National Marine Fisheries Service
Endangered Species Act Section 7

Biological Opinion

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Acronyms

BE – Biological Evaluation

CL – confidence limits

DC – direct current

DDE – dichlorodiphenyl dichloroethylene

DDT – dichloro-diphenyltrichloroethane

DO – dissolved oxygen

DPS – distinct population segment

EPA – Environmental Protection Agency

ESA – Endangered Species Act

GOM – Gulf of Maine

IPCC – Intergovernmental Panel on Climate Change

M – migratory

NARS – National Aquatic Resource Surveys

NMFS – National Marine Fisheries Service

NOAA – National Oceanic and Atmospheric Administration

NRSA – National Rivers and Streams Assessment

OPR – Office of Protected Resources

PBF – physical and biological feature

PCB – polychlorinated biphenyl

PCDD – polychlorinated dibenzo-p-dioxins

PCDF – polychlorinated dibenzofurans

RCP – representative concentration pathways

RPM – reasonable and prudent measure

SHRU – salmon habitat recovery unit

SR – spawning and rearing

TCDD – tetrachlorodibenzo-p-dioxin

TSS – total suspended solids

Units

A – amperes

cm^2 – square centimeters

ft^2 – square feet

Hz – Hertz

km – kilometers

km^2 – square kilometers

m – meters

m^2 – square meters

ppt – parts per thousand

V – volts

W – watts

μm – micrometers

μS – microsiemens

1 INTRODUCTION

The ESA of 1973, as amended (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 critical habitat. Federal agencies must do so in consultation with the NOAA's NMFS for endangered or threatened 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)).

Section 7(b)(3) of the ESA requires that at the conclusion of consultation, NMFS provides an 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 incidental take is expected, section 7(b)(4) requires NMFS to provide an incidental take statement that specifies the impact of any incidental taking and includes RPMs to minimize such impacts and terms and conditions to implement the RPMs.

This programmatic biological opinion considers the effects of the EPA's NRSA program. The NRSA is a recurring 2-year survey that takes places every 5 years as part of the NARS. The NRSA provides a comprehensive assessment for biotic and abiotic health of rivers and streams across the United States. Survey work is limited to April 1 to October 15, but the primary study index period is June through September 30. The EPA Office of Wetlands, Oceans, and Watersheds manages and coordinates these surveys between other EPA offices, states, territories, and other partners.

This consultation, programmatic biological opinion, and incidental take statement, 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. pt. 402), and agency policy and guidance was conducted by NMFS Office of Protected Resources, Endangered Species Act Interagency Cooperation Division (hereafter referred to as "we" or "us").

On July 5, 2022, the U.S. District Court for the Northern District of California issued an order vacating the 2019 regulations that were revised or added to 50 C.F.R. part 402 in 2019 ("2019 Regulations," see 84 FR 44976, August 27, 2019) without making a finding on the merits. On September 21, 2022, the U.S. Court of Appeals for the Ninth Circuit granted a temporary stay of the district court's July 5 order. On November 14, 2022, the Northern District of California issued an order granting the government's request for voluntary remand without vacating the 2019 regulations. The District Court issued a slightly amended order 2 days later on November 16, 2022. As a result, the 2019 regulations remain in effect, and we are applying the 2019 regulations here. For purposes of this consultation and in an abundance of caution, we considered whether the substantive analysis and conclusions articulated in the biological opinion and incidental take statement would be any different under the pre-2019 regulations. We have determined that our analysis and conclusions would not be any different.

This document represents the NMFS opinion on the effects of these actions on ESA-listed species and designated critical habitat. A complete record of this consultation is on file electronically with the NMFS OPR in Silver Spring, Maryland.

1.1 Background

The NRSA provides a comprehensive assessment for rivers and streams across the United States. The NRSA is a recurring survey that takes places every 5 years as part of the NARS. The NARS program also includes estuaries and coasts, lakes and wetland condition surveys, which are undergoing separate analyses. The 2020 survey represents the fourth NRSA since the inception of NARS.

The NRSA collects a variety of physical, chemical and biological measurements and samples from preselected sampling sites that are located at predetermined coordinates. The purpose of NARS is to generate unbiased assessments of the condition of water resources across the U.S. and identify key stressors to these systems. Each iteration of NRSA includes sites selected using a stratified, randomized design (probability sites); a subset of which are sites sampled in previous surveys. The NRSA is designed to answer the following questions about sample site conditions:

1. What percent of rivers and streams support healthy ecological communities and recreation?
2. What are the most common problems?
3. Are conditions improving or getting worse?
4. Are investments in water quality focused appropriately?

In answering these questions, NRSA provides important information about the range of biological taxa and related water quality, riparian habitat and in-stream habitat conditions. While NRSA does not target threatened or endangered species, some of the sites contain critical habitat and are occupied by ESA-listed species. The information collected can support protection and/or restoration efforts for these species and their habitat. Resource managers can use NRSA data to evaluate current restoration and protection efforts, place site-specific data into a broader national and regional context, and initiate additional exploration and research into why certain patterns or changes exist. States and others are currently using NRSA data and results to plan management actions, supplement their existing water monitoring programs, and address Clean Water Act reporting requirements. The surveys are also designed to help expand and enhance state and tribal monitoring programs. Through these surveys, states and Tribes have the opportunity to collect data that can be used to supplement their existing monitoring programs or to begin development of new programs. The EPA seeks collaborative opportunities with NMFS and other stakeholders for exploring the environmental conditions that are important to the recovery of listed species.

1.2 Consultation History

The following dates are important to the history of the current consultation:

- On March 22, 2023, the Services met with EPA to discuss this consultation. At this time, we identified additional information needed to make this a programmatic consultation instead of an individual consultation. We also identified additional conservation measures at this time.
- On March 31, 2023, EPA sent their initiation package to NMFS and requested formal programmatic consultation on the effects of their East Coast sampling sites. West Coast sites are addressed separately. The package was complete and consultation was initiated on the day it was received.
- On May 3, 2023, NMFS requested EPA provide updated information in Tables 3-1, 5-1, and 5-3 of the BE (EPA 2023).
- On May 10, 2023, EPA provided NMFS with an expanded table identifying the upper bounds on sampling in various locations to better evaluate the program.
- On May 25, 2023, NMFS requested clarification on the amount of sampling that may take place in Maryland and Virginia under this program.

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 C.F.R. §402.02).

An ESA section 7 assessment involves the following steps:

Description of the Proposed Action (Section 3), *Deconstructing the Action* (Section 3.2), and *Action Area* (Section 4): We describe the proposed action, all associated activities that are caused by the action, identify any chemical, physical, or biological modifications to land, water, or air (stressors) caused by the action and its associated activities, and describe the action area with the spatial extent of those stressors.

Status of Endangered Species Act Protected Resources (Section 5): We identify the ESA-listed species and critical habitats that are likely to co-occur with those stressors in space and time and evaluate the status of those species and habitats. In this section, we distinguish between those *Stressors that May Affect, but are Not Likely to Adversely Affect* ESA-protected resources

(Sections 5.1 and 5.2), and those that *May Affect, and are Likely to Adversely Affect* ESA-protected resources (Section 5.3).

Environmental Baseline (Section 6): We describe the environmental baseline in the action area as 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 consultation, 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 C.F.R. §402.02).

Effects of the Action (Section 7): We identify the number, age (or life stage), and sex 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 the extent of the PBFs of critical habitat exposed to stressors caused by this action. 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 the response of PBFs of critical habitat to the stressors to which they will be exposed. This is our response analysis.

Cumulative Effects (Section 8): 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).

Integration and Synthesis (Section 9): In this section, we add the *Effects of the Action* (Section 7) to the *Environmental Baseline* (Section 6) and the *Cumulative Effects* (Section 8), taking into account the status of the species, critical habitat, and recovery planning (Section 5.3), to formulate the agency's biological opinion as to whether the EPA can insure its proposed action is not 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 10): In this section, we concisely summarize our conclusions presented in the Integration and Synthesis section. 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 11) that specifies the amount or extent of take anticipated, RPMs to minimize the impact of the take, and terms and conditions to implement the RPMs (ESA section 7 (b)(4); 50 C.F.R. §402.14 (i)). We also provide discretionary *Conservation Recommendations* (Section 12) that may be implemented by the EPA (50 C.F.R. §402.14 (j)). Finally, we identify the circumstances in which *Reinitiation of Consultation* is required (Section 13; 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, Web of Science, literature cited sections of peer-reviewed articles, species listing documentation, and reports published by government and private entities. This programmatic biological opinion is based on our review and analysis of various information sources, including:

- Information submitted by the EPA
- Government reports (including NMFS biological opinions and stock assessment reports)
- NOAA technical memos
- 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 undergoing consultation in this programmatic biological opinion is EPA's NRSA program that assesses the health of U.S. rivers and streams every 5 years through a randomized sampling design. Our analysis considers the legal framework in which the NRSA operates, as well as the stressors generated by this action. The program samples rivers and streams with salinities ranging from 0 to 0.5 ppt. The length of the sampling reach is 40 times the wetted width of that section of water. Depending on water depth, there are wadable and non-wadable sites. Wadable sites are sampled by 4-5 people on foot, while non-wadable sites are sampled by the same number of people working from 2 vessels.

3.1 Program Framework

The discussion of programmatic framework considers the various aspects of the NRSA program. This explains the sampling anticipated in 2023-2024, and how the NRSA program will be carried out in the future.

3.1.1 Legal Framework

The EPA, under section 305(b) of the Clean Water Act, is required to assess the condition of the nation's waters. The EPA carries out the NRSA program on freshwater systems.

NRSA is conducted in partnership by the EPA Office of Wetland Oceans and Watersheds, Office of Research and Development, and regional offices, states, territories, and other partners. The survey coordination, project management, logistics, and quality assurance are managed by the Office of Wetland Oceans and Watersheds staff with contractor and Office of Research and Development technical support.

3.1.2 Collection Locations

The survey target region defines the aquatic habitat type and characteristics where field measurements and samples will be collected. The NRSA target areas consist of streams and rivers that have flowing water during the study index period, including major rivers and small streams. Sites must have > 50% of the reach length with standing water. Sites with water in less than 50% of the reach length are not part of the target population and are dropped. The target population excludes tidal rivers and streams up to head of salt (0.5 ppt or greater) and run-of-the-river ponds and reservoirs with greater than 7-day residence time.

EPA selects sampling locations (base sites) from the target population using a probability-based survey design to obtain data representative of the target population as a whole (Stevens and Olsen 2004). Probability-based survey designs are often used to determine the status of target populations or resources of interest. The probability-based approach allows data from the small subset of sampled sites to be applied to the larger target population in order to make assessments with known confidence bounds.

The NRSA site selection relies on 2 separate designs to address the dual objectives of (1) estimating current status, and (2) estimating change in status:

- Resample design applied to the previous and current NRSA sites (sites selected from previous surveys to be resampled); and
- New site design (newly selected sites).

The National Hydrography Dataset Plus High Resolution data layer is used to derive a list of sites for potential inclusion in NRSA. The survey design is explicitly stratified by state for both designs. The unequal probability categories are specific to the NRSA survey design and were used for the NRSA 2008-09, NRSA 2013-14, and NRSA 2018-19. In all cases, the categories are specific combinations of Strahler order categories (i.e., stream size and position along the headwater-to-river mouth continuum) and 9 NARS aggregated ecoregions (Figure 1). The design ensures that between 20 and 72 sites are included for each of the lower 48 states.

Figure 1. The 9 NARS Ecoregions of the Conterminous United States

Approximately 10% of the total NRSA sites during a 2-year sampling cycle are scheduled for repeated sampling (revisit of sites). Revisit samples are collected for quality assurance purposes including evaluation of the ability of an indicator to distinguish variability **among** sites from the variability **within** individual sites. The revisit will include the full set of indicators and associated parameters. The time period between the initial (Visit 1) and repeat visit (Visit 2) must be at least 2 weeks and should be as long as possible within the same sampling year. Of the 1,808 sites for the 2023-24 cycle, approximately 50% of the sites are new and 50% are previously sampled sites from NRSA 2018-19. An "oversample" list of additional sites was also generated to allow for replacement of non-target sites or sites that could not be sampled.

An element of the NRSA sampling is that field crews make every effort to not disrupt the main channel, riparian, and adjacent terrestrial habitats. The physical habitat sampling protocol documents several components of these habitats, as they are found when the crew arrives at the site. Crews are expected to leave no trace of the sampling visit by avoiding trampling and other activities that would damage the habitat and are required to remove all trash that is generated from the sample collection. The field collection protocol for each indicator is explained in more detail in the NRSA Field Operations Manual (EPA 2023).

3.1.3 Methods

Field methods for the NRSA are designed to be completed in 1 field day for most sites. Depending on the time needed for both the sampling and travel for the day, an additional day may be needed to complete sampling or for pre-departure and post-sampling activities (e.g., cleaning equipment, repairing gear, shipping samples, and traveling to the next site). Remote sites with lengthy or difficult approaches may require more time. Sampling may also take place on more than 1 day if it is delayed due to rain or other hazardous weather events.

A field crew for a wadable site will typically consist of 4 or 5 people. Typically, in wadable sites, 2 crew members will work on the "habitat" crew, and 2 or 3 will work on the "fish" crew.

A field crew for a non-wadable site will typically consist of 4 or 5 people in 2 boats. A minimum of 2 people is always required in a boat to execute the sampling activities and to ensure safety. Typically, at non-wadable sites, 2 crew members will work in the "habitat" boat, and 2 or 3 will work in the "fish" boat. One crew member on each boat is primarily responsible for boat operation and navigation.

3.1.3.1 Physical Habitat Assessment

Physical habitat data are collected from a reach length 40 times the mean wetted width at the time of sampling, with a minimum of 492 ft (150 m) and a maximum of 2.485 miles (4 km). Measurement points are systematically placed to statistically represent the entire reach. Waterbody depth and wetted width are measured at more tightly spaced intervals at and between the transects, whereas channel cross section profiles, substrate, bank characteristics, and riparian vegetation structure are measured at 11 transects. Riparian observations are made from the stream or river while standing in the channel (wadable sites) or on the vessel (non-wadable sites).

At wadable sites, the physical habitat methods are made up of the following components: riparian and channel characterization, wetted width, thalweg profile, woody debris tally, and assessment of channel constraint and floods. Most channel and riparian features are characterized on 11 cross-sections and pairs of riparian plots spaced at 4 channel-width intervals (i.e., transect spacing = 1/10th the total reach length). The thalweg profile measurements are spaced evenly over the entire reach but must be sufficiently close together that they do not miss deep areas and major habitat units.

At non-wadable sites, field data collection for the physical habitat assessment is accomplished in a single float down each sampling reach. The physical habitat methods are made up of the following components: thalweg profile, littoral/riparian cross-sections, and assessments of the entire reach.

3.1.3.2 Benthic Sampling

The NRSA benthic macroinvertebrate sampling protocol is a multihabitat sampling approach designed to collect a representative sample of the benthic macroinvertebrate assemblage from throughout the sample reach. There are 2 sampling protocols, 1 for wadable systems and 1 for non-wadable systems. For both protocols, benthic macroinvertebrate sub-samples are collected at

11 transect locations throughout the sample reach, with transects occurring at every 1/10th of the total sample reach length. The area of disturbance is relatively small (i.e., wadable = 1 ft^2 per transect and a total area of 11 ft^2 [1.02 m^2]; non-wadable = 0.3 m^2 per transect and a total area of 3.3 m^2). The NRSA method is quick (30 seconds per transect). Individual samples are placed in a 500 μm mesh sieve bucket placed inside a larger bucket full of site water while sampling to carry the composite sample to the next transect. Multiple habitats are encountered and sampled using this approach. Habitats include various types of bottom substrate, as well as woody debris, macrophytes, and leaf packs. Once the composite sample from all stations is sieved and reduced in volume, the sample is placed in a 1-liter jar and preserved with 95% ethanol.

Crews collect periphyton from the nearshore shallows at each of the sampling stations located on the 11 cross-section transects established within the sampling reach. The samples are taken at the same transect location as the benthic macroinvertebrate samples immediately after the benthic macroinvertebrate samples have been collected. Crews collect the substrate selected for sampling from a depth no deeper than 1.6 ft (0.5 m) and collect the periphyton from 0.01 ft^2 (12 cm^2) area on the upper surface of that substrate. The process for collecting the sample at different substrate sizes is in the Field Operations Manual.

3.1.3.3 Fish Assemblage Collection

The NRSA fish sampling method is designed to provide a representative sample of the general fish community at the site. It is intended to accurately represent species richness, species guilds, relative abundance, size, and presence of anomalies. The method is not designed to collect individuals of all species present (e.g., rare species). The intended uses of the fish assemblage data are to calculate predictive models of multimetric indicators and, possibly, Observed/Expected taxa richness. In addition, the fish assemblage data provide a starting point for developing potential indicators of ecosystem services related to fish. Crews are to collect a target of 500 fish per site selected for fish sampling.

Because NRSA has 2 broad method categories for sites, wadable vs. non-wadable, the approach for electrofishing is slightly different between the 2 (detailed in the sections below). However, electrofishing is only conducted during “normal” summer-fall water flow and clarity conditions. High flows are avoided for safety reasons and the reduction in sampling efficiency. Periods of high flow increase turbidity, floating debris such as twigs, tree limbs, flotsam, and trash, which reduces the ability of netters to see stunned and immobilized fish. If high flow conditions prevail, sampling is delayed until flows and water clarity return to seasonal, low flow norms.

<u>Wadable site: fish assemblage collection</u>

Wadable site (Figure 2) sampling crews consist of at least 2 crew members: 1 electrofisher operator, 1 dip-netter (1/4 inch (.635 cm) mesh dip net), and an optional bucket carrier (who may also have a net to aid in transferring fish to the livewell). For all wadable sites, sampling in an upstream direction (i.e., from the downstream end of the reach), allocating effort (electric current time) within subreaches (areas between the cross-section transects). The fish are processed (i.e., identified, counted, checked for abnormalities, length estimated) at the end of each subreach to minimize mortality and stress to fish. At smaller streams (mean channel width rounded to the nearest meter and recorded on the stream verification form is less than or equal to 39.3 ft [12 m]), sample all available habitats over the entire sampling reach (40 channel widths). At large wadable streams (mean channel width is greater than or equal to 42.7 ft [13 m]), the effort is focused on habitats along the stream margins. At large wadable streams, the minimum sample reach is 20 channel widths (5 subreaches).

Wadable streams are sampled with pulsed DC electrofishing rigs ranging from battery powered backpack units to generator powered pram mounted or bank set units. Wisconsin ABP-2 or Halltech HT-2000 battery powered backpack electrofishing units are used in the smallest wadable streams where the use of the generator powered units is not necessary. These units operate on approximately 200 watts of power at a peak of 250 V DC at 1-10 A. The effective range of the field is less than 3.3-ft (1-m) diameter and depths of a few cm for the backpack units. The Smith-Root 2.5 GPP unit produces up to 1000 V DC at 2-8 A depending on the relative conductivity and the anode ring size. This unit is also used in low conductivity (under 50-100 µS/cm) streams. The T&J 1736 DCV unit produces 125-250 V DC at 2-4 A and is used in higher conductivity streams (over 100 µS/cm). The effective range is 9.8-13.1 ft (3-4 m) and depths of 3.3 ft (1 m) for the 2.5 GPP unit to 6.6-9.8 ft (2-3 m) and depths under 3.3 ft (1 m) for the T7J unit. The pulse configuration for all units consists of a fast rise, slow decay wave that can be adjusted to 30, 60, or 120 Hz (pulses per second). Generally, electrofishing is conducted at 60 or 120 Hz, depending on which selection is producing the optimum combination of voltage and amperage output and most effectively and safely stunning fish. Total button time (time when electric current is present in the water) will vary between 500 and 700 seconds per subreach.

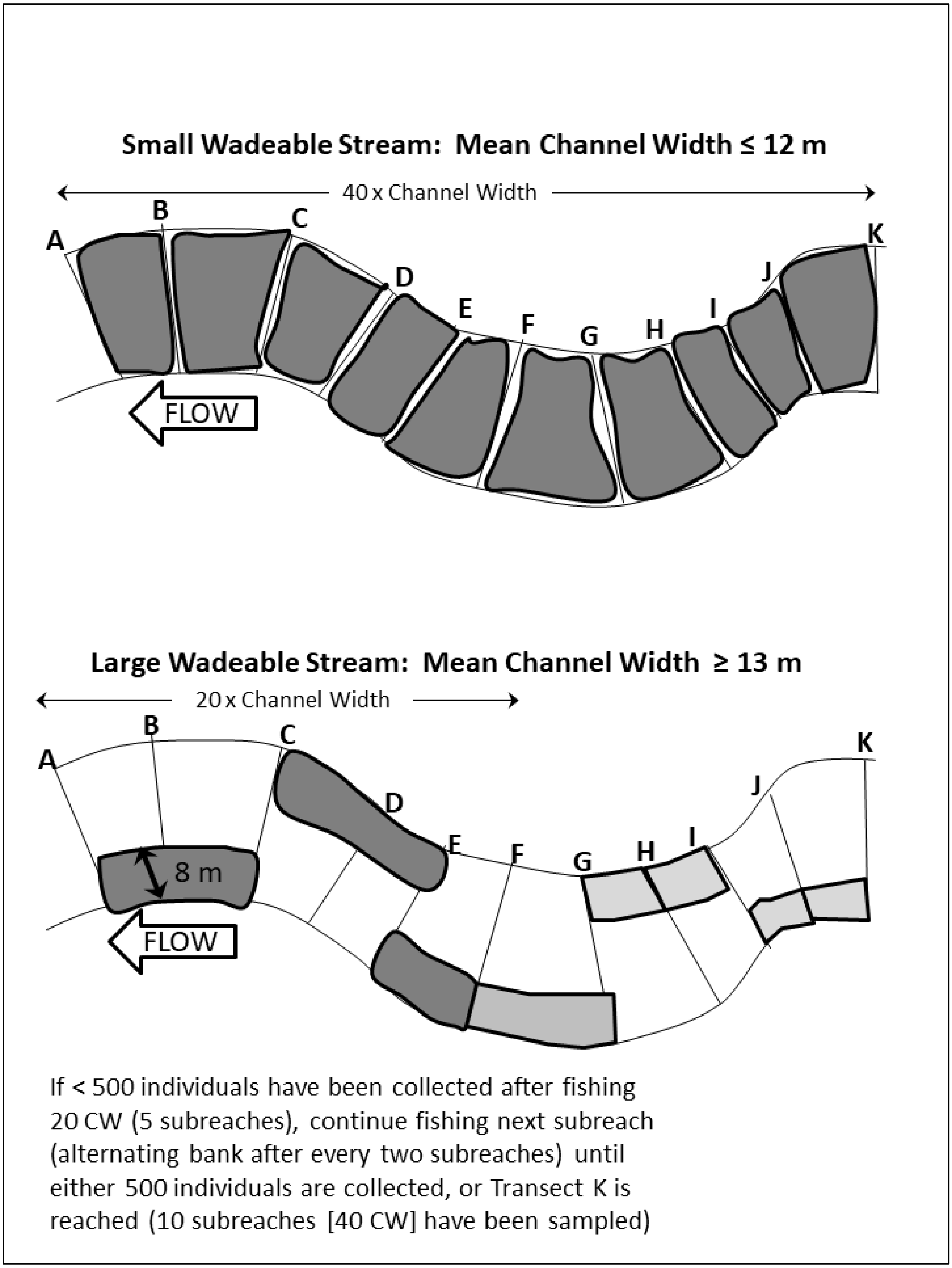

Figure 2. Reach layouts for fish sampling at wadable sites: Dark shaded areas indicate the minimum length of the fish sampling reach and light shaded areas are sampled as needed to meet the required 500 individuals

Non-wadable site: fish assemblage collection

Non-wadable or boatable fish sampling sites (Figure 2) are generally located immediately adjacent to the bank or submerged features such as bedrock ledges and gravel shoals. For the NRSA protocol, the first bank is selected randomly and then alternated every 2-3 transects within a 40 times mean width-long site. Sampling time is specified at a maximum of 700 seconds per transect and a minimum of 3,500 seconds per site as the cumulative time the electric current is applied to the water. A 0.62-mile (1-km) site typically requires between 3,600 and 5,400 seconds of "current time," i.e., the cumulative time that the electric field is activated within a site (the netters operate a foot pedal switch, current is applied intermittently). The variance in time fished is affected by site navigability, current velocity, current types, boat maneuverability, and the number of fish collected. Consequently, the maximum amount of time that electricity could be applied at any site would be approximately 120 minutes, however this is a rare event. In larger rivers, a sampling crew may spend 6-8 hours on the river due to river crossing time from transect to transect and time spent sorting the fish between transects.

Sampling Small Rivers (less than 39.7-ft [12-m] wide)

For small rivers, crews move the boat (or raft) within each subreach to sample both shorelines as well as the mid-channel areas (similar to what is done for a small wadable stream using a backpack electrofishing unit). Based on NRSA protocol, fish sampling reach sizes will be between 150 and 480 m. Each subreach will then be between 15 and 48 m each. If islands are encountered, crews fish bank to bank, including both sides of the island. Total button time will range from 500-700 seconds per subreach. Crews do not need to expend equal button time among the 10 subreaches but can devote more button time to subreaches with more complex habitat.

Sampling Large Rivers (over 42.7-ft [13-m] wide)

For large rivers, crews sample along the shoreline only, starting on the same bank as the habitat crew, the fishing crew move to the opposite bank after every 2 subreaches. Prior to sampling each subreach they determine the most appropriate gear for the subreach (e.g., boat or raft vs. barge or backpack electrofishing units, or seines if the conductivity is too high or too low). Based on the NRSA protocol, fish sampling reach sizes will be between 260 and 4,000 m. Each subreach will be 1/10 of the sampling reach; a minimum of 5 subreaches must be sampled. If islands are encountered, crews only fish the edge of the island that occurs along the main channel. Button time is roughly 700 seconds per subreach. Depending upon the habitat complexity, crews may vary the distance actively fished to allocate the available time with electrical current throughout the subreach. The minimum fish number is 500 unless all 10 subreaches have been fished. After fishing 5 subreaches, if 500 fish have not been collected, crews add subreaches 1 at a time (fishing them in their entirety) until 500 fish are collected or all 10 subreaches (40 channel widths) have been fished.

Backup Fishing Methods: Sampling with "Secondary" Gear

Crews may use hook-and-line as the secondary fish collection methods at sites when electrofishing is not possible (except in Atlantic salmon areas, see Chapter 7 of the BE; EPA 2023). In general, electrofishing does not occur if 1) the site conditions prevent electrofishing (ambient conductivity is too high or too low for electrofishing unit, safety concerns etc.), or 2) site access does not support electrofishing (e.g., no access for boat or raft). Use of hook-and-line is only to collect the 2 fish necessary for the mercury tissue analysis. Hook-and-line would not be used to collect fish assemblage data, only electrofishing is approved for that data collection. It is rare for fishing not to take place in a non-wadable waterbody, it is slightly more likely in a wadable waterbody.

Community Assemblage: Fish Processing

"Processing" fish means to handle, identify, measure, and count each individual caught. During community assemblage fish sampling, netted fish are immediately placed in a bucket or an on-board livewell for processing. Whenever possible, water is aerated to maintain adequate DO levels in the water and to minimize mortality. Every reasonable effort is made to minimize holding and handling times of fish including processing at the end of each subreach to minimize mortality and stress to fish. However, if fish show signs of stress (e.g., loss of righting response, gaping, gulping air, excessive mucus) in the middle of a subreach, crews are directed to change the water in the livewell or stop fishing and initiate processing.

Crews identify and process individuals over 1 inch (25 mm) in total length. Only crew members designated as "taxonomic specialists" by EPA regional coordinators can identify fish species. Ideally, fish are only handled once. Taxonomic specialists identify individual fish to species, examine individual fish for external anomalies, and estimate the total length. The assessment of the body also allows the cataloging of any external injuries to an ESA-listed fish that may have been caused by NRSA sampling methods. Crews do not process individuals with a total length under 25 mm (1 inch) because these are likely young-of-year individuals that cannot be identified confidently to species and these are therefore released immediately. After processing, fish are released in a location that prevents the likelihood of their recapture. Furthermore, special handling procedures included in conservation measures (Chapter 7 of the BE; EPA 2023) will be employed for species of concern as well as any additional measures required by state and Federal agencies.

While ESA-listed species are not targeted by NRSA, it is possible that ESA-listed species could be netted using the identified fishing methods. Crews attempt to identify and enumerate any fish species they are able to net, including if they are listed fish species. Crews process and release ESA-listed species as soon as possible after identification and fish recovery time. Tissue samples are never taken from ESA-listed species. Conservation measures limiting holding and handling of ESA-listed species have been established in Section 7.4 of the BE (EPA 2023) and are incorporated by reference in this programmatic biological opinion.

3.1.3.4 Site Cleanup and Invasive Species Precautions

All equipment and gear must be cleaned and disinfected between sites to reduce the risk of transferring nuisance species and pathogens. Field crews must be aware of local and regional invasive or nuisance species of concern and take appropriate precautions to avoid transfer of these species.

Crews inspect all equipment and vehicles, such as nets, boat trailer, motors, and waders, and clean off any plant and animal material. Crews then rinse equipment and boat with a 1% - 10% bleach solution or other specialized disinfectant to prevent the spread of exotics. Crews clean up all waste material caused by crew presence/activity and dispose of or transport it out of the site, if a trash can is not available.

Before arriving at the next site, if a commercial car wash facility is available, crews are to wash the vehicle, boat, and trailer and rinse thoroughly (hot water pressurized rinse with no soap).

Details on the decontamination protocols, including disposal, for all sampling equipment are found in the NRSA 2023-24 Field Operation Manual.

3.1.4 Fish Collections in Rivers with ESA-Listed Species

This programmatic biological opinion considers sampling of rivers from Maine to Florida. Coastal rivers in these areas have GOM DPS Atlantic salmon (*Salmo salar*); shortnose sturgeon (*Acipenser brevirostrum*); and GOM DPS, New York Bight DPS, Chesapeake Bay DPS, Carolina DPS, and South Atlantic DPS Atlantic sturgeon (*A. oxyrinchus oxyrinchus*). Table 1 shows the extent of past sampling in various habitats, including the number of individuals captured each sampling cycle, the number of sampling locations proposed for 2023-2024, and the maximum number of future sites that will be assessed in the next 20 years.

The location of sampling areas, as planned for the 2023-2024 sampling cycle, in GOM Atlantic salmon range is shown in Figure 3. During this cycle, there are 20 base sites, 1 revisit site, and 5 handpicked locations. In future years, as many as 31 sampling sites within GOM Atlantic salmon habitat may be selected. During the 2008-2009 cycle, the fewest sampling sites in GOM Atlantic salmon habitat were selected (n = 11). No training will take place in the GOM Atlantic salmon range to avoid unnecessary risks.

The location of sampling areas planned for the 2023-2024 sampling cycle in GOM DPS, New York Bight DPS, and Chesapeake Bay DPS Atlantic sturgeon ranges are shown in Figure 4 and planned sampling locations in Carolina DPS and South Atlantic DPS Atlantic sturgeon range are shown in Figure 5. There are 20 planned sampling locations within the 5 Atlantic sturgeon DPSs. The past sampling intensity in each of these DPS ranges is shown in Table 1 (n = 17, 22, and 22) along with the maximum amount of sampling that would occur in any sampling cycle (n = 35). There are 3 possible training locations identified in Atlantic sturgeon habitat: Raritan River, New Jersey; St. Marys River, Florida; and Ogeechee River, Georgia.

The location of sampling areas planned for the 2023-2024 sampling cycle in shortnose sturgeon range is shown in Figure 6. This cycle, there are 22 planned sampling events in shortnose sturgeon habitat, but in the past have been as few as 20 and in the future there could be as many as 28. The only potential training location in shortnose sturgeon habitat is the Ogeechee River, Georgia location identified for Atlantic sturgeon.

