles in the eastern South Pacific Ocean.

Similarly, climate-related changes in important prey species populations are likely to affect predator populations. For example, blue whales, as predators that specialize in eating krill, are likely to change their distribution in response to changes in the distribution of krill (Clapham et al. 1999; Payne et al. 1986; Payne et al. 1990). Pecl and Jackson (2008) predicted climate change will likely result in squid that hatch out smaller and earlier, undergo faster growth over shorter life-spans, and mature younger at a smaller size. This could have negative consequences for species such as sperm whales, whose diets can be dominated by cephalopods. For ESA-listed species that undergo long migrations, if either prey availability or habitat suitability is disrupted by changing ocean temperatures, regimes, the timing of migration can change or negatively impact population sustainability (Simmonds and Eliott 2009).

8.3.2 Directed Harvest

Atlantic sturgeon exhibit an unusual combination of morphology, habits, and life history characteristics, which make them highly vulnerable to impacts from commercial fisheries. Prior to 1890, Atlantic sturgeon populations were at or near carrying capacity. Between 1890 and 1905, Atlantic sturgeon populations were drastically reduced due to overfishing for sale of meat and caviar. Harvest records indicate that fisheries for sturgeon were conducted in every major coastal river along the Atlantic coast at one time, with fishing effort concentrated during spawning migrations (Smith 1985). Approximately 3,350 metric tons (7.4 million pounds) of sturgeon (Atlantic and shortnose combined) were landed in 1890 (Smith and Clugston 1997). The sturgeon fishery during the early years (1870 to 1920) was concentrated in the Delaware River and Chesapeake Bay systems. Between 1920 and 1998, harvest levels remained low due to small remnant populations. During the 1970s and 1980s sturgeon fishing effort shifted to the South Atlantic, which accounted for nearly 80 percent of total U.S. landings (64 metric tons). By 1990 sturgeon landings were prohibited in Pennsylvania, District of Columbia, Virginia, South Carolina, Florida, and waters managed by the Potomac River Fisheries Commission. From 1990 through 1996 sturgeon fishing effort shifted to the Hudson River (annual average 49 metric tons) and coastal areas off New York and New Jersey (Smith and Clugston 1997). By 1996, closures of the Atlantic sturgeon fishery had been instituted in all Atlantic Coast states except for Rhode Island, Connecticut, Delaware, Maryland, and Georgia, all of which adopted a seven-foot minimum size limit. Prompted by research on juvenile production between 1985 and 1995 (Peterson et al. 2000), the Atlantic sturgeon fishery was closed by the ASMFC in 1998 when a coast-wide fishing moratorium was imposed for 20-40 years, or at least until 20 year classes of mature female Atlantic sturgeon were present (ASMFC 2008). NMFS followed this action by closing the Exclusive Economic Zone to Atlantic sturgeon take in 1999. Poaching of Atlantic sturgeon continues and is a potentially significant threat to the species, but the present extent and magnitude of such activity is largely unknown.

Commercial fisheries for Atlantic sturgeon still exist in Canadian waters. Sturgeon belonging to one or more of the ESA-listed DPSs may be harvested in the Canadian fisheries. In particular, the Bay of Fundy sturgeon fishery in the Saint John estuary may capture sturgeon of U.S. origin given that sturgeon from the GOM and New York Bight DPSs have been incidentally captured in other Bay of Fundy fisheries (Wirgin et al. 2015b). Because Atlantic sturgeon are listed under Appendix II of the Convention on International Trade in Endangered Species, the U.S. and Canada are currently working on a conservation strategy to address the potential for captures of U.S. fish in Canadian-directed Atlantic sturgeon fisheries and of Canadian fish incidentally captured in U.S. commercial fisheries. There are no current estimates of the number of Atlantic sturgeon captured or killed in Canadian fisheries each year. Based on geographic distribution, most U.S. Atlantic sturgeon intercepted in Canadian fisheries have originated from the GOM DPS, with a smaller percentage from the New York Bight DPS.

8.3.3 Bycatch

Directed harvest of Atlantic and shortnose sturgeon is prohibited in U.S. waters. However, sturgeon are taken incidentally in fisheries targeting other species in rivers, estuaries, and marine waters throughout their range (ASSRT 2007b; Collins et al. 1996). Atlantic sturgeon (from all five DPSs) and shortnose sturgeon are at risk of bycatch-related mortality in fisheries operating within and beyond the action area. Because sturgeon mix extensively in marine waters and may access several river systems, they are subject to being caught in multiple fisheries throughout their range. Commercial fishery bycatch represents a significant threat to the viability of listed sturgeon species and populations. Bycatch could have a substantial impact on the status of Atlantic sturgeon, especially in rivers or estuaries that do not currently support a large subpopulation (less than 300 spawning adults per year). Reported mortality rates of sturgeon (Atlantic and shortnose) captured in inshore and riverine fisheries range from 8 percent to 20 percent (Bahn et al. 2012; Collins et al. 1996).

Sturgeon are benthic feeders and as a result they are generally captured near the seabed unless they are actively migrating (Moser and Ross 1995). Sturgeon are particularly vulnerable to being caught in commercial gill nets; therefore, fisheries using this type of gear account for a high percentage of sturgeon bycatch and bycatch mortality. Sturgeon have also been documented in the following gears: otter trawls, pound nets, fyke/hoop nets, catfish traps, shrimp trawls, and recreational hook and line fisheries.

Several federally regulated fisheries that may encounter Atlantic sturgeon have fishery management plans (FMPs) that have undergone section 7 consultation with NMFS. On December 16, 2013, NMFS issued a “batched” section 7 biological opinion on the following fisheries: Northeast multispecies; monkfish; spiny dogfish; Atlantic bluefish; Northeast skate complex; mackerel/squid/butterfish; and summer flounder /scup/black sea bass. The Northeast multispecies fishery includes American plaice, Atlantic cod, Atlantic halibut, Atlantic wolfish, haddock, ocean pout, offshore hake, pollock, redfish, red hake, silver hake, white hake, windowpane flounder, winter flounder, witch flounder, and yellowtail flounder. Gill net gear is used by five of the seven fisheries, and bottom trawl gear is used by six of the seven fisheries. It is also possible that bottom longline gear, which is used in the Northeast multispecies, monkfish, and spiny dogfish fisheries, could hook Atlantic sturgeon while foraging, but there have been no reported interactions. The majority (73 percent) of all Atlantic sturgeon bycatch mortality in New England and Mid-Atlantic waters is attributed to the monkfish sink gill net fishery (ASMFC 2007). Observer data from 2001 to 2006 shows 224 recorded interactions between the monkfish fishery and Atlantic sturgeon, with 99 interactions resulting in death, a 44 percent mortality rate.

Fishing activity under the authority of many of the FMPs considered in the batched biological opinion often occurs simultaneously and on the same vessel, making the link between FMPs and sturgeon interactions difficult to quantify. Therefore, interactions with Atlantic sturgeon were analyzed based on gear type. For all seven fisheries, the following take of Atlantic sturgeon was authorized annually: 1,331 trawl interactions of which 42 may be lethal and 1,229 gill net interactions of which 155 may be lethal. These estimates do not account for all actual Atlantic sturgeon bycatch in federal fisheries, but if these take levels are exceeded, consultation must be reinitiated. The 2012 NMFS biological opinion on the Southeast shrimp trawl fishery concluded the fishery is unlikely to jeopardize Atlantic sturgeon. This biological opinion exempted the take of Atlantic sturgeon as follows: 1,731 total interactions, including 243 captures of which 27 are expected to be lethal every three years. In 2012, NMFS provided an updated biological opinion on the Federal shark fisheries, including the smoothhound fishery on ESA-listed species. Observer reports through 2011 indicated that Atlantic sturgeon captures in shark directed gill net sets are uncommon but they do occur and have occurred in similar gears. Atlantic sturgeon bycatch in the smoothhound fishery are known to be significantly higher than in the shark fisheries. For the federal smoothhound fishery and shark fisheries combined, NMFS exempted the take of 321 Atlantic sturgeon over a three-year span, with 66 of those takes expected to be lethal.

Estimated rates of Atlantic sturgeon caught as bycatch in federal fisheries are highly variable and somewhat imprecise due to small sample sizes of observed trips. An estimated 1,385 individual Atlantic sturgeon were killed annually from 1989-2000 as a result of bycatch in offshore gill net fisheries operating from Maine through North Carolina (Stein et al. 2004b). From 2001-2006 an estimated 649 Atlantic sturgeon were killed annually in offshore gill net and otter trawl fisheries. From 2006-2010 an estimated 391 Atlantic sturgeon were killed (out of 3,118 captured) annually in Northeast federal fisheries (Miller and Shepherd 2011).

Given the high prevalence of gill net and otter trawl use in nearshore coastal and inland fisheries, state managed fisheries may have a greater impact on sturgeon than federal fisheries using these same gear types. Commercially important state fisheries that interact with sturgeon include those targeting shrimp, Atlantic croaker, weakfish, striped bass, black drum, spot, shad, and spiny dogfish. The Recovery Plan for shortnose sturgeon (NMFS 1998) lists commercial and recreational shad fisheries as a source of bycatch. Adult shortnose sturgeon are believed to be especially vulnerable to fishing gears for anadromous species (such as shad, striped bass, alewives and herring) during times of extensive migration – particularly their spawning migration (Litwiler 2001). Shortnose sturgeon bycatch in the southern trawl fishery for shrimp (*Penaerrs spp.*) was estimated at 8 percent (Collins et al. 1996). Bycatch of shortnose sturgeon from the shad gillnet fisheries can be quite substantial. Catch rates in drift gillnets are believed to be lower than for fixed nets, longer soak times appear to be correlated with higher rates of mortalities, and the cooler water temperatures likely increase release survivability of shortnose sturgeon. Of the 51 shortnose sturgeon captured in the South Carolina American shad gillnet fishery, 16 percent resulted in bycatch mortality and another 20 percent were visibly injured (Collins et al. 1996).

In 2013, after amending their commercial fishing regulations to minimize incidental capture, the Georgia Department of Natural Resources received an ESA section 10 permit for incidental take of Atlantic sturgeon in the commercial shad fishery in state waters. The ITP allows the capture and live release of up to 180 Atlantic sturgeon annually, with a maximum of five incidental mortalities per year. A mortality rate of approximately 2.3 percent is anticipated based on recent research. The North Carolina Division of Marine Fisheries (NCDMF) developed a Conservation Plan to address Atlantic sturgeon take in the state's inshore gill net fishery, and submitted an application for an ESA ITP to NMFS in April of 2012. In July 2014, NCDMF received an ESA section 10 permit for incidental take of Atlantic sturgeon that allows for take of up to 2,927 juvenile and small subadult Atlantic sturgeon annually, primarily in the form of capture and harassment, but in some cases lethal take.

NCDMF reported that no Atlantic sturgeon were observed in 958 observed tows conducted from 2001 to 2008 by commercial shrimp trawlers working in North Carolina waters (NCDMF 2014). Yet Collins et al. (1996) reported that of 1,534 juvenile Atlantic sturgeon tagged in the Altamaha River, Georgia, 38 out of 97 (39 percent) were recaptured in shrimp trawls with the remainder captured in gill net fisheries. Seven adult Atlantic sturgeon were captured (one killed) by a single shrimp trawler off Winyah Bay, South Carolina in October 2008 (Damon-Randall et al. 2010).

8.3.4 Water Quality and Contaminants

The quality of water in river/estuary systems is affected by human activities conducted in the riparian zone and those conducted more remotely in the upland portion of the watershed. Industrial activities can result in discharge of pollutants, changes in water temperature and levels of dissolved oxygen, and the addition of nutrients. In addition, forestry and agricultural practices can result in erosion, run-off of fertilizers, herbicides, insecticides or other chemicals, nutrient enrichment and alteration of water flow. Coastal and riparian areas are also impacted by real estate development and urbanization resulting in storm water discharges, non-point source pollution, and erosion. The Clean Water Act regulates water quality in the United States and when enforcement of those regulations fails to adequately protect water quality, section 303(d) of the Clean Water Act identifies polluted water bodies that require the establishment of a total maximum daily load for a pollutant in order to improve water quality.

The water quality over the range of Atlantic and shortnose sturgeon varies by watershed but is notably poorer in the north than in the south. The U.S. Environmental Protection Agency (EPA) published its third edition of the National Coastal Condition Report (NCCR III) in 2008, a "report card" summarizing the status of coastal environments along the coast of the United States (EPA 2008; see Table 4 below). The report analyzes water quality, sediment, coastal habitat, benthos, and fish contaminant indices to determine status on a range from good to fair to poor. The results are notably poorer in the north than in the south. The northeast region of the U.S. (Virginia to Maine) was rated fair-poor. The Gulf of Mexico region (Texas to Florida) was rated fair-poor. The southeast region of the U.S. (Florida to North Carolina) was rated good-fair, the best rating in the nation.

