NATIONAL MARINE FISHERIES SERVICE
ENDANGERED SPECIES ACT SECTION 7

BIOLOGICAL OPINION

Title:	Environmental Protection Agency Approval of Virginia's Adoption of Criteria for Aluminum in Freshwater
Consultation Conducted By:	Endangered Species Act Interagency Cooperation Division, Office of Protected Resources, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce
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Table of Contents

Page

Contents

List of Tables

List of Figures

Page

1 INTRODUCTION

The Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.), jointly administered by the U.S. Fish and Wildlife Service and National Marine Fisheries Service (NMFS, taken together, the Services), establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat they depend on. ESA section 7(a)(2) requires Federal agencies to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Federal agencies must do so in consultation with NMFS for threatened or endangered species (ESA-listed), or designated and proposed critical habitat that may be affected by the action that are under NMFS's jurisdiction (50 CFR §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 not likely to jeopardize ESA-listed species or destroy or adversely modify designated critical habitat. If NMFS determines that the action is likely to jeopardize ESA-listed species or destroy or adversely modify critical habitat, in accordance with ESA section 7(b)(3)(A), NMFS provides a reasonable and prudent alternative that allows the action to proceed in compliance with the ESA. Take under the ESA means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct (16 U.S.C. §1532(19)). If the action (or a reasonable and prudent alternative) is expected to cause incidental take without violating section 7(a)(2), section 7(b)(4), as implemented by 50 CFR §402.14(i), requires NMFS to provide an incidental take statement (ITS), which specifies: the impact (i.e., amount or extent of take) of incidental take; reasonable and prudent measures (RPMs) determined necessary or appropriate to minimize such impacts; if appropriate measure from an Marine Mammal Protection Act 101(A)(5) permit; terms and conditions to implement the RPMs; and, procedures to be used to handle or dispose of any individual species actually taken. Incidental take must also be monitored and reported as the action proceeds and consultation must be immediately reinitiated should the amount or extent of incidental take specified in the ITS be exceeded. Any incidental take which occurs in compliance with the terms and conditions in the ITS is exempted from the ESA's prohibition on take (16 U.S.C. §1536(o)(2)).

The Federal action agency for this consultation is the U.S. Environmental Protection Agency Region 3 (EPA). The EPA requested ESA section 7 consultation for the approval of certain Water Quality Standards for Waters of the United States located in Virginia under Clean Water Act section 303(c). The state agency that implements water quality standards is the Virginia Department of Environmental Quality (VADEQ). In January 17, 2022, VADEQ announced for public review and comment a proposed rulemaking that included, among other water quality standards, proposed adoption of aluminum freshwater criteria. Previously, Virginia did not have a freshwater criterion for aluminum and proposed to adopt acute and chronic criteria consistent with EPA's Final Aquatic Life Ambient Water Quality Criteria for Aluminum (EPA-822-R-18-001, 2018). EPA received Virginia's formal submission on February 15, 2023.

This consultation, its biological opinion (opinion), and associated ITS were completed in accordance with ESA section 7, associated implementing regulations (50 CFR §§402.01-402.17), and agency policy and guidance (NMFS/USFWS 1998). The NMFS Office of Protected Resources (OPR) Endangered Species Act Interagency Cooperation Division (hereafter referred to as "NMFS," "we," or "our") conducted this consultation.

On July 5, 2022, the U.S. District Court for the Northern District of California issued an order vacating the 2019 regulations that were revised or added to 50 CFR part 402 in 2019 ("2019 Regulations," see 84 FR 44976, August 27, 2019) without making a finding on the merits. On September 21, 2022, the U.S. Court of Appeals for the Ninth Circuit granted a temporary stay of the district court's July 5 order. On November 14, 2022, the Northern District of California issued an order granting the government's request for voluntary remand without vacating the 2019 regulations. The District Court issued a slightly amended order 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 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 NMFS's opinion on the effects of these actions on shortnose sturgeon (*Acipenser brevirostrum*) and Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, Carolina, South Atlantic, New York Bight, Chesapeake, and Gulf of Maine Distinct Population Segments [DPS]).

A complete record of this consultation was filed electronically by the NMFS Office of Protected Resources in Silver Spring, Maryland.