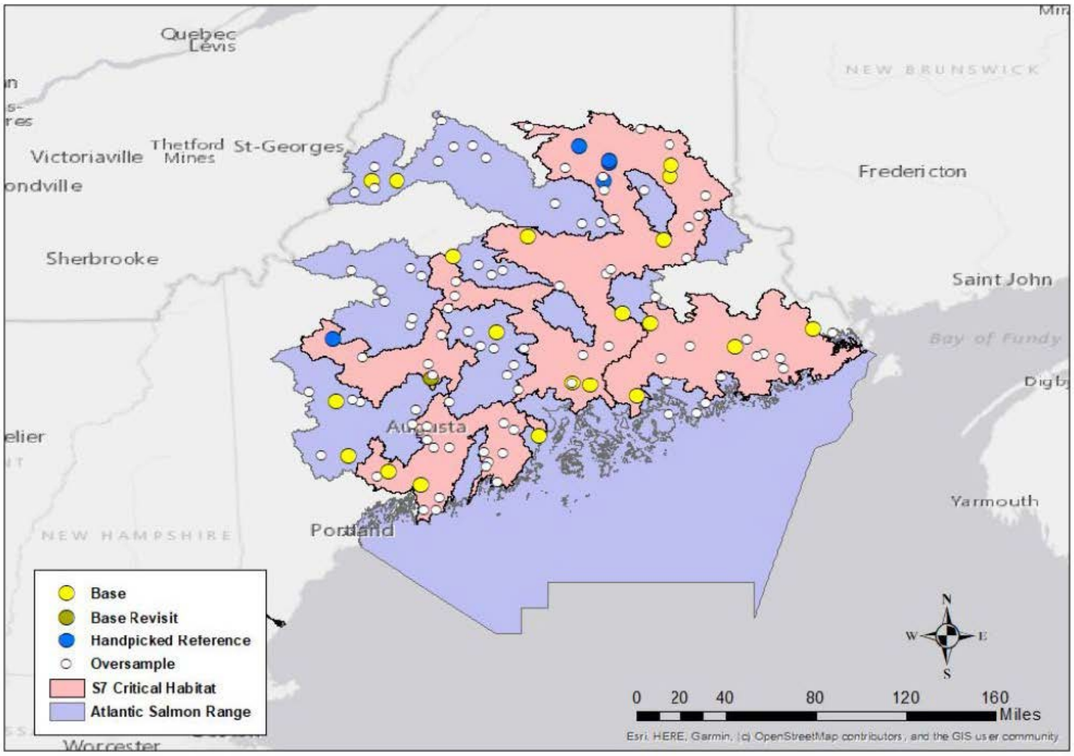

Figure 3. The GOM DPS Atlantic salmon range, critical habitat, and 2023-2024 planned sampling locations

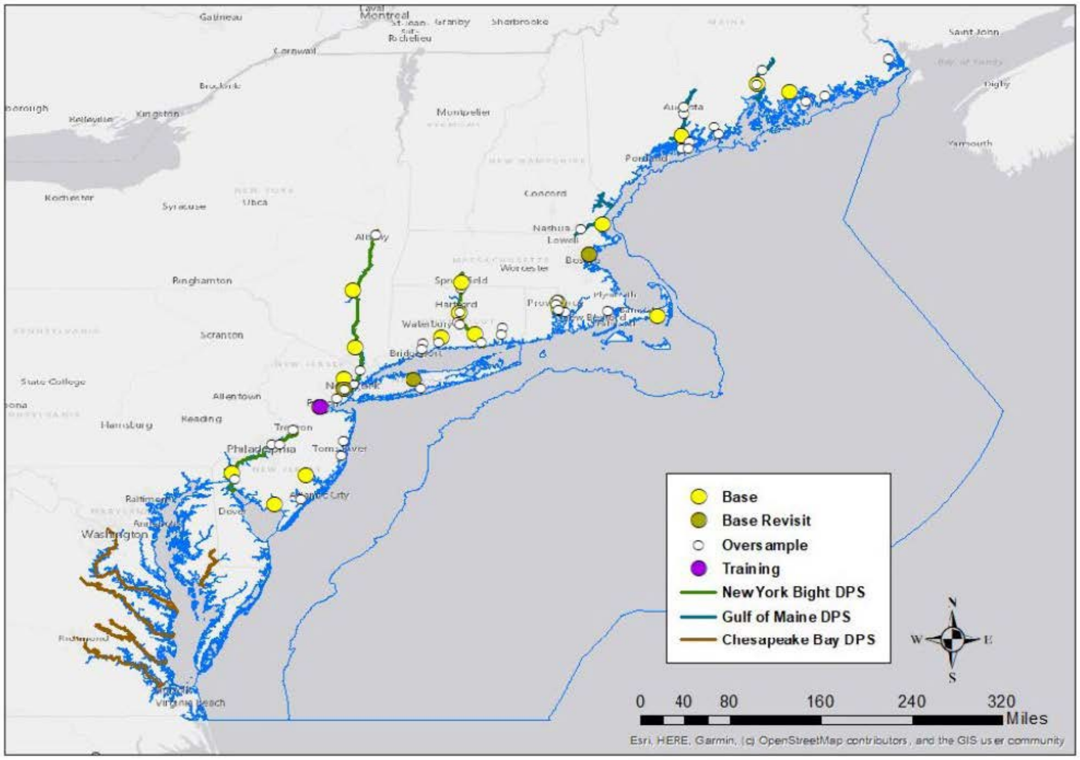

Figure 4. The range (blue) of the GOM, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon and critical habitat for each DPS along with sampling locations for the 2023-2024 sampling cycle

Table 1. ESA-listed species considered in this program, including limitations on the maximum number of sampling locations that will occur within their ranges

Species	Survey Year	Encounters		Sites in Species Range		2023-24 Sites	Maximum Future Sites
		Number	Sites (state)	Number	State		
GOM Atlantic Salmon	2008-09	62	5 (ME)	11	ME	26	31
	2013-14	113	7 (ME)	22	ME		
	2018-19	22	2 (ME)	16	ME		
GOM Atlantic sturgeon	2008-09	0	0	5	MA, ME	5	6
	2013-14	0	0	3	ME		
	2018-19	0	0	1	ME		
NY Bight Atlantic sturgeon	2008-09	0	0	15	CT, MA, NJ, NY	13	19
	2013-14	0	0	16	CT, NJ, NY		
	2018-19	0	0	15	CT, NJ, NY		
Carolina Atlantic sturgeon	2008-09	0	0	2	NC	0	5
	2013-14	0	0	2	NC		
	2018-19	0	0	1	NC		
South Atlantic Atlantic sturgeon	2008-09	0	0	0	FL	2	5
	2013-14	1	1 (GA)	1	FL		
	2018-19	0	0	0	FL		
Shortnose sturgeon	2008-09	0	0	23	CT, MA, ME, NC, NJ, NY	22	28
	2013-14	1	1 (MA)	23	CT, MA, ME, NC, NJ, NY		
	2018-19	0	0	20	CT, MA, ME, NC, NJ, NY		

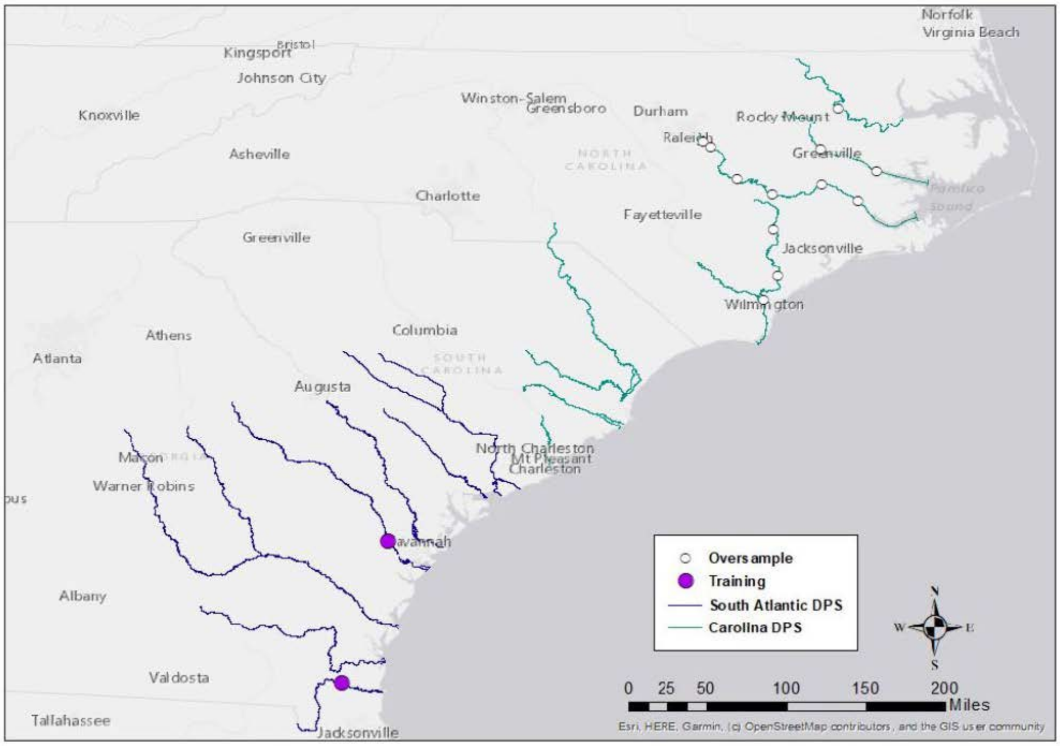

Figure 5. Rivers occupied by the Carolina and South Atlantic DPSs of Atlantic sturgeon along with planned sampling locations for the 2023-2024 cycle

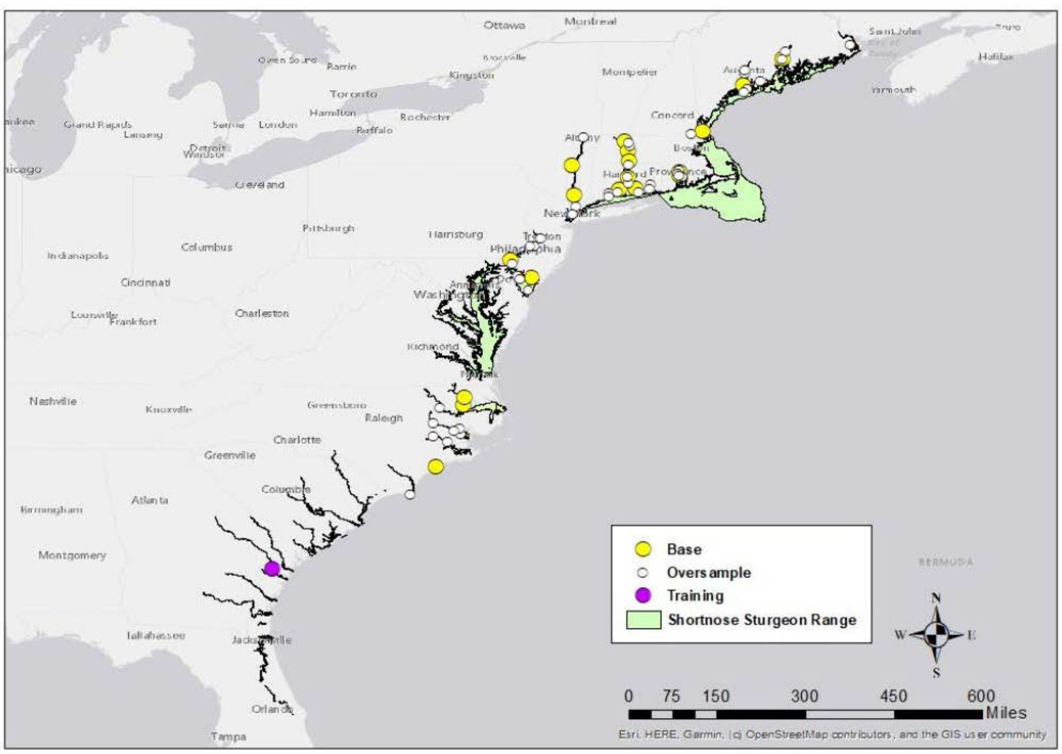

Figure 6. Waters occupied by shortnose sturgeon with planned sampling locations for the 2023-2024 cycle

3.1.5 Programmatic Reporting

EPA will provide field crew leads with the site-specific ESA species lists that were produced during technical assistance and presented in the BE. Crew leads are responsible for establishing awareness of the Federally-listed species and their critical habitats that have the potential to occur at or near a given sampling site. The NRSA conservation measures identified in the BE (see Section 7, EPA 2023) instructs crews to minimize risks to listed species and their critical habitats and to avoid the take of ESA-listed taxa while implementing the collection protocols (e.g., gently return any listed species to their habitat if they are unintentionally collected; process listed fish as soon as possible). The expectations of EPA field crews will be reinforced at the regional field and virtual trainings.

The BE, the Federal Field Crew ESA Requirement document, and this programmatic biological opinion will be shared with the EPA crews. The NRSA ESA lead will clearly communicate the conservation measures, RPMs, allowable incidental take, and reporting requirements to the field crews. Field crew communication and reporting expectations will be established so that the cumulative count of encounters with a species will be regularly updated and made available to all EPA crews to be aware of reinitiation triggers identified in Section 13 of this programmatic biological opinion.

EPA crews are required to report all known encounters with ESA-listed species within the Federal ESA Field Form in the NRSA app. This form documents the species, number of individuals, encounter type, and disposition after encounter, and includes a text box to further describe the encounter. Drop downs include all ESA-listed species in the action area, encounter type (observed at site, no interaction, handling, injured, but non-lethal, death/lethal injury, other) and disposition after encounter (unharmed, injured, dying, dead). Field crews are able to add as many species/rows as needed on a single form. Crews must submit the app data as soon as possible but no later than 1-week after the encounter unless specified otherwise by the EPA or NMFS. If crew activities result in dead or injured ESA-listed species, the crews must contact the NRSA ESA Lead or the NRSA Survey Lead for further instructions as soon as possible (preferably while still at the site but within 24-hours of death or injury of the animal).

3.1.6 Conservation Measures

Conservation measures are identified and explained in Section 7 of the BE (pages 44 through 50 of EPA 2023). They are incorporated by reference as components of the proposed action in this programmatic. The conservation measures address different stages of the research process: reconnaissance, site selection, what to do in areas with ESA-listed species, avoiding species when on-site, general sampling measures, and, finally, taxa-specific conservation measures. These measures also include following standard operating procedures for juvenile Atlantic salmon sampling by electrofishing in wadeable streams, and adhering to relevant time-of-year restriction (no sampling after September 30) and temperature thresholds (no sampling above 23°C or below 6°C).

3.2 Deconstructing the Action

For the purposes of this assessment of the NRSA program, this section identifies all of the physical, chemical, and biological changes caused by this program that are likely to modify land, water, and air (stressors). These changes to the environment that are caused by the actions taking place under this program will be used to define the action area.

3.2.1 Capture during sampling

The EPA intends to capture target species. The EPA will use electrofishing as their primary sampling gear and, when electrofishing cannot be used, hook-and-line sampling will be conducted. The use of hook-and-line sampling will only be to collect 2 fish needed for tissue sampling in survey areas outside of the geographic area designated for ESA-listed GOM DPS Atlantic salmon (Figure 3), and therefore will not affect GOM DPS Atlantic salmon. Both gears proposed for this research could result in the incidental capture of listed species. Different gears cause different levels of stress associated with the capture. Electrofishing stuns fish through a direct current, generally resulting in tetany, where the fish experiences muscle spasms and is unable to swim and floats to the surface. Fish with larger surface-to-body ratios may experience greater exposure to electrical currents in the water. Hook-and-line sampling can damage mouth parts, and the process of retrieving the fish may induce a stress response. Hook-and-line sampling rarely results in the capture of a sturgeon species.

3.2.2 Vessel strike, anchor strike, and vessel noise

Vessels interactions with sturgeon and salmon can be lethal. The vessels are small and move at high speeds between the launch and sample location, but will anchor and turn off the motor during sampling. The vessels have minimal draft, meaning benthic species like sturgeon are unlikely to be near vessels. Salmon are more likely to be present near the surface.

Benthic species could be subject to anchor strikes if they are in the wrong place at the wrong time. Anchors will be used to hold the vessels at the sampling site.

Vessel noise could also elicit a stress response. Small research vessels generate a minimal amount of sound but, as that sound source moves through the water, listed species are expected to detect it and respond in some way. The response may range from minimal movements to stay in the area but away from the sound source, movement towards the sound source, or leaving the area.

3.2.3 Benthic sampling gear, prey removal, and turbidity

The benthos will be sampled along transects, resulting in 11 benthic samples being collected at each sampling location. Benthic samplers are each 1 ft^2 (0.09 m^2) and could directly strike a listed species or generate temporary turbidity plumes that could affect respiration. Grab samples taken from vessels are more likely to strike an endangered fish than a grab sample taken in wadable waters. For smaller salmon and sturgeon, it is also possible that a fish could be collected during sediment collection.

In addition to direct risks posed by benthic sampling, each sample is intended to collect macroinvertebrates and periphyton, both of which could be sources of nutrition for ESA-listed species.

Walking in streams, pulling up anchor, and taking benthic samples will temporarily resuspend sediment and increase turbidity downstream of the site. Some suspension of fine materials and turbidity in the water column is likely to occur. Fine sediment deposited in salmonid spawning gravel can reduce interstitial water flow, leading to depressed DO concentrations during egg development and early emergence, which could result in an overall reduction of juveniles. All suspended sediments that settle out in sturgeon habitat could cover existing hard bottom substrate essential to successful reproduction.

3.2.4 Introduction of Non-Native species

Operation of vessels or wearing submersible clothing in multiple waterbodies poses the risk of moving species between systems. In locations where a species is introduced where it did not previously exist, a new population could be established, altering food web dynamics, interspecies competition, and resource allocation or availability. It is particularly easy to transfer species on boots or waders with felt soles (Root and O'Reilly 2012), where animals can be unknowingly moved from one location to another. The other main vector of introduction is from bilge tanks of small vessels or fouling on the hulls (Johnson et al. 2001).

Aquatic invasive species can cause a wide range of effects to listed species. It is possible some introduced species are a food resource for some species with beneficial effects. Others may be competitors, predators, disease vectors/transmitters, or have no ecological interactions at all. The range of potential effects caused by invasive species can span from beneficial to catastrophic. Because of the potentially adverse effects of introducing non-native species, the EPA has established an entire document for Field Operating Procedures (EPA 2023) that details how to treat vessels, gear, and personnel between locations.

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 proposed action is a program that samples freshwater rivers and streams along the East Coast of the United States. The action area is all freshwater systems with a salinity below 0.5 ppt from Maine to Florida.

5 Status of Endangered Species Act Protected Resources

This section identifies the ESA-listed species that potentially occur within the action area affected by the NRSA program. It then summarizes the biology and ecology of those species and what is known about their life histories in the action area. The ESA-listed species and designated critical habitat potentially occurring within the action area are shown in Table 2 along with their regulatory status.

Table 2. ESA- listed species and critical habitat that may be affected by the EPA's NRSA program

Species	ESA Status	Critical Habitat	Recovery Plan
Shortnose sturgeon (*Acipenser brevirostrum*)	E – 32 FR 4001	-- --	63 FR 69613
Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*)			
Gulf of Maine DPS	T – 77 FR 5880	82 FR 39160	-- --
New York Bight DPS	E - 77 FR 5880	82 FR 39160	-- --
Carolina DPS	E – 77 FR 5914	82 FR 39160	-- --
South Atlantic DPS	E – 77 FR 5914	82 FR 39160	-- --
GOM Atlantic salmon (*Salmo salar*)	E – 74 FR 29344	74 FR 39904	USFWS and NMFS 2019

5.1 Stressors that May Affect, but are Not Likely to Adversely Affect

As discussed earlier, the stressors considered in this programmatic biological opinion are the physical, chemical, and biological changes to land, water, and air caused by implementing the program. NMFS uses 2 criteria to identify the ESA-listed species or critical habitat that are not likely to be adversely affected by the stressors caused by the proposed action or the stressors caused by activities that only occur because of the proposed action.

The first criterion is exposure, or some reasonable expectation of a co-occurrence of any stressor(s) resulting from implementing the program and ESA-listed species or designated critical habitat. The second criterion is the probability of a response given exposure.

An action warrants a "may affect, not likely to adversely affect" finding when its effects are wholly beneficial, discountable, or insignificant. *Wholly beneficial* effects have an immediate positive effect without any adverse effects to the species or habitat. Wholly 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. *Discountable* applies to the likelihood of exposure to a stressor. A determination of discountable would mean that exposure to a stressor is extremely unlikely to occur to the listed species or critical habitat. Based on best judgment, a reasonable person would not expect a listed species or critical habitat to be exposed to a particular stressor. A determination of *insignificant* relates to the response of exposed individuals where the response would be immeasurable or undetectable or an impact to the conservation value of a physical or biological feature of critical habitat would be immeasurable or undetectable. Based on best judgment, a reasonable person would not be able to meaningfully measure, detect, or evaluate insignificant effects on the listed species and critical habitat.

If we conclude that the likelihood of an ESA-listed species or designated critical habitat being exposed to a stressor is discountable, we must also conclude that the species or critical habitat is not likely to be adversely affected by that stressor. Likewise, ESA-listed species or designated critical habitats that are exposed to a stressor but have an insignificant response are also not likely to be adversely affected by that stressor. This decision model applies to each individual stressor associated with the proposed action separately. Where all stressors are wholly beneficial, discountable, or insignificant for a species or for a critical habitat, then we conclude the action may affect, but is not likely to adversely affect that species or critical habitat.

We applied these criteria to the species ESA-listed in Table 2 and we summarize our results below.

5.1.1 GOM Atlantic Salmon

As discussed in Section 3.2, we anticipate a variety of stressors associated with different components of the program. The stressors of turbidity, vessel strikes, grab sample strikes, vessel noise, prey removal, and introduction of non-native species could all have an effect on the GOM DPSs of Atlantic salmon.

5.1.1.1 Turbidity

Electrofishing activities occurring in small stream reaches using the backpack electrofishing unit will temporarily suspend sediment and increase turbidity downstream of the site, and some release of fine materials and turbidity is likely to occur because of the in-water activities such as wading.

Elevated TSS concentrations may affect Atlantic salmon in the action area. According to Herbert and Merkens (1961), the most commonly observed effects of exposure to elevated TSS concentrations on salmonids include: 1) avoidance of turbid waters in homing adult anadromous salmonids, 2) avoidance or alarm reactions by juvenile salmonids, 3) displacement of juvenile salmonids, 4) reduced feeding and growth, 5) physiological stress and respiratory impairment, 6) damage to gills, 7) reduced tolerance to disease and toxicants, 8) reduced survival, and 9) direct mortality. Fine sediment deposited in salmonid spawning gravel can also reduce interstitial water flow, leading to depressed DO concentrations, and can physically trap emerging fry on the gravel.

Studies of the effects of turbid waters on fish suggest that concentrations of suspended solids can reach thousands of milligrams per liter before an acute toxic reaction is expected (Burton 1993). The studies reviewed by Burton demonstrated lethal effects to fish at concentrations of 580 mg/L to 700,000 mg/L depending on species. However, sublethal effects have been observed at substantially lower turbidity levels. Behavioral avoidance of turbid waters may be one of the most important effects of suspended sediments (DeVore et al. 1980; Birtwell et al. 1984; Scannell 1988). Salmonids have been observed to move laterally and downstream to avoid turbid plumes (Sigler et al. 1984; Lloyd 1987; Scannell 1988; Servizi and Martens 1991). Juvenile salmonids tend to avoid streams that are chronically turbid, such as glacial streams or those disturbed by human activities, except when the fish need to traverse these streams along migration routes (Lloyd et al. 1987).

Exposure duration is a critical determinant of the occurrence and magnitude of physical or behavioral effects (Newcombe and MacDonald 1991). Salmonids have evolved in systems that periodically experience short-term pulses (days to weeks) of high suspended sediment loads, often associated with flood events, and are adapted to such high pulse exposures. Adult and larger juvenile salmonids appear to be little affected by the high concentrations of suspended sediments that occur during storm and snowmelt runoff episodes (Bjornn and Reiser 1991). However, research indicates that chronic exposure can cause physiological stress responses that can increase maintenance energy and reduce feeding and growth (Redding et al. 1987, Lloyd 1987, Servizi and Martens 1991). In a review of the effects of sediment loads and turbidity on fish, Newcombe and Jensen (1996) concluded that more than 6 days exposure to TSS greater than ten milligrams per liter is a moderate stress for juvenile and adult salmonids and that a single day exposure to TSS in excess of 50 mg/l is a moderate stress.

At moderate levels, turbidity has the potential to adversely affect primary and secondary productivity, and at high levels has the potential to injure and kill adult and juvenile fish. Turbidity might also interfere with feeding (Spence et al. 1996). Eggs and newly emerged salmonid fry may be vulnerable to even moderate amounts of turbidity (Bjornn and Reiser 1991). Other behavioral effects on fish, such as gill flaring and feeding changes, have been observed in response to pulses of suspended sediment (Berg and Northcote 1985). Fine redeposited sediments also have the potential to adversely affect primary and secondary productivity (Spence et al. 1996), and to reduce incubation success (Bell 1991) and cover for juvenile salmonids (Bjornn and Reiser 1991). Larger juvenile and adult salmon appear to be little affected by ephemeral high concentrations of suspended sediments that occur during most storms and episodes of snowmelt. However, other research demonstrates that feeding and territorial behavior can be disrupted by short-term exposure to turbid water.

In-water work during backpack electrofishing activities will primarily be conducted by several individuals wading in the stream over a limited reach for a short time; therefore, sediment releases are only anticipated during the electrofishing activities from disturbance of the substrate. Single day TSS levels in excess of 50 mg/l are not anticipated during these activities and TSS should return to background levels within a few hours. Atlantic salmon exposed to turbidity are extremely unlikely to have any measurable response to turbidity at levels expected to occur during sampling under the program because turbidity concentrations will not rise to a level that would produce any response. Therefore, any response is expected to be insignificant. Therefore, NMFS concludes that turbidity plumes resulting from implementation of the program may affect, but is not likely to adversely affect the GOM DPS of Atlantic salmon.

5.1.1.2 Vessel, anchor, or benthic sampler strikes

Vessel strikes, anchor strikes, or interactions with sediment samplers could harm Atlantic salmon. Vessel strikes of Atlantic salmon are uncommon and, generally, the smaller the fish, the less likely a vessel interaction is to occur. Strike from anchors or benthic samplers is even less likely to occur. Juvenile Atlantic salmon face predation pressure from predators in water and air. Therefore, they respond quickly to stimuli. If a juvenile Atlantic salmon were below a vessel, anything dropped from the vessel into the water would be extremely unlikely to strike the fish because they would be expected to move out of the way. Because vessels will be used only in larger systems and vessel strikes of Atlantic salmon are uncommon, it is extremely unlikely that implementing the program will result in a vessel strike over the next 20 years. Therefore, the risk of vessel strikes to the GOM DPS of Atlantic salmon is discountable. Likewise, because anchors and dropped benthic samplers will only be used in larger systems requiring the use of vessels, and because Atlantic salmon are expected to be able to see and avoid these falling objects, exposure to these stressors is extremely unlikely. Therefore, the risk to the GOM DPS of Atlantic salmon from anchoring or equipment deployment is discountable. Because the risk of vessel strike, anchor strike, or benthic sampler strike is discountable, NMFS concludes that these particular stressors resulting from implementing the program may affect, but are not likely to adversely affect the GOM DPS of Atlantic salmon.

5.1.1.3 Vessel noise

Studies on the impacts of noise on fish have become more common in recent years. Vessel noise is now commonly recognized as a stressor to fish when it is loud enough to be detected and persistent enough to become stressful (Mitson and Knudsen 2003, De Robertis and Handegard 2013, Celi et al. 2016, Putland et al. 2017). Approximately 20% of a school of fish will actively avoid vessel noise (Misund et al. 1996, De Robertis and Handegard 2013) and the louder the noise, the greater the stress response and recovery time (Graham and Cooke 2008). Noise generated by a recreational vessel occurs along a spectrum, where generated noise is lowest by non-motorized vessels, slightly more by low horsepower combustion engines, increasing to the most from large diesel engines (Graham and Cooke 2008, De Robertis and Handegard 2013). Because the program activities will be brief and fish are able to move out of the ensonified area, the intensity and duration of the exposure will both be minimal and temporary. The response to that sort of exposure would not be detectable or measurable as anything outside of normal behavior or movement and is expected to be insignificant. Because of this, NMFS concludes that vessel noise resulting from implementation of the program may affect, but is not likely to adversely affect the GOM DPS of Atlantic salmon.

5.1.1.4 Benthic sampling: incidental capture and prey removal

Juvenile Atlantic salmon will feed on a wide variety of prey resources, including benthic invertebrates (Mitchell et al. 1998). The NRSA program research protocols will collect benthic invertebrates from 11 locations at each site. Because sampling will occur before Atlantic salmon adults lay eggs and form redds, it is extremely unlikely that Atlantic salmon larvae will be collected during benthic invertebrate sampling. While the risk of capture is discountable, in the unlikely event that larvae are collected, conservation measures within the program require biologists to inspect benthic samples and remove larval fish if captured. The other stressor associated with benthic invertebrate sampling is the removal of food resources for Atlantic salmon. The total sampled area for wadable streams will be 1.02 m^2 while the total sampled areas in non-wadable streams will be 3.3 m^2. While this will remove some benthic macroinvertebrates that could be available as a forage resource, this is a small portion of the sample reach (e.g. for a 10-m wide stream, this would be 0.25%). This project component would remove a small amount of food resources relative to the sample reach, and an immeasurable amount of resources from the river itself. This is not expected to result in a measurable effect to GOM Atlantic salmon and is thus considered insignificant. Because the risk of accidental capture of larval Atlantic salmon is discountable and the loss of food resources will be insignificant, NMFS concludes that the stressors associated with benthic sampling under the program may affect, but are not likely to adversely affect the GOM DPS of Atlantic salmon.

5.1.1.5 Non-native species

All animals can have a range of responses to aquatic invasive species from beneficial to extirpation. Because of the uncertainty around different species of fish's response to a wide variety of introduced species, EPA has established explicit equipment clean up guidelines. The guidelines are based on recommendations from the Aquatic Nuisance Species Task Force, the US Geological Survey Nonindigenous Species website, the Sea Grant Program, and the US Department of Agriculture Animal and Plant Health Inspection Service. Guidelines are established for cleaning vessels, sampling equipment, any other research equipment or clothes that came into contact with water. These procedures are identified in the BE (section 4.6.1; EPA 2023). Because of the mitigation measures in place, it is extremely unlikely that any non-native species will be introduced to new environments as a result of the program. The risk from non-native species is discountable and therefore, NMFS concludes that this stressor may affect, but is not likely to adversely affect the GOM DPS of Atlantic salmon.

5.1.2 Shortnose and Atlantic Sturgeon

As discussed in Section 3.2, we anticipate a variety of stressors associated with different aspects of the program. Turbidity, vessel strikes, anchoring and equipment deployment strikes, vessel noise, prey removal, and introduction of non-native species could all affect shortnose sturgeon and each of the DPSs of Atlantic sturgeon.

5.1.2.1 Turbidity

Turbidity is a well-known stressor to fish generally that can affect the gills and eyes, leading to reduced growth and survival (Sigler et al. 1984; Martin and Servizi 1993; Sutherland and Meyer 2007; Lowe et al. 2015). Sturgeon however are a benthic species adapted to living in turbid conditions (Allen and Cech 2007; Wildhaber et al. 2007; French et al. 2014). Some studies have shown that lake sturgeon increase movement and foraging in increasingly turbid water (Rodrigues et al. 2023). Other studies on Atlantic sturgeon suggest they neither move to nor avoid the increased turbidity around dredges (Reine et al. 2014). The turbidity associated with this action will be below levels (50 mg/L) documented to produce a response in either sturgeon species. It will be caused by people walking in streams, anchoring and pulling anchor, and sediment sampling. Sturgeon are generally more oriented to the thalweg in river systems and, if they are in the area where work will be done, they would likely leave during the times of disturbance. The extent of the turbidity suspended by these activities and the short duration of the turbidity plumes are unlikely to cause any measurable response from any of the 5 DPSs of Atlantic sturgeon or from shortnose sturgeon. Because these sturgeon are extremely unlikely to be exposed to sediment plumes while sampling is underway, the risk of exposure plumes at the time of sampling or anchoring is discountable. Additionally, because sturgeon are extremely unlikely to have any measurable response to increased turbidity or to sediment plumes downstream from or after sampling activities, their response is expected to be insignificant. Therefore, NMFS concludes that turbidity may affect, but is not likely to adversely affect shortnose sturgeon or Gulf of Maine, New York Bight, Carolina, or South Atlantic DPSs of Atlantic sturgeon.