Table 4. Summary of the Environmental Protection Agency's National Coastal Condition Report (third edition) for the United States east coast published by (EPA 2008) grading coastal environments. (Northeast region=Virginia to Maine; southeast region=Florida to North Carolina; and Gulf of Mexico=Texas to Florida)

	Region		
Status Index	**Northeast**	**Gulf of Mexico**	**Southeast**
Water quality	Fair	Fair	Fair
Sediment	Fair-poor	Poor	Fair
Coastal Habitat	Good-fair	Poor	Fair
Benthos	Poor	Poor	Good
Fish Tissue	Poor	Good	Good-fair
Overall	**Fair-poor**	**Fair-poor**	**Good-fair**

Chemicals such as chlordane, dichlorodiphenyl dichloroethylene (DDE), DDT, dieldrin, PCBs, cadmium, mercury, and selenium settle to the river bottom and are later consumed by benthic feeders, such as macroinvertebrates, and then work their way higher into the food web (e.g., to sturgeon). Some of these compounds may affect physiological processes and impede a fish's ability to withstand stress, while simultaneously increasing the stress of the surrounding environment by reducing dissolved oxygen, altering pH, and altering other physical properties of the water body.

8.3.5 Scientific Research

Information obtained from scientific research is essential for understanding the status of ESA-listed species, obtaining specified critical biological information, and achieving species recovery goals. Research on ESA-listed species is granted an exemption to the ESA take prohibitions of section 9 through the issuance of section 10(a)(1)(A) permits. Research activities authorized on wild and captive sturgeon through scientific research permits can produce various stressors on individual shortnose and Atlantic sturgeon resulting from capture, handling, and research procedures. As required by regulation, research conducted under a section 10(a)(1)(A) research permit cannot operate to the disadvantage of the species. Scientific research permits issued by NMFS are conditioned with mitigation measures to ensure that the impacts of research activities on target and non-target ESA-listed species are as minimal as possible.

There are currently 20 active section 10(a)(1)(A) shortnose and Atlantic sturgeon scientific research permits. Six of these permits will expire in 2021; one permit expires in 2022. Most of the current permit holders have submitted their new permit applications to continue sturgeon research in 2021 and beyond. Each permit authorizes sampling of adult through juvenile life stages, and some permits have authorization to collect early life stages (early life stages). A biological opinion was issued for each of the five-year permits authorized for Atlantic and shortnose sturgeon, including the requirement for consideration of cumulative effects to the species (as defined for the ESA). For each permit, the biological opinion concluded that permit issuance was not likely to jeopardize the continued existence of the species or DPS.

Since 2006, conservative mitigation measures implemented by NMFS through permit conditions (e.g., reduced soak times at warmer temperatures or lower DO concentrations, minimal holding or handling time) and additional precautions taken by sturgeon researchers have significantly reduced the lethal and sublethal effects of capture in gill, trammel and trawl nets on Atlantic and shortnose sturgeon. Shortnose sturgeon mortality from capture in research nets has declined over time due to these mitigation measures. Prior to 2005, permitted sturgeon researchers reported 26 shortnose sturgeon killed by capture gear out of 5,909 captured, for a capture mortality rate of 0.44 percent. From 2006 through 2016, researchers reported only two shortnose sturgeon killed by capture gear out of 7,019 captured, for a capture mortality rate of 0.03 percent. Since they were listed in 2012, the mortality rate associated with Atlantic sturgeon capture in scientific research is 0.22 percent (14 killed out of 6,466 captured). This overall mortality rate is inflated by a single incidence of mortality where nine Atlantic sturgeon subadults were reported killed.

Section 10(a)(1)(A) permits are also issued to research facilities and educational display facilities for the captive research and educational display of shortnose and Atlantic sturgeon. Enhancement and scientific research involving captive, or cultured, sturgeon has been identified in the Shortnose Sturgeon Recovery Plan (NMFS 1998) and the Atlantic Sturgeon Status Review (ASSRT 2007a) as important objectives for the recovery of each species. Through the study of captive animals, sturgeon research facilities contribute valuable scientific information about wild fish without negatively affecting wild sturgeon populations, other species, or their habitat. Captive sturgeon research facilities include the USFWS Bears Bluff Fish Technology Center (Wadmalaw Island, South Carolina; Warm Springs, Georgia; Orangeburg, South Carolina; and Welaka, Florida), the USFWS Northeast Fisheries Technology Center (Lamar, PA), Maryland Department of Natural Resources (DNR) Manning Hatchery (Brandywine, Maryland), Maryland DNR Cooperative Oxford Lab (Oxford, Maryland), Maryland DNR Crane Aquaculture Facility (College Park, Maryland), University of Maryland Center of Environmental Science (Cambridge, Maryland), and the NRG Energy Chalk Point Generating Station Aquaculture Center (Aquasco, Maryland). Combined, these facilities currently hold around 10-15 adult shortnose sturgeon, 98 adult Atlantic sturgeon, and 200 juvenile Atlantic sturgeon.

Educational display facilities (e.g., aquariums, zoos, and museums) can also play a role in the conservation and recovery of ESA-listed species by increasing public awareness. There are currently six display facilities with active sturgeon permits: Maritime Aquarium (Norwalk, Connecticut); Virginia Museum (Newport News, Virginia); North Carolina Aquarium (Wilmington, North Carolina); North Carolina Zoo (Asheboro, North Carolina); Springfield Museum (Springfield, Massachusetts); and Riverbanks Zoo (Columbia, South Carolina).

Negative impacts of maintaining cultured shortnose or Atlantic sturgeon at research and educational display facilities are limited to a large degree to the facilities because the captive sturgeon at these facilities are managed as research or display animals with strict quarantine measures. However, because research and display facilities are located typically near or on river systems, there is still a potential for escapement. Potential threats to wild populations resulting from such escapement include genetic alterations, increased competition for space and resources, and transmission of pathogens and diseases.

9 ENVIRONMENTAL BASELINE

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, 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 consultations, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

9.1 Climate Change

Regarding the effects of climate change in the action area, available information largely focuses on effects that rising water levels may have on the human environment (Barnett and Dobshinsky 2008) and the availability of water for human use (e.g., Ayers et al. 1993).

Kreeger et al. (2010) considers effects of climate change on the Delaware Estuary. Using the average of 14 models, an air temperature increase of 1.9 to 3.7 degrees Celsius (3.4 to 6.7 degrees Fahrenheit) over this century is anticipated, with the amount dependent on emissions scenarios. No predictions related to increases in river water temperature are provided. There is also a 7 to 9 percent increase in precipitation predicted as well as an increase in the frequency of short term drought, a decline in the number of frost days, and an increase in growing season length predicted by 2100.

The report notes that the Mid-Atlantic States are anticipated to experience sea level rise greater than the global average (Karl et al. 2009). While the global sea level rise is largely attributed to melting ice sheets and expanding water as it warms, there is regional variation because of gravitational forces, wind, and water circulation patterns. In the Mid-Atlantic region, changing water circulation patterns are expected to increase sea level by approximately 10 centimeters over this century (Kreeger et al. 2010). Subsidence and sediment accretion also influence sea level rise in the Mid-Atlantic, including in the Delaware estuary. As described by Kreeger et al. (2010), postglacial settling of the land masses has occurred in the Delaware system since the last Ice Age. This settling causes a steady loss of elevation, which is called subsidence. Through the next century, subsidence is estimated to hold at an average 1 to 2 millimeters of land elevation loss per year (Kreeger et al. 2010). Rates of subsidence and accretion vary in different areas around the Delaware Estuary, but the greatest loss of shoreline habitat is expected to occur where subsidence is naturally high in areas that cannot accrete more sediment to compensate for elevation loss plus absolute sea-level rise. The net increase in sea-level compared to the change in land elevation is referred to as the rate of relative sea-level rise (RSRL). Kreeger et al. (2010) states that the best estimate for RSLR by the end of the century is 0.8 to 1.7 meters in the Delaware Estuary.

Sea level rise combined with more frequent droughts and increased human demand for water has been predicted to result in a northward movement of the salt wedge in the Delaware River (Collier 2011). Currently, the normal average location of the salt wedge is at approximately RKM 114 (median monthly salt front ranges from RKM 107.8 to RKM 122.3; DRBC 2017). Collier (2011) predicts that without mitigation (e.g., increased release of flows into downstream areas of the river), at high tide in the peak of the summer during extreme drought conditions, the salt line could be as far upstream as RKM 183 in 2050 and RKM 188 in 2100. The farthest north the salt line has historically been documented was approximately RKM 166 during a period of severe drought in 1965; thus, she predicts that over time, during certain extreme conditions, the salt line could shift up to 17 kilometers further upstream by 2050 and 22 kilometers further upstream by 2100.

Ross et al. (2015) sought to determine which variables have an influence on the salinity of the Delaware Estuary. Many factors have an influence on salinity and water quality in an estuary including stream flow, oceans salinity, sea level and wind stress (Ross et al. 2015). By creating statistical models relying on long-term (1950 to present) data collected by USGS and the Haskin Shellfish Research Laboratory, the authors found that after accounting for the influence of streamflow and seasonal effects, several locations in the estuary show significant upward trends in salinity. These trends are positively correlated with sea level rise, and salinity appears to be rising 2.5-4.4 parts per thousand per meter of sea level rise. Ross et al. (2015) noted that dredging can also impact salinity, but suggested that dredging at Chester (i.e., increased depth to 45 feet) has not influenced long-term salinity trends as the statistical models did not detect a significant salinity trend in the area.

A hydrologic model for the Delaware River, incorporating predicted changes in temperature and precipitation was compiled by (Hassell and Miller 1999). The model results indicate that when only the temperature increase is input to the hydrologic model, the mean annual streamflow decreased, the winter flows increased due to increased snowmelt, and the mean position of the salt front moved upstream. When only the precipitation increase was input to the hydrologic model, the mean annual streamflow increased, and the mean position of the salt front moved further downstream. However, when both the temperature and precipitation increase were input to the hydrologic model the mean annual streamflow changed very little, with a small increase during the first four months of the year. Ross et al. (2015) found that regardless of any change in streamflow, future sea-level rise will cause salinity to increase.

Water temperature in the Delaware River varies seasonally. Temperatures for the period from 1964 to 2000, with lowest temperatures recorded in April (10 to 11 degrees Celsius (50 to 51.8 degrees Fahrenheit)) and peak temperatures observed in August (approximately 26 to 27 degrees Celsius (78.8 to 80.6 degrees Fahrenheit)). Kaushal et al. (2010) found that water temperatures are increasing in many streams and rivers throughout the US with the Delaware River near Chester, Pennsylvania, having the most rapid rate of increase (of 0.077 degrees Celsius (0.14 degrees Fahrenheit) per year; 1965 to 2007). There was also a significant increase ($P < 0.05$) at the Ben Franklin Bridge (near Philadelphia, Pennsylvania; 1965-2007; Kaushal et al. 2010). However, not every site along the Delaware River showed significant increases, and those sites with the most rapid increase rates were located in downstream urban areas (Kaushal et al. 2010). Moberg and DeLucia (2016) compiled recent literature and information including USGS data from 2005-2014 showing higher river temperatures (27 to 29 degrees Celsius (80.6 to 84.2 degrees Fahrenheit)) in the Delaware in recent years.

Information from a recent effort to develop high-resolution future projections of air temperature and surface water temperature for the Chesapeake Bay out to 2100 can be used to provide insights for the Delaware Bay (Muhling et al. 2017). Muhling et al. (2017) also projected salinity, but these conclusions would likely be specific to just the Chesapeake Bay based on the complexities noted above (e.g., Ross et al. 2015). Air temperature has been used for coastal and freshwater water temperature trends (Tommasi et al. 2015) so may be more easily applied to a regional scale, including the Delaware River. Projected annual air temperature increase between 1979 and 2008 versus 2071 and 2100 indicates that future warming between the Chesapeake and Delaware and their major watersheds will be reasonably similar (see air temperature including RCP 8.5 and all models at NOAA’s Climate Change Web Portal; https://www.esrl.noaa.gov/psd/ipcc/cmip5/).

Potential future surface water temperature increases in the Chesapeake Bay of 2.5 to 5.5 degrees Celsius (4.5 to 9.9 degrees Fahrenheit) by the end of the century were projected over late 20th century values, with the wide range of values primarily a result of differences in the four global climate models (Muhling et al. 2017), and would probably be similar to the Delaware Bay. Muhling et al. (2017) noted that summer surface water temperatures may increase to between 27 and 30 degrees Celsius (80.6 and 86 degrees Fahrenheit) depending on the climate model, which represents a moderate to potentially lethal change in conditions for species such as Atlantic sturgeon. Using data from (Muhling et al. 2017) over the time period of the action (2017 to 2068), annual mean air temperatures at the Thomas Point buoy (latitude 38.9 degrees North, longitude 76.4 degrees West) may range from ~14.9 to 16.9 degrees Celsius (58.8 to 62.4 degrees Fahrenheit), using projections from the coolest (MRI-CGCM-3) and warmest (GFDL-CM3) models, respectively, compared to a late 20th century mean of ~13.6 degrees Celsius (56.5

degrees Fahrenheit). Annual mean surface water temperatures across the whole Chesapeake Bay were projected to range from ~16.5 to 18.3 degrees Celsius (61.7 to 64.9 degrees Fahrenheit) from the same two models over the same time period, compared to a late 20th century mean of ~15.4 degrees Celsius (59.7 degrees Fahrenheit).