1.1 Background

Under the ESA, it is the policy of Congress that all Federal agencies shall seek to conserve threatened and endangered species, use their authorities in furtherance of the ESA, and cooperate with state and local agencies to resolve water resource issues in concert with conserving endangered species (16 U.S.C.§1531). Water quality standards are regulations established under the Clean Water Act that are intended to: protect public health and welfare; enhance the quality of water; restore and maintain the chemical, physical, and biological integrity of State, territory, or Tribe waters; and provide water quality protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water. Water quality standards include designated uses and narrative or numeric criteria to protect those uses. Narrative water quality criteria describe the desired conditions of a water body as being "free from" certain negative conditions. Numeric water quality criteria are maximum allowable concentrations of toxic pollutants or acceptable aquatic chemistry conditions (e.g., pH or temperature range, nutrients). This opinion uses the term "criteria" when discussing the numeric water quality criteria EPA proposes to approve to distinguish these from the broader term "water quality standards" that also describe the desired condition of water bodies and the means by which conditions will be protected or achieved.

The uses designated for State, territory, or Tribe waters inform the narrative and numeric water quality criteria that will apply for each use designation. Numeric and narrative criteria are used to determine whether the waters meet their designated use. Numeric criteria are used to set permit limits for effluent discharges and pollutant loading limits to restore pollution-impaired waters. Only those permitted effluent discharges of substances that have a reasonable potential to cause an aquatic impairment have permit limits and require monitoring. Specifically 40 CFR §122.44(d)(1) reads: "Limitations must control all pollutants or pollutant parameters (either conventional, nonconventional, or toxic pollutants) which the [EPA] Director determines are or may be discharged at a level which will cause, have the reasonable potential to cause, or contribute to an excursion above any State water quality standard."

Because the numeric criteria set the exposure conditions for each stressor, NMFS's analysis determines whether adverse effects may result from exposure to the stressor within the limits of its criteria. Clean Water Act section 303(c)(2)(B) requires States, territories, and Tribes to adopt numeric criteria for all toxic pollutants for National Recommended Water Quality Guidelines (National Criteria) that have been published under Clean Water Act section 304(a). Most of the National Criteria were developed by EPA under the 1985 *EPA Guidelines for Deriving Numerical National Water Quality Criteria* (EPA Guidelines, Stephen 1985). Some National Criteria are calculated using models that account for bioaccumulation or the effects of site-specific aquatic chemistry on biological availability and thus toxicity.

Clean Water Act Section 303(c) requires that, at least once every 3 years, States, territories, and Tribes review and, when necessary, modify their water quality standards or adopt new water quality standards to protect waters under their jurisdiction. Implementation of State, territory, or Tribe water quality standards can also affect water quality in neighboring entities when rivers cross or delineate borders. As required by Clean Water Act section 303(c) and 40 CFR 131, EPA reviews water quality standards proposed for adoption by a State, territory, or Tribe, and cannot be implemented under the Clean Water Act until approved by EPA.

In terms of ESA section 7 consultations for Clean Water Act-related actions, the goal of the 2001 Memorandum of Agreement among EPA, NMFS, and the U.S. Fish and Wildlife Service is to enhance coordination under both statutes. The EPA consults with the Services on newly proposed and/or revised water quality standards to ensure that any adopted water quality standards are protective of ESA-listed species and critical habitats in waters under that State, territory, or Tribe's jurisdiction and have a water quality standards description that includes the protection and propagation of fish, shellfish, and wildlife.

1.1.1 Prior Consultations

NMFS has not consulted with EPA on approvals of any water quality standards for the Commonwealth of Virginia prior to this one. NMFS has consulted with EPA on approvals for aluminum for the Commonwealth of Massachusetts and for other chemicals for the states of Maine, New Hampshire, Massachusetts, Delaware, Maryland, North Carolina, South Carolina, Georgia, Florida, and Mississippi. The basis of our determinations in prior consultations are not identical for each state because each state has differing pollutant sources associated with waters where ESA-listed species under NMFS's jurisdiction, availability and quality of monitoring data for the pollutant, and the state's planned implementation of the criteria[1] (FPR-2017-9229, OPR-2019-03141, OPR-2021-00175, OPR-2022-00203, OPR-2022-02170, and OPR-2022-03042).