5.1.2.2 Vessel, anchor, or benthic sampler strikes

Vessel strikes, anchor strikes, or interactions with sediment samplers could harm sturgeon. There are numerous documented sturgeon killed by large vessel propellers (Brown and Murphy 2010; Balazik et al. 2012; Demetrus et al. 2020) and many documented injuries from recreational vessel strikes (J. Kahn, NOAA Fisheries, unpublished data in Figure 7 and Figure 8). Sturgeon are generally benthically oriented unless they are migrating. Regardless of orientation in the water column, they are vulnerable to vessel strike from large vessels and are most vulnerable to strike from recreational vessels when migrating. As Atlantic sturgeon first move into a spawning river, they tend to follow the thalweg and be near the surface. Shortnose sturgeon also migrate upriver for spawning and back downriver after spawning. Recreational vessel strike is less likely during times of the year when sturgeon would be intentionally benthically oriented (foraging, spawning). The likelihood of recreational vessel strike is always relatively small; however, the cumulative volume of vessels increases the risk to a point where those strikes are major threats to the species. In most cases, EPA would sample reaches by foot but, in larger systems, they would use a small vessel. When using a vessel, EPA would only operate it over a small area for a single day at each location. There are 3 main factors to consider to understand the likelihood of a vessel strike from the NRSA program: 1) the presence of the vessel, 2) the presence of the sturgeon at the surface, and 3) the vessel (sampling nearshore areas) occurring in the same place at the same time as the sturgeon near the surface (generally in the thalweg). Because the vessels and the sturgeon are not expected to be in the same place (thalweg vs nearshore) and because the presence of program vessels in the river or migrating sturgeon at the surface are each rare events, the co-occurrence of the vessels and sturgeon are extremely unlikely to occur. Therefore, the risk of a strike by a vessel carrying out program activities is discountable. NMFS concludes that strikes by vessels implementing the program may affect, but are not likely to adversely affect shortnose sturgeon or any DPS of Atlantic sturgeon.

Figure 7. Adult female Atlantic sturgeon with evidence of propeller strike through its gill plate, but alive (J.E. Kahn)

Figure 8. Scar through the dorsal scutes of an adult male Atlantic sturgeon (J.E. Kahn)

Additionally, sturgeon may be struck by an anchor or a sediment sampler. The concept of anchor strike has also not been explored in the literature but is extremely unlikely to affect any fish in this study because they are larger and able to easily move out of the way of a falling anchor. Likewise, sediment samples taken in shallow locations allow biologists to see the stream bottom, so a strike from benthic sampling techniques should only be possible from a vessel. For spring spawning sturgeon, during the summer sampling period, there could be larval sturgeon nearby, but larvae would be in the thalweg of rivers as they drift downstream. Affecting any life stage of sturgeon with anchors or benthic sampling gear is extremely unlikely such that the risk of anchor or equipment impact is expected to be discountable. Therefore, NMFS concludes that anchor strikes and benthic sampler strikes resulting from implementation of the program may affect, but are not likely to adversely affect shortnose sturgeon or any DPS of Atlantic sturgeon.

5.1.2.3 Vessel noise

Studies on the impacts of noise on fish have become more common in recent years. Vessel noise is now commonly recognized as a stressor to fish when it is loud enough to be detected and persistent enough to become stressful (Mitson and Knudsen 2003, De Robertis and Handegard 2013, Celi et al. 2016, Putland et al. 2017). Approximately 20% of a school of fish will actively avoid vessel noise (Misund et al. 1996, De Robertis and Handegard 2013) and the louder the noise, the greater the stress response and recovery time (Graham and Cooke 2008). Noise generated by a recreational vessel occurs along a spectrum, where generated noise is lowest from non-motorized vessels, slightly more from low horsepower combustion engines, and increasing to the most from large diesel engines (Graham and Cooke 2008, De Robertis and Handegard 2013). Because the research activities will be brief and fish are able to move out of the ensonified area, the intensity and duration of the exposure will both be minimal and temporary. The response to that sort of exposure would not be detectable or measurable as anything outside of normal behavior or movement and is expected to be insignificant. Because of this, NMFS concludes that vessel noise resulting from implementation of the program may affect, but is not likely to adversely affect shortnose sturgeon or any DPS of Atlantic sturgeon.

5.1.2.4 Benthic sampling: incidental capture and prey removal

Sturgeon are benthic foragers, relying on their barbels and Ampullae of Lorenzini to locate food in soft bottom habitats (Bain 1997). The NRSA program research protocols will collect benthic invertebrates from 11 locations at each site. It is not expected that and shortnose or Atlantic sturgeon larvae will be collected during benthic invertebrate sampling, but conservation measures within the program require biologists to inspect benthic samples and remove larval fish, if captured. The other stressor associated with benthic invertebrate sampling is the removal of food resources for sturgeon. The total sampled area for wadable streams will be 1.02 m^2 while the total sampled areas in non-wadable streams will be 3.3 m^2. While this will remove some benthic macroinvertebrates that could have been available as a forage resource, this is a small portion of the sample reach (e.g. for a 10-m wide stream, this would be 0.25%). This project component would remove a small amount of food resources relative to the sample reach, and an immeasurable amount of resources from the river itself and from a location where shortnose and

Atlantic sturgeon would not be expected to forage (along the edges of a stream rather than the thalweg). Therefore, the removal of food resources will not cause a measurable effect to shortnose or Atlantic sturgeon and will be insignificant. Because the accidental capture of larval sturgeon is discountable and the loss of food resources will be insignificant, the stressors associated with benthic sampling may affect, but are not likely to adversely affect shortnose sturgeon or any DPS of Atlantic sturgeon.

5.1.2.5 Non-native species

Because of the mitigation measures in place, it is extremely unlikely that any non-native species will be introduced to new environments as a result of program activities (see discussion in section 5.1.1.5). The risk from non-native species is discountable and therefore, this stressor may affect, but is not likely to adversely affect shortnose sturgeon or any DPS of Atlantic sturgeon.

5.2 Critical Habitat that May be Affected, but is Not Likely to be Adversely Affected

Critical habitat for Atlantic sturgeon and Atlantic salmon is present in the action area. This section evaluates the likely consequences to the PBFs for each critical habitat designation.

5.2.1 GOM Atlantic Salmon Critical Habitat

Gulf of Maine Atlantic salmon critical habitat designation identified PBFs for spawning, rearing, and migrating. The PBFs that could be affected by the stressors produced by the NRSA program are identified in Table 3. Of the stressors likely to be generated by the NRSA program, the stressor of turbidity and electrofishing could affect PBFs in Table 3. The spawning and rearing PBFs focus on space, habitat heterogeneity, good water quality, and food resources. The migratory PBFs focus on protection from predation, unobstructed habitat for smolts (when considering possible exposure only to juveniles), and good water quality. We discussed food resources in section 5.1.1.4.

Table 3. The PBFs for GOM DPS Atlantic salmon that may be affected by the NRSA program.

Affected PBFs for SR Habitat	
SR4	Freshwater rearing sites with space to accommodate growth and survival of Atlantic salmon parr.
SR5	Freshwater rearing sites with a combination of river, stream, and lake habitats that accommodate parr's ability to occupy many niches and maximize parr production.
SR6	Freshwater rearing sites with cool, oxygenated water to support growth and survival of Atlantic salmon parr.
SR7	Freshwater rearing sites with diverse food resources to support growth and survival of Atlantic salmon parr.
Affected PBFs for M Habitat	

M3	Freshwater and estuary migration sites with abundant, diverse native fish communities to serve as a protective buffer against predation.
M4	Freshwater and estuary migration sites free from physical and biological barriers that delay or prevent emigration of smolts to the marine environment.
M5	Freshwater and estuary migration sites with sufficiently cool water temperatures and water flows that coincide with diurnal cues to stimulate smolt migration.
M6	Freshwater migration sites with water chemistry needed to support sea water adaptation of smolts.

5.2.1.1 Turbidity

The actions under the NRSA program will generate turbidity at the sample site, which is expected to quickly re-settle once sampling activity is complete. This program will not introduce new sediment into any rivers, instead disturbing, re-suspending, and ultimately facilitating the transport of sediment around the sampling location and, to a certain extent, downstream. While sediment is suspended, it is expected that Atlantic salmon will avoid those locations, preferring less turbid areas outside of the sampling location. By avoiding these locations, there could be short-term effects to the function of the PBFs shown in Table 3. However, all effects to the PBFs will be short-term, lasting only for the day that the disturbance is taking place then returning to the same level of functionality as prior to the sampling. Because of the small amounts of sediment suspended, natural background conditions, and the short duration, the response to small increases in turbidity and downstream transport of sediment is expected to be insignificant. Therefore, NMFS concludes that turbidity and sediment transport caused by implementing this program may affect, but is not likely to adversely affect GOM DPS Atlantic salmon critical habitat.

5.2.1.2 Electrofishing

When conducting fish surveys, EPA crews will be using electrofishing techniques. The electrical current used for electrofishing will not prevent migration, a PBF, at a site because it will affect a small area around the people or boat conducting sampling. Further, the electrical current is temporary and brief, the equipment is not stationary but instead moving throughout the site resulting in no specific barrier, and the current is limited and narrow in wavelength. When the crew is done surveying, the electrical current is immediately gone from the water. Surveys are expected to last 1 day in each location and the full day will not be spent sampling for fish. Atlantic salmon lack ampullae of Lorenzi and cannot detect and avoid small changes in electric current, so they could be temporarily stunned. In such cases, the NRSA conservation measures limiting holding and handling of ESA-listed species will be followed. These are described in Section 7.4 of the BE (EPA 2023). Atlantic salmon not captured by the electrical current are expected to avoid the sampling location. Therefore, we would expect most Atlantic salmon to avoid these areas for rearing and migration. This may reduce the total area for foraging temporarily or delay migratory movements (if some Atlantic salmon refused to move past in the non-electrified parts of these rivers and streams), but the salmon would spend at most a few hours with reduced rearing habitat or impeded migratory habitat. These actions are likely to cause temporary periods of inaccessible habitat but conditions are expected to return to pre-sampling status within minutes after all sampling is completed. Because of this, there will be brief exposure of PBFs to stressors that will reduce rearing habitat and impede migration through parts of the river, though these areas are expected to cause an insignificant effect to critical habitat for the GOM DPS of Atlantic salmon. NMFS concludes that program electrofishing activities may affect, but are not likely to adversely affect the migration and rearing PBFs of Atlantic salmon critical habitat.

5.2.1.3 GOM DPS Atlantic sturgeon critical habitat conclusion

After evaluating the stressors caused by the NRSA program and the likely consequences that would result from interactions with the PBFs, we expect all effects of the proposed in-water work on critical habitat designated for the Gulf of Maine DPS of Atlantic salmon to be temporary and insignificant. Therefore, NMFS concludes that the program may affect, but is not likely to adversely affect critical habitat for the Gulf of Maine DPS of Atlantic salmon.

5.2.2 Atlantic Sturgeon Critical Habitat

Atlantic sturgeon critical habitat is designated in estuarine and riverine areas of the East Coast from Florida to the US border with Canada. The PBFs of critical habitat essential for the conservation of Atlantic sturgeon are:

1. Hard bottom substrate for spawning;
2. Aquatic habitat for gradual downstream salinity gradient;
3. Water of appropriate depth and free of passage barriers; and
4. Water from river mouths to spawning habitat of sufficient quality (temperature, salinity, and DO) to support all life stages.

Of the stressors considered above, turbidity could affect PBFs of Atlantic sturgeon critical habitat. It is also possible the collection techniques could temporarily act as passage barriers.

5.2.2.1 Turbidity

Two PBFs, hard bottom substrate for spawning and water of sufficient quality to support all life stages, could be affected by increases in turbidity. Hard bottom substrate for spawning is indirectly affected by turbidity because the effects to the substrate occur once the suspended sediments settle out downriver. If enough sediment is suspended from a location that the hard bottom substrates downstream would be covered, this would adversely affect the PBF of Atlantic sturgeon critical habitat. Likewise, the PBF supporting water quality is important to the conservation of sturgeon because they are very sensitive to high temperatures and low DO (Cech et al. 1984; Jenkins et al. 1993; Secor and Gunderson 1998; Campbell and Goodman 2004). Suspension of sediment often releases buried organic matter, which can allow bacteria to flourish, reducing DO. As noted earlier, Atlantic sturgeon are a benthic species adapted to living in turbid conditions (Allen and Cech, 2007; Wildhaber et al., 2007; French et al., 2014).

The suspended sediment generated when implementing the program will be minimal. East Coast rivers supporting Atlantic sturgeon spawning habitat are naturally turbid and any increases in turbidity caused by these actions are not likely to be detectable beyond a few feet downstream.

Because of this, we anticipate that the hardbottom substrate and water quality PBFs of Atlantic sturgeon critical habitat will be exposed to increased turbidity but, because of the small amounts of suspended sediment, natural background conditions, and sturgeon adaptations, the response to turbidity at the scale expected from program activities is expected to be insignificant. Therefore, NMFS concludes that turbidity resulting from program activities may affect, but is not likely to adversely affect Atlantic sturgeon critical habitat.

5.2.2.2 Sampling Impeding Migratory Pathways

As an anadromous species, an important PBF necessary for accessing spawning habitats is water of an appropriate depth and free of passage barriers. When conducting fish surveys, EPA crews will be using electrofishing techniques. The electrical current used for electrofishing will not stop fish passage at a site because it will affect a small area around the boat (assuming migratory sturgeon would not be in wadable streams because they prefer deeper water). Further, the electrical current is temporary and short-term, the equipment is not stationary but instead moving throughout the site resulting in no specific barrier, and the current is limited and narrow in size. When the crew is done surveying, the electrical current is immediately gone from the water. Surveys are expected to last 1 day in each location and the full day will not be spent sampling for fish. Sturgeon have ampullae of Lorenzini, transdermal electro-reception organs along their lateral line that detect small differences in electric potential, making them highly sensitive to electrical currents. From observations of electrofishing in sturgeon rivers, it is rare for sturgeon to be affected by this technique, presumably because they avoid the electrical fields (Moser et al. 2000). Therefore, we would expect most sturgeon to go around these areas as they migrate, but, if some refused to pass until the current was out of the water, they would spend at most a few hours before resuming their migration. These activities are likely to cause temporary periods of inaccessible habitat but are expected to resolve back to normal or pre-sampling status within minutes after all sampling actives are completed. Thus, there will be brief exposure of critical habitat to actions that will block migration through parts of the river, though these areas are expected to cause an insignificant effect to the passage PBF of Atlantic sturgeon critical habitat. NMFS concludes that migration blockage resulting from program activities may affect, but is not likely to adversely affect Atlantic sturgeon critical habitat.

5.2.2.3 Atlantic Sturgeon Critical Habitat Conclusion

After evaluating the stressors caused by the NRSA program and the likely consequences resulting from interactions with the PBFs, we conclude that the NRSA program may affect, but is not likely to adversely affect Atlantic sturgeon critical habitat.

5.3 Species Likely to be Adversely Affected

Shortnose sturgeon, all DPSs of Atlantic sturgeon, and Atlantic salmon are likely to be adversely affected by the fish collection component of the program.

5.3.1 GOM DPS Atlantic Salmon

The GOM DPS of anadromous Atlantic salmon was initially listed by USFWS and NMFS (collectively, the Services) as an endangered species on November 17, 2000 (65 FR 69459). A subsequent rule issued by the Services (74 FR 29344) expanded the geographic range for the GOM DPS of Atlantic salmon. The GOM DPS of Atlantic salmon is defined as all anadromous Atlantic salmon whose freshwater range occurs in the watersheds from the Androscoggin River northward along the Maine coast to the Dennys River, and wherever these fish occur in the estuarine and marine environment. The marine range of the GOM DPS extends from the Gulf of Maine, throughout the Northwest Atlantic Ocean, to the coast of Greenland. Included in the GOM DPS are all associated conservation hatchery populations used to supplement these natural populations; currently, such conservation hatchery populations are maintained at Green Lake National Fish Hatchery and Craig Brook National Fish Hatcheries, both operated by the USFWS, as well as private watershed-based facilities (Downeast Salmon Federation's East Machias and Pleasant River facilities). Excluded from the GOM DPS are landlocked Atlantic salmon and those salmon raised in commercial hatcheries for the aquaculture industry (74 FR 29344).

Coincident with the June 19, 2009 endangered listing, we designated critical habitat for the GOM DPS of Atlantic salmon (74 FR 29300). The final rule was revised on August 10, 2009. In this revision, designated critical habitat for the expanded GOM DPS of Atlantic salmon was reduced to exclude trust and fee holdings of the Penobscot Indian Nation and a table was corrected (74 FR 39003).

5.3.1.1 Status

The GOM DPS of Atlantic salmon currently exhibits critically low spawner abundance, poor marine survival, and is confronted with a variety of additional threats. Some locations within the DPS have experienced extirpations. The abundance of GOM DPS Atlantic salmon has been low and either stable or declining over the past several decades. The proportion of fish that are of natural origin is extremely low (approximately 6% over the last ten years) and is continuing to decline. The spatial distribution of the GOM DPS has been severely reduced relative to historical distribution patterns. The conservation hatchery program assists in slowing the decline and helps stabilize populations at low levels, but has not contributed to an increase in the overall abundance of salmon and has not been able to halt the decline of the naturally reared component of the GOM DPS. Continued reliance on the conservation hatchery program could prevent extinction in the short term, but recovery of the GOM DPS must be accomplished through increases in naturally reared salmon.

5.3.1.2 Threats

Atlantic salmon face a number of threats to their survival, most of which are outlined in the Recovery Plan (NMFS and USFWS 2018) and the latest status review (Fay et al. 2006). We consider the following to be the most significant threats to the GOM DPS of Atlantic salmon:

1. Dams
2. Inadequacy of existing regulatory mechanisms for dams
3. Continued low marine survival rates for U.S. stocks of Atlantic salmon

4. Lack of access to spawning and rearing habitat due to dams and road-stream crossings
5. Degraded water quality
6. Aquaculture practices, which pose ecological and genetic risks
7. Climate change
8. Depleted diadromous fish communities
9. Incidental capture of adults and parr by recreational anglers
10. Introduced fish species that compete or prey on Atlantic salmon
11. Poaching of adults
12. Recovery hatchery program (potential for artificial selection/domestication)
13. Sedimentation of spawning and rearing habitat
14. Water extraction
15. Diseases
16. Predation
17. Greenland Mixed Stock Fishery.

A wide variety of activities have focused on protecting Atlantic salmon and restoring the GOM DPS, including hatchery supplementation; removing dams or providing fish passage; improving road crossings that block passage or degrade stream habitat; protecting riparian corridors along rivers; reducing the impact of irrigation water withdrawals; limiting effects of recreational and commercial fishing; reducing the effects of finfish aquaculture; outreach and education activities; and research focused on better understanding the threats to Atlantic salmon and developing effective restoration strategies.

Starting in the 1960s, Greenland implemented a mixed stock Atlantic salmon fishery off its western coast (Sheehan et al. 2015). The fishery primarily takes 1 sea winter North American and European origin Atlantic salmon that would potentially return to natal waters as mature, 2 sea winter spawning adults or older. Because of international concerns that the fishery would have deleterious on the contributing stock complexes, a quota system was agreed upon and implemented in 1976, and since 1984, catch regulations have been established by the North Atlantic Salmon Conservation Organization (Sheehan et al. 2015). In recent years, Greenland had limited the mixed stock salmon fishery for internal consumption only, which in the past has been estimated at 20 metric tons.

In 2015, Greenland unilaterally set a 45-ton commercial quota for 2015, 2016, and 2017 (Sheehan et al. 2015). Based on historic harvest estimates, it is estimated that on average, approximately 100 adult salmon of U.S. origin would be harvested annually under a 45-ton quota. With recent U.S. returns of Atlantic salmon averaging less than 1,500 individuals per year, the majority of which originated from hatcheries, this harvest constitutes a substantial threat to the survival and recovery of the GOM DPS. As such, the United States continued to negotiate with the government of Greenland and participants of the fishery both within and outside of the North Atlantic Salmon Conservation Organization to ultimately establish a new regulatory measure in 2018. The new regulatory measure agreed to includes a 30-ton quota and a number of elements that, if well implemented, will significantly improve the management and control of the fishery.

The final rule designating critical habitat for the GOM DPS identifies a number of activities that have and will likely continue to impact the biological and physical features of spawning, rearing, and migration habitat for Atlantic salmon. These include agriculture, forestry, changing land-use and development, hatcheries and stocking, roads and road-crossings and other instream activities (such as alternative energy development), mining, dams, dredging, and aquaculture. Most of these activities have or still do occur, at least to some extent, throughout the Gulf of Maine.

Hare et al. (2016) gave Atlantic salmon a Vulnerability Rank of Very High (100% certainty from bootstrap analysis) as well as a Climate Exposure rank of Very High and Distributional Vulnerability Rank of Moderate (87% certainty from bootstrap analysis). The authors conclude that the effect of climate change on Atlantic salmon in the Northeast U.S. Shelf Ecosystem is very likely to be negative (>95% certainty in expert scores) due to the effects of warming on freshwater and marine habitats and the potential to effect the phenology of Atlantic salmon migration. Ocean acidification could also affect olfaction, which Atlantic salmon use for natal homing.

Adult returns for the GOM DPS remain well below conservation spawning escapement (the number of fish arriving at a natal stream or river to spawn). For all GOM DPS rivers in Maine, current Atlantic salmon populations (including hatchery contributions) are well below conservation spawning escapement levels required to sustain themselves (Fay et al. 2006), which is further indication of their poor population status. The abundance of Atlantic salmon in the GOM DPS has been low and either stable or declining over the past several decades. The proportion of fish that are of natural origin is very small (approximately 6% over the last ten years) and is continuing to decline. The conservation hatchery program has assisted in slowing the decline and helping to stabilize populations at low levels, but has not contributed to an increase in the overall abundance of salmon and has not been able to halt the decline of the naturally reared component of the GOM DPS.

5.3.1.3 Population dynamics and distribution

The reproduction, distribution, and abundance of Atlantic salmon within the range of the GOM DPS have been generally declining since the 1800s (Fay et al. 2006). A comprehensive time series of adult returns to the GOM DPS dating back to 1967 exists (Fay et al. 2006, USASAC 2013). Contemporary abundance levels of Atlantic salmon within the GOM DPS are several orders of magnitude lower than historical abundance estimates. For example, Foster and Atkins (1869) estimated that roughly 100,000 adult salmon returned to the Penobscot River alone before the river was dammed, whereas estimates of abundance for the entire GOM DPS have rarely exceeded 5,000 individuals in any given year since 1967 (Fay et al. 2006, USASAC 2013).

After a period of population growth between the 1970s and the early 1980s, adult returns of salmon in the GOM DPS peaked between approximately 1984 and 1991 before declining during the 2000s. Adult returns fluctuated over the last few years, with increases observed from 2008 to 2011, and a decrease again in 2012, 2013, and 2014 (Figure 9). Presently, the majority of all adults in the GOM DPS return to a single river, the Penobscot, which accounted for over 90% of all adult returns to the GOM DPS over the last decade. The population growth observed in the 1970s is likely attributable to favorable marine survival and increases in hatchery capacity, particularly from the Green Lake National Fish Hatchery (constructed in 1974). Marine survival remained relatively high throughout the 1980s, and salmon populations in the GOM DPS remained relatively stable until the early 1990s. In the early 1990s, marine survival rates decreased, leading to the declining trend in adult abundance observed throughout the 1990s and early 2000s. The increase in abundance of returning adult salmon observed between 2008 and 2011 may be an indication of improving marine survival; however, the declines in 2012 - 2014 may suggest otherwise. Returns to U.S. waters in 2013 were only 611 fish (the sum of documented returns to traps and returns estimated by redd counts on selected Maine rivers), which ranks 43rd in the 47-year time-series (USASAC 2014). Estimated returns to rivers of the U.S. in 2016 totaled 626 and ranks 24 out of 26 years for the 1991-2016 time series. The returns in 2019 - 2020 were much higher, a dip in 2021 was followed by an increase in 2022 (USASAC 2023). Despite consistent smolt production, there has been extreme variability in annual returns over the last 5 years (Figure 9).

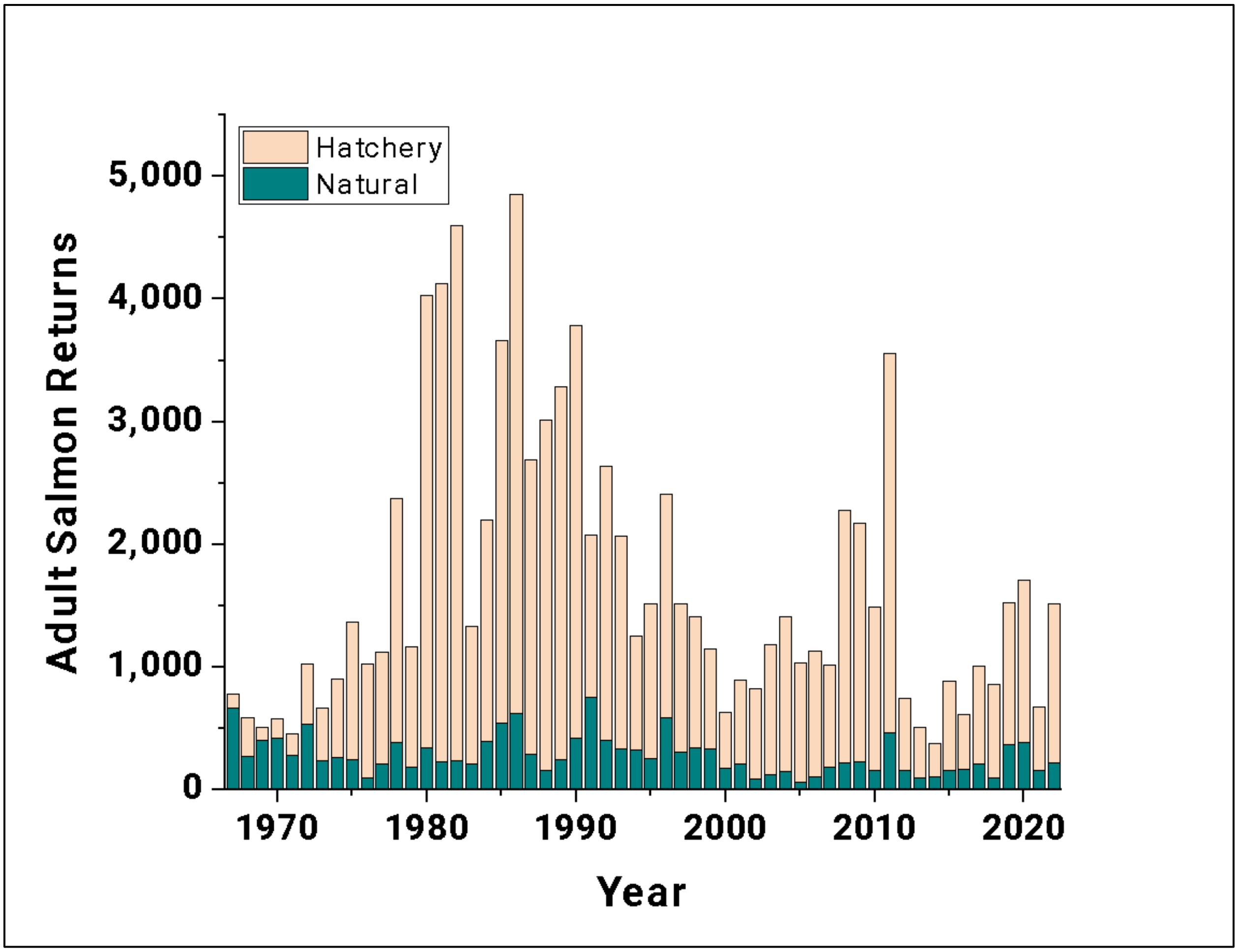

Figure 9. Summary of natural vs hatchery adult salmon returns to the GOM DPS rivers between 1967 and 2022 (USASAC 2023)

Since 1967 when numbers of adult returns were first recorded, the vast majority of adult returns have been the result of smolt stocking; only a small portion of returning adults were naturally reared (Figure 9). Natural reproduction of the species is contributing to only a fraction of Atlantic salmon returns to the GOM DPS. The term naturally reared includes fish originating from both natural spawning and from stocked hatchery fry (USASAC 2012). Hatchery fry are included as naturally reared because hatchery fry are not marked, and therefore cannot be distinguished from fish produced through natural spawning. Low abundances of both hatchery-origin and naturally reared adult salmon returns to Maine demonstrate continued poor marine survival.

The abundance of Atlantic salmon in the GOM DPS has been low, and the trend has been either stable or declining over the past several decades. The proportion of fish that are of natural origin is very small (approximately 6% over the last ten years), but appears stable. The conservation hatchery program has assisted in slowing the decline and helping to stabilize populations at low levels. However, stocking of hatchery fry and smolts has not contributed to an increase in the overall abundance of salmon and, as yet, has not been able to increase the naturally reared component of the GOM DPS. Continued reliance on the conservation hatchery program is expected to prevent extinction in the short term, but recovery of the GOM DPS will not be accomplished without significant increases in naturally reared salmon.

The historic distribution of Atlantic salmon in Maine has been described extensively by Baum (1997) and Beland (1984), among others. In short, substantial populations of Atlantic salmon existed in nearly every river in Maine that was large enough to maintain a spawning population. The upstream extent of the species' distribution extended far into the headwaters of even the largest rivers. Today, the spatial structure of Atlantic salmon is limited by obstructions to passage and also by low abundance levels and the majority of all adults return to the Penobscot River. Within the range of the GOM DPS, the Kennebec, Androscoggin, Union, and Penobscot Rivers contain dams that severely limit passage of salmon to significant amounts of spawning and rearing habitat. Atlantic salmon presently have unobstructed access to only about 5% of their historic habitat in the Penobscot River (NMFS and USFWS 2009).

5.3.1.4 Life History

Atlantic salmon are anadromous and display a complicated life cycle (Figure 10). The majority of adult Atlantic salmon in Maine enter freshwater between May and mid-July (Meister 1958, Baum 1997), but may enter at any time between early spring and late summer if river temperatures are favorable for migration. Salmon that return in early spring spend nearly 5 months in the river before spawning, often seeking cool water refuge (e.g., deep pools, springs, and mouths of smaller tributaries) during the summer months when water temperatures increase and the urge to migrate is somewhat suppressed. Accordingly, the authorized summer work window effectively minimizes the chances for adults to move into the proposed action area during construction. The adults migrate again during the fall freshets when the water levels rise and the temperatures are cooler. Typically, adults will spawn in late October early November and will be around suitable spawning habitat in the tails of large pools where the gravel is loose enough to enable the female to dig redds to deposit eggs. Spawning sites are positioned within flowing water, particularly where upwelling of groundwater occurs, allowing for percolation of water through the gravel (Danie et al.1984). These sites are most often positioned at the head of a riffle (Beland et al. 1982), the tail of a pool, or the upstream edge of a gravel bar where water depth is decreasing and water velocity is increasing (McLaughlin and Knight 1987; White 1942).

Typically, habitat around dams has been altered by the presence of the dam and would not contain any suitable spawning habitat to specifically attract adults to the area.

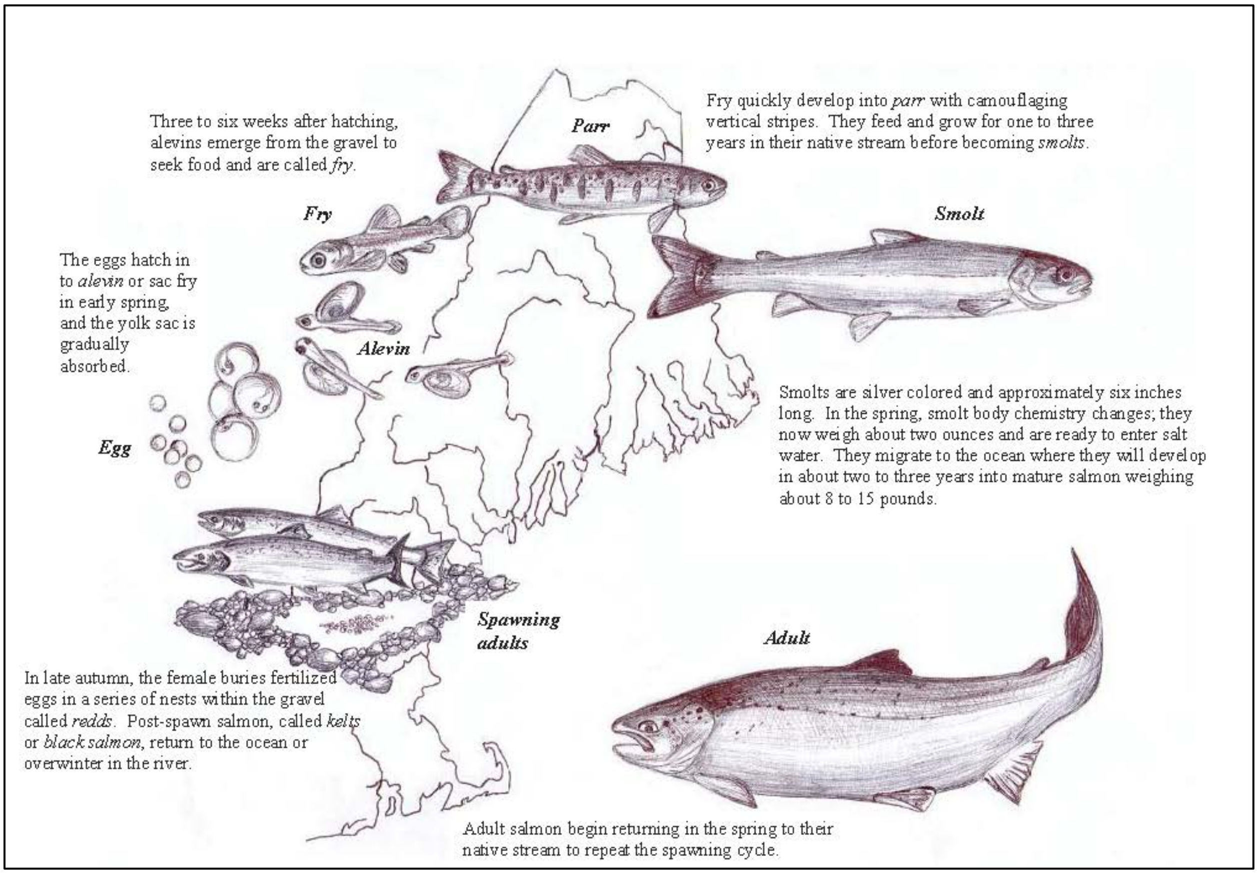

Figure 10. Life cycle of the Atlantic salmon (diagrams by Katrina Mueller)

Adult Atlantic salmon prefer to hold in cooler water temperatures and have been observed resting in the lower mainstem of larger rivers below hydroelectric dams such as in the Kennebec and Penobscot. If accessible, above hydroelectric facilities in the deeper stretches of large tributaries such as the Sandy River and East Branch Penobscot or around the mouths of smaller tributaries with cold water. In small coastal rivers such as the Machias, Dennys, Narraguagus, East Machias and Pleasant they have been observed in the deeper stretches of these rivers during the warmer summer months. When water temperatures start to decline in the fall, adults will migrate during periods of increased flow from seasonal rains. Based on acoustic telemetry studies, adults typically move to cooler areas of the river during the summer months, but return to the sites they explored earlier in the season to spawn.