Expected consequences of climate change for river systems could be a decrease in the amount of dissolved oxygen in surface waters (Murdoch et al. 2000). Moberg and DeLucia (2016) compiled recent studies and information including USGS data showing a relationship between increasing temperature and decreasing dissolved oxygen in the Delaware River. For example, Moberg and DeLucia (2016) highlighted that dissolved oxygen levels less than 4.0 milligrams per liter occurred when temperatures were greater than 25 degrees Celsius (77 degrees Fahrenheit) and dissolved oxygen levels less than 5.0 milligrams per liter occurred when temperatures were greater than 23 degrees Celsius (73.4 degrees Fahrenheit) during observations in July and August 2005 to 2014.

9.2 Water Quality and Contaminants

Life histories of Atlantic and shortnose sturgeon (i.e., long lifespan, extended residence in estuarine habitats, benthic foraging) predispose sturgeon to long-term, repeated exposure to environmental contamination and potential bioaccumulation of heavy metals and other toxicants (Dadswell 1979; NMFS 1998; NMFS and USFWS 1998). However, there has been little work on the effects of contaminants on sturgeon to date. Shortnose sturgeon collected from the Delaware and Kennebec Rivers had total toxicity equivalent concentrations of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), PCBs, DDE, aluminum, cadmium, and copper above adverse effect concentration levels reported in the literature (Environmental Research and Consulting 2002).

Heavy metals and organochlorine compounds accumulate in sturgeon tissue, but their long-term effects are not known (Ruelle and Henry 1992; Ruelle and Keenlyne 1993). High levels of contaminants, including chlorinated hydrocarbons, in several other fish species are associated with reproductive impairment (Billsson et al. 1998; Cameron et al. 1992; Giesy et al. 1986; Hammerschmidt et al. 2002; Longwell et al. 1992; Mac and Edsall 1991; Matta et al. 1998), reduced survival of larval fish (Berlin *et al.* 1981, Giesy *et al*. 1986), delayed maturity (Jorgensen et al. 2004) and posterior malformations (Billsson et al. 1998). Pesticide exposure in fish may affect anti-predator and homing behavior, reproductive function, physiological maturity, swimming speed, and distance (Beauvais et al. 2000; Moore and Waring 2001; Scholz et al. 2000; Waring and Moore 2004).

Sensitivity to environmental contaminants also varies by life stage. Early life stages of fish appear to be more susceptible to environmental and pollutant stress than older life stages (Rosenthal and Alderdice 1976). Dwyer et al. (2005) compared the relative sensitivities of common surrogate species used in contaminant studies to 17 listed species including shortnose and Atlantic sturgeons. The study examined 96-hour acute water exposures using early life stages where mortality is an endpoint. Chemicals tested were carbaryl, copper, 4-nonphenol, pentachlorophenal, and permethrin. Of the listed species, Atlantic and shortnose sturgeon were ranked the two most sensitive species tested (Dwyer et al. 2005). Additionally, a study examining the effects of coal tar, a byproduct of the process of destructive distillation of bituminous coal, indicated that components of coal tar are toxic to shortnose sturgeon embryos and larvae in whole sediment flow-through and coal tar elutriate static renewal (Kocan et al. 1993).

Contaminants such as raised fecal coliform and estradiol concentrations affect all wildlife that use the river as a habitat. The impact of many of these waterborne contaminants on shortnose sturgeon is unknown, but they are known to affect other species of fish in rivers and streams. These compounds may enter the aquatic environment via wastewater treatment plants, agricultural facilities, as well as runoff from farms (Culp et al. 2000; Folmar et al. 1996; Wallin et al. 2002; Wildhaber et al. 2000). For instance estrogenic compounds are known to affect the male to female sex ratio in streams and rivers via decreased gonadal development, physical feminization and sex reversal (Folmar et al. 1996). Although the effects of these contaminants are unknown in shortnose sturgeon, Omoto et al. (2002) found that by varying the oral doses of estradiol-17β or 17α-methyltestosterone given to captive hybrid (*Huso huso* female × *Acipenser ruthenus* male) “bester” sturgeon they could induce abnormal ovarian development or a lack of masculinization. These compounds, along with high or low dissolved oxygen concentrations, can result in sub-lethal effects that may have negative consequences for small populations.

9.3 Dams

Hydroelectric dams may affect Atlantic and shortnose sturgeon by restricting habitat, altering river flows or temperatures necessary for successful spawning and/or migration, and causing mortalities to fish that become entrained in turbines. In all but one of the northeast rivers supporting sturgeon populations (Connecticut River), the first dam on the river marks the upstream limit of the shortnose sturgeon’s population range (Kynard 1997). In all of these rivers, shortnose sturgeon spawning sites occur just below the dams, while Atlantic sturgeon spawning sites are generally unknown. In both cases, all life stages occur downstream of the dams leaving the sturgeon vulnerable to perturbations of natural river conditions caused by the dam’s operation.

Sturgeon appear unable to use some fishways (e.g., ladders) but have been transported in fish lifts (Kynard 1997). Because sturgeon require adequate river flows and water temperatures for spawning, any alterations that dam operations pose on a river's natural flow pattern, including increased or reduced discharges, can be detrimental to sturgeon reproductive success (ASSRT 2007a; NMFS 1998). Additionally, dam maintenance activities, such as minor excavations along the shore, release silt and other fine river sediments that could be deposited in nearby spawning sites and degrade critical spawning habitat.

9.4 Power Plants

Atlantic and shortnose sturgeon are susceptible to impingement on cooling water intake screens at power plants. Electric power and nuclear power generating plants can affect sturgeon by impinging larger fish on cooling water intake screens and entraining larval fish (EPA 2013). The operation of power plants can have unforeseen and extremely detrimental impacts to water quality which can affect sturgeon.

Two nuclear power plants, the Salem and Hope Creek Generating Stations, 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 completed consultation with the U.S. Nuclear Regulatory Commission in 2014 and issued a biological opinion considering the effects of operations under renewed operating licenses (issued in 2011). In the opinion NMFS concluded that the continued operation of the Salem and Hope Creek Nuclear Generating Stations through the duration of extended operating licenses may adversely affect but was not likely to jeopardize the continued existence of any listed species. The associated ITS exempted take of shortnose and Atlantic sturgeon (injure, kill, capture, or collect) resulting from the operation of the cooling water system. The ITS also exempted the capture of one live shortnose sturgeon and one live Atlantic sturgeon during gillnet sampling associated with the Radiological Environmental Monitoring Program for either Salem or Hope Creek.

9.5 Dredging

The dissolved oxygen concentrations can also be affected by maintenance dredging of federal navigation channels and other waters. Some of the consequences of dredging include entrainment on the pump heads and changing dissolved oxygen and salinity gradients in, and around, the channels (Campbell and Goodman 2004; Jenkins et al. 1993; Secor and Niklitschek 2001). Hydraulic dredges can kill sturgeon by entraining sturgeon in dredge dragarms and impeller pumps. Mechanical dredges have also been documented to kill shortnose sturgeon. Dredging operations may pose risks to shortnose sturgeon by destroying, or adversely modifying, their benthic feeding areas, disrupting spawning migrations, and filling spawning habitat with resuspended fine sediments (Jones 1986; Van Dolah et al. 1984). Since shortnose sturgeon are benthic omnivores, the modification of the benthos could affect the quality, quantity and availability of sturgeon prey species (Haley 1998).

9.6 Ship Strikes

Large sturgeon are susceptible to vessel collisions. The factors relevant to determining the risk to sturgeon from vessel strikes are currently unknown, but are likely related to 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 behavior of sturgeon in the area (e.g., foraging, migrating, etc.). The ASSRT determined Atlantic sturgeon in the Delaware River are at a moderately high risk of extinction because of ship strikes, and sturgeon in the James River are at a moderate risk from ship strikes (ASSRT 2007b). Balazik et al. (2012) estimated up to 80 sturgeon were killed between 2007 and 2010 in these two river systems. Brown and Murphy (2010) examined 28 dead Atlantic sturgeon from the Delaware River from 2005 through 2008 and found that fifty percent of the mortalities resulted from apparent vessel strikes, and 71 percent of these (10 out of 14) had injuries consistent with being struck by a large vessel. Eight of the fourteen vessel-struck sturgeon were adult-sized fish which, given the time of year the fish were observed, were likely migrating through the river to or from the spawning grounds. Ship strikes may also be threatening Atlantic sturgeon populations in the Hudson River where large ships move from the river mouth to ports upstream through narrow shipping channels. The channels are dredged to the approximate depth of the ships, usually leaving less than 6 feet of clearance between the bottom of ships and the river bottom. Any aquatic life along the bottom is at risk of being sucked up through the large propellers of these ships.

Large sturgeon are most often killed by ship strikes because their size means they are unable to pass through the ship's propellers without making contact. Shortnose sturgeon may not be as susceptible due to their smaller size in comparison to the larger Atlantic sturgeon, for which ship strikes have been documented more frequently. There has been only one confirmed incidence of a ship strike on a shortnose sturgeon in the Kennebec River, and two suspected ship strike mortalities in the Delaware River (SSSRT 2010).

10 EFFECTS OF THE ACTION

Section 7 regulations define "effects of the action" as all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 CFR 402.17).

The jeopardy analysis relies upon the regulatory definition of "to jeopardize the continued existence of a listed species," which is "to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 C.F.R. §402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species. The purpose of this assessment and, ultimately, of this consultation is to determine if it is reasonable to expect the proposed action to have effects on ESA-listed sturgeon that could appreciably reduce their likelihood of surviving and recovering in the wild.

The destruction and adverse modification analysis considers whether the action produces means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species (50 C.F.R. §402.02).

10.1 Exposure Analysis

The *Exposure Analysis* identifies, as possible, the number, age (or life stage), and gender of the individual ESA-listed New York Bight DPS Atlantic sturgeon and shortnose sturgeon that are likely to be exposed to the stressors (Section 5) that may result from the proposed action (Section 3), including vessel strikes, entrainment, and impingement.

10.1.1 Vessel Strikes

All life stages of Atlantic sturgeon could be present in the vicinity of Eddystone's receiving dock during some part of the year; however, early life stages (i.e., eggs and larvae) are not vulnerable to vessel strike and small juveniles appear to be less vulnerable than larger juveniles (i.e., subadults) and adults, based on reported mortalities (Brown and Murphy 2010). Atlantic sturgeon spawning has been documented from RKM 125-211 (RM 78-131) during the spring and summer (NMFS 2017e). Subadult and adult Atlantic sturgeon may be present in the waters adjacent to Eddystone as they spawn, forage, or move between spawning and overwintering habitats.

The factors relevant to determining the risk to Atlantic and shortnose sturgeon from vessel strikes are currently unknown, but based on what is known for other species we expect they are related to 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 behavior of sturgeon in the area (e.g., foraging, migrating, etc.). Geographic conditions (e.g. narrow channels, restrictions, etc.) and size of the sturgeon may also be relevant risk factors. Larger sturgeon take a longer time to move through the prop zone and are therefore more likely to be struck. Large vessels have been typically implicated in striking sturgeon 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 (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. In larger water bodies it is less likely that fish would be killed since they would have to be close to the propeller to be drawn in. In a relatively shallow or narrow area a big vessel with a deep draft and a large propeller would leave little space for a nearby fish to maneuver.

Only one of 28 vessel-struck Atlantic sturgeon reported between 2005 and 2008 was found between Eddystone and Philadelphia (Brown and Murphy 2010); more recently, NMFS (2017b) reported that an estimated 25 vessel-related mortalities of Atlantic sturgeon may occur annually in the Delaware. Given the distribution of reported vessel mortalities in the Delaware from the earlier period (2005-2008), it is reasonable to assume that few of the 25 annual mortalities (i.e., approximately one out of 25 based on the results presented by Brown and Murphy (2010)) occur between Eddystone and Philadelphia. Assuming conservatively that 10 percent of the 25 annual vessel mortalities (i.e., 3 sturgeon mortalities) occur between Eddystone and Philadelphia, and given that the maximum annual number of oil delivery trips to Eddystone by vessels with drafts of at least 20 feet account for 0.12 percent of the annual traffic of vessels of this size, less than 0.01 Atlantic sturgeon could be struck by vessels traveling to or from Eddystone per year.

More conservatively, if all 25 sturgeon mortalities occurred between Philadelphia and Eddystone, there could be an annual increase of 0.03 sturgeon mortalities associated with oil delivery vessels transiting to and from the Station. These levels of sturgeon mortality are close to zero, and the mortality associated with assuming that all 25 vessel-related sturgeon mortalities occur between Eddystone and Philadelphia (i.e., 0.03 sturgeon annually) is comparable in magnitude to the annual mortality that NMFS (2017a) concluded would not result in an incidental take (i.e., 0.0125 sturgeon annually). However, over a 10-year operating period, the number of vessel-related sturgeon mortalities is estimated to be 0.30 sturgeon (i.e., 0.03 sturgeon per year for 10 years).