1.2 Preconsultation

On December 9, 2021, staff from EPA Region 3 and NMFS Office of Protected Resources, Interagency Cooperation Division (NMFS OPR), held a conference call to discuss coordination on upcoming EPA approvals of state-proposed water quality criteria under section 303(c) of the Clean Water Act. During this call NMFS OPR stated that a prior consultation determined that EPA's recommended freshwater aluminum criteria were determined likely to adversely affect sturgeon. NMFS indicated that consultation for Virginia's aluminum criteria would need to consider the protectiveness of the criteria along with the consequent implementation of criteria in permitting discharges, listing impaired waters, and establishing total maximum daily pollutant loads (TMDLs) or other restoration plans to recover impaired waters where sturgeon occur. NMFS OPR forwarded a link to the NMFS Greater Atlantic Region Consultation Mapper that identifies waters where ESA-listed Atlantic and shortnose sturgeon occur. EPA subsequently transmitted Virginia's draft 2022 Integrated Water Quality Report of assessed and impaired waters on July 5, 2022.

1.3 Consultation History

On February 21, 2023, EPA Region 3 sent NMFS OPR a consultation request letter, a Biological Evaluation (BE), and, anticipating a likely to adversely affect determination, proposed RPMs for review and comment.

On March 7, 2023, NMFS informed EPA Region 3 that consulting on criteria for aluminum in the absence of information on how the state would address pH, hardness and dissolved organic carbon-dependent calculation of aluminum criteria would be difficult.

On March 8, 2023 EPA Region 3 proposed to add the following RPM to the Incidental Take Statement (ITS):

> EPA will work with/encourage the state in developing implementation procedures for these revised aluminum criteria that can be incorporated into VA's Clean Water Act regulatory programs (e.g., assessment, TMDLs, permitting etc...). Until these implementation procedures are established by the state, EPA will provide annual status updates to NMFS on progress towards meeting this objective.

On March 27, 2023, NMFS informed EPA Region 3 that the acceptability of this RPM would be conditioned on the expected timeline for developing implementation guidelines and that NMFS may need to apply temporal guardrails to the RPM. EPA Region 3 responded that EPA Office of Water's 2021 "*Draft Technical Support Document: Implementing the 2018 Recommended*

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[1] For example, some states limit hardness values used in calculators of hardness-based criteria.

Aquatic Life Water Quality Criteria for Aluminum" (hereafter referred to as the Aluminum TSD, USEPA 2021) and that the implementation support will be finalized by the end of the calendar year and is not expected to change significantly from the draft.

On March 30, 2023, NMFS OPR sent EPA Region 3 a letter confirming initiation of formal consultation.

On May 15, 2023, NMFS contacted EPA Region 3 to confirm that Virginia is expected to follow EPA Office of Water's technical support document for implementing the aluminum criteria.

On June 5, 2023, NMFS asked EPA Region 3 if there was potential for VADEQ to rely on the Metals Aquatic Life Criteria and Chemistry Map (MetALiCC-MAP v1.0) in implementing the aluminum criteria.

On June 6, 2023, EPA Region 3 responded that they have encouraged VADEQ to use MetALiCC-MAP when site-specific data isn't available.

On June 8, 2023, EPA Region 3 and NMFS met to discuss the RPM and terms and conditions for implementing aluminum criteria.

On June 9, 2023, EPA Region 3 shared the draft implementation technical support document and indicated they were still working on RPM language.

On June 14, 2023, EPA Region 3 indicated they shared the RPMs and terms and conditions with VADEQ and VADEQ needed a few days to brief their management.

Between June 20 and July 8, 2023 EPA Region 3 and NMFS shared additional edits to RPMs and terms and conditions.

On July 17, 2023, NMFS requested an update and EPA Region 3 reported that it was still working on RPMs.

On August 28, 2023, EPA Region 3 transmitted revised RPMs but did not include the complete tracked changes version.

On August 29, 2023, EPA Region 3 transmitted a tracked changes version of the revised RPMs, which excluded Virginia's development of implementation guidelines.

On September 5, 2023, NMFS contacted EPA Region 3 to inform them that the BE included some errors in identifying potentially exposed ESA-listed whale species. Sperm, sei, and blue whale are pelagic species that would not be exposed to water quality conditions affected by Virginia's implementation of freshwater aluminum criteria. EPA replied that inclusion of the pelagic whale species was an error on their part.

On September 28, 2023, EPA Region 3 and NMFS finalized RPMs.

2 THE ASSESSMENT FRAMEWORK

ESA section 7(a)(2) 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 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 CFR §402.02).

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

The assessment framework is designed to logically conclude whether EPA is able to ensure this action satisfies section 7(a)(2) of the ESA. This consultation involves the following steps:

Description of the Action (Section 3): Action is defined in the regulations at 50 CFR §402.02 and includes all direct and indirect modifications to land, water, or air. We describe the numeric water quality criteria EPA proposes to approve and their expected implementation.