After spawning, eggs remain in redds for approximately 6 months until hatching in April and May. Larval salmon (alevins) grow and live off of a yolk sac for the first 3 to 4 weeks of life before emerging from the gravels to actively hunt for prey. Some studies indicate that parr (river resident juveniles) can move relatively large distances, particularly when moving to overwintering habitat, summer foraging habitat, and just prior to smoltification (Cunjak et al. 1989; McCormick et al. 1999). The distances are still relatively short when compared to distances traveled by smolts (Figure 11). Parr have been observed leaving their natal streams to move to other nearby streams that may be too small for spawning but that provide food resources or ideal temperatures for development. McCormick et al. (1999) observed that these fish may move to these small streams in the summer, and leave as smolts the following year. Similarly, another study documented Atlantic salmon parr moving out of their natal river to the estuary in the spring, where they spent the summer (Cunjak et al. 1989). Given this information, parr distribution is not necessarily limited to areas where eggs and fry occur.

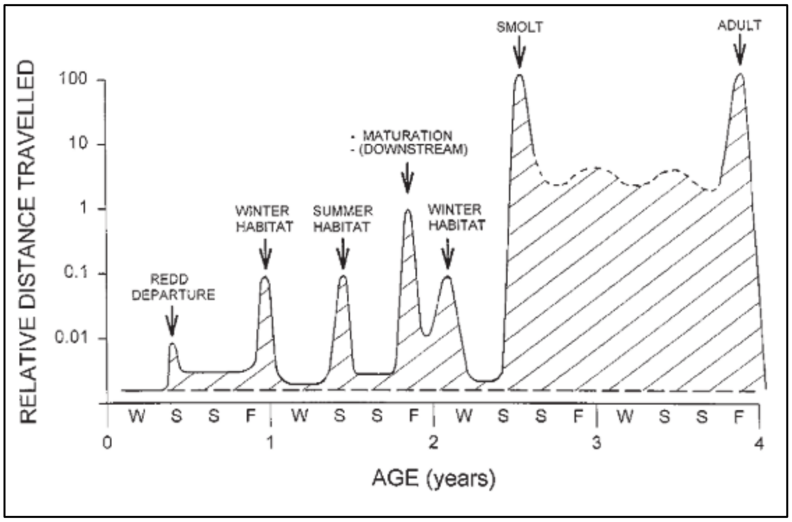

Figure 11. Distance Atlantic salmon migrate during their life cycle

The parr stage can last for 1 to 3 years and generally around 6 inches in length, they will undergo smoltification. The spring migration of smolts to the marine environment takes 25 to 45 days. Most smolts migrate rapidly, exiting the estuary within several tidal cycles (Lacroix and McCurdy 1996; Lacroix et al. 2004; Lacroix and Knox 2005; Hyvärinen et al. 2006). Based on NMFS Penobscot River smolt trapping studies in 2000 - 2005, smolts migrate from the Penobscot between late April and early June with a peak in early May (Fay et al. 2006). These data also demonstrate that the majority of the smolt migration appears to take place over a 2-week period after water temperatures reach 10 °C (Figure 12). Timing of smolt migrations differs amongst rivers within the GOM DPS (Table 4). Data collected from 4 rivers in the GOM DPS between 2011 and 2015 show that migration could last between 1 and 5 weeks depending on river conditions.

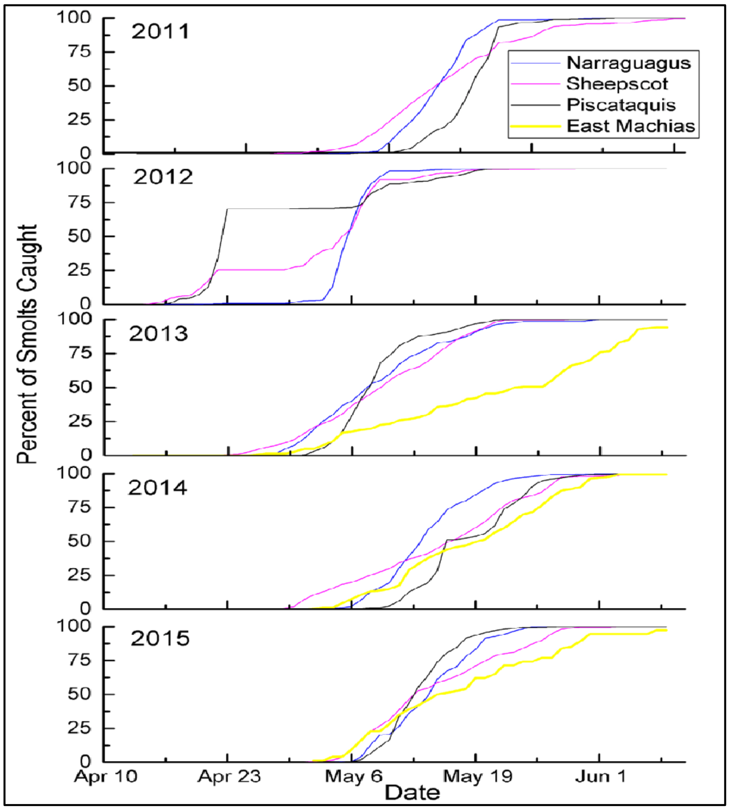

Figure 12. Cumulative percent smolt capture from Narraguagus, Sheepscot, Piscataquis, and East Machias Rivers by date (2011-2015; USASAC 2016)

Table 4. Atlantic salmon smolt trap deployments, total captures, and capture timing by river of origin, 2019

River	Total Captures	First Capture	Capture Date	Last Capture
East Machias (Hatchery)	202	30-Apr	19-May	17-Jun
East Machias (Wild)	18	26-Apr	18-May	7-Jun
Narraguagus (Route 9, Wild)	115	7-May	16-May	31-May
Narraguagus (Little Falls, Hatchery)	380	5-May	12-May	31-May
Narraguagus (Little Falls, Wild)	140	8-May	21-May	3-Jun
Sheepscot (Hatchery)	167	1-May	26-May	8-Jun

Sheepscot (Wild)	141	30-Apr	16-May	4-Jun
Total	1,163			

Approximately 5-10% of stocked salmon smolts, technically parr, may hold over in the vicinity of their stocking location, rather than migrating to sea, as they are not physiologically ready for the transition to saltwater. These juvenile salmon likely move to rearing habitat in the mainstem or in nearby tributaries prior to migrating to the ocean the following year. The smolt migration window (i.e., the time period when smolts migrate downstream to the estuary) is typically late April to mid-June (Table 4).

5.3.1.5 Critical Habitat

See discussion in Section 5.2.2.

5.3.1.6 Recovery Planning

In January 2019, the USFWS and NMFS issued the final recovery plan for the 2009 expanded listing of the GOM DPS of Atlantic salmon (USFWS and NMFS 2018). The 2018 Final Recovery Plan presents a new recovery planning approach (termed the Recovery Planning and Implementation) which has been adopted by the USFWS. Recovery Planning and Implementation plans focus on the statutory elements of recovery criteria, recovery actions, and time and cost estimates. The 2018 plan presents a recovery strategy based on the biological and ecological needs of the species as well as current threats and conservation accomplishments that affect its long-term viability.

The overall goal of the 2018 recovery plan is to remove the GOM DPS of Atlantic salmon from the Federal List of Endangered and Threatened Wildlife. The interim goal is to reclassify the DPS from endangered to threatened status. Provided below are the biological criteria for reclassification and delisting.

Biological Criteria for Reclassification – Reclassification of the GOM DPS from endangered to threatened will be considered when all of the following biological criteria are met:

1. *Abundance*: The DPS has total annual returns of at least 1,500 adults originating from wild origin, or hatchery stocked eggs, fry or parr spawning in the wild, with at least 2 of the 3 SHRUs having a minimum annual escapement of 500 naturally reared adults.
2. *Productivity*: Among the SHRUs that have met or exceeded the abundance criterion, the population has a positive mean growth rate greater than 1.0 in the 10-year (2-generation) period preceding reclassification.
3. *Habitat*: In each of the SHRUs where the abundance and productivity criterion have been met, there is a minimum of 7,500 units of accessible and suitable spawning and rearing habitats capable of supporting the offspring of 1,500 naturally reared adults.

Biological Criteria for Delisting - Delisting of the GOM DPS will be considered when all of the following criteria are met:

1. *Abundance*: The DPS has a self-sustaining annual escapement of at least 2,000 wild origin

adults in each SHRU, for a DPS-wide total of at least 6,000 wild adults.

2. *Productivity*: Each SHRU has a positive mean population growth rate of greater than 1.0 in the 10-year (2-generation) period preceding delisting. In addition, at the time of delisting, the DPS demonstrates self-sustaining persistence, whereby the total wild population in each SHRU has less than a 50% probability of falling below 500 adult wild spawners in the next 15 years based on population viability analysis projections.
3. *Habitat*: Sufficient suitable spawning and rearing habitat for the offspring of the 6,000 wild adults is accessible and distributed throughout the designated Atlantic salmon critical habitat, with at least 30,000 accessible and suitable Habitat Units in each SHRU, located according to the known migratory patterns of returning wild adult salmon. This will require both habitat protection and restoration at significant levels.

5.3.2 Shortnose Sturgeon

We used information available in the Shortnose Sturgeon Recovery Plan (NMFS 1998), the 2010 NMFS Biological Assessment (SSSRT 2010), and the listing document to summarize the status of the species. Shortnose sturgeon were listed as endangered throughout its range on March 11, 1967, pursuant to the Endangered Species Preservation Act of 1966. Shortnose sturgeon remained on the list as endangered with enactment of the ESA in 1973. Shortnose sturgeon occur along the Atlantic Coast of North America, from the Saint John River in Canada to the Saint Johns River in Florida. The Shortnose Sturgeon Recovery Plan describes 19 shortnose sturgeon populations that are managed separately in the wild. Two additional geographically separated 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). The 2010 status review indicates that the Connecticut River shortnose sturgeon population is impeded, but not completely isolated, by the Holyoke dam.

5.3.2.1 Status

Shortnose sturgeon spawning has been documented in several rivers across its range (including but not limited to: Kennebec River, Maine, Connecticut River, Hudson River, Delaware River, Pee Dee River, South Carolina, Savannah, Ogeechee, and Altamaha rivers, Georgia), status for many other rivers remain unknown. Populations in the Kennebec, Hudson, Delaware, and Altamaha Rivers are relatively large and stable (Table 5). Populations in other rivers are smaller if they are still extant, with a large gap in their range through the mid-Atlantic region where little to no reproduction occurs from the Chesapeake Bay through Pamlico Sound. The Connecticut River population appears stable, though is adversely impacted by the presence of a series of dams separating optimal spawning habitat from optimal foraging habitat.

Table 5. Abundance estimates for shortnose sturgeon from all monitored rivers along the East Coast of the United States

River	Abundance	Citations
Kennebec	9,436	Wippelhauser and Squiers 2015

Androscoggin	3,000	Squiers et al. 1993
Merrimack	3,786	Santec Consulting Services 2023
Connecticut	1,500-1,800	Savoy 2004
Hudson	61,000	Bain et al. 2000
Delaware	12,000	Brundage and O'Herron 2003
Cape Fear	100	Kynard 1997
Cooper	200	Cooke et al. 2004
Savannah	1,400-2,400	Bahr and Peterson 2017
Ogeechee	400	Peterson 2007 annual report
Altamaha	6320	Devries 2006
Satilla	100	Peterson 2007 annual report

5.3.2.2 Threats

The viability of sturgeon populations is highly sensitive to juvenile mortality resulting in lower numbers of sub-adults recruiting into the adult breeding population. The 1998 recovery plan for shortnose sturgeon (NMFS 1998) identify habitat degradation or loss (resulting, for example, from dams, bridge construction, channel dredging, and pollutant discharges), and mortality (for example, from impingement on cooling water intake screens, dredging, and incidental capture in other fisheries) as principal threats to the species' survival. Introductions and transfers of indigenous and nonindigenous sturgeon, intentional or accidental, may threaten wild shortnose sturgeon populations by imposing genetic threats, increasing competition for food or habitat, or spreading diseases. Sturgeon species are susceptible to viruses enzootic to the west coast and fish introductions could further spread these diseases. Shortnose sturgeon populations are at risk from incidental bycatch, loss of habitat, dams, dredging and pollution.

5.3.2.3 Population dynamics and distribution

Historically, shortnose sturgeon are believed to have inhabited nearly all major rivers and estuaries along the entire east coast of North America. The shortnose sturgeon recovery plan identifies 19 extant populations (NMFS 1998). Both mtDNA and nDNA analyses indicate effective (with spawning) coastal migrations are occurring between adjacent rivers in some areas, particularly within the Gulf of Maine and the Southeast (King et al. 2014).

The distribution of shortnose sturgeon is disjointed across their range, with northern populations separated from southern populations by a distance of about 400 km near their geographic center in Virginia. Genetic components of sturgeon in rivers separated by more than 400 km appear to be connected by very little migration, while rivers separated by less than 20 km would experience high migration rates. 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 (Wirgin et al. 2005).

5.3.2.4 Life History

The shortnose sturgeon is a relatively slow growing, late maturing, and long-lived fish species. 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). Older juveniles or sub adults 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 (Bain 1997) but prefer freshwater to oligohaline habitats. This preference means shortnose sturgeon juveniles rear slightly upriver of Atlantic sturgeon juveniles natal to the same river.

While shortnose sturgeon do not undertake the long saltwater migrations documented for Atlantic sturgeon, telemetry data indicate that shortnose sturgeon do make localized coastal migrations (Dionne et al. 2013; Wippelhauser et al. 2017). Inter-basin movements have been documented among rivers within the Gulf of Maine, between the Gulf of Maine and the Merrimack, between the Connecticut and Hudson rivers, between the Delaware River and Chesapeake Bay, and among the rivers in the Southeast region (Welsh et al. 2002; Finney et al. 2006; Fernandes et al. 2010; Dionne et al. 2013). Non-spawning movements include rapid, directed post-spawning movements to downstream feeding areas in the spring, and localized, wandering movements in the summer and winter (Dadswell et al. 1984, Buckley and Kynard 1985). In the northern extent of their range, shortnose sturgeon exhibit 3 distinct movement patterns. These migratory movements are associated with spawning, feeding and overwintering activities. In the spring, as water temperatures reach between 7.0 and 9.7 ºC, pre-spawning shortnose sturgeon move from overwintering grounds to spawning areas.

Estimates of annual egg production for shortnose sturgeon are difficult to calculate and are likely to vary greatly in this species because females do not spawn every year. Fecundity estimates that have been made range from 27,000 to 208,000 eggs/female, with a mean of 11,568 eggs/kg body weight (Dadswell et al. 1984). At hatching, shortnose sturgeon are 7 to 11 millimeters (mm) long and resemble tadpoles (Buckley and Kynard 1981). In 9 to 12 days, the yolk sac is absorbed and the sturgeon develops into larvae which are about 15 mm total length (Buckley and Kynard 1981). Sturgeon larvae are believed to begin downstream migrations at about 20 mm total length.

5.3.2.5 Critical habitat

Critical habitat is not designated for shortnose sturgeon.

5.3.2.6 Recovery planning

The recovery plan identifies 19 population segments within their range with a goal of each segment maintaining a minimum population size to maintain genetic diversity and avoid extinction (NMFS 1998). The actions needed are:

1. Establish listing criteria for shortnose sturgeon population segments;
2. Protect shortnose sturgeon and their habitats;
3. Rehabilitate shortnose sturgeon populations and habitats; and
4. Implement recovery tasks.

5.3.3 Atlantic sturgeon

The range of Atlantic sturgeon ranges from the St. John River in Canada to the St. Johns River in Florida. Five DPSs of Atlantic sturgeon were designated and listed under the ESA on February 6, 2012 (Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic). The Gulf of Maine was listed as threatened while the New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs were listed as endangered.

5.3.3.1 Status

Below we present the information available for each DPS.

5.3.3.1.1 Gulf of Maine DPS

Generally what is known about the status of the GOM DPS of Atlantic sturgeon is relatively recent. An open population estimate of marine-oriented Atlantic sturgeon (sub-adult and adult) foraging in the Saco River from May to November is between 1,400 and 6,800 individuals annually (Flanigan et al. 2021). The Kennebec River effective population size and 95% CL were estimated at 67.0 (52.0-89.1) and 79.4 (60.3-111.7) by Waldman et al. (2019; n = 62) and White et al. (2021a; n = 48). Effective population size is essentially an estimate of the number of breeding individuals in a population required to maintain the amount of genetic variability observed within samples from that population. Furthermore, 2 larval Atlantic sturgeon were captured just above the Kennebec River estuary between 24 and 25 °C in mid-July, confirming successful reproduction in this location (Wippelhauser et al. 2017). It is thought the Penobscot may have historically supported a spawning population, but it is possibly extirpated (ASMFC 2017). Wippelhauser et al. (2017) suggest Atlantic sturgeon use the upper Kennebec River, the Kennebec River estuary, and the Androscoggin River estuary for reproduction. It is unknown whether the Merrimack River supports a reproductive population of Atlantic sturgeon (ASMFC 2017). And while the Androscoggin represents an additional known spawning location for this DPS, non-spawning individuals were observed to use the Penobscot, Androscoggin, Saco, Merrimack, St. John, and Minas Passage (Altenritter et al. 2017; Novak et al. 2017; Wippelhauser et al. 2017). Survival rates of all ages are estimated to be approximately 74% annually (95% CL, 15-99%; ASMFC 2017).

5.3.3.1.2 New York Bight DPS

The Connecticut, Hudson, and Delaware Rivers all support reproductive populations while the Taunton River population appears to be extirpated. A recent assessment of relatedness of these populations to others along the coast reveals, as was the case at the time of listing, that the Hudson and Delaware populations appear to be a separate group from other populations but also different from one another (White et al. 2021a). The Connecticut River was not included in that study. A recent study using acoustic telemetry to estimate spawning duration and return intervals shows that Hudson River adults return much more frequently than previously thought; females every 1.66 years and males every 1.28 years (Breece et al. 2021). In the Hudson River, males were on spawning grounds on average from May 27 through July 11 and females from June 8 through June 29. The average male is also more likely to travel further upriver than the average female (Breece et al. 2021).

There are a number of updated abundance estimates for each river. The Hudson River most likely supports the largest population of Atlantic sturgeon in the United States. Effective population estimates for the Hudson River are 156 (95% CL, 138.3-176.1; n = 459; Waldman et al. 2019) and 145.1 (82.5-299.4; n = 307; White et al. 2021a). Kazyak et al. (2020) produced an abundance estimate of the 2014 adult spawning run size of 466 individuals (95% CL, 310-745). While this spawning run size is nearly identical to that estimated by Kahnle et al. (2007) from the end of the commercial fishery (1986-1995), monitoring of relative abundance of juveniles from 2004 through 2019 has shown production may have doubled during those 16 years (Pendelton and Adams 2021).

In the Delaware River, the effective population size has been estimated to be 40 (95% CL, 34.7-46.2; n = 108) and 60.4 (42-85.6; n = 488) by Waldman et al. (2019) and White et al. (2021a), respectively. The significant difference between estimates is likely due to sample size. Therefore, White et al.'s (2021a) estimate is likely most accurate. Additionally, a recent close-kin mark-recapture estimate was produced for the Delaware River and suggests there are fewer than 250 adults (census) in the Delaware River population (White et al. 2021b).

In the Connecticut River, despite only limited collection of juvenile sturgeon (n = 47), there is an estimate of effective population size of 2 (95% CL, 2-2.7; Waldman et al. 2019). This would suggest there has been a single spawning event in the Connecticut River that produced all of the juvenile fish collected or the spawning adults were so closely related as to be indistinguishable from a single pair. Either way, it is clear there is limited genetic diversity in this population and, unless these adults continue returning to the Connecticut River, it could take approximately 20 years to learn whether these juveniles have survived in sufficient numbers to sustain this new population.

Recent survival estimates do not suggest much of an improvement since the last estimates made during the commercial fishery (Boreman 1997; Kahnle et al. 1998). Melnychuk et al. (2017) provided an updated estimate of survival of Hudson River Atlantic sturgeon of approximately 88.22%, while for similar life stages over a longer time frame, the Atlantic States Marine Fisheries Service (ASMFC 2017) estimated survival of the entire New York Bight to be 91% (95% confidence limits, 71-99%).

Distribution of fish from the different populations of Atlantic sturgeon in the New York Bight DPS can be measured from north to south or inshore to offshore. While there has been no change to the range along the East Coast, there are detection data of acoustic transmitters much further offshore than had previously been documented (Ingram et al. 2019).

To understand movement along the coast, White et al. (2021c) assessed the river of origin of Atlantic sturgeon harvested during the commercial fishery. This was a duplication of a study done by Waldman et al. (1996), but with a greatly expanded genetic baseline since Waldman's work (White et al. 2021a), showed fish harvested in the Hudson River were from many locations other than the Hudson. The makeup of the harvested fish in the 1990s was 82.3% Hudson, 7.3% Delaware, 4.7% James River spring run, 2.4% St. Lawrence, 2.1% Kennebec, 1.3% Pee Dee spring run, rather than 98% Hudson as had been estimated during the fishery. Conversely, Wirgin et al. (2018) sampling 148 sub-adult sturgeon in the Hudson River estuary and relying on microsatellite DNA, found 142 of those were of Hudson River origin with additional contributions from the Kennebec (2), Delaware (2), Ogeechee (1), and James (1) Rivers. This may suggest sub-adults are more likely to spend time in their natal estuaries, while adults only return to their natal estuaries for spawning runs.

In terms of nearshore habitat use, Breece et al. (2018a) showed habitat selection is driven by depth, time of year, sea surface temperature, and light absorption by seawater, while sex and natal river do not seem to be important predictors of habitat selection. Therefore, regardless of the makeup of the mixed populations in these estuarine areas, the drivers of where the fish are located affect all sexes and populations similarly. Inshore and offshore movement is highly dependent on photoperiod and temperature, with fish residing offshore from November to January and inshore from June to September (Ingram et al. 2019). Fish gradually move inshore from February to May but rapidly move offshore during October (Ingram et al. 2019). In the Delaware Bay, when fish have moved inshore for the spring and summer months, Breece et al. (2018b) showed Atlantic sturgeon prefer shallow water and warmer bottom temperatures primarily in the eastern portion of the bay during residency but that this preference changes to deep, cool water and the western edge of the bay during migration.

Kazyak et al. (2021) studied the offshore composition of sturgeon between Cape Hatteras and Cape Cod (mid-Atlantic, which comprises the New York Bight, Chesapeake Bay, and part of the Carolina DPSs) and found that 37.5% and 30.7% of all bycaught fish in this region were from the New York Bight and Carolina DPSs, respectively. This was primarily driven by 27.3% of fish from the Albemarle complex and 26.2% from the Hudson River. Estuarine bycatch in this area was primarily from Albemarle Complex, with many of the samples being obtained in waters of North Carolina, and most offshore fish were from the Hudson and James Rivers.

5.3.3.1.3 Carolina DPS

The Carolina DPS is the least studied. Spawning likely occurs in the Roanoake, Tar/Pamlico, Neuse, Cape Fear, Pee Dee, Santee, and Cooper Rivers. Census abundance is not available for any system. The effective population size of juveniles collected in the Albemarle Sound is approximately 19 (95% CL, 16.5-20.6; n = 88; Waldman et al. 2019) to 29.5 (24.2-36.3; n = 71; White et al. 2021a). There is also a new effective population size estimate for the Pee Dee River spring (n = 66) and fall (n = 50) spawning runs, amounting to 13.5 (11.9-15.3) and 82 (60.3-122.1), respectively (White et al. 2021a). Also, updating Hightower et al. (2015), the ASMFC (2017) produced an updated survival estimate for the entire Carolina DPS, suggesting Atlantic sturgeon survival rates are approximately 78% (95% CL, 39-99%).

Relatedness of known spawning populations was also assessed for the Carolina DPS, both in terms of its relationships to other populations outside of the DPS and within. Once the York River is isolated as being unique and different from all other southeastern populations, those populations then break into 2 groups with a bit of overlap. One group is the Albemarle Complex, Pee Dee spring run, Pee Dee fall run, Edisto spring run, Ogeechee spring run, and Satilla River populations while the other group is the Albemarle Complex, Pee Dee fall run, Edisto fall run, Savannah, Ogeechee fall run, and Altamaha populations (White et al. 2021a). When compared amongst each other further, those groupings break out into 1) the Albemarle Complex, Pee Dee spring run, and Pee Dee fall run separate from the rest of the southeastern rivers (White et al. 2021a).

Little is known about the distribution of this DPS along the Atlantic Coast. As mentioned in the discussion of the New York Bight DPS sturgeon distribution, the Carolina DPS made up 30.7% of detections between Cape Cod and Cape Hatteras. This DPS also makes up 6.2% of detections south of Cape Hatteras (Kazyak et al. 2021). From Cape Cod to Florida, Carolina DPS fish were most likely to be encountered in nearshore waters. Rulifson et al. (2020), relying on acoustic telemetry, showed that, similar to what has been documented for New York Bight and Chesapeake Bay DPS fish, Carolina DPS sturgeon move inshore and offshore seasonally. The greatest number of detections along the North Carolina Atlantic Coast occur from November to April (Rulifson et al. 2020).

5.3.3.1.4 South Atlantic DPS

Spawning occurs in the Edisto, Savannah, Ogeechee, Satilla, Altamaha, and St. Marys rivers. The Edisto and Ogeechee Rivers appear to have a spring and a fall run (White et al. 2021a). When exploring the possibility of spring and fall spawning migrations, without any knowledge of the reproductive condition of the individuals, Vine et al. (2019a) identified temperature as a primary driver of upriver movement in both the spring and fall. In the spring, Atlantic sturgeon moved upriver as temperatures increased between 11 and 15 °C and in the fall, as temperatures were descending, between 29 and 24 °C (Vine et al. 2019a). For Atlantic sturgeon, discharge did not influence upriver movement (Vine et al. 2019a).

Information about South Atlantic DPS abundance is better than most other DPSs. Prior to the 5 DPSs being listed under the ESA, the only adult abundance estimate available was for the Altamaha River, which was estimated to be 324 to 386 individuals in consecutive year spawning runs. However, Ingram and Peterson (2016) later showed that Atlantic sturgeon in the Altamaha River 1) spawn in the fall (the abundance estimates were obtained during the spring), and 2) they have 2 different migratory strategies, such that approximately 37% of the population migrates into the river in the spring (when that sampling occurred) and are joined by the rest of the spawning run who move directly upriver so they all spawn together in the fall. This may suggest annual spawning abundances of closer to 1,000 individuals. Schueller and Peterson (2010) reported that age-1 and -2 Atlantic sturgeon population densities ranged from about 1,000 to 2,000 individuals over a 4-year period from 2004 to 2007 in the Altamaha River. A census estimate was produced for the upper 20 km of the Savannah River (river kilometers 281-301) to estimate the number of purported spawning adults in that stretch on a given day over 50 sampling occasions. The maximum estimate of daily abundance in those 20 km was 35 to 55 adults of unknown sex (Vine et al. 2019b).

Effective population estimates were also produced for many rivers in the South Atlantic DPS. The Edisto River was estimated to have an effective population of 60 (95% CL, 51.9-69.0, n = 145; Waldman et al. 2019), but was broken into 2 spawning populations by White et al. (2021a) following the identification of 2 distinct spawning groups (Farrae et al. 2017) for estimates of a spring run of 16.4 (12.8-20.6, n = 123) and a fall run of 47.9 (25.3-88.8, n = 373). The Savannah River was estimated to have an effective population size of approximately 123 (103.1-149.4, n = 161) and also of approximately 154.5 (99.6-287.7, n = 134) by Waldman et al. (2019) and White et al. (2021a), respectively. The Ogeechee River was estimated to have an effective population of 26 (23.9-28.2, n = 200; Waldman et al. 2019), but was also broken into 2 spawning populations by White et al. (2021a) for estimates of a spring run of 31.1 (24.3-40.2, n = 92) and a fall run of 56.5 (36.3-103.6, n = 55). The Altamaha River appears to support the largest Atlantic sturgeon population in the South Atlantic DPS, and one of the largest on the East Coast, with effective population estimates of 149 (128.7-174.3; n = 245; Waldman et al. 2019) and 141.7 (73.4-399; n = 189; White et al. 2021a). The effective population estimates for the Satilla River population are 21 (18.7-23.2; n = 68; Waldman et al. 2019) and 11.4 (9.1-13.9; n = 74; White et al. 2021a). Work in the St. Marys River on the Florida-Georgia border captured 25 fish including 14 river resident juveniles. Analysis of those individuals reveals an effective population size of 1 (1.3-2.0), but this is a known under-estimate because those individuals were from a single spawning event (Fox et al. 2018a, Waldman et al. 2019). The St. Johns River in Florida does not appear to support an extant population (Fox et al. 2018b). Survival within the entire DPS was estimated to be approximately 86% (54-99%; ASMFC 2017).

The relatedness of the populations reveals 3 groups of related clusters within this DPS. The first cluster includes the Edisto spring run, the Ogeechee Spring run, and the Satilla River populations; the second includes the Edisto River fall run and Ogeechee River fall run; and the third includes the largest populations of the Savannah and Altamaha Rivers, but also the Ogeechee River fall run (White et al. 2021a). As was seen with other rivers with dual spawning populations, the spring and fall runs are genetically differentiated.

South of Cape Hatteras, Kazyak et al. (2021) showed that 91.2% of fisheries bycatch was from the South Atlantic DPS. In terms of population level distribution and susceptibility to commercial fisheries, 35.7% were from the Altamaha River, 21.4% from the Edisto River fall-run, 18.9% from the Savannah River, 7.2% from the Ogeechee River (both spring and fall), 5.5% Satilla, 3.7% Pee Dee (both spring and fall), and 2.0% Edisto spring-run. In the south, most offshore fish were from the Altamaha, followed by the Savannah (Kazyak et al. 2021). Within river movement studies also revealed that age-1 fish that were tagged in the summer remained in the rivers and overwintered before outmigrating between December and March (Fox and Peterson 2019). When observing the likelihood of becoming a coastally wandering sub-adult or remaining a river resident for another year, Fox and Peterson (2019) found that 36.7% returned as age 2 fish while 30.4% outmigrated as age 2. The St. Johns River, the furthest south in the South Atlantic DPS, has periodic use by sub-adults and adults, but is no longer spawning or rearing habitat.

5.3.3.2 Threats

Of the stressors evaluated in the 2007 status review (ASSRT 2007), bycatch mortality, water quality, lack of adequate state and/or Federal regulatory mechanisms, and dredging activities were most often identified as the most significant threats to the viability of Atlantic sturgeon populations. Additionally, some populations were affected by unique stressors, such as habitat impediments (e.g., Cape Fear and Santee-Cooper Rivers) and apparent ship strikes (e.g., Delaware and James Rivers).