Based on the historical estimates of vessel-related sturgeon mortalities in the Delaware River, the recent level of vessel activity associated with oil deliveries to Eddystone between 2013 and 2017, and the level of vessel activity anticipated for Eddystone in 2020, Exelon proposes a ten-year take limit for vessel activity of 1 Atlantic sturgeon, commensurate with the rounded up value of 0.3 sturgeon over 10 years. Vessel strikes are thought to predominantly occur between May through July and likely affect adults migrating through the river to spawning grounds (Brown and Murphy 2010). Exelon proposes to make all reasonable efforts to schedule fuel oil deliveries outside this timeframe. With this explanation, we adopt the lethal exposure estimate of 1 New York Bight DPS Atlantic sturgeon to vessel strike.

The risk of vessel strike for shortnose sturgeon appears to be less than that for Atlantic sturgeon based on the low number of reported vessel strikes for shortnose sturgeon in the Delaware (NMFS 2017b), which was less than half that reported for Atlantic sturgeon based on vessel mortalities reported between 2008 and 2016. Therefore we do not expect any shortnose sturgeon to be struck by vessels as a result of the proposed action.

10.1.2 Entrainment

Entrainment is the transport of sturgeon or their prey items through the cooling water system past the 3/8 inch mesh openings of the intake screens as the sturgeon are too small to be retained by the traveling screens. Planktonic organisms are susceptible to entrainment because their small size and limited swimming ability reduce the potential for escape from the entrained water mass and allow passage through the mesh of the traveling screens. Entrained fish are typically limited to the younger life stages of fish and this is the case for Atlantic sturgeon. Any entrained larvae pass through the circulating pumps and condenser tubes along with the cooling water. The cooling water and any entrained fish larvae then enter the discharge canal or conduit for return to the Estuary. During their passage through the plant, entrained individuals experience a variety of stresses, some of which may cause death. Survival rates for fish larvae entrained by power plants depend on the species' hardiness as well as their responses to thermal stresses.

Early life stages (i.e., eggs and larvae) of Atlantic sturgeon may occur in the vicinity of

Eddystone's CWIS. Tracking of acoustic tagged adults by Breece et al. (2013) during the spring spawning season has indicated that the largest densities of potential spawning adults occur just upstream of the salt front near Claymont, DE (RKM 125 (RM 78)) and Chester, PA (RKM 130 (RM 81)). While the highest densities of spawning adults occur downstream from Eddystone, spawning has been documented from Marcus Hook Bar (RKM 125 (RM 78)) to Trenton, NJ (RKM 211 (RM 131)). As sturgeon eggs are adhesive and demersal, it is unlikely that sturgeon eggs would be entrained. However, larvae could be present in the water column, and over three years of entrainment sampling, one yolk-sac larva was found entrained at the Station in 2017. Therefore, larval Atlantic sturgeon could be susceptible to entrainment from Eddystone's CWIS.

Exelon consulted with AKRF, Inc., and a Poisson probability distribution model was used to develop annual entrainment take estimates, upon NMFS' recommendation. The annual estimates were based on average entrainment rates over the three years of entrainment sampling and year-specific historical water withdrawal rates at Eddystone. Two statistical models, with slightly different underlying assumptions, were used to estimate annual numbers of yolk-sac larval sturgeon entrained. For the two models, the five-year averages (2013 to 2017) of annual estimates of numbers of Atlantic sturgeon entrained at Eddystone were 4,181 and 6,271 larval sturgeon. For the two models, the five-year averages of the annual upper 95 percent confidence limits for the estimates of annual numbers entrained were 16,722 and 22,993 larval Atlantic sturgeon.

Based on the results of the estimates of historical entrainment at Eddystone (i.e., based on historical cooling water withdrawal rates), the estimated annual take for entrainment of Atlantic sturgeon was 41,805 larvae. However, for combinations of relatively few days of sampling and relatively many days of circulating water pump operation, the observed take was less than 1 yolk-sac larval sturgeon collected. Extrapolated values calculated with a zero-inflated Poisson regression anticipated, given the frequency of water intake, 62,707 larvae (three age-1 equivalent sturgeon) may be entrained each year and 627,070 larvae entrained over the ten-year duration of the project.

However, actual intake flows were reduced by 41 percent from April through July in 2019 as a result of intake flow mitigation implementation (see Section 3.5.1) (Exelon 2020b). Therefore, the operation of Eddystone would result in the entrainment of approximately 27,000 larval sturgeon (two age-1 equivalents) per year, which translates to 270,000 larval sturgeon over Eddystone's 10-year permit term (Exelon 2020a). Therefore, over the life of the permit, it is anticipated that 270,000 larval New York Bight DPS Atlantic sturgeon may be entrained at Eddystone. This is in contrast to an entrainment estimate of 627,070 larvae prior to the implementation of the mitigation measures in 2018 leading to decreased intake flows.

10.1.3 Impingement

Juvenile and older Atlantic and shortnose sturgeon may occur around the vicinity of Eddystone and may be susceptible to impingement on Eddystone's intake screens. Impingement is physical contact with the intake screens during Eddystone's withdrawal of cooling water by sturgeon large enough to be retained by the 3/8 inch traveling screens. To keep condensers from clogging with solid materials and biota, power plant cooling water intake systems use a combination of large- and finer-mesh screens. Typically, the large-mesh screens or bar racks (3-4 inch slot width) are fixed in place while the finer-mesh screens can move to facilitate cleaning. Sturgeon too large to pass through the large-mesh screens would be adults or sub-adults. The movable finer-mesh screens are called traveling screens. As the water passes through these screens, organisms larger than the mesh openings, such as larger invertebrates and fish, can be impinged against the screens. As mentioned in Section 3.2, the traveling screens are run on a timer to operate one rotation every eight hours during non-freezing ambient conditions, one rotation every four hours during freezing conditions, and continuously as needed during the fall leaf season. Because of their more limited swimming abilities, most fish impinged are less than 1 year old.

Swimming performance information reflects the morphology of a species and its life stage and body size (Webb 1984). Knowledge of swimming performance provides information on the ability of a fish to move through the aquatic environment under typical and extreme conditions (i.e., current velocity and water temperature). Common metrics of swimming performance include sustained speeds (swim speeds that fish maintain for extended periods of time, i.e., greater than 200 minutes) and burst speeds, which are indicative of the maximum swim speed over short periods (i.e., less than 30 seconds). Sustained speeds are associated with migrations and small-scale movements while burst speeds are associated with predator avoidance, prey capture, and other situations requiring a short, but energetically costly, burst of energy. Swim tunnel performance studies of juvenile and sub-adult Atlantic, white, and lake sturgeon have demonstrated that fish are capable of burst swim speeds of approximately 65 centimeters per second (2.1 feet per second) and prolonged swim speeds of 45 centimeters per second (1.5 feet per second) (Clarke 2011, as cited in NMFS 2014b). Critical swim speeds for juvenile Atlantic sturgeon under exposure to a range of sediment concentrations varied from 21 to 31 centimeters per second (0.7 to 1.0 feet per second) (Wilkens et al. 2015).

Members of the *Acipenser* genus, in general, share similar morphological characteristics; therefore, given the limited information available for Atlantic sturgeon, it is reasonable to consider swimming performance of other *Acipenser* species in North America (i.e., green, lake, pallid, shortnose, shovelnose, and white sturgeon). Swimming performance studies of lake and pallid sturgeon report sustained swim speeds of juveniles (less than 18 centimeters (7 inches) in total length, ranging from 10 to 45 centimeters per second (0.3 to 1.5 feet per second) (Hoover et al. 2011). A study examining movements of larger-bodied (sub-adult to sexually mature adult) green sturgeon (1.0 to 1.5 meters (3.3 to 5.0 feet) in total length) in San Francisco Bay found that fish had average swimming speeds of 50 to 60 centimeters per second (1.6 to 2 feet per second) and reached a maximum of 2.1 meters per second (7 feet per second) (Kelly and Klimley 2012). Reported maximum burst speeds for white, lake, and pallid sturgeon range from 40 to 70 centimeters per second (1.3 to 2.3 feet per second) (Boysen and Hoover 2009; Hoover et al. 2011). Critical swim speed of shovelnose, lake, and white sturgeon appears to be linearly related to fish length for fish measuring less than 20 centimeters (7.9 inches) to approximately 1.2 meters (3.9 feet), ranging from near 20 centimeters per second (0.66 feet per second) to over 1.0 meter per second (3.28 feet per second). Sturgeon also employ bottom holding behaviors; some studies suggest this behavior peaks at intermediate flow speeds between 20 to 50 centimeters per second (0.7 to 1.6 feet per second) while others show that the frequency of bottom holding increases at flows greater than 40 centimeters per second (1.3 feet per second) (Adams et al. 1997, 1999, as cited in Peake 2004).

The critical swimming speed of young-of-the-year shortnose sturgeon has been measured at approximately 34 centimeters per second (1.0 foot per second), but performance depended on temperature and was lower at reduced temperatures (e.g., at 5 degrees Celsius (41 degrees Fahrenheit)). At 10 degrees Celsius (50 degrees Fahrenheit), critical swimming speeds were 26.0 to 28.9 centimeters per second (0.9 to 1.0 foot per second) (Deslauriers and Kieffer 2012; Kieffer et al. 2009). Young-of-the-year shortnose sturgeon were found to be vulnerable to impingement at velocities greater than 30.5 centimeters per second (1.0 foot per second), but larger juvenile and adult shortnose sturgeon (greater than 58 centimeters (22.8 inches) in total length) were not impinged at velocities up to 91.4 centimeters per second (3.0 feet per second) (Kynard et al. 2005, as cited in NMFS 2016). Because morphology and body size are indicative of swimming performance (Webb 1984), swimming performance is expected to be similar among sturgeon species at a given body size. Therefore, the information on swimming performance provided for Atlantic sturgeon and other North American sturgeons can also be used to evaluate swimming performance of shortnose sturgeon of similar body size.

The collective insight from these studies of sturgeon swimming performance helps to bound the expected performance of Atlantic and shortnose sturgeon under typical and more extreme environmental conditions. The traveling screens at Eddystone have a through-screen velocity of 26.8 centimeters per second (0.88 feet per second) and an approach velocity of 13.1 centimeters per second (0.43 feet per second) at mean low water when the Station is operating at design flow. Based upon the swim performance described above, juvenile Atlantic sturgeon should be capable of avoiding impingement at velocities equal to or greater than those experienced at Eddystone. Therefore, the potential for impingement of juvenile Atlantic and shortnose sturgeon on the traveling screens at Eddystone is likely very low.

Impingement sampling was conducted at Eddystone in 1976-1978, 1987-1992, and 2005-2006. No Atlantic or shortnose sturgeon were collected during those years of impingement sampling.

Data from those impingement sampling programs were used to estimate average annual numbers of Atlantic and shortnose sturgeon impinged on traveling screens at Eddystone (Exelon 2019).

AKRF, Inc. used two approaches to estimate annual numbers impinged. A likelihood function analysis was performed based on the observation (or lack thereof) of Atlantic and shortnose sturgeon in impingement samples at Eddystone. A Bayesian posterior probability distribution analysis was also performed utilizing impingement sampling results to inform the prior for annual number impinged. The results of the likelihood function analysis showed a very low likelihood that the annual numbers of Atlantic and shortnose sturgeon impinged were greater than one. The Bayesian analysis also resulted in a very low likelihood (0.01) that the annual numbers of Atlantic and shortnose sturgeon impinged at Eddystone were greater than one. Based on the results of the likelihood function and Bayesian analyses, the estimated annual take of sturgeon due to impingement is one young-of-the-year or older Atlantic and shortnose sturgeon (Exelon 2019).

AKRF, Inc. developed potential impingement sampling schedules for ITP monitoring based on historical operations at Eddystone and planned operations under Eddystone's selected impingement compliance option. These potential sampling schedules were then evaluated to estimate the number of Atlantic and shortnose sturgeon that would be collected in impingement sampling. Exelon proposed annual take of seven young-of-the-year or older Atlantic and shortnose sturgeon (Exelon 2019).

However, actual intake flows were reduced by 32 percent in 2019 as a result of intake flow mitigation implementation (see Section 3.5.1) (Exelon 2020b). Therefore, Exelon is proposing the estimated take of five young-of-the-year or older Atlantic and shortnose sturgeon per year, which translates to 50 young-of-the-year or older Atlantic and shortnose sturgeon over the 10-year permit term (Exelon 2020b). With this explanation, we adopt the incidental take estimate of 50 New York Bight DPS Atlantic sturgeon and 50 shortnose sturgeon to traveling screen impingement at Eddystone over the 10-year duration of this ITP, a nearly 29 percent take reduction for each species since the implementation of the mitigation measures leading to decreased intake flows.

10.2 Effects and Response Analysis

The *Effects and Response Analysis* evaluates the available evidence to determine how individuals of those ESA-listed species are likely to respond given their probable exposure. Given the exposure detailed above, here we describe the range of responses among ESA-listed species that may result from the stressors associated with the proposed action. These include stressors associated with the following activities: vessel activity (vessel strike) and operation of the CWIS (intake forebay entrainment and traveling screen impingement). Our effects and response analysis considers and weighs evidence of adverse consequences, as well as evidence suggesting the absence of such consequences.

10.2.1 Vessel Strikes

The effects of vessels on Atlantic sturgeon may involve disturbance or injury/mortality due to collisions. The majority of vessel strikes are lethal; collisions with the propeller are evidenced by examiniations of sturgeon carcasses being severed through the head or torso region and it is unlikely that these are post-mortem injuries (Brown and Murphy 2010).