Action Area (Section 4): We describe the action and those aspects (or potential stressors) of the action that may cause modifications to the physical, chemical, and biotic features of land, water, and air. We describe the action area with the spatial extent of the modifications from those actions.

ESA-Listed Species and Critical Habitat (Section 5): We identify the ESA-listed species and critical habitat that are likely to co-occur with the potential stressors caused by the action in space and time and evaluate the status of those species and habitat. We provide our concurrence with EPA Region 3 in section 5.1 for those species and critical habitats that may be affected, but are not likely to be adversely affected by the stressors caused by this action. We then identify the status of the remaining species and critical habitat likely to be adversely affected (Section 5.2).

Environmental Baseline (Section 6): We describe the environmental baseline as the condition of the listed species or its critical habitat in the action area, without the consequences to the listed species or critical habitat caused by the 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 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 critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR §402.02).

Effects of the Action (Section 7): refers to all consequences to listed species or critical habitat that are caused by the action, including the consequences of other activities that are caused by the action. A consequence is caused by the action if it would not occur but for the 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 (50 CFR §402.02). In this consultation, if EPA approves adoption of water quality criteria for specific toxicants, a consequence of that approval is the implementation of the criteria. Once criteria are approved by EPA, VADEQ may:

- Issue Virginia Pollution Discharge Elimination System permits (VPDES) that take the place of the National Pollution Discharge Elimination System (NPDES) permits for discharges of these pollutants;
- Use the criteria to assess and list aquatic impairments under sections 305(b) and 303(d) of the Clean Water Act, respectively; and
- Where necessary, calculate load limits for impaired waters based on the presence of pollutants above criteria limits.

After introducing aluminum, summarizing its uses, sources, environmental fate, mechanism(s) of effect, the BE analysis, and the criteria, the effects analysis in this opinion is as follows:

Section 7.1 Exposure to Aluminum within the Action Area: Identifies sources within the action area and evaluates monitoring and permitting data for aluminum to characterize current and future implementation of the criteria. This section also identifies the life stages of ESA-listed individuals that are likely to be exposed to water quality conditions affected by VADEQ implementation of the aluminum criteria in freshwaters based on their potential presence in areas where the criteria will be implemented.

Section 7.2 Responses to Aluminum within Criteria Limits: Analyzes the available evidence, using data from surrogate species when necessary and appropriate, to determine how individuals of ESA-listed species are likely to respond to exposures to aluminum within criteria limits. This section also evaluates responses of forage species exposed within criteria limits.

Section 7.3 Risk Analysis: The risk analysis for likely to adversely affect determinations summarizes the evidence supporting the determination then evaluates the consequences of effects in individuals to the populations those individuals represent, and the species those populations comprise. Where adverse effects to critical habitat are expected, the risk analysis also considers the impacts of the action on the physical or biological features of critical habitat.

Risk hypotheses are statements that organize an analysis by describing the relationships among stressor, exposure, and the environmental values to be protected. Generally speaking, the values to be protected are the survival and fitness of individuals and the value of critical habitat for conservation of an ESA-listed species. The applicable risk hypotheses for direct stressors like toxic substances are straightforward: EPA's approval will be likely to adversely affect an ESA-listed species if exposures to the toxic pollutant within criteria limits will result in:

- Reduced survival of individuals through direct mortality or effects favoring predation (e.g., immobility, reduced predator detection);
- Reduced growth of individuals through direct effects of toxicity or effects impairing foraging (e.g., swimming, deformity, prey detection, strike success);
- Reduced fecundity through direct effects of toxicity (e.g., reduced hatch, egg mass, egg counts) or effects impairing reproduction (e.g., impaired nest tending, gonad mass);
- Reduced survival, growth, and/or fecundity due to diminished quantity or quality of forage due to toxic effects on forage species abundance or toxic effects of body burdens of the stressor in forage species; and/or
- Toxic effects on biological features (e.g., forage species or vegetative habitat) of critical habitat that are essential to the conservation of the species.

Cumulative Effects (Section 8): Cumulative effects are the effects to ESA-listed species and critical habitat of future non-Federal or private activities that are reasonably certain to occur within the action area (50 CFR §402.02). Effects from future Federal actions that are unrelated to the action under consideration are not addressed because they require a separate ESA section 7 jeopardy analysis.

Integration and Synthesis (Section 9): In this section, we integrate the analyses of Effects of the Action (Section 8), the Environmental Baseline (Section 6), and the Cumulative Effects (Section 9) and place this in context of the Status of Species and Critical Habitat (Section 5) to formulate the agency's biological opinion as to whether the action agency has insured its action is not likely to reduce appreciably the likelihood of survival and recovery of an ESA-listed species in the wild or appreciably diminish the value of critical habitat as a whole for the conservation of a listed species.