5.3.3.3 Population dynamics and distribution

As noted above, Atlantic sturgeon spawn in approximately 27 river systems and there is genetic information for about 21 populations (White et al., 2021a). Atlantic sturgeon display longevity and maturation gradients along the coast, living longer and maturing later in the north (Dadwell, 2006; Kahn et al. 2023). Spawn timing, once thought to be uniformly as waters begin to warm in the spring (Smith 1985) is now known to vary by river with some rivers supporting a single spawning run and some rivers supporting multiple runs. In the rivers with multiple runs, the runs appear to be genetically differentiated (White et al., 2021a). From the Delaware River and north, all of those rivers only support a single spawning run and it occurs in the spring. However, from the Chesapeake Bay and south, all rivers that support a single spawning run display fall spawning, but some rivers have genetic evidence of both spring and fall spawning runs (Balazik et al. 2017; Farrae et al. 2017; White et al. 2021a). Only the Edisto River has had females observed spawning during the spring and the fall (Collins et al. 2000).

Survival rates are available for a number of different Atlantic sturgeon populations. Verreault and Trencia (2011) estimate survival rates in the St. Lawrence River, Canada, of 88.5%. Survival in the St. John River, Canada, is estimated to be 90.9%. Hudson River survival, based on the longevity of Atlantic sturgeon, is estimated to be 93% (Boreman 1997, Kahnle et al. 1998). Empirical studies conducted in the Roanoke, Cape Fear, the Ashepoo, Combahee, and Edisto Rivers, and Altamaha Rivers (Hightower et al. 2015) calculated survival rates of adult and sub-adult Atlantic Sturgeon using a Cormack-Jolly-Seber model. The apparent annual survival rate is 83.9% in the Roanoke River Atlantic sturgeon population, 77.8% in the Cape Fear River population, 87.1% in the Ashepoo, Combahee, and Edisto Rivers population, and 84.2% in the Altamaha River population (Hightower et al. 2015). Peterson et al. (2008) used catch curve data of adults from 2 sampling years to estimate adult survival in the Altamaha River between 78.7 and 82.7% per year. A coastwide assessment of survival at the DPS level was made using a Cormack-Jolly-Seber model (ASMFC 2017) showing the likely annual survival of the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs were 74%, 91%, 88%, 78%, and 86%, respectively.

Little is known about Atlantic sturgeon sex ratios. Smith et al. (1984) report the ratio skewed towards females with a sex ratio in the South Carolina fishery from 1:2 to 1:4 between 1978 and 1982. Collins et al. (2000) found the sex ratio on spawning runs in South Carolina rivers was dominated by males with a ratio of 3:1. Kahnle et al. (2007) identified a very consistent 4.1:1 ratio on spawning runs in the Hudson River estuarine fishery between 1980 and 1995. Dadswell et al. (2017) report spawning run ratios of 1.2:1 in the St. John River commercial fishery from 2009 to 2016. Kahn et al. (2021) report annual sex ratios on spawning runs ranging from 3:1 to 1.8:1. Kahn et al. (2021) also calculated a total population sex ratio of approximately 51% male, 49% female.

5.3.3.4 Life history

The general life history pattern of Atlantic sturgeon is that of a long lived, late-maturing, iteroparous, anadromous species. Males tend to spawn nearly every year and females spawn usually every 2 years but sometimes 3 (Hager et al. 2020; Breece et al. 2021). Fecundity increases with age and body size (ranging from 400,000 – 2 million eggs, Smith et al. 1982; Van Eenennaam and Doroshov 1998; Dadswell 2006). The average age at which 50% of maximum lifetime egg production depends on age at maturity, but is generally estimated to be 29 years, approximately 3-10 times longer than for other bony fish species examined (Boreman 1997).

While few specific spawning locations have been identified, at least 21 rivers are known to support reproducing populations. White et al. (2021a) showed there are a number of rivers, all located in the Chesapeake Bay and to the south, that have genetically distinct spawning populations within the same river. When that occurs, spring spawning populations from neighboring rivers appear to be more closely related to one another than to the fall spawning populations from the same river (White et al., 2021a). Otherwise, the typical spawning pattern along the coast is for spring spawning in the Delaware River and all rivers to the north and for fall spawning in the Chesapeake Bay and all rivers to the south.

Limited information on the status of Atlantic sturgeon populations is available. Atlantic sturgeon juveniles congregate near the saltwater interface in salinities from 0 to 10 parts per thousand. Older juveniles are more tolerant of higher salinities as juveniles typically spend at least 2 years and sometimes as many as 5 years in freshwater before eventually becoming coastal residents as sub-adults (Smith 1985, Boreman 1997, Schueller and Peterson 2010). After leaving their natal rivers, they range widely in nearshore and estuarine habitats, returning as adults to their natal rivers to spawn. Sturgeon eggs are highly adhesive and are deposited in freshwater or tidal freshwater reaches of rivers on the bottom substrate, usually on hard surfaces such as cobble (Gilbert 1989; Smith and Clugston 1997). Hatching occurs approximately 94-140 hours after egg deposition, and larvae assume a bottom-dwelling existence (Smith et al. 1980). The yolk sac larval stage is completed in about 8-12 days, during which time larvae move downstream to rearing grounds over a 6 to 12-day period (Kynard and Horgan 2002). During the daytime, larvae use benthic structure (e.g., gravel matrix) as refugia (Kynard and Horgan 2002).

5.3.3.5 Critical habitat

See discussion in section 5.2.1.

5.3.3.6 Recovery planning

While there is no recovery plan in place for Atlantic sturgeon, a recovery outline is available (NMFS 2018). The goal for recovery is to have reproductive populations across their historic range of sufficient size and diversity to support reproduction and recovery from mortality events. There have been no new threats identified since the DPSs were designated.

6 Environmental Baseline

The "environmental baseline" is 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 consultation, 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 C.F.R. §402.02)

The action area for this program is the freshwater portions of all rivers along the East Coast. These areas have undergone significant physical, biological, and ecological changes over the past few centuries. These changes are primarily the result of human population growth and associated activities that have drastically altered the natural environment in this region. This section provides an overview of several past and ongoing anthropogenic threats to shortnose sturgeon, all DPSs of Atlantic sturgeon, and GOM Atlantic salmon. In some cases, because these are all migratory species, it may be appropriate to discuss threats occurring outside of the action area that affect the condition of individuals likely to be exposed to stressors caused by the program within the action area.

6.1 Climate Change

For both species of East Coast sturgeon and Atlantic salmon that undergo long migrations, individual movements are usually associated with prey availability or habitat suitability. If either is disrupted, the timing of migration can change or negatively impact population sustainability (Simmonds and Eliott 2009). Global climate change has led to changes in air and sea surface temperatures, which can affect marine ecosystems in several ways. Direct effects decrease sea ice, altering ocean acidity, increases sea surface temperatures, causes more extreme precipitation patterns, and raises sea level. Indirect effects of climate change include altered reproductive seasons/locations, shifts in migration patterns, reduced distribution and abundance of prey, and changes in the abundance of competitors and/or predators. Variations in sea surface temperature can affect an ecological community's composition and structure, alter migration and breeding patterns of fauna and flora and change the frequency and intensity of extreme weather events. Over the long term, increases in sea surface temperature can also reduce the amount of nutrients supplied to surface waters from the deep sea leading to declines in productivity and trophic abundance (EPA 2010). Acevedo-Whitehouse and Duffus (2009) proposed that the rapidity of environmental changes, such as those resulting from global warming, can harm immunocompetence and reproductive parameters in wildlife to the detriment of population viability and persistence.

Information on how climate change will impact the action area is extremely limited. However, since the turn of the century, temperatures in Florida have increased by 1.1 °C (2 °F), North Carolina have increased by 0.6 °C (1 °F), New Jersey have increased 1.9 °C (3.5 °F), New York have increased 1.4 °C (2.5 °F), and from Connecticut to Maine have increased by 1.9 °C (3.5 °F; Kunkel et al. 2022). Temperatures in each area are expected to continue increasing through the century. As reported by the University of Maine's Climate Change Institute (Fernandez et al. 2020), refined models predict that Maine's annual temperature is projected to increase between 1.7–2.8 °C by 2050, with continued increases in precipitation frequency and intensity. Under moderate to high emissions scenarios ocean temperatures in the Gulf of Maine are also expected to rise as much as 1.2 °C (2.2 °F) by 2050 and 2.2 °C (3.9 °F) by 2100, and sea levels are expected to rise as much as 30 to 90 cm by 2050 and 1.10 to 3.3 m by 2100. These rising sea levels would likely shift the salt wedge in the lower estuarine portions of rivers in the GOM DPS. Because there remains uncertainty in the rate and timing of change as well as the effect of any changes that may be experienced in the action area due to climate change, it is difficult to predict the impact of these changes on Atlantic salmon.

In the action area, it is possible that changing seasonal temperature regimes could result in changes in the timing of seasonal migrations for the GOM DPS of Atlantic salmon. The timing of spawning could shift later into the fall as water temperatures warm and spawning migrations could occur earlier in the year. However, because salmon spawning is not triggered solely by water temperature, but also by day length (which would not be affected by climate change) and river flow (which could be affected by climate change), it is not possible to predict how any change in water temperature or river flow alone will affect the seasonal movements of salmon throughout the action area. Increasing water temperatures will also likely increase energy consumption of upstream migrating Atlantic salmon, depleting energy reserves that may lead to lower spawning success and post spawn recovery (Rubenstein 2021).

Dams and their associated impacts have been shown to exacerbate the effects of climate change because changes in streamflow, including dam impoundments and flow management through dams, can significantly affect water temperatures due to changes in thermal capacity, with water temperature being inversely related to discharge (Webb et al. 2003). Furthermore, any delays in the migration of Atlantic salmon that increase their exposure time to warmer temperatures can negatively affect their reproductive success (Mantua et al. 2010; Rubenstein 2021).

Over the long term, global climate change may affect Atlantic salmon by affecting the location of the salt wedge, distribution of prey, water flows, temperature and quality. However, there is significant uncertainty, due to a lack of scientific data, on the degree to which these effects may be experienced over the term of the proposed action. While we can make some predictions on the likely effects of climate change on this species, without modeling and additional scientific data, these predictions remain speculative. Additionally, these predictions do not take into account the adaptive capacity of this species, which may allow them to deal with change better than predicted.

As reported by the University of Maine’s Climate Change Institute (Fernandez et al. 2020), models predict that Maine’s annual temperature is projected to increase between 1.7–2.8°C by 2050, with continued increases in precipitation frequency and intensity. Under moderate to high emissions scenarios, ocean temperatures in the Gulf of Maine are also expected to rise as much as 1.2ºC (2.2ºF) by 2050 and 2.2ºC (3.9ºF) by 2100, and sea levels are expected to rise as much as 1 to 3 inches (30 to 90 cm) by 2050 and 3.6 to 10.8 ft (1.10 to 3.3 m) by 2100. These rising sea levels would likely shift the saltwater wedge in the lower estuarine portions of rivers in the GOM DPS. Because there remains uncertainty in the rate and timing of change, as well as the effect of any changes that may be experienced in the action area due to climate change, it is difficult to predict the impact of these changes on Atlantic salmon.

As described in Hare et al. (2016), several studies have examined the effects of climate on the abundance and distribution of Atlantic salmon. In a review, Jonsson and Jonsson (2009) concluded that the thermal niche of Atlantic salmon will likely shift northward causing decreased production and possibly extinction at the southern end of the range. The Gulf of Maine DPS is the southernmost populations of Atlantic salmon in the Northwest Atlantic Ocean.

Friedland et al. (2007) found that declines in post-smolt survival were associated with ocean warming and hypothesized that in the Northwest Atlantic, the decline in survival was a result of early ocean migration by post-smolts. Mills et al. (2013) suggested that poor trophic conditions, likely due to climate-driven environmental factors, and warmer ocean temperatures are constraining the productivity and recovery of Atlantic Salmon in the Northwest Atlantic. Available evidence suggests that climate change and long-term climate variability will reduce the productivity of the Gulf of Maine DPS of Atlantic Salmon.

Sturgeon species first appear in the fossil record between 260 and 320 million years ago (Ruban 2023) and they have survived extreme global temperature events without going extinct, however, the pace at which they needed to adapt to those changes is very different today than under naturally occurring conditions (Marcott et al. 2013). While the Altamaha River (Georgia) population is one of the largest remaining populations, there are indication of recent extirpations and year class failures at the southern extent of Atlantic sturgeon range (Fox et al. 2018a, 2018b). Likewise, the southernmost shortnose sturgeon populations are also either extirpated or most at risk of extirpation (SSSRT 2010). The risk to anadromous species is amplified because they consistently return to their natal rivers with minimal straying (Grunwald et al. 2008; King et al. 2014; Kazyak et al. 2021). There is evidence of recently colonized northern rivers, which may be a good sign for Atlantic sturgeon (Savoy et al. 2017). It is also interesting that it appears a fish from the South Atlantic DPS contributed to the new spawning population in the Connecticut River.

The potential for invasive species to spread may increase under the influence of climatic change. If water temperatures warm in marine ecosystems, native species may shift poleward to cooler habitats, opening ecological niches that can be occupied by invasive species introduced via ships ballast water or other sources (Ruiz et al. 1999; Philippart et al. 2011). Anadromous species return to their natal rivers to spawn regardless of habitat conditions at the time of spawning and without knowledge of changing extreme temperatures at other times of the year when their offspring would be rearing. The stationary nature of anadromous fish reproduction in an otherwise shifting area of habitat occupation could make some populations vulnerable to invasive species. Invasive species that are better adapted to warmer water temperatures can also outcompete native species that are physiologically geared towards lower water temperatures (Lockwood and Somero 2011). Altered ranges can also result in the spread of novel diseases to new areas via shifts in host ranges (Simmonds and Eliott 2009). For example, it has been suggested that increases in harmful algal blooms could result from increases in sea surface temperature (Simmonds and Eliott 2009).

Changes in the marine ecosystem caused by global climate change (e.g., ocean acidification, salinity, oceanic currents, DO levels, nutrient distribution) is already changing 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 East Coast sturgeon and Atlantic salmon and altering the marine regions that allow for greatest bioenergetic growth. When adults struggle to find sufficient resources, their egg production is lower than normal and body condition in the action area will be poorer.

6.2 Human Population Density, Development, and Urbanization

Many stream and riparian areas within the action area have been degraded by the effects of land and water use associated with urbanization, road construction, forest management, agriculture, mining, transportation, water development, and other human activities. Development activities contribute to a variety of interrelated factors that lead to the decline of sturgeon and Atlantic salmon. These include reduced in-channel and off-channel habitat, restricted lateral channel movement, increased flow velocities, increased erosion, decreased cover, reduced prey sources, increased contaminants, increased water temperatures, degraded water quality, and decreased water quantity.

Urbanization and increased human population density within a watershed result in changes in stream habitat, water chemistry, and the biota (plants and animals) that live there. In many cases, these changes negatively impact species, particularly those with small population sizes. The most obvious effect of urbanization is the loss of natural vegetation and increases in impervious cover, which results in dramatic changes to the natural hydrology of urban and suburban streams. Urbanization generally involves land clearing, soil compaction, modification and/or loss of riparian buffers, and modifications to natural drainage features. The increased impervious cover in urban areas leads to increased volumes of runoff, increased peak flows and flow duration, and greater stream velocity during storm events.

Runoff from urban areas also contains chemical pollutants from vehicles and roads, industrial sources, and residential sources. Urban runoff is typically warmer than receiving waters and can significantly increase temperatures, particularly in smaller streams (Hester and Bauman 2013). Municipal wastewater treatment plants replace septic systems, resulting in point discharges of nutrients and other contaminants not removed in the processing. Where septic systems have not been replaced, some are failing. Municipalities with combined sewer/stormwater overflows or older treatment systems may directly discharge untreated sewage following heavy rainstorms. Urban and suburban nonpoint and point source discharges affect water quality and quantity in basin surface waters, such as landscape management, golf courses, and industrial or institutional campuses. Dikes and levees constructed to protect infrastructure and agriculture have isolated floodplains from their river channels and restricted fish access. The many miles of roads and rail lines that parallel streams within the action area have degraded stream bank conditions and decreased floodplain connectivity by adding fill to floodplains. Culvert and bridge stream crossings have similar effects and create additional problems for fish when they act as physical or hydraulic barriers that prevent fish access to spawning or rearing habitat, or contribute to adverse stream morphological changes upstream and downstream of the crossing itself.

The Northeastern coastal zone covers approximately 14,347 mi^2 (37,158 km^2) in 8 states (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey). Some of the highest population densities in the United States are found in coastal counties within this zone from Massachusetts through New Jersey (U.S. Census Bureau, www.census.gov). Primary land-cover classes are forests and developed land, which account for more than 70% of the ecoregion. Water, wetlands, and agriculture are secondary land cover classes found in smaller, less frequent concentrations in the Northeast coastal zone. Developed land increased an estimated 4% (583 mi^2 [1,510 km^2]) from 1973 to 2000, to approximately 27% of the ecoregion's area (USGS 2017). Much of the new development came from forest loss, with a decrease of 3.7% (526 mi^2 [1,361 km^2]) during this same period. Agricultural land-cover decreased by 0.8%. Other land cover changes in the Northeastern coastal zone from 1973 to 2000 included slight decreases in wetlands and slight increases in mechanically disturbed lands and mining (USGS Land Cover Trends Project). Increased development was the primary reason for these changes (i.e., wetlands converted to development, increased aggregate mining for construction materials, and forest land being cleared—mechanically disturbed—for pending development).

The Middle Atlantic coastal plain ecoregion covers approximately 34,630 mi^2 (89,691 km^2) that stretches from Delaware Bay and the Delmarva Peninsula in the north to Jacksonville, Florida (USGS Land Cover Trends Project). Portions of 9 states are included in this ecoregion: New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Florida. Coastal states from Virginia through Florida experienced much faster population growth (14.3%) from 2000 to 2010 compared to Northeastern states from Maryland through Maine (3.2%) (U.S. Census Bureau, www.census.gov). The topography of the ecoregion is primarily flat, and many soil types are poorly drained. The dominant land uses within the Middle Atlantic coastal plain are farming and forestry, with urban development being locally significant. The land cover is primarily a mosaic of forest, wetlands, and agriculture cropland (i.e., soybeans, cotton, tobacco, soybeans and corn). Livestock production is most pronounced as confined animal feeding operations, such as for hogs in North Carolina and poultry on the Delmarva Peninsula (USDA 1999). Wetlands are common across the ecoregion and include coastal marshes, bottomland hardwood forests, and shrub bogs. Two of the Middle Atlantic Coastal Plain's dominant land covers, forest and wetlands, experienced net loss in coverage from 1973 and 2000 of -3.3 and -1.3%, respectively). The Middle Atlantic coastal plain ecoregion gained an estimated 867.6 mi^2 (2,247 km^2) of new developed land from 1973-2000 representing an increase of 2.6%. The majority of the newly developed land came from forestland (675 mi^2 [1,747 km^2]), with much small amounts of agricultural land (97.7 mi^2 [253 km^2]) and wetlands (51.8 mi^2 [134 km^2]) being converted for development.

6.3 Dams

Dams impound water for water resource projects such as hydropower generation, irrigation, navigation, flood control, industrial and municipal water supply, and recreation. Dams can also have profound effects on anadromous species by fragmenting populations, impeding access to spawning and foraging habitat, and altering natural river hydrology and geomorphology, water temperature regimes, and sediment and debris transport processes (Pejchar and Warner 2001; Wheaton et al. 2004). The loss of historic habitat ultimately affects anadromous fish in 2 ways: 1) it forces fish to spawn in sub-optimal habitats that can lead to reduced reproductive success and recruitment, and 2) it reduces the carrying capacity (physically) of these species and affects the overall health of the ecosystem (Patrick 2005). Physical injury and direct mortality occurs as fish pass through turbines, bypasses, and spillways. Indirect effects of passage through all routes may include disorientation, stress, delay in passage, exposure to high concentrations of dissolved gases, elevated water temperatures, and increased vulnerability to predation. Activities associated with dam maintenance, such as dredging and minor excavations along the shore, can release silt and other fine river sediments to nearby spawning habitat. Dams can also reduce habitat diversity by forming a series of homogeneous reservoirs; these changes generally favor different predators, competitors and prey, than were historically present in the system (Auer 1996).

The detrimental effects of dams on populations of shortnose and Atlantic sturgeon are generally well documented (Cooke and Leach 2004; Kynard 1998). Perhaps the biggest impact of dams on sturgeon is the loss of upriver spawning and rearing habitat (Table 6). Migrations of sturgeon and Atlantic salmon in rivers without barriers are wide-ranging with total distances exceeding 124.3 miles (200 km) or more, depending on the river system (Kynard 1997). Observations of spawning immediately below dams suggests that they are unable to reach their preferred spawning habitat upriver. Although dams constructed at the fall line of some rivers have not impacted spawning, dams of many other rivers block upriver passage, restricting spawning activities to areas below the impoundment and leaving sturgeon and salmon vulnerable to perturbations of natural river conditions at different life stages (Cooke and Leach 2004; Kynard 1997). Atlantic sturgeon spawning sites remain unknown for the majority of rivers in their range, while more is known about shortnose sturgeon and Atlantic salmon. Overall, 91% of historic sturgeon habitat seems to be accessible, but the quality of the remaining portions of habitat as spawning and nursery grounds is unknown. Thus, dams may be one of the primary causes of the extirpation of sturgeon and salmon populations on the East Coast.

Table 6. First upstream dam locations and year built for major rivers within the action area

River	First dam (Year built)	River kilometer
Penobscot	Milford (1906) and Orono (1851)	53.5
Androscoggin	Brunswick (1948)	44
Kennebec	Lockwood (1919)	98
Merrimack	Essex Dam (1848)	46
Connecticut	Holyoke Dam (1849)	140
Housatonic	Derby Dam (1870)	23
Hudson	Troy Dam (1825)	245
Susquehanna	Conowingo Dam (1928)	16
Potomac	Little Falls Dam (1959)	189
Roanoke	Roanoke Rapids Dam (1955)	221
Chowan River Basin	Emporia Dam, Meherrin (1918)	203

Tar-Pamlico (Tar River)	Rocky Mount Mills Dam (1971)	199
Neuse	Milburnie Dam (1903)	341
Cape Fear	Lock and Dam #1 (1915)	97
Winyah Bay/Pee Dee	Blewett Falls Dam (1912)	330
Santee	Santee (1940s) and St Stephens Dam (1985)	143 and 92
Cooper	Pinopolis Dam (1942)	77
Savannah	New Savannah Bluff Lock & Dam (1937)	317
Ogeechee	Jordan Mill Pond Dam	375
St. Johns, Ocklawaha River	Rodman Dam (1968)	13

The suitability of riverine habitat for anadromous species spawning and rearing depends on annual fluctuations in water flow, which can be greatly altered or reduced by the presence and operation of dams (Cooke and Leach 2004; Jager et al. 2001). Effects on spawning and rearing may be most dramatic in hydropower facilities that operate in peaking mode (Auer 1996; Secor and Niklitschek 2002). Daily peaking operations store water above the dam when demand is low and release water for electricity generation when demand is high, creating substantial daily fluctuations in flow and temperature regimes. Kieffer and Kynard (2012) reported extreme flow fluctuations for hydroelectric power generation on the Connecticut River affected access to shortnose sturgeon spawning habitat, possibly deterred spawning, and left rearing shoals either completely scoured during high flows or dry and exposed during low flows.

6.4 Water Quality and Contaminants

Water quality in rivers and streams is affected by human activities conducted in the riparian zone, as well as 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 DO, and the addition of nutrients. In addition, forestry and agricultural practices can result in erosion, runoff of fertilizers, herbicides, insecticides or other chemicals, nutrient enrichment, and alteration of water flow. Coastal and riparian areas are also heavily impacted by real estate development and urbanization resulting in stormwater discharges, non-point source pollution, and erosion. The Clean Water Act regulates pollution discharges into waters of the United States from point sources; however, it does not regulate non-point source pollution.

Chemicals such as chlordane, 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 and salmon). Some of these chemicals have recently been documented to affect physiological processes and development of larval life stages, impede a fish's ability to withstand stress, while simultaneously increasing the stress of the surrounding environment by reducing DO, altering pH, and altering other physical properties of the water body (Chambers et al. 2012).

Water quality along the East Coast varies by region and watershed. The EPA recently published its fifth edition of the National Coastal Condition Report, a "report card" summarizing the status of coastal environments as of 2010 (EPA 2015). 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. A summary of the results for the Northeast (Virginia to Maine) and Southeast (North Carolina to Florida) regions is shown below in Figure 13 and Figure 14, respectively. More than half of the coastal areas in both regions along the Atlantic coast were rated as either poor or fair for phosphorous, chlorophyll, and overall water quality index. Ecological fish tissue quality also received low ratings, particularly in the Southeast region where over half of the coastal area was rated as "poor" for this criterion.

Life histories of sturgeon species, more so than Atlantic salmon (i.e., long lifespan, extended residence in estuarine habitats, benthic foraging), predispose them to long-term, repeated exposure to environmental contamination and potential bioaccumulation of heavy metals and other toxicants (Dadswell 1979). 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 PCDDs, PCDFs, PCBs, DDE, aluminum, cadmium, and copper all above adverse effect concentration levels reported in the literature (Brundage 2021). Dioxin and furans were detected in ovarian tissue from shortnose sturgeon caught in the Sampit River/Winyah Bay system (South Carolina). Early life stage Atlantic and shortnose sturgeon are vulnerable to PCB and TCDD toxicities of less than 0.1 parts per billion (Chambers et al. 2012).

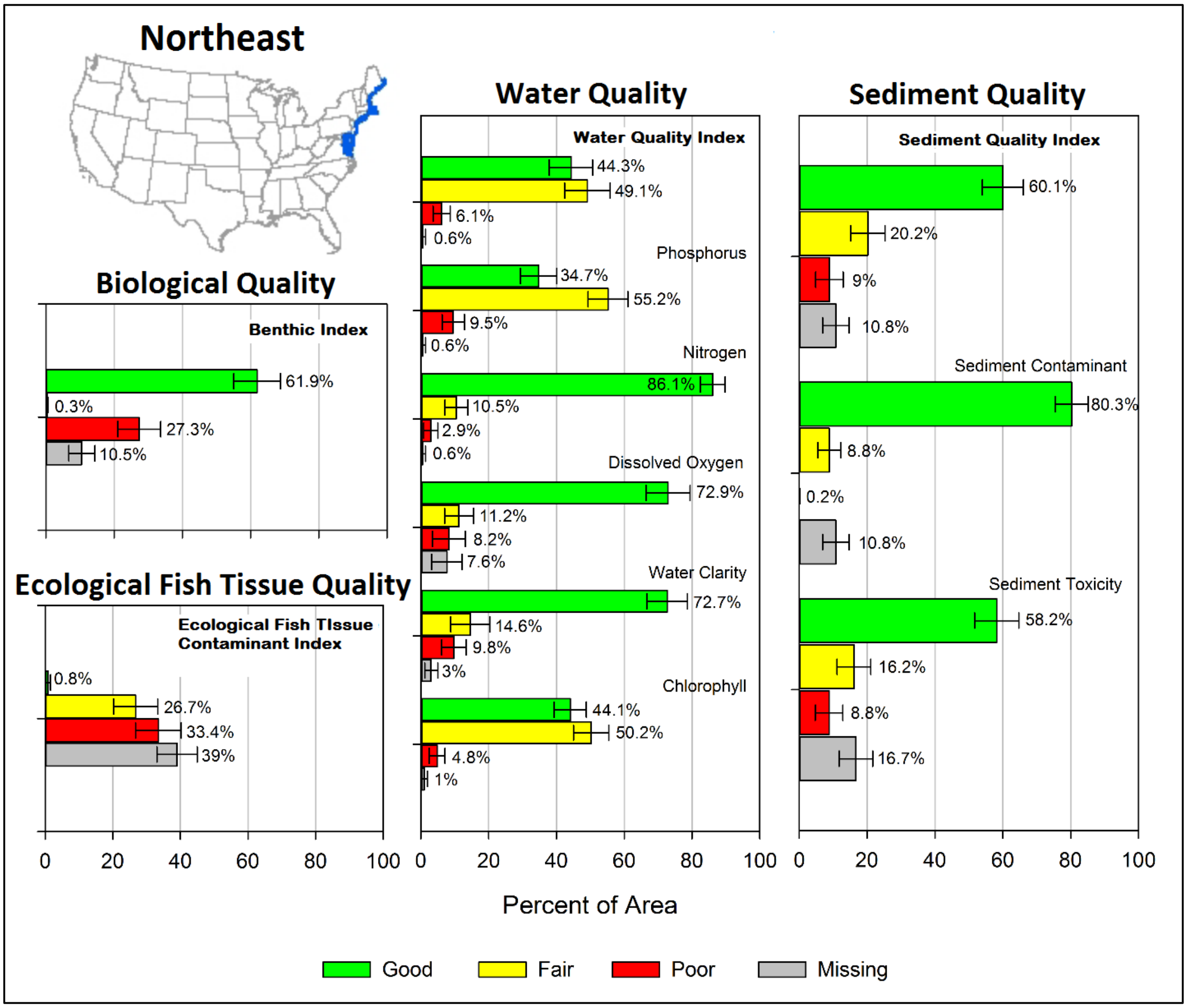

Figure 13. National Coastal Condition Assessment 2010 Report findings for the Northeast Region. Bars show the percentage of coastal area within a condition class for a given indicator. Error bars represent 95% confidence levels (EPA 2016)

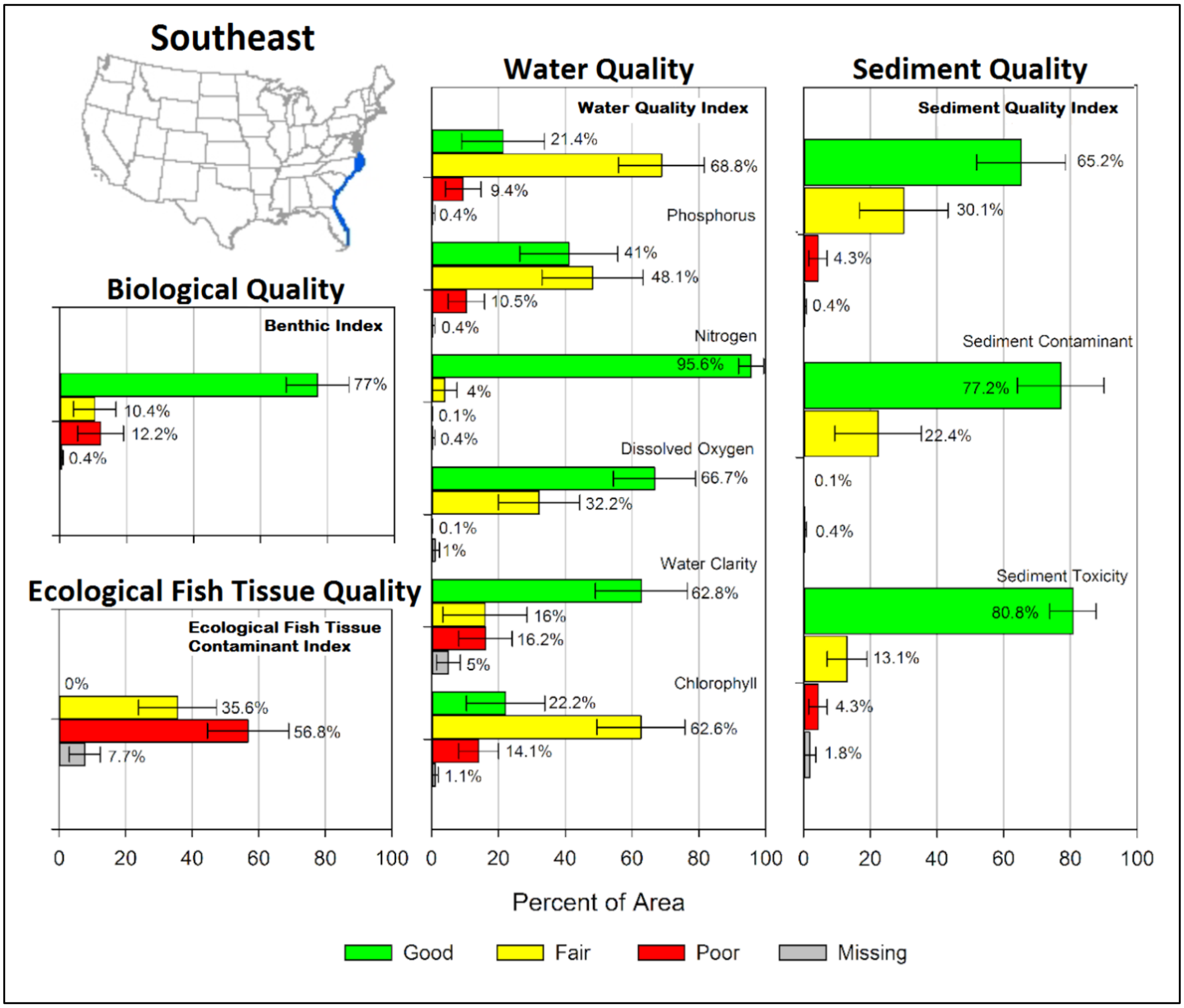

Figure 14. National Coastal Condition Assessment 2010 Report findings for the Southeast Region. Bars show the percentage of coastal area within a condition class for a given indicator. Error bars represent 95% confidence levels (EPA 2016)

Heavy metals and organochlorine compounds accumulate in fish tissue, but their long-term effects are not known (Ruelle and Keenlyne 1993). High levels of contaminants, including chlorinated hydrocarbons, in several fish species are associated with reproductive impairment (Giesy et al. 1986; Billsson 1998; Cameron et al. 1992; Hammerschmidt et al. 2002), reduced survival of larval fish (Willford et al. 1981), delayed maturity and posterior malformations (Billsson 1998). Pesticide exposure in salmonids may affect anti-predator and homing behavior, reproductive function, physiological maturity, swimming speed, and distance (Beauvais et al. 2000; 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). Increased doses of PCBs and TCDD have been correlated with reduced physical development of Atlantic sturgeon larvae, including reductions in head size, body size, eye development and the quantity of yolk reserves (Chambers et al. 2012). Juvenile shortnose sturgeon raised for 28 days in North Carolina's Roanoke River had a 9% survival rate compared to a 64% survival rate at non-riverine control sites (Cope et al. 2011). The reduced survival rate could not be correlated with contaminants, but significant concentrations of retene, a paper mill by-product with dioxin-like effects on early life stage fish, were detected in the river (Cope et al. 2011).