10.2.2 Entrainment

As entrained organisms pass through the intake they can be injured from abrasion or compression. Within the cooling system, they encounter physical impacts in the pumps and condenser tubing; pressure changes and shear stress throughout the system; thermal shock within the condenser; and exposure to chemicals (Mayhew et al. 2000 in NRC 2011). Death can occur immediately or at a later time from the physiological effects of heat, or it can occur after organisms are discharged if stresses or injuries result in an inability to escape predators, a reduced ability to forage, or other impairments. All entrained larval sturgeon are likely to be killed.

10.2.3 Impingement

Impingement can kill organisms immediately or contribute to death resulting from exhaustion, suffocation, injury, or exposure to air when screens are rotated for cleaning. The potential for injury or death is generally related to the amount of time an organism is impinged, its susceptibility to injury, and the physical characteristics of the screenwashing and fish return system that the plant operator uses. Below, NMFS considers the available data on the impingement of shortnose and Atlantic sturgeon at the facility and then considers the likely rates of mortality associated with this impingement.

Generally, impingement occurs when a fish cannot or does not swim fast enough to escape the intake (e.g., the fish’s swimming ability is overtaken by the velocity of water being sucked into the intake). A few studies have been carried out to examine the swimming ability of sturgeon and their vulnerability to impingement. Fish swimming ability, and therefore ability to avoid impingement and entrainment, are affected not just by the flow velocity into the intakes, but also fish size and age, water temperature, level of fatigue, ability to remain a head-first orientation into the current, whether the fish senses danger, and whether the fish is sick or injured.

10.3 Risk Analysis

In this section, we assess the consequences of the responses of the individuals that have been exposed to the stressors we have identified as adversely impacting ESA-listed sturgeon, the populations those individuals represent, and the species those populations comprise. Whereas the *Response Analysis* (Section 10.2) identified the potential responses of ESA-listed species to the proposed action, this section summarizes our analysis of the expected risk to individuals, populations, and species given the expected exposure to those stressors (as described in Section 10.1) and the expected responses to those stressors (as described in Section 10.2). For designated critical habitat, we assess the consequences of these responses on the value of the critical habitat for the conservation of the species for which the habitat has been designated.

We measure risk to individuals of threatened and endangered species based upon effects on the individual's "fitness," which may be indicated by changes to the individual's growth, survival, annual reproductive fitness, and lifetime reproductive success. When we do not expect ESA-listed animals exposed to an action's effects to experience reductions in fitness, we will not expect the action to have adverse consequences on the viability of the populations those individual represent or the species those populations comprise. As a result, if we conclude that ESA-listed animals are not likely to experience reductions in their fitness, we will conclude that the action is not likely to adversely affect listed species. If, however, we conclude that individual animals are likely to experience reductions in fitness, we will assess the consequences of those fitness reductions on the population(s) that those individuals belong to.

For the New York Bight DPS of Atlantic sturgeon, the estimated incidental take due to entrainment in the intake forebay is 27,000 larval sturgeon annually.

The estimated incidental take due to impingement is five young-of-the-year sturgeon annually.

We estimate one sub-adult or adult sturgeon will be killed due to vessel strikes over the 10-year period of the permit.

Therefore, we estimate over the 10-year period of the permit, there would be incidental lethal take of 270,000 larval New York Bight DPS Atlantic sturgeon and 51 sub-adult/adult New York Bight DPS Atlantic sturgeon from the proposed action.

We estimate that over 76 million larval sturgeon are present in the Delaware River estuary based on reported survival rates of larvae and young-of-the-year (Kahnle et al. 2007) and Hale et al. (2016)'s estimate of 3,656 (95 percent confidence interval from 1,935 to 33,041) juvenile (ages 0–1) Atlantic sturgeon that were using the Delaware River estuary as a nursery in 2014. Therefore, only a very small percentage (around 0.35 percent) of the population of New York Bight DPS Atlantic sturgeon in the Delaware River could be expected to experience mortality or injury due to interaction with the operating CWIS and vessels delivering oil to Eddystone over the 10-year duration of this ITP. In the mid-Atlantic, only one in approximately 14,000 Atlantic sturgeon larvae is expected to survive to become an age-1 sturgeon, and only one in approximately six age-1 Atlantic sturgeon are expected to survive to reach the fully reproductive age of 21 years old (reviewed in Exelon 2020b). Therefore, the possible entrainment and mortality of 270,000 larval sturgeon during the operation of Eddystone over the next ten years is likely much smaller than the number of larval sturgeon that do not survive under normal circumstances.

For shortnose sturgeon, the estimated incidental take due to impingement is five young-of-the-year sturgeon annually. We therefore estimate an incidental take of 50 young-of-the-year shortnose sturgeon over the 10-year duration of the ITP.

The abundance estimate of shortnose sturgeon in the Delaware River is approximately 13,000 and the trend is unchanged. Therefore, only a small percentage of the stable population of shortnose sturgeon in the Delaware River (around 0.38 percent) could be expected to experience mortality or injury due to interaction with the operating CWIS over the 10-year duration of this ITP.

11 CUMULATIVE EFFECTS

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 C.F.R. §402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

This section attempts to identify the likely future environmental changes and their impact on ESA-listed or proposed species and their critical habitats in the action area. This section is not meant to be a comprehensive socio-economic evaluation, but a brief outlook on future changes in the environment. Projections are based upon recognized organizations producing best-available information and reasonable rough-trend estimates of change stemming from these data. However, all changes are based upon projections that are subject to error and alteration by complex economic and social interactions.

We expect that those aspects described in the *Environmental Baseline* (Section 9) will continue to impact ESA-listed resources into the foreseeable future. We expect anthropogenic effects that include climate change, oceanic temperature regimes, vessel interactions (vessel strikes and whale watching), fisheries (fisheries interactions and aquaculture), pollution (marine debris, pesticides and contaminants, and hydrocarbons), aquatic nuisance species, and scientific research and enhancement activities, to continue into the future for sturgeon. Many of these activities would involve a federal nexus and thus be subject to future ESA section 7 consultation. An increase in these activities could result in an increased effect on ESA-listed species; however, the magnitude and significance of any anticipated effects remain unknown at this time. The best scientific and commercial data available provide little specific information on any long-term effects of these potential sources of disturbance on ESA-listed sturgeon populations. Therefore, NMFS expects that the levels of interactions between human activities and sturgeon described in the *Environmental Baseline* will continue at similar levels into the foreseeable future. Movements towards the reduction of vessel strikes and fisheries interactions or greater protections of ESA-listed sturgeon from these anthropogenic effects may aid in abating the downward trajectory of some populations and lead to recovery of other populations.

During this consultation, we searched for information on future state, tribal, local, or private (non-Federal) actions reasonably certain to occur in the action area. We conducted electronic searches of *Google* and other electronic search engines for other potential future state or private activities that are likely to occur in the action area. We are not aware of any non-Federal actions that are likely to occur in the action area during the foreseeable future that were not considered in the *Environmental Baseline* (Section 9) or *Cumulative Effects* (Section 11) for this consultation.

12 INTEGRATION AND SYNTHESIS

The *Integration and Synthesis* section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the *Effects of the Action* (Section 10) to the *Environmental Baseline* (Section 9) and the *Cumulative Effects* (Section 11) to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a ESA-listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the *Status of the Species* (Section 8). For this consultation, we determined that the effects were not likely to adversely affect designated critical habitat; therefore only the risk to ESA-listed sturgeon (i.e., New York Bight DPS Atlantic sturgeon and shortnose sturgeon) are analyzed in this section.

The following discussions separately summarize the probable risks the proposed action poses to endangered species and critical habitat that are likely to be exposed to stressors resulting from the issuance of ITP No. 23148. These summaries integrate the exposure profiles presented previously with the results of our response analyses for each of the actions considered in this opinion.

12.1 Atlantic Sturgeon – New York Bight Distinct Population Segment

The Delaware River once supported the largest spawning subpopulation of Atlantic sturgeon in the United States, with 3,200 metric tons of landings in 1888 (ASSRT 2007a; Secor 2002; Secor and Waldman 1999). Population estimates based on juvenile mark and recapture studies and commercial logbook data indicate that the Delaware subpopulation has continued to decline rapidly since 1990. Based on genetic analyses, the majority of subadults captured in the Delaware Bay are thought to be of Hudson River origin (ASSRT 2007a). However, a more recent study by Hale et al. (2016) suggests that a spawning population of Atlantic Sturgeon exists in the Delaware River and that some level of early juvenile recruitment is continuing to persist despite current depressed population levels. They estimated that 3,656 (95 percent confidence interval from 1,935 to 33,041) juveniles (ages 0–1) used the Delaware River estuary as a nursery in 2014.

Vessel strikes in the Delaware River are thought to predominantly occur between May through July and likely affect adult New York Bight DPS Atlantic sturgeon migrating through the river to spawning grounds (Brown and Murphy 2010). Exelon proposes to make all reasonable efforts to schedule fuel oil deliveries outside this timeframe. Thus Exelon requests a ten-year take limit for vessel activity of 1 New York Bight DPS Atlantic sturgeon, commensurate with the rounded up value of 0.3 Atlantic sturgeon over 10 years. We conclude that an annual incidental take of 1

New York Bight DPS Atlantic sturgeon from vessel strike will not significantly affect the continued recovery of this population in the Delaware River.

The effects of entrainment associated with Eddystone's CWIS operations are not likely to further reduce the likelihood of the survival and recovery of the species in the wild. The ITP authorizes the lethal take by entrainment of 27,000 larval sturgeon from the New York Bight DPS per year for 10 years.

This should not have a measurable effect on the size, reproductive potential, or growth of the New York Bight DPS of Atlantic sturgeon for several reasons. First, the loss of larvae, even at potentially high numbers, is small compared to the number of eggs that an individual female can produce (from 800,000 to 2.4 million eggs) when it spawns (Smith 1985). Second, the estimate of juvenile abundance in the Delaware River estuary by Hale et al. (2016) mentioned above, when extrapolated, translates to over 76 million larval sturgeon in the estuary. Therefore, only a very small percentage (around 0.35 percent over ten years) of the population of larval New York Bight DPS Atlantic sturgeon in the Delaware River could be expected to experience mortality or injury due to interaction with the operating CWIS. In terms of egg production, each fully mature Atlantic sturgeon is equivalent to roughly 84,000 larvae. Therefore, the take of a larval sturgeon would have a much smaller impact on the sturgeon population as a whole compared to the take of a reproductively mature adult (reviewed in Exelon 2020b). Third, mortality of sturgeon during larval life stages is naturally high due to small body size, limited swimming ability, predation, and sensitivity to variations in their surrounding environment (reviewed in Hardy and Litvak 2004). In the mid-Atlantic, only one in approximately 14,000 Atlantic sturgeon larvae is expected to survive to become an age-1 sturgeon, and only one in approximately six age-1 Atlantic sturgeon are expected to survive to reach the fully reproductive age of 21 years old (reviewed in Exelon 2020b). Entrainment of larval sturgeon at Eddystone would be considered a compensatory factor of larval mortality. Therefore, the possible entrainment and mortality of 270,000 larval sturgeon during the operation of Eddystone over the next ten years is likely much smaller than the number of larval sturgeon that do not survive under normal circumstances.

The ITP also authorizes the incidental take of five young-of-the-year/sub-adult Atlantic sturgeon per year over 10 years due to impingement. These lethal takes coupled with the lethal take of larval Atlantic Sturgeon by entrainment will not significantly affect the recovery of this population in the Delaware River. The entrainment estimate of 270,000 larval New York Bight DPS Atlantic sturgeon over ten years translates to entrainment of 20 age-1 equivalent sturgeon for the ten-year duration of this ITP. The impacts of the entrainment and impingement authorized by the ITP are equivalent to the removal of 70 young-of-the-year/sub-adults from the New York Bight DPS. With the one additional adult sturgeon taken from a vessel strike, we anticipate a lethal take of 71 individuals from the New York Bight DPS over ten years. The loss of 70 juveniles translates to a loss of about two percent of the juvenile population of the New York Bight DPS in the Delaware River. The loss of one adult translates to a loss of less than one percent of the adult population of the New York Bight DPS in the Delaware River.

ASMFC (2017) estimated that the New York Bight DPS had a 31 percent chance of having a mortality rate greater than one that would result in a loss of 50 percent of the egg production in an unexploited population (“$Z_{50\%EPR}$”). At the coastwide level, Atlantic sturgeon were estimated to have a seven percent chance of having a mortality rate greater than $Z_{50\%EPR}$. There is also evidence that the stock and DPS have recovered to some degree since 1998 (ASMFC 2017). Mortality rate calculations rely in large part on tagging studies, but these are likely overestimates of the true mortality rate, as tags malfunction and/or are lost. With this information, the low number of observed takes of Atlantic sturgeon at Eddystone, and the multiple mitigation measures in place (see Section 3.5), we conclude that the continued operation of Eddystone will not significantly affect the continued recovery of the New York Bight DPS Atlantic sturgeon in the Delaware River.