Dwyer et al. (2005) compared the relative sensitivities of common surrogate species used in contaminant studies to 17 ESA-listed species. 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 ESA-listed species, Atlantic sturgeon were ranked the most sensitive species tested for 4 of the 5 chemicals (Atlantic and shortnose sturgeon were found to be equally sensitive to permethrin). 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).

Fecal coliform, estradiol and other hormones, caffeine, personal care products, and pharmaceuticals may also affect ESA-listed fish species. These compounds can enter the aquatic environment via wastewater treatment plants, agricultural facilities, and runoff from farms. Estrogenic compounds are particularly concerning because they are known to affect the male to female sex ratio of carp via decreased gonadal development, physical feminization and sex reversal (Folmar et al. 1996). Although the effects of these contaminants are unknown in ESA-listed sturgeon and salmon, Omoto et al. (2002) found that by varying the oral doses of estradiol-17β or 17αmethyltestosterone 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 DO concentrations, can result in sub-lethal effects that may have negative consequences for at risk fish populations.

6.5 Non-Native and Invasive Species

When non-native plants and animals are introduced into habitats where they do not naturally occur they are typically less suited to compete in that environment. However, in degraded habitats (like described above), non-native species may be better suited to utilize resources as native species struggle to endure changing abiotic conditions. These non-native species can have significant impacts on ecosystems and native fauna and flora. Non-native species can be introduced through infested stock for aquaculture and fishery enhancement, ballast water discharge, and from the pet and recreational fishing industries. Non-native species can reduce native species abundance and distribution, and reduce local biodiversity by out-competing native species for food and habitat. They may also displace food items preferred by native predators, disrupting the natural food web. The introduction of non-native species is considered one of the primary threats to ESA-listed species (Wilcove and Chen 1998). Non-native species were cited as a contributing cause in the extinction of 27 species and 13 subspecies of North American fishes over the past 100 years (Miller et al. 1989).

The introduction of invasive blue (*Ictalurus furcatus*) and flathead (*Pylodictis olivaris*) catfish along the Atlantic coast has the potential to adversely affect ongoing anadromous fish restoration programs and native fish conservation efforts, including Atlantic sturgeon restoration in mid-Atlantic and south Atlantic river basins (Brown et al. 2005; Kahn 2016; Bunch et al. 2021). East Coast sturgeon evolved with the largest predators being striped bass (*Morone saxatilis*), which have a maximum gape size of approximately 8.7 inches (22 cm; Baird et al. 2020), while blue and flathead catfish are essentially not gape limited in their prey sizes (Slaughter and Jacobson 2008; Locher et al. 2022) and are more consistent with a marine predator (Scharf et al. 2000; Fabrizio et al. 2021). Likewise, several non-native fish species have been stocked throughout the range of Gulf of Maine DPS of Atlantic salmon. Those that are known to prey upon Atlantic salmon include smallmouth bass, largemouth bass, chain pickerel, northern pike, rainbow trout, brown trout, splake, yellow perch, and white perch (Baum 1997). Yellow perch, white perch, and chain pickerel were historically native to Maine, although their range has been expanded by stocking and subsequent colonization. Dams create slow water habitat that is preferred by chain pickerel and concentrate emigrating smolts in these head ponds by slowing migration speeds (McMenemy and Kynard 1988; Spicer et al. 1995).

7 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 C.F.R. §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.

Section 5.2 determined that no critical habitat is likely to be adversely affected by this action and therefore there is no destruction or adverse modification analysis in this programmatic biological opinion.

In Section 5.1, we discussed all of the stressors that may affect, but are not likely to adversely affect listed species. This considered and then eliminated most of the stressors mentioned in Section 3.2. The stressors remaining that may adversely affect shortnose sturgeon, Atlantic sturgeon, and Atlantic salmon are capture by electrofishing and capture by hook and line sampling. The probability of individuals of ESA-listed species being exposed to these stressors is based on the best scientific and commercial evidence available, and the probable responses of those individuals (given probable exposures) based on the available evidence. As described in Section 2 of this programmatic biological opinion, for any responses that would be expected to reduce an individual's fitness (i.e., growth, survival, annual reproductive success, or lifetime reproductive success), the assessment would consider the risk posed to the viability of the population(s) those individuals comprise and to the ESA-listed species composed of those populations. The purpose of this assessment and, ultimately, of this consultation is to determine if it is reasonable to expect the proposed action will have effects on ESA-listed species that could appreciably reduce their likelihood of surviving and recovering in the wild.

7.1 Exposure Analysis

Exposure analyses identify the ESA-listed species that are likely to co-occur with the physical, chemical, and biological alterations to land, water, and air in space and time. We then identify the nature of that co-occurrence in terms of timing, location, duration, frequency, and intensity. The exposure analysis also identifies, as possible, the number, age or life stage, and gender of the individuals likely to be exposed to the actions' effects and the population(s) or subpopulation(s) those individuals represent.

The NRSA program intends to sample in Maine, Massachusetts, Connecticut, New York, New Jersey, North Carolina, and Florida over the next 20 years. The EPA teams will not sample in Georgia, South Carolina, Virginia, Maryland, or Delaware. The sampling targets freshwater areas. Sampling will take place during 2 of every 5 years; meaning in 2023 and 2024 as the first 5-year period under this programmatic. The program has established limits such that the most any Atlantic salmon streams will be sampled in any given 5-year period is 31 times. For Atlantic sturgeon, the maximum number of sample sites in a 5-year period will be 6 in the GOM DPS, 19 in the New York Bight DPS, 0 in the Chesapeake Bay DPS, 5 in the Carolina DPS, and 5 in the South Atlantic DPS. For shortnose sturgeon, the maximum number of sites will be 28 throughout their range.

There are 2 types of sampling that may affect shortnose sturgeon, Atlantic sturgeon, and Atlantic salmon: electrofishing and hook-and-line. Electrofishing will be conducted in wadable streams by personnel with backpack gear and in non-wadable streams using electrofishing boats. Hook-and-line sampling will not be conducted in Atlantic salmon habitat. Atlantic salmon could be affected by either electrofishing sampling method. Shortnose sturgeon and Atlantic sturgeon would not be in close proximity to a biologist in a wadable stream section, so they are only likely to be affected by boat electrofishing and hook and line sampling.

7.1.1 GOM Atlantic salmon

Due to the short-term nature of the instream work and the timing of the work window in relation to the adult run-timing, it is anticipated that a small proportion of the total annual run could be migrating upstream in rivers within the geographic range of the GOM DPS at the time that electrofishing activities are underway. However, given the recent adult returns to small GOM DPS rivers, restricted upstream access for adults in the Penobscot River captured at Milford Dam fish lift along with features of smaller riverine habitat considered in the site selection (e.g., depth, velocity and substrate); the likelihood of an adult being present at any given site is extremely low. Given the level of instream activity associated with setting up the site and other electrofishing-related activities along the stream banks, any adult salmon present in the project areas would very likely be disturbed and move out of the survey area. Therefore, we do not believe that exposure of an adult salmon to electrofishing is reasonably likely to occur.

An Atlantic salmon habitat unit is 120 square yards (100 m^2). As described in Figure 2, a wide range of areas could make up the sampling locations. Electrofishing will occur at select reaches within that entire area, with electrofishing occurring until 500 fish have been collected or 10 reaches have been sampled. While some sampling locations will be smaller and some larger, given the description of sampling reach sizes, we anticipate the average area of a sampling location to be approximately 478.4 square yards (400 m^2), or 4 Atlantic salmon habitat units. This will be used to estimate the number of individual parr that could be exposed to electrofishing survey methods considered under this programmatic consultation.

Based on recent surveys by Maine Department of Marine Resources, median density of GOM Atlantic salmon juveniles is 3.6 per 120 square yards (100 m^2; Table 7, Figure 15; USASAC 2016, 2019). Assuming this average density, we anticipate that up to 14.4 juvenile Atlantic salmon (3.6 juveniles/unit x 4 habitat units affected) may be exposed to electrofishing and subsequent handling from removal and relocation to suitable habitat out of the action area. There are 26 planned sampling events in GOM Atlantic salmon habitat in the 2023-24 sampling cycle and as many as, but no more than, 31 sampling sites may be selected during each of the 3 subsequent sampling cycles in GOM Atlantic salmon habitat. This would mean up to 119 sampling sites with GOM Atlantic salmon juveniles could sampled. Therefore, we anticipate 1,714 juvenile GOM Atlantic salmon could be exposed to electrofishing over the next 20 years.

Table 7. Minimum (min), median, and maximum (max) relative abundance of juvenile Atlantic salmon (fish per minute) based on timed single pass catch per unit effort sampling in selected Maine Rivers, 2016

		Parr				Young of Year			
Drainage	Year	N	Min	Median	Max	n	Min	Median	Max
Dennys	2016	2	1.5	1.9	2.3	2	2.4	2.8	3.2
East Machias	2016	24	0	3	11.6	24	0	0	3.8
Machias	2016	3	0.4	2.8	3	3	3.2	8.5	9.9
Narraguagus	2016	12	0	0.1	3.2	12	0	0.4	3.4
Pleasant	2016	6	0.2	0.6	2.4	6	0	1	3.2
Sandy River	2016	39	0	0.2	2.0	39	0	0.2	9.4
Sheepscot	2016	24	0	0.2	3.6	24	0	0.5	10.1
Mattawamkeag	2016	15	0	0.3	1.7	15	0	1.0	6.5
Penobscot	2016	32	0	1.1	3.2	32	0	1.7	18.3
Piscataquis	2016	31	0	0.9	4.6	31	0	1.8	10.6

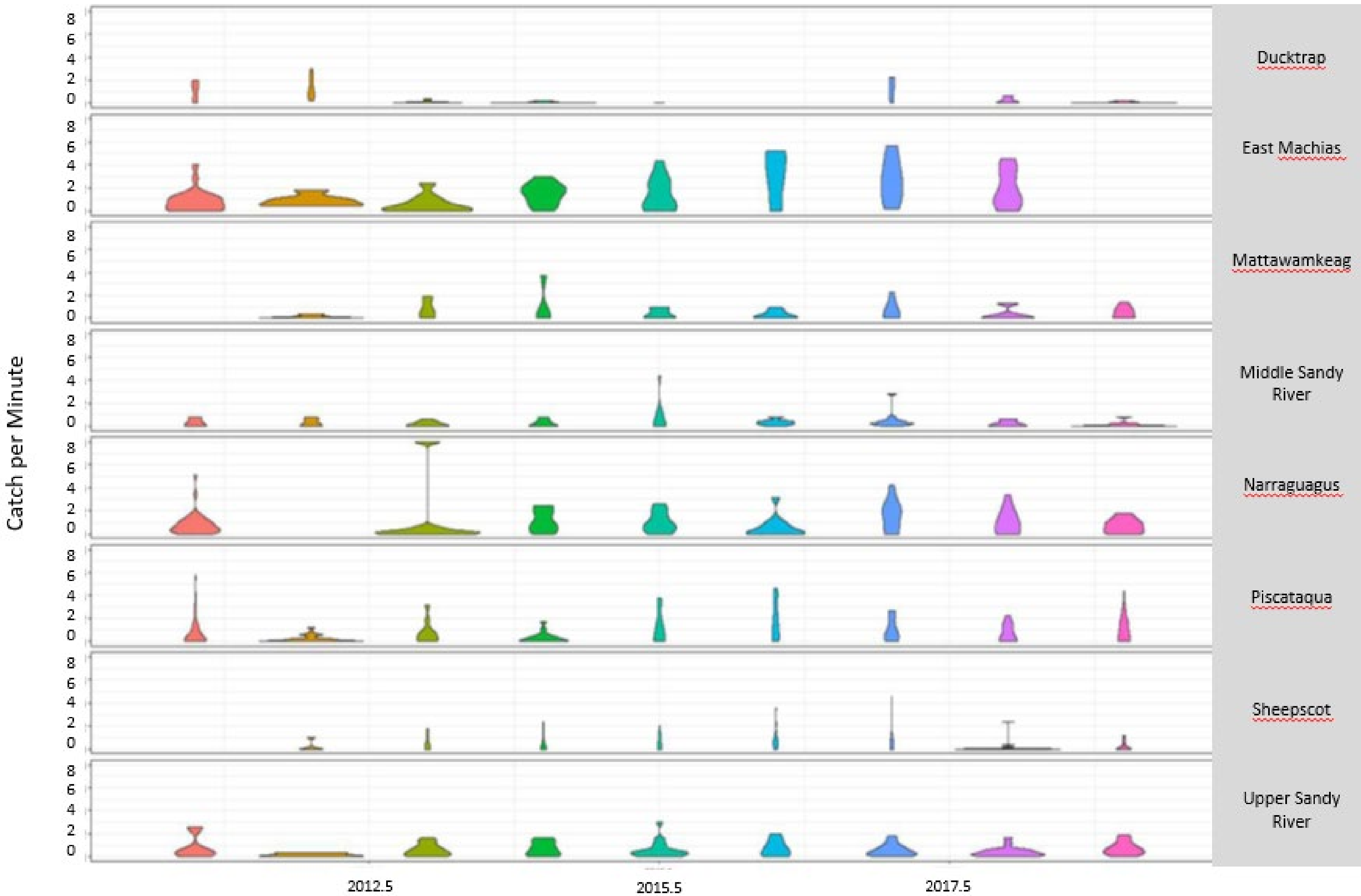

Figure 15. Catch per minute of parr across Gulf of Maine DPS rivers 2011 to 2019. The East Machias was not surveyed under the generalized sampling selection in 2019

7.1.2 Shortnose and Atlantic sturgeon

Sturgeon have ampullae of Lorenzini, which are sensory organs that are highly sensitive to electrical currents, along their rostra. If the electrofishing current were constant, shortnose and Atlantic sturgeon would avoid the area and be unaffected (Moser et al. 2000). However, because the electrofishing is conducted intermittently with breaks to collect stunned fish, sturgeon could be in the electrified area when sampling first starts and be affected by that capture methodology. Total sampling duration, to sample all 10 locations within a site, is not expected to exceed 4 hours.

Sturgeon are only likely to be present and affected by boat electrofishing because they infrequently visit shallow river edges and would be scared off by biologists walking in these areas. Exposures of juvenile Atlantic and shortnose sturgeon are expected to be rare because they favor salinities between 0 and 20 ppt, generally favoring salinities over 0.5 ppt (Fox and Peterson 2019; Pendleton et al. 2021). But, while a majority of juveniles may be rearing downstream of sampling locations in brackish water, a small proportion may still be found in sampling locations. Adult Atlantic and shortnose sturgeon could also be present in any river during the sampling period. Atlantic sturgeon adults would either have spawned and would be leaving the river in June and July or would be arriving early to spawn in September or October. Shortnose sturgeon adults would all be post-spawn and moving downriver into saline foraging habitats.

In the 3 previous iterations of this program (2008-09, 2013-14, and 2018-19), despite sampling in 62 Atlantic sturgeon locations and 66 shortnose sturgeon locations, only 1 shortnose sturgeon and 1 Atlantic sturgeon were captured by electrofishing. The life stages of the captured sturgeon were not documented.

In the next 20 years, sampling is expected to take place a minimum of 25 times over the 2-year sampling periods each 5-year cycle, and a maximum of 35 in each of the next 3 sampling cycles. This means, in the next 20 years, as many as 130 sampling days could be spent in Atlantic sturgeon habitat. Likewise, for shortnose sturgeon, there are expected to be 18 site visits this 5-year cycle and as many as 28 in the subsequent 3 cycles for a total of 102 sampling days in shortnose sturgeon habitat. Based on past sampling, there is a probability of 0.016 to capture an Atlantic sturgeon and 0.015 to capture a shortnose sturgeon. Sturgeon are long-lived and late to mature with a generation time of approximately 15-20 years, so we would not anticipate a significant change in abundance during the timeframe of this program. Therefore, we expect the capture of 2.08 Atlantic sturgeon (130 sampling days * 0.016) and 1.53 shortnose sturgeon (102 sampling days * 0.015) by this program in the next 20 years, or approximately 2 each. However, capture probability of sturgeon using electrofishing gear ranges from 1 to 4% depending on the abiotic characteristics of the area being sampled (Spurgeon et al. 2018). While this seems low, these estimates are consistent with other studies (Hense et al. 2010). Relying on the electrofishing capture probabilities presented by Spurgeon et al. (2018), mean capture probability from each location combined comes to 2.2%. Therefore, the actual number of Atlantic and shortnose sturgeon that are likely exposed to electrofishing is equal to the number captured divided by the capture probability. This would equate to 95 Atlantic sturgeon and 70 shortnose sturgeon.

Because sampling will not take place evenly across Atlantic sturgeon DPSs, we need to estimate the proportion of individuals from each DPS most likely to be exposed. Ideally, we would estimate the probability of exposure based on relative abundances in each of the rivers that was sampled during the previous 3 sample cycles and what is expected to occur during the next 4 cycles. That would weight the probability of exposure based on the relative size of each population. However, those data do not exist. We decided to estimate the probability of exposure based on planned sampling events, essentially making the assumption that all populations of Atlantic sturgeon and shortnose sturgeon are equally abundant. This is not the case, but, as can be seen from the populations that do have abundance estimates, the range in abundance is not substantially different for Atlantic sturgeon populations, ranging from point estimates of 150 to 466 adults per year (Peterson et al. 2008; Kazyak et al. 2020; Kahn et al. 2021; White et al. 2021c). Likewise, most shortnose sturgeon populations have over 1,000 individuals (Squiers et al. 1993; Bain 2000; Brundage and O'Herron 2003; Savoy 2004; Wippelhauser and Squiers 2015; Santec Consulting Services 2023), with the exception being the Cape Fear River in North Carolina (Kynard 1997). While this produces a biased estimate, the estimates should be a reasonable approximation of exposure and utilize the best available scientific and commercial information available. Further, this method is conservative because it will likely underestimate the number of exposures in the largest, healthiest populations and overestimate the exposure in the smallest, most vulnerable populations.

Proportionally, sampling will be conducted 17% (6/35) of the time in the GOM DPS, 54% (19/35) in New York Bight DPS, 0% in Chesapeake Bay DPS, 14% (5/35) in Carolina DPS, and 14% (5/35) in South Atlantic DPS. Given the potential for 95 Atlantic sturgeon exposures, these would equate roughly to 17 GOM DPS Atlantic sturgeon, 52 New York Bight DPS Atlantic sturgeon, 0 Chesapeake Bay DPS Atlantic sturgeon, 13 Carolina DPS Atlantic Sturgeon, and 13 South Atlantic DPS Atlantic sturgeon over the next 20 years.

Hook-and-line sampling is the other method that will be used to sample fish at the sample sites. Sturgeon would not be the target species, but, depending on the bait used, could be caught by this method. All life stages of shortnose sturgeon feed in freshwater, but there is no evidence that adults feed while in freshwater, so only juveniles may be captured by this method. Hook-and-line will not be the primary method of catching fish. If hook-and-line fishing must be used, it will only be used to collect the fish for tissue sampling and not for the community assessment. Where electrofishing is successful, then there is no need for hook-and-line sampling. Further, in the thousands of hours that people spend fishing with baits that would be food for sturgeon (invertebrates), very few sturgeon (shortnose or Atlantic) are captured by this method. Because this method will be used infrequently, if at all, and because Atlantic and shortnose sturgeon generally do not consume baits and are very rarely captured by recreational anglers, it is extremely unlikely, and, therefore discountable, that sturgeon will be captured by hook-and-line sampling. Because of this, the stressor of hook-and-line sampling may affect, but is not likely to adversely affect shortnose sturgeon or any of the DPSs of Atlantic sturgeon.

7.2 Response Analysis

Given the exposure estimated above, in this section, we describe the responses that are reasonably certain to occur from exposure to electrofishing. First, we discuss Atlantic salmon responses to electrofishing, which have been well-studied. Then, we discuss responses of sturgeon, which relied on a limited number of studies that are directly applicable to the NRSA program.

7.2.1 GOM Atlantic salmon

Atlantic salmon may be killed or more likely temporarily disturbed, displaced, or injured by electrofishing activities. Capturing and handling salmon can cause physiological stress and lead to physical injury or death, including cardiac or respiratory failure from electrofishing (Snyder 2003). Studies have shown that all aspects of fish handling are stressful and can lead to immediate or delayed mortality (Murphy and Willis 1996). Direct mortality may occur when fish are handled roughly, not properly restrained, sedated during handling, or kept out of the water for extended periods. Fish injured during handling, in association with a disease epizootic, typically die within 1 to 14 days. Examples of injuries that can lead to disease problems are loss of mucus, loss of scales, damage to the integument, and internal damage.

Despite precautions, some mortality is possible during the sampling of fish. The EPA has agreed to work with the Maine Department of Marine Resources when sampling rivers and streams with Atlantic salmon in Maine to minimize handling and avoid duplicative sampling of juvenile Atlantic salmon parr during the year. The Maine Department of Marine Resources annually reports juvenile salmon mortality rates associated with electrofishing activities in GOM DPS waters. Between 2001 and 2009, Maine Department of Marine Resources captured and handled between 3,698 and 5,872 juvenile salmon each year via electrofishing. Mortality rates during that time were 1.0% (Mears 2011). Modifications to the Maine Department of Marine Resources protocols have reduced the injury rates to as low as 0.02% (Mears 2011) with an average during a trial analysis of 0.44%.

It is assumed that all juvenile salmon exposed to electrofishing will be captured. Capture probability of Atlantic salmon varies substantially, but typically ranges from 20 to 50% (Hedger et al. 2018), we anticipate that the individuals that are stunned, and, therefore, captured are the fish exposed to electrofishing. If other juveniles are being exposed to electrofishing, they are not responding (being stunned) and, therefore, due to the lack of response, we do not believe that exposure would rise to the level of take (harassment, as defined in NMFS policy document 02-110-19). Some captured Atlantic salmon may also be injured. The number of injuries or mortalities can be quantified based on SHRU-specific estimates of juvenile densities, as well as the estimated mortality that may occur during capture and relocation.

7.2.2 Shortnose and Atlantic sturgeon

Electrofishing gear poses documented risks and potentially lethal effects to all sturgeon species (Moser et al. 2000, Holliman and Reynolds 2002). Because of this, NMFS (Kahn and Mohead 2010) does not allow electrofishing as an intentional capture method for sturgeon. However, those same sampling protocols (Kahn and Mohead 2010) also note that low voltage, straight DC is safest for sturgeon. Because this project will use pulsed DC, we anticipate adverse responses.

This project has been undertaken during 3 different sampling periods prior to this programmatic consultation. The capture probability of Atlantic and shortnose sturgeon was calculated in the exposure analysis (Section 7.1; 0.016 and 0.015, respectively). Based on the maximum number of sampling events discussed in the exposure analysis (Section 7.1), we anticipate 2 Atlantic sturgeon and 2 shortnose sturgeon are likely to be captured. Further, we expect all sturgeon that are exposed to electrofishing (95 Atlantic sturgeon and 70 shortnose sturgeon) to be taken. Below, we evaluate the proportion of exposed individuals expected to be captured, harassed, or harmed.

In a pilot study of 48 pulsed DC shocking events in 8 different tanks, Moser et al. (2000) demonstrated that shortnose sturgeon displayed a range of responses to electrofishing. Depending on the distance from the electrical current, the response was either avoidance, if the stimulus was not nearby, or muscular reactions that ranged from 1) rapid twitching but still swimming and stressed to 2) a lateral roll accompanied by a state of rigor where the fish would form a rigid S-shape to 3) belly up loss of equilibrium. It is likely that Atlantic sturgeon display similar responses. Moser et al. (2000) also observed that sturgeon were more than twice as likely to roll to their sides or completely lose equilibrium than catfish but that 75% of shortnose sturgeon recovered immediately and then moved to avoid the current after recovery. Because of this, it is likely that all sturgeon (Atlantic or shortnose) are harassed when exposed to pulsed DC electrofishing current. The longest recovery time observed for shortnose sturgeon was 5 minutes. There were no injuries reported, though no fish were sacrificed to look for hemorrhaging.

Holliman and Reynolds (2002) worked on white sturgeon ranging from 9.5 to 21.25 inches (24 to 54 cm), which is very similar to juvenile shortnose sturgeon sizes (shortnose sturgeon become adults around 23.6 inches [60 cm]). In straight DC, 10% (4/40) displayed hemorrhaging while, in pulsed DC, 67.5% (27/40) had evidence of hemorrhaging. Further, the hemorrhaging was broken into 4 categories:

Class 0 – none apparent;

Class 1 – 1 or more wounds in the muscle;

Class 2 – 1 or more small wounds (less than the width of 2 notochord segments) on the spine; and

Class 3 – 1 or more large wounds (the width of more than 2 notochord segments) on the spine.

Of the 27 that experienced hemorrhaging when exposed to pulsed DC, 1 had Class 1, 25 had Class 2, and 1 had Class 3. There was no difference in the likelihood of hemorrhaging based on the size of the fish, though the range of sizes tested was limited compared to the sizes sturgeon can attain. Like Moser et al. (2000), 70% recovered immediately when removed from the current and none of the sturgeon died as a result of exposure to pulsed DC. The Holliman and Reynolds

(2002) study showed that larger fish (over 13.8 inches [35.5 cm FL]) required longer recovery times of approximately 90 seconds, on average. Because the hemorrhaging can only be observed on necropsy and Moser et al. did not conduct necropsies, it is reasonable to assume the fish analyzed by Moser et al. (2000) were also injured when exposed to pulsed DC.

We anticipate Atlantic and shortnose sturgeon are likely to have similar responses to those identified as the best available science. It is likely that 67.5% of those sturgeon exposed to pulsed DC electrical currents will be injured. Of the remaining group, we anticipate 2 will be captured and the rest will be harassed.

7.3 Summary of Effects

In this section, we assess the consequences of the responses by the individuals that may be exposed to electrofishing. We combine the anticipated exposure, as identified in Section 7.1, with the anticipated response, as described in Section 7.2, to produce a final determination of the number of individuals that will experience each type of response identified in this effects analysis.

7.3.1 Atlantic salmon

The NRSA program is likely to take 1,714 GOM Atlantic salmon over the next 20 years. Most of these takes will be in the form of capture, though a subset is likely to be killed. The anticipated mortality rate associated with pulsed DC sampling is 0.44%. We, therefore, anticipate no more than 8 lethal interactions with juvenile Atlantic salmon over the next 20 years (0.44% x 1,714 fish = 8 fish). The result of the NRSA program effects is the capture of 1,706 GOM Atlantic salmon and mortality of 8.

7.3.2 Atlantic sturgeon

The NRSA program is likely to take 95 Atlantic sturgeon. Research suggests 67.5% of exposed sturgeon are likely to be injured. Therefore, we anticipate 2 Atlantic sturgeon will be captured, 29 (95 total - 64 injured - 2 captured) harassed, and 64 (95 * 0.675) harmed.

For Atlantic sturgeon, those 95 takes can be roughly broken into effects to DPSs by using the same calculations on the anticipated numbers to be exposed from each DPS. Those exposures by DPS are: 17 GOM DPS Atlantic sturgeon, 52 New York Bight DPS Atlantic sturgeon, 0 Chesapeake Bay DPS Atlantic sturgeon, 13 Carolina DPS Atlantic Sturgeon, and 13 South Atlantic DPS Atlantic sturgeon over the next 20 years. The expected response of those captures is 67.5% of the captured fish being injured. Therefore, the breakdown of types of take for each DPS is: 5 GOM DPS Atlantic sturgeon harassed and 11 harmed; 16 New York Bight DPS Atlantic sturgeon, 35 harmed and 1 captured, 0 Chesapeake Bay DPS Atlantic sturgeon, 4 Carolina DPS Atlantic sturgeon harassed and 9 harmed, and 4 South Atlantic DPS Atlantic sturgeon harassed and 9 harmed. Additionally, 1 of the estimates of “harass” from the GOM, Carolina, or South Atlantic DPS of Atlantic sturgeon will actually be a capture.

7.3.3 Shortnose sturgeon

The NRSA program is likely to take 70 shortnose sturgeon. Of the 70 shortnose sturgeon that we anticipate will be taken, we anticipate 2 will be captured, 20 (70 total - 48 injured - 2 captured) harassed, and 48 (70 * 0.675) harmed.

8 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 areas of the Federal actions subject to consultation (50 C.F.R. §402.02). Future Federal actions that are unrelated to this proposed action are not considered because they require separate consultation pursuant to section 7 of the ESA.

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 did not find any information about non-Federal actions other than what has already been described in the environmental baseline, which we expect will continue in the future. Anthropogenic effects include climate change, ship strikes, sound, fisheries, dams, and pollution. 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.

9 INTEGRATION AND SYNTHESIS

This programmatic biological opinion includes a jeopardy analysis for GOM DPS Atlantic salmon, shortnose sturgeon, GOM DPS Atlantic sturgeon, New York Bight DPS Atlantic sturgeon, Carolina DPS Atlantic sturgeon, and South Atlantic DPS Atlantic sturgeon. Section 7(a)(2) of the Act and its implementing regulations require every Federal agency, in consultation with and with the assistance of the Secretary (16 U.S.C. §1532(15)), to insure that any action it authorizes, funds, or carries out, in whole or in part, in the United States or upon the high seas, is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. The jeopardy analysis therefore relies upon the regulatory definitions of jeopardize the continued existence of and destruction or adverse modification.

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 a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 C.F.R. §402.02). Recovery, used in that definition, means "improvement in the status of listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the Act" (50 C.F.R. §402.02).

The Integration and Synthesis section is the final step in our jeopardy analysis. In this section, we add the effects of the action (Section 7) to the environmental baseline (Section 5) and the cumulative effects (Section 8), taking into account the status of the species, and recovery planning (Section 5.3), to formulate the agency's programmatic biological opinion as to whether the EPA can insure its proposed action is not likely to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution. Effects to critical habitat were determined to be discountable or insignificant (Section 5.2) and are not discussed here.

9.1 Survival and Recovery of GOM Atlantic Salmon

The GOM DPS of Atlantic salmon currently exhibits critically low spawner abundance, poor marine survival, and is confronted with a variety of additional threats. Some locations within the DPS have experienced extirpations. The abundance of GOM DPS Atlantic salmon has been low and either stable or declining over the past several decades. The proportion of fish that are of natural origin is extremely low (Figure 9) and is continuing to decline. The spatial distribution of the GOM DPS has been severely reduced relative to historical distribution patterns.

The criteria for downlisting and delisting GOM DPS Atlantic salmon are discussed in Section 5.3.1.6. and identify specific targets of abundance, productivity, and habitat as measurable and achievable metrics.

The condition of GOM DPS Atlantic salmon in the freshwater reaches of their spawning rivers is affected by factors such as climate change and being surrounded by areas that are heavily populated and polluted. Dams also affect many of the populations throughout Maine. Critical habitat was established to protect spawning, rearing, and migratory habitat in the spawning rivers, which may slowly ameliorate the impaired baseline conditions and improve the health of Atlantic salmon in Maine during later sampling periods covered by this program. Some analyses of spawning habitat and spawn timing suggest climate change, generally observed as increased temperatures later in the year and more drought conditions punctuated with large storms, may pose a risk to Atlantic salmon.