12.2 Shortnose Sturgeon

The 2010 shortnose sturgeon SRT conducted a three-step risk assessment for shortnose sturgeon at a riverine scale: (1) assess population health, (2) populate a “matrix of stressors” by ranking threats, and (3) review assessment by comparing population health scores to stressor scores. The Hudson River had the highest estimated adult abundance (30,000 to 61,000), followed by the Delaware (12,000), Kennebec Complex (9,000), and Altamaha (6,000) (SSSRT 2010). The SSSRT found evidence of an increasing abundance trend for the Kennebec Complex and ACE Basin populations; a stable trend for the Merrimack, Connecticut, Hudson, Delaware, Winyah Bay Complex, Cooper, Savannah, Ogeechee, and Altamaha populations; and a declining trend only for the Cape Fear population (all other populations had an unknown trend) (SSSRT 2010). Based on these data, we conclude that an annual incidental take of 50 young-of-the-year/sub-adult shortnose sturgeon through impingement will not significantly affect the continued recovery of this species in the Delaware River, because the number of individuals removed from the population would be a small percentage of the overall population.

13 CONCLUSION

After reviewing the current status of the ESA-listed species, the environmental baseline within the action area, the effects of the proposed action, and cumulative effects, it is NMFS’ biological opinion that the proposed action is not likely to jeopardize the continued existence of the New York Bight DPS of Atlantic sturgeon and shortnose sturgeon.

14 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. “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 regulation to include significant habitat modification or degradation that results in death or injury to ESA-listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering.

"Harass" is further defined as an act that "creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding or sheltering" (NMFSPD 02-110-19). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Section 7(o)(2) provides that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS.

14.1 Amount or Extent of Take

Section 7 regulations require NMFS to specify the impact of any incidental take of endangered or threatened species; that is, the amount or extent, of such incidental taking on the species (50 C.F.R. §402.14(i)(1)(i)). The amount of take represents the number of individuals that are expected to be taken by actions.

For the proposed action of the issuance of ITP No. 23148, incidental take is authorized for the New York Bight DPS of Atlantic sturgeon and shortnose sturgeon.

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 (young-of-the-year/sub-adults)

Total: 1 sub-adult/adult, 270,000 larvae, and 50 young-of-the-year/sub-adults over 10 years

Shortnose sturgeon

Impingement: 5 per year (young-of-the-year/sub-adults)

Total: 50 young-of-the-year/sub-adults over 10 years

14.2 Reasonable and Prudent Measures

Reasonable and prudent measures are non-discretionary actions (50 C.F.R. §402.02) that must be undertaken for the exemption in Section 7(o)(2) to apply. Section 7(b)(4) of the ESA requires that when a proposed agency action is found to be consistent with section 7(a)(2) of the ESA and the proposed action may incidentally take individuals of ESA-listed species, NMFS will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. To minimize such impacts, reasonable and prudent measures, and term and conditions to implement the measures, must be provided. Only incidental take resulting from the agency actions and any specified reasonable and prudent measures and terms and conditions identified in the ITS are exempt from the taking prohibition of section 9(a), pursuant to section 7(o) of the ESA. Section 10 actions are unique in that they have the requirement under Section 10(a)(2)(B)(ii) to minimize and mitigate the impacts of taking to the maximum extent practicable. No additional mitigation is neccesary for this action. The mitigation, monitoring, and reporting are described in Section 3.5 of this opinion and are binding requirements of the Conservation Plan and ITP.

In addition to the mitigation proposed by the applicant, we believe it is necessary and appropriate to minimize take of listed species and their critical habitat, and for the Endangered Species Conservation Division to monitor and report the effects of the actions considered in this opinion to us by March 1, each year.

14.3 Terms and Conditions

There are no terms and conditions associated with the reasonable and prudent measure above.

15 CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on ESA-listed species or critical habitat, to help implement recovery plans or develop information (50 C.F.R. §402.02). There are no conservation recommendations associated with this proposed action.

16 REINITIATION NOTICE

This concludes formal consultation for the NMFS Endangered Species Conservation Division's issuance of an ITP for the operation of Eddystone. As 50 C.F.R. §402.16 states, 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 ITS is exceeded.
(2) New information reveals effects of the agency action that may affect ESA-listed species or critical habitat in a manner or to an extent not previously considered.
(3) The identified action is subsequently modified in a manner that causes an effect to ESA-listed species or designated critical habitat that was not considered in this opinion.
(4) A new species is listed or critical habitat designated under the ESA that may be affected by the action.

17 REFERENCES

Able, K. W., and M. P. Fahay. 2010. Ecology of Estuarine Fishes: Temperate Waters of the Western North Atlantic. Johns Hopkins University Press, Baltimore, Maryland.

Ackerman, R. A. 1997. The nest environment and the embryonic development of sea turtles. Pages 83-106 *in* P. L. M. Lutz, J. A. , editor. The Biology of Sea Turtles. CRC Press, Boca Raton.

Akçakaya, H., and W. Root. 2007. RAMAS red list professional. Spatial and temporal data analysis for threatened species classifications under uncertainty. New York, NY: Applied Biomathematics.

Antonelis, G. A., J. D. Baker, T. C. Johanos, R. C. Braun, and A. L. Harting. 2006. Hawaiian monk seal (*Monachus schauinslandi*): status and conservation issues. Atoll Research Bulletin 543:75-101.

ASMFC. 2007. Special Report to the ASMFC Atlantic Sturgeon Management Board: Estimation of Atlantic Sturgeon Bycatch in Coastal Atlantic Commercial Fisheries of New England and the Mid-Atlantic Atlantic States Marine Fisheries Commission, Arlington, VA

ASMFC. 2008. Addendum II to the Fishery Management Plan for American eel.

ASMFC. 2012. Habitat Addendum IV to Amendment 1 to the Interstate Fishery Management Plan for Atlantic sturgeon.

ASMFC. 2017. 2017 Atlantic Sturgeon Benchmark Stock Assessment and Peer Review Report.

ASSRT. 2007a. Status Review of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*).

ASSRT. 2007b. Status Review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). National Marine Fisheries Service, Northeast Regional Office.

Ayers, M. A., D. M. Wolock, G. J. McCabe, L. E. Hay, and G. D. Tasker. 1993. Sensitivity of water resources in the Delaware River basin to climate variability and change. U.S. Geological Survey, Reston, Virgina.

Bahn, R. A., J. E. Fleming, and D. L. Peterson. 2012. Bycatch of Shortnose Sturgeon in the commercial American shad fishery of the Altamaha River, Georgia. North American Journal of Fisheries Management 32(3):557-562.

Bahr, D. L., and D. L. Peterson. 2017. Status of the Shortnose Sturgeon Population in the Savannah River, Georgia. Transactions of the American Fisheries Society 146(1):92-98.

Bain, M. B. 1997. Atlantic and shortnose sturgeons of the Hudson River: common and divergent life history attributes. Pages 347-358 *in* Sturgeon Biodiversity and Conservation. Springer.

Bain, M. B., and coauthors. 2007. Recovery of a US endangered fish. PloS one 2(1):e168.

Bain, M. B., D. L. Peterson, K. K. Arend, and N. Haley. 1999. Atlantic sturgeon population monitoring for the Hudson River Estuary: Sampling design and gear recommendations. Hudson Rivers Fisheries Unit, New York State Department of Environmental Conservation and The Hudson River Foundation, New Paltz, New York and New York, New York.

Baker, J. D., C. L. Littnan, and D. W. Johnston. 2006. Potential effects of sea level rise on the terrestrial habitats of endangered and endemic megafauna in the Northwestern Hawaiian Islands. Endangered Species Research 2:21-30.

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. PloS one 12(7).

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

Barnett, J., and A. Dobshinsky. 2008. Climate change: Impacts and responses in the Delaware River basin. University of Pennsylvania, Department of City and Regional Planning, Philadelphia, Pennsylvania.

Bartron, M., S. Julian, and J. Kalie. 2007. Genetic assessment of Atlantic sturgeon from the Chesapeake Bay: Temporal comparison of juveniles captured in the Bay.

Beans, B. E., and L. Niles. 2003. Endangered and Threatened Wildlife of New Jersey, Illustrated edition. Rutgers University Press.

Beauvais, S. L., S. B. Jones, S. K. Brewer, and E. E. Little. 2000. Physiological measures of neurotoxicity of diazinon and malathion to larval rainbow trout (*Oncorhynchus mykiss*) and their correlation with behavioral measures. Environmental Toxicology and Chemistry: An International Journal 19(7):1875-1880.

Billsson, K., L. Westerlund, M. Tysklind, and P. E. Olsson. 1998. Developmental disturbances caused by polychlorinated biphenyls in zebrafish (*Brachydanio rerio*). Marine Environmental Research 46(1-5):461-464.

Blunden, J., and D. S. Arndt. 2016. State of the Climate in 2015. Bulletin of the American Meteorological Society 97(8).

Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Environmental Biology of Fishes 48(1-4):399-405.

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

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:e81321.

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

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

Brundage, H. M., and J. C. O'Harron. 2009. Investigations of juvenile shortnose and Atlantic sturgeons in the lower tidal Delaware River. Bulletin of the New Jersey Academy of Sciences 54:1-8.

Buckley, J., and B. Kynard. 1985. Yearly movements of shortnose sturgeons in the Connecticut River. Transactions of the American Fisheries Society 114(6):813-820.

Burton, W. H., H. M. Brundage, and J. C. O'Harron. 2005. Delaware River adult and juvenile sturgeon survey, Winter 2005. Prepared for U.S. Army Corps of Engineers, Philadelphia District.

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.

Campbell, J. G., and L. R. Goodman. 2004. Acute sensitivity of juvenile shortnose sturgeon to low dissolved oxygen concentrations. Transactions of the American Fisheries Society 133:772-776.

Cheng, L., and coauthors. 2017. Improved estimates of ocean heat content from 1960 to 2015. Science Advances 3(3):e1601545.

Clapham, P. J., S. B. Young, and R. L. Brownell Jr. 1999. Baleen whales: Conservation issues and the status of the most endangered populations. Mammal Review 29(1):35-60.

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., C. Norwood, and A. Rourk. 2006. Shortnose and Atlantic sturgeon age-growth, status, diet, and genetics. Final Report to National Fish and Wildlife Foundation. South Carolina Department of Natural Resources, Charleston, South Carolina.

Collins, M. R., S. G. Rogers, T. I. Smith, and M. L. Moser. 2000. 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., S. G. Rogers, and T. I. J. Smith. 1996. Bycatch of sturgeons along the southern Atlantic coast of the USA. North American Journal of Fisheries Management 16(1):24 - 29.

Culp, J. M., R. B. Lowell, and K. J. Cash. 2000. Integrating mesocosm experiments with field and laboratory studies to generate weight-of-evidence risk assessments for large rivers. Environmental Toxicology and Chemistry: An International Journal 19(4):1167-1173.

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

Dadswell, M. 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., and coauthors. 2017. Population characteristics of adult Atlantic sturgeon captured by the commercial fishery in the Saint John River Estuary, New Brunswick. Transactions of the American Fisheries Society 146(2):318-330.

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.

Damon-Randall, K., and coauthors. 2010. Atlantic sturgeon research techniques. NOAA Technical Memorandum NMFS-NE 215:64pp.

Deslauriers, D., and J. D. Kieffer. 2012. The effects of temperature on swimming performance of juvenile shortnose sturgeon (*Acipenser brevirostrum*). Journal of Applied Ichthyology 2012:1-6.

Dickinson, W. H. 1974. Circulating water system. Eddystone Station. Philadelphia Electric Company. Pennsylvania Electric Association, Philadelphia, Pennsylvania.

Doney, S. C., and coauthors. 2012. Climate change impacts on marine ecosystems. Marine Science 4.

Dovel, W. L., and T. J. Berggren. 1983. Atlantic sturgeon of the Hudson River estuary, New York. New York Fish and Game Journal 30:140-172.

DRBC. 2016. 2016 Delaware River and Bay water quality assessment.

DRBC. 2017. Salt Line. Delaware River Basin Commission.

Dwyer, F. J., and coauthors. 2005. Assessing contaminant sensitivity of andangered and threatened aquatic species: Part I. Acute toxicity of five chemicals. Archives of Environmental Contamination and Toxicology 48(2):143-154.

Environmental Research and Consulting, I. 2002. Contaminant analysis of tissues from two shortnose sturgeon (Acipenser brevirostrum) collected in the Delaware River. Prepared for NOAA Fisheries., Kennett Square, Pennsylvania.

Environmental Research and Consulting, I. 2008. Final report of investigations of shortnose sturgeon early life stages in the Delaware River, Spring 2007 and 2008. Prepared for NJ Division of Fish and Wildlife Endangered and Nongame Species Program.

Environmental Research and Consulting, I. 2015. Sturgeon in the Mid-Atlantic Region: a multi-state collaboration of research and conservation. Final report of identification of shortnose sturgeon spawning sites and characterization of early life history habitat in the non-tidal Delaware River and distribution and habitat use of juvenile Atlantic sturgeon in New Jersey waters. Prepared for NJ Division of Fish and Wildlife.

Environmental Resources Management. 2014. CORMIX modeling of Eddystone Generating Station's thermal plume.

Environmental Resources Management. 2018. Memorandum: Bottom contact area for the Eddystone thermal plume.

EPA. 2008. National Coastal Condition Report III. United States Environmental Protection Agency, Washington, DC.

EPA. 2013. ESA Biological Evaluation for CWA Section 316(b) Rulemaking. O. o. W. Engineering and Analysis Division, editor, Washington, D.C.

ERC. 2006. Final report of Shortnose Sturgeon population studies in the Delaware River, January 1999 through March 2003. Environmental Research and Consulting.

Evans, P. G. H., and A. Bjørge. 2013. Impacts of climate change on marine mammals. Marine Climate Change Impacts Parternship: Science Review:134-148.

Exelon. 2019. Application for an Individual Incidental Take Permit under the Endangered Species Act of 1973 and 50 CFR 222.307 and Habitat Conservation Plan. Eddystone Generating Station, Eddystone, Pennsylvania.

Exelon. 2020a. Eddystone IITP 3rd Supplemental Submission to NMFS. Exelon Generating Company, LLC, Kennett Square, Pennsylvania.

Exelon. 2020b. Individual Incidental Take Permit Supplemental Information, March 2020. Exelon Generation Company, LLC.

Exelon, ARCADIS, V. E. Consulting, and I. Normandeau Associates. 2008. Design and construction technology plan, Eddystone Generating Station, Eddystone, Pennsylvania.

Farrae, D. J., W. C. Post, and T. L. Darden. 2017. Genetic characterization of Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*, in the Edisto River, South Carolina and identification of genetically discrete fall and spring spawning. Conservation Genetics:1-11.

FFWCC. 2007. Shortnose sturgeon population evaluation in the St. Johns River, FL: has there ever been a shortnose sturgeon population in Florida’s St. Johns River?

Flournoy, P. H., S. G. Rogers, and P. S. Crawford. 1992. Restoration of shortnose sturgeon in the Altamaha River, Georgia. Final Report to the US Fish and Wildlife Service, Atlanta, Georgia.

Folmar, L. C., and coauthors. 1996. Vitellogenin induction and reduced serum testosterone concentrations in feral male carp (*Cyprinus carpio*) captured near a major metropolitan sewage treatment plant. Environmental Health Perspectives 104(10):1096-1101.

Frankham, R. 1995. Conservation genetics. Annual review of genetics 29(1):305-327.

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.

Fritts, M. W., and D. L. Peterson. 2011. Status of Atlantic and Shortnose Sturgeon in the Satilla and St. Marys Rivers, GA, Univ. Georgia, Athens, GA.

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.

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. Pages 85 *in* American Fisheries Society Symposium. American Fisheries Society.

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., and coauthors. 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.

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

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

Hammerschmidt, C. R., M. B. Sandheinrich, J. G. Wiener, and R. G. Rada. 2002. Effects of dietary methylmercury on reproduction of fathead minnows. Environmental Science and Technology 36(5):877-883.

Hardy, R. S., and M. K. Litvak. 2004. Effects of temperature on the early development, growth, and survival of shortnose sturgeon, *Acipenser brevirostrum*, and Atlantic sturgeon, *Acipenser oxyrhynchus*, yolk-sac larvae. Environmental Biology of Fishes 70:145-154.

Hassell, K. S., and J. R. Miller. 1999. Delaware River water resources and climate change [online]. The Electronic Bulletin of Undergraduate Research.

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 10:337-341.

Hayhoe, K., and coauthors. 2018. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* (Reidmiller, D.R., et al. [eds.]). U.S. Global Change Research Program, Washington, DC, USA.

Hazel, J., I. R. Lawler, H. Marsh, and S. Robson. 2007. Vessel speed increases collision risk for the green turtle *Chelonia mydas*. Endangered Species Research 3(2):105-113.

Hazen, E. L., and coauthors. 2012. Predicted habitat shifts of Pacific top predators in a changing climate. Nature Climate Change 3(3):234-238.

HDR. 2018. Pre-Peer Review Draft Clean Water Act §316(b) evaluation to support 40 CFR §122.21(r)(10). Engineering feasibility report. Exelon Generation Company, LLC. Eddystone Generating Station.

Heidt, A., and R. Gilbert. 1979. Movements of shortnose sturgeon, *Acipenser brevirostrum*, in the Altamaha River, Georgia. ASB Bulletin 26.

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.

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 27:369-375.

Ingram, E. C., and D. L. Peterson. 2016. Annual spawning migrations of adult Atlantic sturgeon in the Altamaha River, Georgia. Marine and Coastal Fisheries 8(1):595-606.

IPCC. 2014. Climate change 2014: Impacts, adaptation, and vulnerability. IPCC Working Group II contribution to AR5. Intergovernmental Panel on Climate Change.

IPCC. 2018. Summary for Policymakers. In: *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* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland:32pp.

Jay, A., and coauthors. 2018. In: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA:33-71.

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. Pages 476-484 *in* A. G. Eversole, editor 47th Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, Atlanta, Georgia.

Jones, A. R. 1986. The effects of dredging and spoil disposal on macrobenthos, Hawkesbury Estuary, N. S. W. Marine Pollution Bulletin 17(1):17-20.

Jorgensen, E. H., O. Aas-Hansen, A. G. Maule, J. E. T. Strand, and M. M. Vijayan. 2004. PCB impairs smoltification and seawater performance in anadromous Arctic charr (Salvelinus alpinus). Comparative Biochemistry and Physiology C Toxicology and Pharmacology 138(2):203-212.

Kahn, J., and M. Mohead. 2010. A protocol for use of shortnose, Atlantic, Gulf, and green sturgeons. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources.

Kahn, J. E., C. Hager, J. C. Watterson, N. Mathies, and K. J. Hartman. 2019. Comparing abundance estimates from closed population mark-recapture models of endangered adult Atlantic sturgeon. Endangered Species Research 39:63-76.

Kahnle, A. W., K. A. Hattala, and K. A. McKown. 2007. Status of Atlantic sturgeon of the Hudson River Estuary, New York, USA. American Fisheries Society Symposium 56:347-363.

Karl, T. R., J. M. Melillo, and T. C. Peterson. 2009. Global climate change impacts in the United States. Cambridge University Press, New York City.

Kaushal, S. S., and coauthors. 2010. Rising stream and river temperatures in the United States. Frontiers in Ecology and the Environment 8(9):461-466.

Kelly, J. T., and A. P. Klimley. 2012. Relating the swimming movements of green sturgeon to the movement of water currents. Environmental Biology of Fishes 93:151-167.

Kieffer, J. D., L. M. Arsenault, and M. K. Litvak. 2009. Behavior and performance of juvenile shortnose sturgeon *Acipenser brevirostrum* at different water velocities. Journal of fish biology 74:674-682.

Kieffer, M. C., and B. Kynard. 1993. Annual movements of shortnose and Atlantic sturgeons in the Merrimack River, Massachusetts. Transactions of the American Fisheries Society 122(6):1088-1103.

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

King, T. L., and coauthors. 2014. A Nuclear DNA Perspective on Delineating Evolutionarily Significant Lineages in Polyploids: The Case of the Endangered Shortnose Sturgeon (*Acipenser brevirostrum*). PloS one 9(8):e102784.

Kintisch, E. 2006. As the seas warm: Researchers have a long way to go before they can pinpoint climate-change effects on oceangoing species. Science 313:776-779.

Kocan, R. M., M. B. Matta, and S. Salazar. 1993. A laboratory evaluation of Connecticut River coal tar toxicity to shortnose sturgeon (Acipenser brevirostrum) embryos and larvae. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Kreeger, D., and coauthors. 2010. Climate change and the Delaware Estuary: Three case studies in vulnerability assessment and adaptation planning. Partnership for the Delaware Estuary, Inc., Wilmington, Delaware.

Kynard, B. 1997. Life history, latitudinal patterns, and status of the shortnose sturgeon, *Acipenser brevirostrum*. Environmental Biology of Fishes 48(1-4):319-334.

Kynard, B., and coauthors. 2016. Life history and status of Shortnose Sturgeon (*Acipenser brevirostrum* LeSueur, 1818). Journal of Applied Ichthyology 32(S1):208-248.

Kynard, B., P. Bronzi, and H. Rosenthal. 2012. Life History and behavior of Connecticut River shortnose and other sturgeons.

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.

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.

Lazzari, A. M., J. C. O'Herron, and R. W. Hastings. 1986. Occurence of juvenile Atlantic sturgeon, *Acipenser oxyrhynchus*, in the upper tidal Delaware River. Estuaries 9:356-361.

Learmonth, J. A., and coauthors. 2006. Potential effects of climate change on marine mammals. Oceanography and Marine Biology: an Annual Review 44:431-464.

Litwiler, T. 2001. Conservation plan for sea turtles, marine mammals and the shortnose sturgeon in Maryland. Fisheries 410:226-0078.

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.

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.

MacLeod, C. D. 2009. Global climate change, range changes and potential implications for the conservation of marine cetaceans: A review and synthesis. Endangered Species Research 7(2):125-136.

MacLeod, C. D., and coauthors. 2005. Climate change and the cetacean community of north-west Scotland. Biological Conservation 124(4):477-483.

Mangin, E. 1964. Growth in length of three North American Sturgeon: *Acipenser oxyrhynchus*, Mitchill, *Acipenser fulvescens*, Rafinesque, and *Acipenser brevirostris* LeSueur. Limnology 15:968-974.

Matta, M. B., C. Cairncross, and R. M. Kocan. 1998. Possible effects of polychlorinated biphenyls on sex determination in rainbow trout. Environmental Toxicology and Chemistry: An International Journal 17(1):26-29.

McMahon, C. R., and G. C. Hays. 2006. Thermal niche, large-scale movements and implications of climate change for a critically endangered marine vertebrate. Global Change Biology 12(7):1330-1338.

Miller, T., and G. Shepherd. 2011. Summary of discard estimates for Atlantic sturgeon. Population Dynamics Branch, Northeast Fisheries Science Center 47.

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.

Moore, A., and C. P. Waring. 2001. The effects of a synthetic pyrethoid pesticide on some aspects of reproduction in Atlantic salmon (Salmo salar L.). Aquatic Toxicology 52(1):1-12.

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.

MSPO. 1993. Kennebec River Resource Management Plan.

Muhling, B. A., and coauthors. 2017. Potential Salinity and Temperature Futures for the Chesapeake Bay Using a Statistical Downscaling Disaggregation Framework [online]. Estuaries and Coasts.

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.

NCDMF. 2014. Application for an individual incidental take permit under the Endangered Species Act of 1973: Atlantic sturgeon (*Acipenser oxyrinchus*). North Carolina Division of Marine Fisheries.

Nellis, P., and J. Munro. 2007. Macrobenthos assemblages in the St. Lawrence estuarine transition zone and their potential as food from Atlantic sturgeon and lake sturgeon. American Fisheries Society Symposium 56:105-128.

Niklitschek, E. J. 2001. Bioenergetics modeling and assessment of suitable habitat for juvenlie Atlantic and shortnose sturgeons (*Acipenser oxyrinchus* and *A. brevirostrum*) in the Chesapeake Bay. University of Maryland at College Park.

NMFS. 1998. Recovery Plan for the Shortnose Sturgeon (*Acipenser brevirostrum*), Silver Spring, MD.

NMFS. 2013a. Endangered Species Act Section 7 Consultation Biological Opinion. Continued operations of the Indian Point Nuclear Generating Station, Units 2 and 3, pursuant to existing and proposed renewed operating licenses. Pages 163 *in* N. N. R. Office, editor.

NMFS. 2013b. Maintenance of the 40-foot Delaware River Federal Navigation Channel. Biological Opinion. Gloucester, Massachusetts.

NMFS. 2014a. Endangered Species Act Section 7 Consultation Biological Opinion. Continued operation of Salem and Hope Creek Nuclear Generating Stations. Pages 246 *in* N. G. A. R. F. Office, editor.

NMFS. 2014b. Endangered Species Act Section 7 Consultation Biological Opinion. Tappan Zee Bridge Replacement. Pages 199 *in* N. G. A. R. F. Office, editor.

NMFS. 2016. Endangered Species Act Section 7 Consultation Biological Opinion. Tappen Zee Bridge Replacement. Pages 203 *in*.

NMFS. 2017a. Endangered Species Act Section 7 Consultation Biological Opinion, CENAP-OP-R-2016-0181-39 DRP Gibbstown Shipping Terminal and Logistic Center. Pages 227 *in*.

NMFS. 2017b. Endangered Species Act Section 7 Consultation Biological Opinion. Tappan Zee Bridge Replacement. Pages 252 *in*.

NMFS. 2017c. Final Rule. Designation of Critical Habitat for the endangered New York Bight, Chesapeake Bay, Carolina, and South Atlantic Distinct Population Segments of Atlantic sturgeon and the threatened Gulf of Maine Distinct Population Segment of Atlantic sturgeon.

NMFS. 2017d. GARFO master ESA species table - marine mammals [Portable Document Format (.pdf)].

NMFS. 2017e. Greater Atlantic Regional Fisheries Office master ESA species table - Atlantic sturgeon.

NMFS. 2017f. Greater Atlantic Regional Fisheries Office master ESA species table - shortnose sturgeon.