In the effects analysis above, we considered the effects to Atlantic salmon resulting from in-water work conducted under the NRSA program. As explained in the Summary of Effects for GOM DPS of Atlantic salmon (Section 7.3.1), we determined that the NRSA program for the next 20 years will result in the capture, handling, and relocating of up to 1,706 parr, no more than 8 of these parr are likely to be injured or killed. Parr captured, collected, and released from any river or stream alive and uninjured are not expected to experience any reductions in fitness and will quickly recover. All other effects of in-water work on this species will be insignificant or discountable.

The reproductive potential of the GOM DPS will not be affected in any way other than through a reduction in the numbers of juveniles. The handling and relocation of 1,706 parr over the next 20 years is not expected to have lasting ramifications and the ultimate effect to the population as a whole will be insignificant. Further, these captured juveniles are anticipated to have an equal likelihood of reproducing in the wild as any other returning adult. The loss of 8 juvenile Atlantic salmon over a 20-year period will have the effect of reducing the amount of potential reproduction, as any dead Atlantic salmon has no potential for future reproduction. However, this reduction in potential future adult spawners is so small, it is likely undetectable. This is due to the high natural mortality of juvenile Atlantic salmon, the low adult return rate (i.e., the number of juveniles that return from the marine environment to spawn as adults). In addition, the loss will occur over a 20-year period, which limits the impact on any particular year class. Given this, we expect that the future reduction in the number of eggs laid or juveniles produced will have an undetectable effect on the strength of subsequent year classes. Even considering the potential future adult spawners that could be produced by the individuals that will be killed because of the proposed action, any effect to future year classes is anticipated to be undetectable. We also do not expect the distribution of Atlantic salmon to be affected either by the capture of 1,706 individuals or from the loss of 8 GOM DPS Atlantic salmon.

Based on the information provided above, including the consideration of the death of up to 8 juvenile Atlantic salmon over a 20-year period, the proposed programmatic framework for NRSA survey activities will not appreciably reduce the numbers, reproduction, or distribution of GOM DPS Atlantic salmon. This action will not decrease the likelihood that the species will continue to persist into the future with sufficient resilience to allow for the potential recovery from endangerment. The action will not affect GOM DPS Atlantic salmon in a way that prevents the species from having a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, and it will not result in effects to the environment that would prevent Atlantic salmon from completing their entire life cycle, including reproduction, sustenance, and shelter. These factors represent the recovery criteria of abundance, productivity, and habitat. This is the because a large percentage of fish handled during the term of this programmatic will be unharmed, survive and have an equal chance of contributing to the next generation of returning adults. Additionally, the death of up to 8 juveniles over the next 20 years is an extremely small percentage of multiple generations and will not change the status or trends of the species as a whole; the loss of up to 8 juveniles over the 20-year term of this programmatic will not result in the loss of any age class; the loss of up to 8 juveniles will not have an effect on the levels of genetic heterogeneity in the population; the loss of up to 8 juveniles over the next 20 years will have an immeasurable effect on reproductive output such that it will not change the status or trends of the species; and the NRSA program will have no effect on the ability of GOM DPS Atlantic salmon to shelter or forage throughout the GOM DPS. Further, we have determined that the action will not appreciably reduce the likelihood that the GOM DPS will survive in the wild, which includes consideration of recovery potential.

As this analysis shows, we do not anticipate appreciable reductions to GOM DPS Atlantic salmon abundance, reproduction, or distribution. We have determined that the EPA, in implementing the NRSA program, is able to insure their action will not appreciably reduce the likelihood that GOM DPS Atlantic salmon will survive or recover in the wild. Therefore, the EPA is able to insure its action is not likely to jeopardize the continued existence of GOM DPS Atlantic salmon.

9.2 Survival and Recovery of Atlantic Sturgeon

This program will affect Atlantic sturgeon in Maine, Massachusetts, Connecticut, New York, New Jersey, North Carolina, and Florida. The EPA will be sampling 25 times in Atlantic sturgeon habitat in the 2023-24 sampling period and then up to 35 times per cycle after that. The Atlantic sturgeon spawning rivers in these areas are the Kennebec, Penobscot, Connecticut, Hudson, Delaware, Roanoke, Neuse, Tar/Pamlico, Cape Fear, and St. Marys Rivers. There are other rivers in these areas that serve as foraging habitat, but sturgeon would not be expected to travel into their freshwater reaches.

Gulf of Maine Atlantic sturgeon are threatened while New York Bight, Carolina, and South Atlantic DPS Atlantic sturgeon are endangered. There are no abundance estimates for rivers in the GOM DPS, but effective population estimates for the Kennebec River suggest the abundance is somewhat larger than the Delaware River. Recent spawning run estimates suggest the Delaware Rive supports approximately 250 individuals per year (White et al. 2021b). The Penobscot River population may be extirpated or it is extremely small (Altenritter et al. 2017). The Connecticut River population was recently established (Savoy et al. 2017) and is also very small. The Hudson River likely supports the largest population on the East Coast and has shown possible signs of increasing juvenile abundance since the end of the commercial fishery (Pendleton and Adams 2021). However, assessments of the adult population show little change in abundance since the end of the commercial fishery, with spawning abundance estimates of 466 per year (Kahnle et al. 2007, Kazyak et al. 2020). There are no estimates of abundance or effective population size of the populations through North Carolina and Florida, though there is evidence of periodic reproductive failures or intermittent spawning in the St. Marys River (Fox et al. 2018a).

There is a recovery outline for Atlantic sturgeon (NMFS 2018), but no formal recovery plan. The recovery outline broadly intends to return reproductive populations throughout their historic range and increase the abundance of those spawning populations to a point where they would be resilient to large mortality events.

The condition of Atlantic sturgeon in the freshwater reaches of their spawning rivers is affected by factors such as climate change and being surrounded by areas that are heavily populated and polluted. Dams also affect the Connecticut and Cape Fear River populations. Dams could also be a leading factor for why there may no longer be populations in the Penobscot, Androscoggin, Merrimack, Housatonic, and St. Johns River in the action area. Critical habitat was established to protect water quality for spawning and rearing in the known spawning rivers, which may slowly ameliorate the impaired baseline conditions and improve the health of Atlantic sturgeon in the action area during later sampling periods covered by this program. Some analyses of spawning habitat and spawn timing suggest climate change, generally observed as increased temperatures later in the year and more drought conditions punctuated with large storms like hurricanes rather than typical afternoon thunderstorms, may pose a risk to Atlantic sturgeon. To date, there is no evidence of failed spawning due to dissynchrony of optimal temperatures and optimal photoperiod (Hager et al. 2020).

This program is being assessed over the next 20 years, which is essentially a single Atlantic sturgeon generation. In that time, 95 Atlantic sturgeon are likely to be affected by electrofishing. The estimated distribution of effects would mean those 95 fish break out to 17 GOM DPS Atlantic sturgeon, 52 New York Bight DPS Atlantic sturgeon, 0 Chesapeake Bay DPS Atlantic sturgeon, 13 Carolina DPS Atlantic Sturgeon, and 13 South Atlantic DPS Atlantic sturgeon. The expected response of those captures is 68% of the captured fish being injured. This would mean 12 GOM DPS Atlantic sturgeon, 35 New York Bight DPS Atlantic sturgeon, 0 Chesapeake Bay DPS Atlantic sturgeon, 9 Carolina DPS Atlantic sturgeon, and 9 South Atlantic DPS Atlantic sturgeon are likely to be injured. No Atlantic sturgeon are expected to be killed by electrofishing.

There are no census estimates of total abundance, spawning run abundance, juvenile abundance, or any other estimates in the GOM DPS region. Published effective population estimates suggest there is slightly more genetic diversity (suggesting a slightly more robust population) in the Kennebec River population than in the Delaware River (Waldman et al. 2019; White et al. 2021a). The Delaware River is estimated to support approximately 250 spawning adults each year, representing a small segment of the total adult population (White et al. 2021b). Electrofishing over the next 20 years may affect 17 fish from this area, likely causing 12 of those to have hemorrhages along their notochord. Averaged out, that suggests fewer than 1 fish a year will be affected by electrofishing and approximately 1 fish every other year will be injured by electrofishing. This level of effect will not reduce appreciably the numbers of Atlantic sturgeon in this DPS. Because the sampling period is after the spawning period, we would not anticipate any effects from electrofishing on spawning success. Further, the effects of electrofishing to 17 individuals over a 20-year period is not expected to affect the distribution of fish in this DPS.

The New York Bight DPS of Atlantic sturgeon is one of the best studied. There are census estimates (annual spawning run abundance) available for the Hudson and Delaware Rivers and effective population estimates available for the Connecticut, Hudson, and Delaware Rivers. There are no other known spawning populations in this DPS. Most of the sampling by the NRSA program will take place within the New York Bight DPS, resulting in an estimate of 52 Atlantic sturgeon being affected and 35 being injured by electrofishing over the next 20 years. This averages out to approximately 2.5 Atlantic sturgeon being affected each year and fewer than 2 per year being injured. No Atlantic sturgeon is expected to die because of electrofishing. Each year, approximately 466 adults and 250 adults return to the Hudson and Delaware Rivers (Kazyak et al. 2020, White et al. 2021b). In terms of relative abundance, juvenile catch rate has increased in standardized sampling since the commercial fishery, suggesting there are more juveniles present now (Pendleton and Adams 2021). Adults and juveniles will be in freshwater when sampling takes place, though most spawning should be completed before sampling begins (Breece et al. 2021). Therefore, this level of effect will not reduce appreciably the numbers of Atlantic sturgeon in any population or in this DPS. No sturgeon are expected to be killed by this sampling technique. There should be no detectable effects to reproduction from this electrofishing effort because all of the sampling for the next 20 years will occur after spawning takes place. It is also unlikely that this level of electrofishing within the watersheds of this DPS will affect the distribution of Atlantic sturgeon.

The status of the populations of the Carolina DPS of Atlantic sturgeon has only recently begun to be the focus of research. The reproductive strategies of this DPS are complicated. In the GOM and New York Bight DPSs, all reproduction occurs in the spring; summer water temperatures generally do not reach levels that are stressful for juvenile sturgeon, resulting in first year growth through the onset of winter. In the Carolina DPS, there are several rivers that have spring and fall spawning populations. Somewhat complicating matters, the 2 spawning populations of the Carolina DPS in some rivers are distinct from one another. The spring spawning populations may be from straying of individuals with that life history strategy because the spring spawning populations are more closely related to one another than to other fall spawning populations (White et al. 2021a). Because summer temperatures in the Carolina DPS are stressful to all life stages of Atlantic sturgeon (Niklitschek 2001), effective population analyses (White et al. 2021a) suggest spring spawning populations are smaller than fall spawning populations. There hasn't been sufficient sampling in North Carolina to understand those spawning populations, with most information about this DPS coming from South Carolina. What we know of North Carolina is from Albemarle Sound, an estuary likely supporting rearing habitat for several spawning populations, but at least 1 from the Roanoke River (Smith et al. 2015). The effective population of juvenile Atlantic sturgeon captured in Albemarle Sound is between 19 and 29 (Waldman et al. 2019; White et al. 2021a).

The amount of work NRSA will do in North Carolina will result in 13 individuals being taken by electrofishing, 9 of which will be injured over the next 20 years. Averaged out over the next 20 years, that suggests just over 1 fish every other year will be affected by electrofishing and just under 1 fish every other year will be injured by electrofishing. This level of effect will not reduce appreciably the numbers of Atlantic sturgeon in any population or in this DPS. NRSA collections will occur in the summer, so it is possible some pre-spawning adults will be harassed, but, due to the quick recovery times and the extent of injuries compared with surgical procedures (NMFS 2017), we do not expect more than short-term delays to migratory behavior. Likewise, the known spawning populations in North Carolina are likely small, but they are well established, and the harassment or non-lethal injury to this number of Atlantic sturgeon will not affect the distribution of any populations or the DPS.

The South Atlantic DPS of Atlantic sturgeon is composed of 2 large populations (Altamaha and Savannah Rivers) and a number of small and moderate sized populations. However, the populations in Florida are the smallest and most vulnerable. It is likely that there is no extant population in the St. Johns River (Fox et al. 2018b) and, therefore, despite the presence of adults and juveniles in the estuary, it is unlikely any Atlantic sturgeon will be encountered in freshwater. The St. Marys River population has intermittent reproductive success (Fox et al. 2018a), though that success is so infrequent that previous efforts concluded this population was likely extirpated (Fritts 2011). Fox et al. (2018a) concluded the St. Marys population persists "precariously close to extirpation." The factors contributing to the declines and struggles of this population are likely from water quality (high summer water temperatures, high salinities, and seasonal DO minimums; Fritts 2011). Fritts (2011) did note the presence of adults during that study, so it is probable that spawning events occur each year, but, as Fritts (2011) notes, juvenile survival is hindered by summer water quality. Based on sampling effort in Florida, assuming fish are present to be affected during the years of sampling under the NRSA program, we would anticipate 13 individuals will be taken by electrofishing, 9 of which will be injured over the next 20 years. Averaged out over the next 20 years, that suggests just over 1 fish every other year will be affected by electrofishing and just under 1 fish every other year will be injured by electrofishing. No Atlantic sturgeon is expected to be killed because of electrofishing. Despite the perilously small population in the St. Marys River, this level of effect will not reduce appreciably the numbers of Atlantic sturgeon there and certainly not within this DPS. NRSA collections will occur in the summer, so it is possible juveniles rearing in freshwater (not the normal behavior) to find non-lethal water quality or some pre-spawning adults will be harassed or injured, but, due to the quick recovery times and the extent of injuries compared with surgical procedures (NMFS 2017), we do not expect more than short-term delays to migratory behavior. It appears a limited number (similar effective population sizes as the York River in Virginia and larger than the Connecticut River) of adults use the river to spawn. The distribution of South Atlantic DPS Atlantic sturgeon will not be affected by this program even with the anticipated harassment or non-lethal injury.

As this analysis shows, we do not anticipate appreciable reductions to GOM, New York Bight, Carolina, or South Atlantic DPS Atlantic sturgeon abundance, reproduction, or distribution in the wild. This project should result in no change in abundance, no loss of reproduction, and no change in the distribution of these DPSs of Atlantic sturgeon and therefore will not appreciably reduce the likelihood of survival in the wild. While the recovery outline generally identifies a goal of increasing abundance, this program will not prevent that from occurring and therefore will not appreciably reduce the likelihood of recovery. Therefore, the NRSA program is not likely to jeopardize the continued existence of GOM, New York Bight, Carolina, or South Atlantic DPS Atlantic sturgeon.

9.3 Survival and Recovery of Shortnose Sturgeon

This program will affect shortnose sturgeon in Maine, Massachusetts, Connecticut, New York, New Jersey, and North Carolina. At most, every 5 years, surveys in these rivers will be conducted in up to 28 locations within shortnose sturgeon habitat (all in freshwater). These locations mean sampling in the Kennebec, Penobscot, Androscoggin, Merrimack, Connecticut, Hudson, Delaware, and Cape Fear Rivers that could support shortnose sturgeon populations.

Shortnose sturgeon are endangered throughout their range. Populations have been generally steady in extant rivers, with populations north of the Chesapeake Bay generally being relatively large with a large gap in the mid-Atlantic south of the Delaware River with no extant populations until the Cape Fear River (the southernmost in North Carolina) that likely only supports about 100 individuals. The populations through the southeastern United States appear to be smaller than 1,000 individuals with the exception of the Savannah (1,400-2,400) and Altamaha (6,400) Rivers. The Hudson, Kennebec, and Merrimack River populations have increased in abundance over the years (Bain et al. 2000; Wippelhauser and Squiers 2015, Santec Consulting Services 2023).

Despite being protected since 1967, shortnose sturgeon recovery planning does not include measurable objectives. There is, instead, a focus on each individual population recovering, as well as an emphasis on increasing abundance in each system. While not explicitly stated, because some populations are so small, there is currently a risk of range contraction, which, due to the low straying rates between systems and the limited evidence of newly colonized spawning habitat since the species was listed, poses significant threats to the species' ability to achieve recovery.

The condition of shortnose sturgeon in the Kennebec, Penobscot, Androscoggin, Merrimack, Connecticut, Hudson, Delaware, and Cape Fear Rivers is affected by factors such as climate change and being surrounded by areas that are heavily populated and polluted. In the Connecticut and Cape Fear Rivers, dams affect the well-being of sturgeon populations. Each of these factors can adversely affect the physical health of fish. These consequences are difficult to measure, but we can see that abundances have only increased in 2 rivers over the last 56 years. And, while there are a number of ongoing stressors in each of these river systems, we could not identify any new, non-Federal stressors that are reasonably certain to begin in the foreseeable future. Therefore, while these stressful conditions are expected to continue along the same trajectory, that trajectory is not anticipated to get worse.

This program is being assessed over the next 20 years, which is essentially a single shortnose sturgeon generation. In that time, 70 shortnose sturgeon will be taken via electrofishing. Of those, 48 will be injured. This amounts to approximately 18 individuals electroshocked each 5-year sampling period with 12 of those being injured. None of the injuries are expected to result in mortality.

With the exception of the Cape Fear River population, the populations likely to be affected have abundances of more than 1,000 individuals. The lone shortnose sturgeon captured by electrofishing in the past occurred in Massachusetts and we would expect most sturgeon shocked by electrofishing will be in these larger populations in the northeast United States. Sampling in shortnose sturgeon habitat in North Carolina is limited to up to 5 locations (18% of the total sampling effort in shortnose sturgeon habitat) every 5 years. However, interactions with shortnose sturgeon in the Cape Fear River are less likely because the numbers of shortnose sturgeon there amount to 0.1% of the shortnose sturgeon found in the 28 sampling locations in shortnose sturgeon habitat. We expect all or almost all of the 70 shortnose sturgeon that will be electroshocked to be from the larger systems in the northeast United States. Therefore, there is no reason to expect the extirpation of the Cape Fear River population or a risk of range contraction. These effects, particularly because no mortalities are expected, should not significantly affect the numbers of shortnose sturgeon in these rivers.

The sampling will take place following shortnose sturgeon spawn timing (Kynard 1997) and, therefore, is not expected to have any effect on reproductive rates, proportion of eggs fertilized, or reproductive success of any individuals. Further, because shortnose sturgeon spawn in their natal areas and it is unlikely any shortnose sturgeon in the Cape Fear River will be affected, this program is not expected to have any effect on shortnose sturgeon distribution.

As this analysis shows, we do not anticipate appreciable reductions to shortnose sturgeon abundance, reproduction, or distribution. This project should result in no change in abundance, no loss of reproduction, and no change in the distribution of shortnose sturgeon and therefore will not appreciably reduce the likelihood of survival in the wild. While the recovery plan generally identifies a goal of increasing abundance in each of the 19 spawning populations, this program will not prevent any populations from increasing in abundance and therefore will not appreciably reduce the likelihood of recovery of these wild populations. Therefore, the NRSA program is not likely to jeopardize the continued existence of shortnose sturgeon.

10 Conclusion

After reviewing the current status of the ESA-listed species, the environmental baseline within the action area, the effects of the proposed action, effects of the action, and cumulative effects, it is NMFS' biological opinion that the EPA is able to insure the NRSA program is not likely to reduce appreciably the likelihood of both the survival and recovery of the GOM DPS Atlantic salmon, shortnose sturgeon, GOM DPS Atlantic sturgeon, New York Bight DPS Atlantic sturgeon, Carolina DPS Atlantic sturgeon, or South Atlantic DPS Atlantic sturgeon. Thus, the program will not jeopardize the continued existence of these species.

Additionally, the NRSA program may affect, but is not likely to adversely affect, critical habitat of GOM DPS Atlantic salmon, GOM DPS Atlantic sturgeon, New York Bight DPS Atlantic sturgeon, Carolina DPS Atlantic sturgeon, or South Atlantic DPS Atlantic sturgeon.

11 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 "create[s] 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" (NMFS PD 02-110-19).

Incidental take is defined as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 C.F.R. §402.02). Section 7(b)(4) and section 7(o)(2) provide 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 an incidental take statement.

This incidental take statement specifies the impact of any incidental taking of endangered or threatened species, as well as the specific levels of incidental take anticipated. This specific level of anticipated take serves as a quantifiable metric to determine when the Federal action agency must reinitiate consultation (50 C.F.R. §402.14(i)(4). It also provides RPMs that are necessary or appropriate to minimize impacts of the take, and sets forth mandatory terms and conditions in order to implement the RPMs.

11.1 Amount or Extent of Take

For NRSA program, take is authorized for GOM Atlantic sturgeon DPS, New York Bight Atlantic sturgeon DPS, Carolina Atlantic sturgeon DPS, South Atlantic Atlantic sturgeon DPS, shortnose sturgeon, and GOM Atlantic salmon. We anticipate the program will result in the take of ESA-listed as shown in Table 8.

Table 8. Anticipated numbers of forms of take for GOM Atlantic salmon, shortnose sturgeon, and Atlantic sturgeon by the NRSA program for the next 20 years

Species	Captures	Harass	Harm	Mortality
Shortnose sturgeon	2	20	48	0
Gulf of Maine DPS Atlantic sturgeon	1*	5	11	0
New York Bight DPS Atlantic sturgeon	1	16	35	0
Carolina DPS Atlantic sturgeon	1*	4	9	0
South Atlantic DPS Atlantic sturgeon	1*	4	9	0
Gulf of Maine DPS Atlantic salmon	1,706	0	8[¥]	8[¥]

* = There is a likelihood of 2 total Atlantic sturgeon being captured, 1 in the New York Bight DPS and 1 from either the GOM, Carolina, or South Atlantic DPSs of Atlantic sturgeon.

¥ = The estimates for harm and mortality are the same individuals broken out further to distinguish between injuring and killing.

The amount of take identified in Table 8 will be exempted if the RPMs and terms and conditions below are implemented. For the sturgeon species, the vast majority of these anticipated takes will not be observable. However, the estimates of individuals likely to be harassed and harmed is derived from the numbers of Atlantic and shortnose sturgeon that are anticipated to be captured based on the amount of sampling effort from past NRSA sampling cycles. We can use the numbers (2 Atlantic sturgeon and 2 shortnose sturgeon over 20 years) of anticipated captures of Atlantic and shortnose sturgeon as a surrogate for the other forms of take that we anticipate. Therefore, if more than 2 Atlantic sturgeon (from any DPS) or 2 shortnose sturgeon are captured under this program, the EPA will be required to request reinitiation of consultation (50 C.F.R. §402.14(i)(4) and 50 C.F.R. §402.16(a)(1)).

11.2 Reasonable and Prudent Measures

Reasonable and prudent measures are measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 C.F.R. §402.02). They must be implemented as binding conditions for the exemption in section 7(o)(2) to apply. The NRSA program has a number of minimization and mitigation measures built in, minimizing the risks associated with their sampling protocols (EPA 2023, Sections 7.3 and 7.4). NMFS has a duty to ensure the monitoring, avoidance, and minimization measures included in the program are carried out appropriately. If the EPA fails to adhere to the terms and conditions of the incidental take statement, or fails to retain the oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

NMFS believes it is necessary and appropriate to minimize the impacts of take of listed species under the NRSA program for EPA to be required to:

1. Monitor and report the effects of the action to the NMFS Office of Protected Resources.
2. Over the 20 years of this program, the EPA must update and adhere to the current Best Management Practices for protecting listed species during sampling with electrofishing equipment.
3. Report to NMFS upon the start and end of in-water work each year.

11.3 Terms and Conditions

The terms and conditions described below are non-discretionary, and EPA must comply with them in order to implement the RPMs (50 C.F.R. §402.14). In order to be exempt from the prohibitions of section 9 of the ESA, the Federal action agency must comply with the following terms and conditions:

To implement RPM #1, EPA must:

1. Maintain records of interactions with NMFS trust resources, and report the record of those interactions at the completion of each NRSA sampling season.

2. Contact NMFS Office of Protected Resources (nmfs.hq.esa.consultations@noaa.gov) within 24 hours in the event the number of captures or mortalities identified in Section 11.1 is exceeded.

3. Contact NMFS Office of Protected Resources (nmfs.hq.esa.consultations@noaa.gov) within 24 hours in the event any ESA-listed species is killed during sampling.

To implement RPM #2, EPA must:

1. Continue to work with NMFS to identify and incorporate the Best Management Practices and the State of Maine Department of Marine Resources Electrofishing guidelines at the start of each sampling cycle.
2. These guidelines must be incorporated into EPA's training for conducting electrofishing in Maine.
3. Report any incidences when these BMPs could not be followed.

To implement RPM #3, EPA must:

1. Report to GARFO (via email: David.Bean@noaa.gov) and within 48 hours of the start of in-water work and again within 48-hours of the completion of all in-water work.

12 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 suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information. (50 C.F.R. §402.02).

NMFS Office of Protected Resources suggests the EPA develop and implement a program to monitor the cumulative effects of environmental toxins on Atlantic salmon, Atlantic sturgeon, and shortnose sturgeon and their ecosystems.

In order for us to be kept informed of actions minimizing or avoiding adverse effects on, or benefiting, ESA-listed species or their critical habitat, EPA should notify us of any conservation recommendations implemented in the final action.

13 Reinitiation of Consultation

This concludes formal consultation on the EPA's NRSA program. 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 incidental take statement is exceeded;

(2) new information reveals effects of the action that may affect 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 the listed species or critical habitat that was not considered in the biological opinion or written concurrence; or

(4) a new species is listed or critical habitat designated that may be affected by the identified action.

14 References

Acevedo-Whitehouse, K., and A. L. J. Duffus. 2009. Effects of environmental change on wildlife health. Philosophical Transactions of the Royal Society of London B Biological Sciences 364(1534):3429-3438.

Alexander, M.A., S. Shin, J.D. Scott, E. Curchitser, and C. Stock. 2020. The response of the Northwest Atlantic Ocean to climate change. Jourla of Climate 33:405–428. https://doi.org/10.1175/JCLI-D-19-0117.1.

Altenritter, M.N., G.B. Zydlewski, M.T. Kinnison, and G.S. Wippelhauser. 2017. Atlantic sturgeon use of the Penobscot River and marine movements within and beyond the Gulf of Maine. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 9:216-230.

Allen, P.J. and J.J. Cech. 2007. Age/size effects on juvenile green sturgeon, Acipenser medirostris, oxygen consumption, growth, and osmoregulation in saline environments. Environ Biol Fish 79:211–229. https://doi.org/10.1007/s10641-006-9049-9.

ASMFC (Atlantic States Marine Fisheries Commission). 2017. Atlantic sturgeon benchmark stock assessment and peer review report. Alexandria, Virginia.

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

Auer, N. A. 1996. Response of spawning lake sturgeons to change in hydroelectric facility operation. Transactions of the American Fisheries Society 125(1):66-77.

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 146:92-98. DOI: 10.1080/00028487.2016.1245215.

Bain, M.B. 1997. Atlantic and shortnose sturgeons of the Hudson River: Common and divergent life history attributes. Environmental Biology of Fishes 48(1-4):347-358.

Bain, M. B., N. Haley, D. L. Peterson, K. K. Arend, K. E. Mills and P. J. Sullivan. 2000. Shortnose sturgeon of the Hudson River: an endangered species recovery success. Paper presented at the Annual Meeting of the American Fisheries Society, St. Louis, MO, 23-24 August 2000.

Baird, S.E., A.E. Steel, D.E. Cocherell, J.B. Poletto, R. Follenfant, and N.A. Fangue. 2020. Experimental assessment of predation risk for juvenile green sturgeon, Acipenser medirostris, by two predatory fishes. Journal of Applied Ichthyology 36:14-24.

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

Balazik, M.T., D.J. Farrae, T.L. Darden, G.C. Garman. 2017. Genetic differentiation of spring-spawning and fall-spawning male Atlantic sturgeon in the James River, Virginia. PloS One 12(7): e0179661. https://doi.org/10.1371/journal.pone.0179661

Baum, E. T. 1997. Maine Atlantic Salmon: A National Treasure. Atlantic Salmon Unlimited, Hermon, Maine.

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 19:1875-1880.

Beland, K. 1984. Strategic plan for management of Atlantic salmon in the state of Maine. Atlantic Sea Run Salmon Commission. Bangor, ME.

Beland, K.F., R.M. Jordan and A.L. Meister. 1982. Water depth and velocity preferences of spawning Atlantic salmon in Maine Rivers. North American Journal of Fisheries Management 2:11-13.

Bell, M.C. 1991. Fisheries handbook of engineering requirements and biological criteria. Fish Passage Development and Evaluation Program. U.S. Army Corps of Engineers. North Pacific Division.

Berg, L. and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (Oncorhynuchus kisutch) following short-term pulses of suspended sediment. Canadian Journal of Fishies and Aquatic Sciences 42(8):1410-1417.

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

Birtwell, I.K, G. Hartman, B. Anderson, D.J. McLeay and J.G. Malik. 1984. A brief investigation of Arctic grayling (*Thymallus arcticus*) and aquatic invertebrates in the Minto Creek drainage, Mayo, Yukon Territory Canadian Technical Report on Fisheries and Aquatic Sciences 1287.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 in Meehan, W.R., editor. (1991) Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication19.

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

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

Breece M.W., D.A. Fox, D.E. Haulsee, I.I. Wirgin, and M.J. Oliver. 2018a. Satellite-driven distribution models of endangered Atlantic sturgeon occurrence in the mid-Atlantic bight. ICES Journal of Marine Science 75:562-571.

Breece, M.W., D.A. Fox, and M.J. Oliver. 2018b. Environmental drivers of adult Atlantic sturgeon movement and residency in the Delaware Bay. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 10:269-280.

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

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

Brundage, H.M. III. 2021. Occurrence of shortnose sturgeon in the tidal Schuylkill River, an urbanized and industrialized tributary of the Delaware River. Urban Naturalist 47:1-11.

Brundage, H.M. and J.C. O'Herron. 2003. Population estimate for shortnose sturgeon in the Delaware River. Presented at the 2003 Shortnose Sturgeon Conference, 7-9 July 2003.

Buckley, J., & B. Kynard. 1981. Spawning and rearing of shortnose sturgeon from the Connecticut River. Progressive Fish Culturist 43:74-76.

Buckley, J., & B. Kynard. 1985. Habitat use and behavior of pre-spawning and spawning shortnose sturgeon, *Acipenser brevirostrum*, in the Connecticut River. Pages 111-117 in: F.P. Binkowski & S.I. Doroshov, eds. North American sturgeons: biology and aquaculture potential. Developments in Environmental Biology of Fishes 6. Dr. W. Junk Publishers, Dordrecht, Netherlands. 163pp.

Bunch, A.J., K.B. Carlson, F.J. Hoogakker, L.V. Plough, and H.K. Evans. 2021. Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus* Mitchill, 1815) early life stage consumption evidenced by high-throughput DNA sequencing. Journal of Applied Ichthyology 37:12-19.

Burton, W. 1993. Effects of bucket dredging on water quality in the Delaware River and the potential for effects on fisheries resources. Prepared by Versar, Inc. for the Delaware Basin Fish and Wildlife Management Cooperative, unpublished report. 30 pp.

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

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(1-3):239-256.

Cech, J.J., S.J. Mitchell, and T.E. Wragg. 1984. Comparative growth of juvenile white sturgeon and striped bass: effects of temperature and hypoxia. Estuaries 7:12–18.

Celi, M. F. Filiciotto, G. Maricchiolo, L. Genovese, E. M. Quinci, V. Maccarrone, S. Mazzola, M. Vazzana, and G. Buscaino. 2016. Vessel noise pollution as a human threat to fish: assessment of the stress response in gilthead sea bream (*Sparus aurata*, Linnaeus 1758). Fish Physiology and Biochemistry 42:631-641.

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

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.

Cooke, D.W. and S.D. Leach. 2004. Implications of a migration impediment on shortnose sturgeon spawning. North American Journal of Fisheries Management 24(4):1460-1468.

Cope, W.G., Holliman, F.M., Kwak, T.J., Oakley, N.C., Lazaro, P.R., Shea, D., Augspurger, T., Law, J.M., Henne, J.P., and Ware, K.M. 2011. Assessing water quality suitability for shortnose sturgeon in the Roanoke River, North Carolina, USA with an in situ bioassay approach. Journal of Applied Icthyology 27:1-12.

Cunjak, R.A. 1988. Behavior and microhabitat of young Atlantic salmon (Salmo salar) during winter. Canadian Journal of Fisheries and Aquatic Sciences 45(12):2156-2160.

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., B.D. Taubert, T.S. Squiers, D. Marchette and J. Buckley. 1984. Synopsis of biological data on shortnose sturgeon, Acipenser brevirostrum LeSueur, 1818. NOAA Technical Report-14. 53pp.

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

Dadswell, M.J., C. Caepa, A.D. Spares, N.D. Stewart, R.A. Curry, R.G. Bradford, and M.J.W. Stokesbury. 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 146:318-330.

Danie, D.S., J.G. Trial, and J.G. Stanley. 1984. Species profiles: life histories and environmental requirements of coastal fish and invertebrates (North Atlantic) – Atlantic salmon. U.S. Fish and Wildlife Service. FW/OBS-82/11.22. U.S. Army Corps of Engineers, TR EL-82-4. 19 pp.