NMFS. 2018. Biological Opinion: Deepening and Maintenance of the Delaware River Federal Navigation Channel. G. A. R. O. National Marine Fisheries Service, editor.

NMFS. 2020. Interactive North Atlantic Right Whale Sightings Map Tool.

NMFS, and USFWS. 1998. Status Review of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*).

NMFS, and USFWS. 2007a. 5-year review: Summary and evaluation, green sea turtle (*Chelonia mydas*). National Oceanic and Atmospheric Administration, National Marine Fisheries Service and U.S. Fish and Wildlife Service.

NMFS, and USFWS. 2007b. Loggerhead sea turtle (*Caretta caretta*) 5-year review: Summary and evaluation. National Marine Fisheries Service and U.S. Fish and Wildlife Service, Silver Spring, Maryland.

NMFS, and USFWS. 2013a. Hawksbill sea turtle (*Eretmochelys imbricata*) 5-year review: Summary and evaluation National Marine Fisheries Service and U.S. Fish and Wildlife Service, Silver Spring, Maryland.

NMFS, and USFWS. 2013b. Leatherback sea turtle (*Dermochelys coriacea*) 5-year review: Summary and evaluation. National Marine Fisheries Service and U.S. Fish and Wildlife Service, Silver Spring, Maryland.

NMFS, and USFWS. 2015. Kemp's ridley sea turtle (*Lepidochelys kempii*) 5-year review: Summary and evaluation. National Marine Fisheries Service and U.S. Fish and Wildlife Service, Silver Spring, Maryland.

Normandeau Associates, I. 2018. Report for entrainment characterization study at Eddystone Generating Station, January 2016 through December 2017.

NRC. 1990. Decline of the sea turtles: causes and prevention. National Academy Press, Washington, D. C.

NRC. 2011. Supplement to Biological Assessment to NMFS for Indian Point relicensing.

O'Herron, J. C., T. Lloyd, and K. Laidia. 1993. Movements of shortnose sturgeon (*Acipenser brevirostrum*) in the Delaware River. Estuaries 16:235-240.

Omoto, N., and coauthors. 2002. Effects of estradiol-17β and 17α-methyltestosterone on gonal sex differentiation in the F2 hybrid sturgeon, the bester. Fisheries Science 68(5):1047-1054.

Pace, R. M., and G. K. Silber. 2005. Simple analyses of ship and large whale collisions: Does speed kill? (Abstract). Pages 215-216 *in* Sixteenth Biennial Conference on the Biology of Marine Mammals, San Diego, California.

Payne, P. M., J. R. Nicolas, L. O'brien, and K. D. Powers. 1986. The distribution of the humpback whale, Megaptera novaeangliae, on Georges Bank and in the Gulf of Maine in relation to densities of the sand eel, Ammodytes americanus. Fishery Bulletin 84(2):271-277.

Payne, P. M., and coauthors. 1990. Recent fluctuations in the abundance of baleen whales in the southern Gulf of Maine in relation to changes in prey abundance. Fishery Bulletin 88(4):687-696.

Peake, S. J. 2004. Swimming and Respiration. Pages 147-166 *in* G. T. O. Lebreton, F. W. H. Beamish, and S. R. McKinley, editors. Sturgeons and Paddlefishes of North America. Kluwer Academic Press, Netherlands.

Pecl, G. T., and G. D. Jackson. 2008. The potential impacts of climate change on inshore squid: Biology, ecology and fisheries. Reviews in Fish Biology and Fisheries 18:373-385.

Pennsylvania Department of Environmental Protection. 2014. Authorization to Discharge Under the National Pollutant Discharge Elimination System Discharge Requirements for Industrial Wastewater Facilities.

Peterson, D. L., M. B. Bain, and N. Haley. 2000. Evidence of declining recruitment of Atlantic sturgeon in the Hudson River. North American Journal of Fisheries Management 20(1):231-238.

Peterson, D. L., and M. S. Bednarski. 2013. Abundance and size structure of Shortnose Sturgeon in the Altamaha River, Georgia. Transactions of the American Fisheries Society 142(5):1444-1452.

Polyakov, I. V., V. A. Alexeev, U. S. Bhatt, E. I. Polyakova, and X. Zhang. 2009. North Atlantic warming: patterns of long-term trend and multidecadal variability. Climate Dynamics 34(3-Feb):439-457.

Public Service Enterprise Group. 2002. PSEG Estuary Enhancement Program. Biological monitoring report - 2002 annual report.

Public Service Enterprise Group. 2003. PSEG Estuary Enhancement Program. Biological monitoring report - 2003 annual report.

Public Service Enterprise Group. 2004. PSEG Estuary Enhancement Program. Biological monitoring report - 2004 annual report.

Quattro, J., T. Greig, D. Coykendall, B. Bowen, and J. Baldwin. 2002. Genetic issues in aquatic species management: the shortnose sturgeon (*Acipenser brevirostrum*) in the southeastern United States. Conservation Genetics 3(2):155-166.

Robinson, R. A., and coauthors. 2005. Climate change and migratory species. Defra Research, British Trust for Ornithology, Norfolk, U.K. .

Rogers, S., and W. Weber. 1995. Movements of shortnose sturgeon in the Altamaha River system, Georgia. Contributions Series 57.

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.

Ross, A. C., and coauthors. 2015. Sea-level rise and other influences on decadal-scale salinity variability in a coastal plain estuary. Estuarine, Coastal, and Shelf Science 157 (Supplement C):79-92.

Ruelle, R., and C. Henry. 1992. Organochloride compounds in pallid sturgeon.

Ruelle, R., and K. D. Keenlyne. 1993. Contaminants in Missouri River pallid sturgeon. Bulletin of Environmental Contamination and Toxicology 50(6):898-906.

Sapp, A. 2010. Influence of small vessel operation and propulsion system on loggerhead sea turtle injuries. School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, Georgia.

Savoy, T. 2007. Prey eaten by Atlantic sturgeon in Connecticut waters. Pages 157 *in* American Fisheries Society Symposium. American Fisheries Society.

Scholz, N. L., and coauthors. 2000. Diazinon disrupts antipredator and homing behaviors in chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 57(9):1911-1918.

Schueller, P., and D. L. Peterson. 2010. Abundance and recruitment of juvenile Atlantic Sturgeon in the Altamaha River, Georgia. Transactions of the American Fisheries Society 139(5):1526-1535.

Secor, D. H. 2002. Atlantic sturgeon fisheries and stock abundances during the late nineteenth century. Pages 89-100 *in* American Fisheries Society Symposium. American Fisheries Society.

Secor, D. H., and E. J. Niklitschek. 2001. Hypoxia and Sturgeons.

Secor, D. H., and J. R. Waldman. 1999. Historical abundance of Delaware Bay Atlantic sturgeon and potential rate of recovery. Pages 203-216 *in* American Fisheries Society Symposium.

Shirey, C., C. C. Martin, and E. J. Stetzar. 1998. Abundance of sub-adult Atlantic sturgeon and areas of concentration within the Lower Delaware River. Final Report.

Simmonds, M. P., and W. J. Eliott. 2009. Climate change and cetaceans: Concerns and recent developments. Journal of the Marine Biological Association of the United Kingdom 89(1):203-210.

Simmonds, M. P., and S. J. Isaac. 2007. The impacts of climate change on marine mammals: Early signs of significant problems. Oryx 41(1):19-26.

Simpson, P. C., and D. A. Fox. 2007. Atlantic sturgeon in the Delaware River: contemporary population status and identification of spawning areas.

Smith, J. A., H. J. Flowers, and J. E. Hightower. 2015. Fall spawning of Atlantic Sturgeon in the Roanoke River, North Carolina. Transactions of the American Fisheries Society 144(1):48-54.

Smith, T., D. Marchette, and R. Smiley. 1982. Life history, ecology, culture and management of Atlantic sturgeon, Acipenser oxyrhynchus oxyrhynchus, Mitchill. South Carolina. South Carolina Wildlife Marine Resources. Resources Department, Final Report to US Fish and Wildlife Service Project AFS-9 75.

Smith, T. I. 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., E. K. Dingley, and D. E. Marchette. 1980. Induced spawning and culture of Atlantic sturgeon. The Progressive Fish-Culturist 42(3):147-151.

Smith, T. I. J., and J. P. Clugston. 1997. Status and management of Atlantic sturgeon, *Acipenser oxyrinchus*, in North America. Environmental Biology of Fishes 48(1-4):335-346.

SSSRT. 2010. A Biological Assessment of Shortnose Sturgeon (*Acipenser brevirostrum*). Report to National Marine Fisheries Service, Northeast Regional Office, Gloucester, MA.

Stein, A. B., K. D. Friedland, and M. Sutherland. 2004a. 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.

Stein, A. B., K. D. Friedland, and M. Sutherland. 2004b. 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.

Stetzar, E. J. 2002. Population characterization of sea turtles that seasonally inhabit the Delaware estuary. Delaware State University, Dover, Delaware.

Stevenson, J. 1997. Life history characteristics of Atlantic sturgeon (*Acipenser oxyrinchus*) in the Hudson River and a model for fishery management. Master's thesis. University of Maryland, College Park.

Stevenson, J., and D. Secor. 2000. Age determination and growth of Hudson River Atlantic sturgeon, *Acipenser oxyrinchus*. Fishery Bulletin 98(1):153-166.

Tommasi, D., and coauthors. 2015. Effect of envrionmental conditions on juvenile recruitment of alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) in fresh water: a coastwide perspective. Canadian Journal of Fisheries and Aquatic Sciences 72(7):1037-1047.

United States Geological Survey. 2018. National Water Information System. USGS 01463500 Delaware River at Trenton, NJ.

Van Dolah, R. F., D. R. Calder, and D. M. Knott. 1984. Effects of dredging and open-water disposal on benthic macroinvertebrates in a South Carolina estuary. Estuaries 7(1):28-37.

Van Eenennaam, J., and S. Doroshov. 1998. Effects of age and body size on gonadal development of Atlantic sturgeon. Journal of fish biology 53(3):624-637.

Vanderlaan, A. S. M., and C. T. Taggart. 2007. Vessel collisions with whales: The probablility of lethal injury based on vessel speed. Marine Mammal Science 23(1):144-156.

Waldman, J., C. Grunwald, J. Stabile, and 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., and coauthors. 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.

Wallin, J. M., M. D. Hattersley, D. F. Ludwig, and T. J. Iannuzzi. 2002. Historical assessment of the impacts of chemical contaminants in sediments on benthic invertebrates in the tidal Passaic River, New Jersey. Human and Ecological Risk Assessment 8(5):1155-1176.

Waring, C. P., and A. Moore. 2004. The effect of atrazine on Atlantic salmon (*Salmo salar*) smolts in fresh water and after sea water transfer. Aquatic Toxicology 66(1):93-104.

Webb, P. W. 1984. Form and function in fish swimming. Scientific American 251:72-82.

Weber, W. 1996. Population size and habitat use of shortnose sturgeon, *Acipenser brevirostrum*, in the Ogeechee River system, Georgia. University of Georgia, Athens, Georgia.

Welsh, S. A., M. F. Mangold, J. E. Skjeveland, and A. J. Spells. 2002. Distribution and movement of shortnose sturgeon (*Acipenser brevirostrum*) in the Chesapeake Bay. Estuaries 25(1):101-104.

Wildhaber, M. L., and coauthors. 2000. Natural and anthropogenic influences on the distribution of the threatened Neosho madtom in a Midwestern warmwater stream. Transactions of the American Fisheries Society 129(1):243-261.

Wilkens, J. L., A. W. Katzenmeyer, N. M. Hahn, J. J. Hoover, and B. C. Suedel. 2015. Laboratory test of suspended sediment effects on short-term survival and swimming performance of juvenile Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, Mitchill, 1815). Journal of Applied Ichthyology 31:984-990.

Willis-Norton, E., and coauthors. 2015. Climate change impacts on leatherback turtle pelagic habitat in the Southeast Pacific. Deep Sea Research Part II: Topical Studies in Oceanography 113:260-267.

Wirgin, I., and coauthors. 2015a. Origin of Atlantic sturgeon collected off the Delaware Coast during spring months. North American Journal of Fisheries Management 35:20-30.

Wirgin, I., and coauthors. 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., C. Grunwald, J. Stabile, and J. Waldman. 2007. Genetic evidence for relict Atlantic sturgeon stocks along the mid-Atlantic coast of the USA. North American Journal of Fisheries Management 27(4):1214-1229.

Wirgin, I., C. Grunwald, J. Stabile, and J. R. Waldman. 2010. Delineation of discrete population segments of shortnose sturgeon *Acipenser brevirostrum* based on mitochondrial DNA control region sequence analysis. Conservation Genetics 11(3):689-708.

Wirgin, I., L. Maceda, C. Grunwald, and T. King. 2015b. Population origin of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus* by-catch in US Atlantic coast fisheries. Journal of fish biology 86(4):1251-1270.

Ziegeweid, J. R., C. A. Jennings, D. L. Peterson, and M. C. Black. 2008. Effects of salinity, temperature, and weight on the survival of young-of-year shortnose sturgeon. Transactions of the American Fisheries Society 137:1490-1499.