De Robertis, A. and N.O. Handegard. 2013. Fish avoidance of research vessels and the efficacy of noise-reduced vessels: a review. ICES Journal of Marine Science 70(1):34-45.

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

DeVore, P.W., L.T. Brooke, and W.A. Swenson. 1980. The effects of red clay turbidity and sedimentation on aquatic life in the Nemadji River System. Impact of nonpoint pollution control on western Lake Superior. EPA Report 905/9-79-002-B. U.S. Environmental Protection Agency, Washington, D.C.

DeVries, R.J. 2006. Population dynamics, movements, and spawning habitat of the shortnose sturgeon, Acipenser brevirostrum, in the Delaware River. Master's Thesis, University of Georgia. 103 p.

Dionne, P.E., G.B. Zydlewski, M.T. Kinnison, J. Zydlewski, and G.S. Wippelhauser. 2013. Reconsidering residency: characterization and conservation implications of complex migratory patterns of shortnose sturgeon (*Acispenser brevirostrum*). Canadian Journal of Fisheries and Aquatic Sciences 70(1):119-127.

Dwyer, F.J., D.K. Hardesty, C.E. Henke, C.G. Ingersoll, D.W. Whites, T. Augspurger, T.J. Canfield, D.R. Mount, & F.L. Mayer. 2005. Assessing contaminant sensitivity of endangered and threatened aquatic species: part III. Effluent toxicity tests. Archives of Environmental Contamination and Toxicology 48: 174-183.

EPA (Environmental Protection Agency). 2010. Climate Change Indicators in the United States: Weather and Climate. Page 14. Evironmental Protection Agency.

EPA. 2016. National Coastal Condition Assessment. 2010. U.S. Environmental Protection Agency., Office of Water and Office of Research and Development (EPA-841-R-15-006).

EPA. 2023. Biological Evaluation of the National Rivers and Streams Assessment: Atlantic Coast Species and Critical Habitats. March 31, 2023, 108p.

Fabrizio, M.C., T.D. Tuckey, J.R. Buchanan, and R.A. Fisher. 2021. Predation impacts of invasive blue catfish on blue crabs in estuarine environments. Virginia Institute of Marine Science, William & Mary. https://scholarworks.wm.edu/reports/2531.

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. DOI 10.1007/s10592-017-0929-7.

Fay, C., M. Bartron, S. Craig, A. Hecht, J. Pruden, R. Saunders, T. Sheehan, and J. Trial. 2006. Status review of anadromous Atlantic salmon (Salmo salar) in the United States. National Marine Fisheries Service and United States Fish and Wildlife Service.

Fernandes, S.J., G.B. Zydlewski, J.D. Zydlewski, G.S. Wippelhauser, and M.T. Kinnison. 2010. Seasonal distribution and movements of shortnose sturgeon and Atlantic sturgeon in the Penobscot River Estuary, Maine. Transactions of the American Fisheries Society 139(5):1436-1449.

Fernandez, I., S. Birkel, C. Schmitt, J. Simonson, B. Lyon, A. Pershing, E. Stancioff, G. Jacobson, and P. Mayewski. 2020. Maine's Climate Future 2020 Update. Orono, ME: University of Maine. Climatechange.umaine.edu/climate-matters/maines-climate-future/.

Finney, S.T., J.J. Isely, and D.W. Cooke. 2006. Upstream migration of two pre-spawning shortnose sturgeon passed upstream of Pinopolis Dam, Cooper River, South Carolina. Southeastern Naturalist 5(2):369-375.

Flanigan, A., N.G. Perlut, and J.A. Sulikowski. 2021. A preliminary abundance estimate of an Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) contingent within an open riverine system. Journal of Northwest Atlantic Fisheries Science 52:39-47.

Folmar L., N. Denslow, Rao V, Chow M, Crain A, Enblom J, Marcino J, Guillette L Jr (1996) Vitellogenin introduction and reduced serum testosterone concentrations in feral male carp (*Cyprinus carpio*) captured near a major metropolitan wastewater treatment plant. Environ Health Perspect 104:1096–1100. Doi:10.2307/3433123.

Foster and Atkins (1869Fox, A.G. and D.L. Peterson. 2019. Movement and out-migration of juvenile Atlantic sturgeon in Georgia, USA. Transactions of the American Fisheries Society 148:952-962.

Fox, A.G., E.S. Stowe, K.J. Dunton, and D.L. Peterson. 2018b. Seasonal occurrence of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) in the St. Johns River, Florida. Fishery Bulletin 116:219-228.

Fox, A.G., I.I. Wirgin, and D.L. Peterson. 2018a. Occurrence of Atlantic Sturgeon in the St. Marys River, Georgia. Marine and Coastal Fisheries 10:606-618.

French, W.E., B.D.S. Graeb, S.R. Chipps, and R.A. Klumb. 2014. Vulnerability of age-0 pallid sturgeon Scaphirhynchus albus to predation; effects of predator type, turbidity, body size, and prey density. Environ Biol Fish 97:635–646. https://doi.org/10.1007/s10641-013-0166-y

Friedland, K.D. and J.D. Hare. 2007. Long-term trends and regime shifts in sea surface temperature on the continental shelf of the northeast United States. Continental Shelf Research 27(18):2313–2328. Doi: 10.1016/j.csr.2007.06.001

Fritts, M.W. 2011. Status of imperiled sturgeon species in the Satilla and St. Marys Rivers, Georgia. Master's Thesis, University of Georgia. 46 p.

Giesy, J.P., J. Newsted, and D.L. Garling. 1986. Relationships between chlorinated hydrocarbon concentrations and rearing mortality of chinook salmon (*Oncorhynchus tshawytscha*) eggs from Lake Michigan. Journal of Great Lakes Research 12(1):82-98.

Gilbert, C.R. 1989. Atlantic and shortnose sturgeons. United States Department of Interior Biological Report 82: 28 pp.

Graham, A. L. and S.J. Cooke. 2008. The effects of noise disturbance from various recreational boataing activities common to inland waters on the cardiac phyiology of a freshwater fish, the largemouth bass (*Micopterus salmoides*). Aquatic Conservation: Marine and Freshwater Ecosystems 18:1315-1324.

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 9:1111-1124.

Hager, C.H., J.C. Watterson, and J.E. Kahn. 2020. Spawning frequency and drivers of endangered Atlantic Sturgeon in the York River system. Transactions of the American

Fisheries Society 149(4):474-485. https://afspubs.onlinelibrary.wiley.com/doi/10.1002/tafs.10241

Hall, J.W., T.I.J. Smith, and S.D. Lamprecht. 1991. Movements and habitats of shortnose sturgeon, *Acipenser brevirostrum*, in the Savannah River. Copeia 1991(3):695-702.

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

Hare JA, Morrison WE, Nelson MW, Stachura MM, Teeters EJ, Griffis RB, et al. (2016) A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf. PloS ONE 11(2): e0146756. Doi:10.1371/ journal.pone.0146756

Hedger, R.D., O.H. Diserud, O.T. Sandlund, L. Saksgård, O. Ugedal, and G. Bremset. 2018. Bias in estimates of electrofishing capture probability of juvenile Atlantic salmon. Fisheries Research 208:286-295.

Hense, Z., R.W. Martin, and J.T. Petty. 2010. Electrofishing capture efficiencies for common stream fish species to support watershed-scale studies in the Central Appalachians. North American Journal of Fisheries Management 30:1041-1050.

Herbert, D.W. and J.C. Merkens. 1961. The effect of suspended mineral solids on the survival of trout. International Journal of Air and Water Pollution 5:46-55.

Hester, E.T. and K.S. Bauman. 2013. Stream and retention pond thermal response to heated summer runoff from urban impervious Surfaces 1. JAWRA Journal of the American Water Resources Association 49:328-342.

Hightower J.E., M. Loeffler, W.C. Post, and D.L. Peterson. 2015. Estimated survival of subadult and adult Atlantic sturgeon in four river basins in the southeastern United States. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 7:514-522.

Holliman, F.M. and J.B. Reynolds. 2002. Electroshock-induced injury in juvenile white sturgeon. North American Journal of Fisheries Management 22:494-499.

Hyvarinen, P., P. Suuronen and T. Laaksonen. 2006. Short-term movement of wild and reared Atlantic salmon smolts in brackish water estuary – preliminary study. Fish. Mgmt. Eco. 13(6): 399 –401.

Ingram E. C. and D. L. Peterson. 2016. Annual spawning migration of adult Atlantic sturgeon in the Altamaha River, Georgia. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 8:595-606.

Ingram, E.C., R.M. Cerrato, K.J. Dunton, and M.G. Frisk. 2019. Endangered Atlantic sturgeon in the New York wind energy area: implications of future development in an offshore wind energy site. Nature Scientific Reports 9:12432.

Jager H.I., J.A. Chandler, K.B. Lepla, and W. Van Winkle. 2001. A theoretical study of river fragmentation by dams and its effects on white sturgeon populations. Enviromental Biology of Fishes 60:347–361.

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 Annual Conference of the Southeastern Association of Fish and Wildlife Agencies.

Jenkins, W.E., T.I.J. Smith, L. Heyward, and D.M. Knott. 1993. Tolerance of shortnose sturgeon, Acipenser brevirostrum, juveniles to different salinity and dissolved oxygen concentrations. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 47:476-484.

Johnson, L. E., A. Ricciardi, and J. T. Carlton. 2001. Overland dispersal of aquatic invasive species: a risk assessment of transient recreational boating. Ecological Applications 11(6):1789-1799.

Jonsson, B. and N. Jonsson. 2009. A review of the likely effects of climate change on anadromous Atlantic salmon *Salmo salar* and brown trout *Salmo trutta*, with particular reference to water temperature and flow. Journal of Fish Biology 75:2381-2447.

Kahn, J.E., C. Hager, and C. Watterson. 2016. Abundance of adult Atlantic sturgeon in the York River and an assessment of the primary threat to the population. 2016 East Coast Sturgeon Workshop, May 16, 2016; Session 1: Threats.

Kahn, J. and M. Mohead. 2010. A protocol for use of shortnose, Atlantic, Gulf, and green sturgeon. U.S. Department of Commerce. NOAA Tech. Memo. NMFS-OPR-45,62p.

Kahn, J.E.,1, J.C. Watterson, C.H. Hager, N. Mathies, and K.J. Hartman. 2021. Calculating adult sex ratios from observed breeding sex ratios for wide-ranging, intermittently breeding species. Ecosphere 12:e03504.

Kahn, J.E., C. Hager, J.C. Watterson, N. Mathies, A. Deacy, K.J. Hartman. 2023. Population and Sex-Specific Survival Estimates of Atlantic Sturgeon: Addressing Capture Probability and Tag Loss. Aquatic Biology 32:1-12. https://www.int-res.com/articles/ab2023/32/b032p001.pdf

Kahnle, A.W., K.A. Hattala, K.A. McKown, C.A. Shirey, M.R. Collins, T.S. Squiers, Jr., and T. Savoy. 1998. Stock status of Atlantic sturgeon of Atlantic Coast estuaries. Report for the Atlantic States Marine Fisheries Commission. Draft III.

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

Kazyak, D. C., A. M. Flowers, N. J. Hostetter, J. A. Madsen, M. Breece, A. Higgs, L. M. Brown, J. A. Royle, and D. A. Fox. 2020. Integrated side-scan sonar and acoustic telemetry to estimate the annual spawning run size of Atlantic sturgeon in the Hudson River. Canadian

Journal of Fisheries and Aquatic Sciences efirst online:1-11. https://doi.org/10.1139/cjfas-2019-0398.

Kazyak, D.C., S.L. White, B.A. Lubinski, R. Johnson, and M. Eackles. 2021. Stock composition of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) encountered in marine and estuarine environments along the US Atlantic Coast. Conservation Genetics 22:767-781.

Kieffer, M. and B. Kynard. 2012. Spawning and non-spawning migrations, spawning, and the effects of river regulation on spawning success of Connecticut River shortnose sturgeon. Life history and behaviour of Connecticut River shortnose and other sturgeons. B. Kynard, P. Bronzi & H. Rosenthal (Eds.). WSCS. Demand GmbH, Norderstedt, Spec. Publ 4:73-113.

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

King, T.L., A.P. Henderson, B.E. Kynard, M.C. Kieffer, D.L. Peterson, A.W. Aunins, and B.L. Brown. 2014. A nuclear DNA perspective on delineating evolutionarily significant lineages in polyploids: the case of the endangered shortnose sturgeon (*Acipenser brevirostrum*). PloS One 9:e102784. Doi:10.1371/journal.pone.102784

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.

Kynard, B. 1997. Life history, latitudinal patterns, and status of the shortnose sturgeon, Acipenser brevirostrum. Environmental Biology of Fishes 48: 319–334.

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

Kunkel, K.E., R. Frankson, J. Runkle, S.M. Champion, L.E. Stevens, D.R. Easterling, B.C. Stewart, A. McCarrick, and C.R. Lemery (Eds.), 2022: State Climate Summaries for the United States 2022. NOAA Technical Report NESDIS 150. NOAA/NESDIS, Silver Spring, Maryland.

Lacroix, G. L. and D. Knox. 2005. Distribution of Atlantic salmon (Salmo salar) postsmolts of different origins in the Bay of Fundy and Gulf of Maine and evaluation of factors affecting migration, growth and survival. Can. J. Fish. Aquat. Sci. 62(6): 1363- 1376.

Lacroix, G.L. and McCurdy, P. 1996. Migratory behavior of post-smolt Atlantic salmon during initial stages of seaward migration. J. Fish Biol. 49, 1086-1101.

Lacroix, G. L, McCurdy, P., Knox, D. 2004. Migration of Atlantic salmon post smolts in relation to habitat use in a coastal system. Trans. Am. Fish. Soc. 133(6): pp. 1455-1471.

Lloyd, D. S. 1987. Turbidity as a water quality standard for salmonid habitats in Alaska. North American Journal of Fisheries Management 7:34-45.

Locher, T., J. Wang, T. Holda, and J. Lamer. 2022. Consumption of non-native bigheaded carps by native blue catfish in an impounded bay of the Upper Mississippi River. Fishes 7:80. https://doi.org/10.3390/fishes7020080.

Lockwood, B. L. and G. N. Somero. 2011. Invasive and native blue mussels (genus Mytilus) on the California coast: The role of physiology in a biological invasion☆. Journal of Experimental Marine Biology and Ecology.

Lowe, M. L., M. A. Morrison, and R. B. Taylor. 2015. Harmful effects of sediment-induced turbidity on juvenile fish in estuaries. Marine Ecology Progress Series 539:241-254.

Mantua, N., I. Tohver, and A. Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. Climatic Change 102:187-223.

Marcott, S.A., J.D. Shakun, P.U. Clark, and A.C. Mix. 2013. A Reconstruction of Regional and Global Temperature for the Past 11,300 Years. Science 339:1198-1201. DOI: 10.1126/science.1228026.

Martin, D. W. and J. A. Servizi. 1993. Suspended sediment particles inside gills and spleens of juvenile pacific salmonids (*Oncorhinchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences 50(3):586-590.

McCormick, S. D., R. A. Cunjak, B. Dempson, M. F. O'Dea, and J. B. Carey. 1999. Temperature-related loss of smolt characteristics in Atlantic salmon (Salmo salar) in the wild. Canadian Journal of Fisheries and Aquatic Sciences 56(9): 1649-1658.

McLaughlin, E. and A. Knight. 1987. Habitat criteria for Atlantic salmon. Special Report, U.S. Fish and Wildlife Service, Laconia, New Hampshire. 18 pp.

McMenemy, J. R., and B. Kynard. 1988. Use of inclined-plane traps to study movement and survival of Atlantic salmon smolts in the Connecticut River. North American Journal of Fisheries Management 8:481-488.

Mears, H.C. 2011. Environmental assessment and finding of no significant impact: NOAA award NA11NMF4720235: Maine Department of Marine Resources proposed activities for July 1, 2011 to June 30, 2016.

Meister, A.L. 1958. The Atlantic Salmon (*Salmo salar*) of Cove Brook, Winterport, Maine. M.S. Thesis. University of Maine. Orono, ME. 151 pp.

Melnychuk M.C., K.J. Dunton, A. Jordaan, K.A. McKown, and M.G. Frisk. 2017. Informing conservation strategies for the endangered Atlantic sturgeon using acoustic telemetry and multi-state mark-recapture models. Journal of Applied Ecology 54:914-925.

Miller, R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries 14:22-38.

Mills, K.E., A.J. Pershing, C.J. Brown, Y. Chen, F.S. Chiang, and D.S. Holland, 2013. Fisheries management in a changing climate: lessons from the 2012 ocean heat wave in the Northwest Atlantic. Oceanography 26(2):191–195. doi: 10.5670/oceanog.2013.27

Misund, O. A., J. T. Ovredal, and M.T. Hafsteinsson. 1996. Reactions of herring schools to the sound field of a survey vessel. Aquatic Living Resources 9:5-11.

Mitchell, J., R.S. McKinley, G. Power, and D.A. Scruton. 1998. Evaluation of Atlantic salmon parr responses to habitat improvement structures in an experimental channel in Newfoundland, Canada. Regulated Rivers: Research & Management: An International Journal Devoted to River Research and Management 14:25-39.

Mitson, R. B. and H. P. Knudsen. 2003. Causes and effects of underwater noise on fish abundance estimation. Aquatic Living Resources 16(3):255-263.

Moser, M.L., J. Conway, T. Thorpe, and J.R. Hall. 2000. Effects of recreational electrofishing on sturgeon habitat in the Cape Fear River drainage. North Carolina Sea Grant 99-EP-06. 36p.

Murphy, B.R. and D.W. Willis, editors. 1996. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Newcombe, C.P. and J.O.T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

Newcombe, C.P. and D.D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11:72–82.

NMFS. 1998. Recovery Plan for the shortnose sturgeon (*Acipenser brevirostrum*). Page 104 in Prepared by the Shortnose Sturgeon Recovery Team for the National Marine Fisheries Service, editor., Silver Spring, Maryland.

NMFS and USFWS. 2009. Endangered and threatened species; Determination of endangered status for the Gulf of Maine distinct population segment of Atlantic salmon. Federal Register 74 (117):29344-29387.

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

NMFS. 2017. Biological and Conference Opinion on Proposed Implementation of Program for the Issuance of Permits for Atlantic and Shortnose Sturgeon Research and Enhancement Activities Pursuant to Section 10(a) of the ESA. March 20, 2017, https://doi.org/10.7289/V5D21VSJ. 328 p.

National Marine Fisheries Service (NMFS). 2018b. Recovery Outline for Atlantic Sturgeon Distinct Population Segments. 10 pp.

NMFS and USFWS. 2018. Recovery plan for the Gulf of Maine distinct population segment of Atlantic salmon (*Salmo salar*). 74p.

Novak, A.J., A.E. Carlson, C.R. Wheeler, G.S. Wippelhauser, and J.A. Sulikowski. 2017. Critical foraging habitat of Atlantic sturgeon based on feeding habits, prey distribution, and movement patterns in the Saco River estuary, Maine. Transactions of the American Fisheries Society 146:308-317.

Omoto, N., M. Maebayashi, E. Mitsuhashi, K. Yoshitomi, S. Adachi, and K. Yamauchi. 2002. Effects of estradiol-17β and 17α-methyltestosterone on gonadal sex differentiation in the F2 hybrid sturgeon, the bester. Fisheries Science 68(5):1047-1054.

Patrick, W. S. 2005. Evaluation and mapping of Atlantic, Pacific, and Gulf Coast terminal dams: a tool to assist recovery and rebuilding of diadromous fish populations. Final Report to the NOAA Fisheries, Office of Habitat Conservation, Habitat Protection Division, Silver Spring, Maryland.

Pejchar, L., and K. Warner. 2001. A river might run through it again: criteria for consideration of dam removal and interim lessons from California. Environmental Management 28(5):561-575.

Pendleton, R.M. and R.D. Adams. 2021. Long-term trends in juvenile Atlantic sturgeon abundance may signal recovery in the Hudson River, New York, USA. North American Journal of Fisheries Management 41:1170-1181.

Peterson D. L., P. Schueller, R. DeVries, J. Fleming, C. Grunwald, and I. Wirgin. 2008. Annual run size and genetic characteristics of Atlantic sturgeon in the Altamaha River. Transactions of the American Fisheries Society 137:393-401.

Philippart, C. J. M., R. Anadón, R. Danovaro, J. W. Dippner, K. F. Drinkwater, S. J. Hawkins, T. Oguz, G. O'Sullivan, and P. C. Reid. 2011. Impacts of climate change on European marine ecosystems: Observations, expectations and indicators☆. Journal of Experimental Marine Biology and Ecology.

Putland, R. L., N. D. Merchant, A. Farcas, and C. A. Radford. 2017. Vessel noise cuts down communication space for vocalizing fish and marine mammals. Global Change Biology 2017:1-14.

Redding, J.M., C.B. Shreck, and F.H. Everest. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Transactions of the. American Fisheries Society 116: 737–744.

Reine, K. D. Clarke, M. Balazik, S. O'Haire, C. Dickerson, C. Frederickson, G.Garman, C.Hager, A. Spells, and C.Turner. 2014. Assessing impacts of navigation dredging on Atlantic sturgeon (Acipenser oxyrinchus). US Army Corps of Engineers, ERDC/EL TR-14-12. https://erdc-library.erdc.dren.mil/jspui/bitstream/11681/7131/1/ERDC-EL-TR-14-12.pdf.

Rodrigues, J.N., J.C.G. Ortega, D.K. Petsch, A.A. Padial, D.A.Moi, B.R. Figueiredo. 2023. A meta-analytical review of turbidity effects on fish mobility. Rev Fish Biol Fisheries 1-15. https://doi.org/10.1007/s11160-023-09785-4.

Root, S. and C. M. O'Reilly. 2012. Didymo control: Increasing the effectiveness of decontamination strategies and reducing spread. Fisheries 37:440-448.

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: 2047-2065.

Ruban, G.I. 2023. Modern Concepts on the Origin and Distribution of Acipenserids (Acipenseridae). Journal of Ichthyology 63:206–215. https://doi.org/10.1134/S0032945223020169.

Rubenstein, S.R. 2021. Energetic impacts of passage delays in migrating adult Atlantic Salmon. The University of Maine. Master of Science. 76p.

Ruelle, R. and K.D. Keenlyne. 1993. Contaminants in Missouri River Pallid Sturgeon. Bulletin of Environmental Contamination and Toxicology 50:898-906.

Ruiz, G. M., P. Fofonoff, and A. H. Hines. 1999. Non-indigenous species as stressors in estuarine and marine communities: Assessing invasion impacts and interactions. Limnology and Oceanography 44(3):950–972.

Rulifson, R.A., C.W. Bangley, J.L. Cudney, A. Dell'Apa, K.J. Dunton, M.G. Frisk, M. S. Loeffler, M.T. Balazik, C. Hager, T. Savoy, H.M Brundage III, and W.C. Post. 2020. Seasonal presence of Atlantic sturgeon and sharks at Cape Hatteras, a large continental shelf constriction to coastal migration. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 12:308-321.

Santec Consulting Services. 2023. Merrimack River shortnose sturgeon monitoring, 2020-2023. Prepared for Massachusetts Department of Transportation, Project Number 179410723. 123p.

Savoy, T., 2004: Population estimate and utilization of the lower Connecticut River by shortnose sturgeon. American Fisheries Society Monograph 9:345–352.

Savoy, T., L. Maceda, N.K. Roy, D. Peterson, and I. Wirgin. 2017. Evidence of natural reproduction of Atlantic sturgeon in the Connecticut River from unlikely sources. Plos one 12(4):e0175085.

Scannell, P.O. 1988. Effects of elevated sediment levels from placer mining on survival and Behavior of immature arctic grayling. Alaska Cooperative Fishery Unit, University of Alaska. Unit Contribution 27.

Scharf, F.S., F. Juanes, and R.A. Rountree. 2000. Predator size-prey size relationships of marine fish predators: interspecific variation and effects of ontogeny and body size on trophic-niche breadth. Marine Ecology Progress Series 208: 229-248.

Scholz N.L., N.K. Truelove, B.L. French, B.A. Berejikian, T.P. Quinn, E. Casillas, and T.K. Collier. 2000. Diazinon disrupts antipredator and homing behaviors in Chinook salmon (*Oncorhynchus tshawytscha*). Canadian J. of Fisheries and Aquatic Sciences 57: 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 139:1526-1535.

Secor, D. H., and E. J. Niklitschek. 2002. Hypoxia and sturgeons. University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, Technical Report Series No. TS-314-01-CBL, Solomons, Maryland.

Secor, D.H. and T.E. Gunderson. 1998. Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon, Acipenser oxyrinchus. Fishery Bulletin 96:603-613.

Servizi, J.A. and D.W. Martens. 1991. Effect of temperature, season, and fish size on acute lethality of suspended sediments to coho salmon, Oncorhynchus kisutch. Canadian Journal of Fisheries and Aquatic Sciences 48:493–497.

Sheehan, T.F., D. Deschamps, T. Trinko Lake, S. McKelvey. K. Thomas, S. Toms, R. Nygaard, T.L. King, M.J. Robertson, N.Ó. Maoiléidigh. The International Sampling Program: Continent of Origin and Biological Characteristics of Atlantic Salmon Collected at West Greenland in 2013. October 2015. NEFSC: 15:22, 34pp.

Sigler, J. W., T. C. Bjornn, and F. E. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Transactions of the American Fisheries Society 113:142-150.

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.

Slaughter IV, J.E. and B. Jacobson. 2008. Gape: body size relationship of flathead catfish. North American Journal of Fisheries Management 28:198-202.

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 144:48–54.

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.

Smith, T.I.J. 1985. The Fishery, Biology, and Management of Atlantic sturgeon, *Acipenser oxyrhynchus*, in North America. Environmental Biology of Fishes 14(1): 61-72.

Smith, T.I.J., D.E. Marchette, and G.F. Ulrich. 1984. The Atlantic sturgeon fishery in South Carolina. North American Journal of Fisheries Management 4: 164-176.

Smith, T.I.J., D.E. Marchette and R.A. Smiley. 1982. Life history, ecology, culture and management of Atlantic sturgeon, *Acipenser oxyrhynchus oxyrhynchus*, Mitchill, in South Carolina. South Carolina Wildlife Marine Resources. Resources Department, Final Report to U.S. Fish and Wildlife Service Project AFS-9. 75 p.

Snyder, D.E. 2003. Invited overview: conclusions from a review of electrofishing and its harmful effects on fish. Reviews in Fish Biology and Fisheries 13: 445–453.

Spence, B.C., G.A. Lomincky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmon conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, Oregon.

Spicer, A. V., J. R. Moring, and J. G. Trial. 1995. Downstream migratory behavior of hatcheryreared, radio-tagged Atlantic salmon (Salmo salar) smolts in the Penobscot River, Maine, USA. Fisheries Research 23:255-266.

Spurgeon, J.J., M.A. Pegg, M.J. Hamel, and K.D. Steffensen. 2018. Spatial structure of large-river fish populations across main-stem and tributary habitats. River Research and Applications 34:1-9.

Squiers, T.S., M. Robillard, and N.Gray. 1993. Assessment of potential shortnose sturgeon spawning sites in the upper tidal reach of the Androscoggin River. Final Report to the National Marine Fisheries Service, Gloucester, Massachusetts.

Stevens Jr, D.L. and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

Sutherland, A. B. and J. L. Meyer. 2007. Effects of increased suspended sediment on growth rate and gill condition of two southern Appalachian minnows. Environmental Biology of Fishes 80:389-403.

U.S. Atlantic Salmon Assessment Committee (USASAC). Annual reports between 2001 and 2023. Annual Report of the U.S. Atlantic Salmon Assessment Committee.

USDA. 1999. 1997 Census of agriculture—agricultural atlas of the United States, Washington, D.C.

USGS. 2017. Land Cover Trends Project.

Van Eenennaam, J.P. and S.I. Doroshov. 1998. Effects of age and body size on gonadal development of Atlantic sturgeon. Journal of Fish Biology 53:624-637.

Verreault G. and G. Trencia. 2011. Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) fishery management in the St. Lawrence estuary, Quebec. Pages 527–538 in P. Williot, E. Rochard, J. Gessner, and F. Kirschbaum, eds. Biology and conservation of European sturgeon, *Acipenser sturio* L. Springer-Verlag, Berlin, Germany.

Vine, J.R., S.C. Holbrook, W.C. Post, and B.K. Peoples. 2019a. Identifying environmental cues for Atlantic sturgeon and shortnose sturgeon spawning migrations in the Savannah River. Transactions of the American Fisheries Society 148:671-681.

Vine, J.R., Y. Kanno, S.C. Holbrook, W.C. Post, and B.K. Peoples. 2019b. Using side-scan and N-mixture modeling to estimate Atlantic sturgeon spawning migration abundance. North American Journal of Fisheries Management 39:939-950.

Waldman, J.R., J.T. Hart, and I.I. Wirgin. 1996. Stock composition of the New York Bight Atlantic sturgeon fishery based on analysis of mitochondrial DNA. Transactions of the American Fisheries Society 125:364-371.

Waldman, J., S.E. Alter, D. Peterson, L. Maceda, N. Roy, and I. Wirgin. 2019. Contemporary and historic effective population sizes of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus*. Conservation Genetics. https://doi.org/10.1007/s10592-018-1121-4.

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 66:93-104.

Webb, B.W., Clack, P.D., and Walling, D.E. 2003. Water–air temperature relationships in a Devon River system and the role of flow. Hydrological Processes 17(15):3069-3084.

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

Wheaton, J. M., G. B. Pasternack, and J. E. Merz. 2004. Spawning habitat rehabilitation-I. Conceptual approach and methods. International Journal of River Basin Management 2(1):3-20.

White, H.C. 1942. Atlantic salmon redds and artificial spawning beds. Journal of the Fisheries Research Board of Canada 6:37-44.

White, S.L., D.C. Kazyak, T.L. Darden. D.J. Farrae, B.A. Lubinski, R.L. Johnson, M.S. Eackles, M.T. Balazik, H.M. Brundage III, A.G. Fox, D.A. Fox, C.H. Hager, J.E. Kahn, and I.I. Wirgin. 2021a. Establishment of a microsatellite genetic baseline for North American Atlantic sturgeon (*Acipenser o. oxyrinchus*) and range-wide analysis of population genetics. Conservation Genetics. https://doi.org/10.1007/s10592-021-01390-x.

White, S.L., N.M. Sard, H.M. Brundage III, R.L. Johnson, B.A. Lubinski, M.S. Eackles, I.A. Park, D.A. Fox, and D.C. Kazyak. 2021b. Evaluating sources of bias in pedigree-based estimates of breeding population size. Ecological Applications 32:e2602.

White, S.L., R. Johnson, B.A. Lubinski, M.S. Eackles, D.H. Secor, and D.C. Kazyak. 2021c. Stock composition of the historical New York Bight fishery revealed through microsatellite analysis of archived spines. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 13:720-727.

Wilcove, D. S., and L. Y. Chen. 1998. Management costs for endangered species. Conservation Biology 12:1405-1407.

Wildhaber, M.L., A.J. DeLonay, D.M. Papoulias, D.L. Galat, R.B., Jacobson, D.G. Simpkins, P.J. Braaten, C.E. Korschgen, and M.J. Mac. 2007. A conceptual life history model for pallid and shovelnose sturgeon.USGS Report. https://pubs.usgs.gov/circ/2007/1315/index.html.

Willford, W., R.A. Bergstedt, W.H. Berlin, N.R. Foster, R.J. Hesselberg, M.J. Mac, D.R.M. Passino, R.E. Reinert, and D.V. Rottiers. 1981. Chlorinated hydrocarbons as a factor in the reproduction and survival of lake trout (*Salvelinus namaycush*) in Lake Michigan. Technical Report. U.S. Fish and Wildlife Service.

Wippelhauser, G.S. and T.S. Squiers JR. 2015. Shortnose sturgeon and Atlantic sturgeon in the Kennebec River system, Maine: a 1977-2001 retrospective of abundance and habitat importance. Transactions of the American Fisheries Society 144:591-601.

Wippelhauser, G.S., J. Sulikowski, G.B. Zydlewski, M.A. Altenritter, M. Kieffer, and M.T. Kinnison. 2017. Movements of Atlantic sturgeon of the Gulf of Maine inside and outside of the geographically defined distinct population segment. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 9:93-107.

Wirgin, I., N.K. Roy, L. Maceda, and M.T. Mattson. 2018. DPS and population of origin of sub-adult Atlantic sturgeon in the Hudson River. Fisheries Research 207:165-170.

Wirgin, I., C. Grunwald, E. Carlson, J. Stabile, D.L. Peterson, and J.R. Waldman. (2005). Range-wide population structure of shortnose sturgeon *Acipenser brevirostrum* based on sequence analysis of the mitochondrial DNA control region. Estuaries 28:406–421.