Conclusion (Section 10): The conclusion section summarizes the results of our jeopardy and destruction or adverse modification analyses.

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 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 CFR §402.14(h)(2).

If we determine EPA has satisfied ESA section 7(a)(2) or identify a reasonable and prudent alternative, we include an Incidental Take Statement (Section 11) that specifies the impact of the take, reasonable and prudent measures to minimize the impact of the take, and terms and conditions to implement the reasonable and prudent measures (ESA section 7(b)(4); (50 CFR §402.14(i) and 50 CFR §402.14(g)(7))). We also provide discretionary Conservation

Recommendations (Section 11.3) that may be implemented by the action agency (50 CFR §402.14(j)). Finally, we identify the circumstances in which Reinitiation of Consultation is required (Section 14; 50 CFR §402.16).

> *Note: Discovery of toxicity data, either found or newly generated, indicating ESA-listed species may respond to exposures within criterion limit assessed in this consultation may require criteria revision and subsequent consultation for EPA's approval of revised criteria. Where a not likely to adversely affect determination is based on discountable exposure, new information that indicates exposure is likely to occur to an extent not previously considered may trigger reinitiation of consultation (Section 14) where discretionary involvement or control over the action has been retained or is authorized by law, in this case, the Clean Water Act.*

2.1 Best Scientific and Commercial Data Available for the Consultation

To comply with our obligation to use the best scientific and commercial data available (16 U.S.C. 1536(a)(2)), we collected information identified through searches of Google Scholar, Web of Science, the literature cited sections of peer-reviewed articles identified in these searches, reports published by government and private entities, and species listing documentation. The BE provided by EPA includes summaries of toxicity data EPA used to evaluate whether proposed criteria may result in harm to ESA-listed species and critical habitat. Our assessment considers these summaries, but also considers other data found in EPA's ECOTOXicology Knowledgebase (ECOTOX), particularly data that were not available or considered suitable for the derivation of criteria, including data added or refreshed in the ECOTOX quarterly update. Use of additional data when vetting the criteria for effects to ESA-listed species is consistent with EPA's Guidelines and the requirement under the ESA that determinations be based on the best available data. This opinion is based on our review of this information and various other information sources, including:

- The BE submitted by EPA;
- Government databases, including ECOTOX[2], EPA's Enforcement and Compliance History Online Database and the National Water Quality Monitoring Council's Water Quality Portal that were frequently consulted interactively during the preparation of this opinion;
- Government reports, including NMFS opinions and stock assessment reports;
- National Oceanic and Atmospheric Administration (NOAA) technical memoranda; and
- Peer-reviewed literature.

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[2] The ECOTOX is refreshed quarterly to add new records and correct errors or add additional information to existing records. NMFS collects and screens toxicity data from ECOTOX for various chemicals, including aluminum. These curated datasets are updated from ECOTOX and the open literature as necessary.

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

Because the EPA Guidelines are fundamental to development of criteria for substances in water, the assumptions and procedures directed by the EPA Guidelines are fundamental to the evaluation of the protectiveness of these criteria for ESA-listed species and critical habitats. The NMFS OPR consultation with EPA Region 3 on approval of water quality criteria for Delaware and Maryland addressed the implications of these assumptions and procedures in Section 3.1 of that opinion (NMFS 2023), which is incorporated by reference into the analyses of EPA's approval described in this opinion. The approach NMFS OPR uses when curating and interpreting toxicity data and assessing the consequences of criteria adoption and implementation to ESA-listed species (Section 2.1.2 and Section 2.2) of the Delaware and Maryland opinion are also incorporated by reference into the analyses described in this opinion.

3 DESCRIPTION OF THE ACTION

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR §402.02). The action is EPA Region 3's approval of acute and chronic freshwater criteria for aluminum derived in EPA's 2018 Aluminum Guideline (Table 1, USEPA 2018) proposed for adoption by the Commonwealth of Virginia under Clean Water Act section 303(c). The purpose of the criteria is to maintain or restore water quality conditions that support aquatic life.

3.1 EPA's Oversight Role under the Clean Water Act

The Clean Water Act establishes a system of cooperative federalism under which States, Tribes, and territories are responsible for addressing water pollution and the EPA exercises a largely oversight role. EPA recommends guidelines, under §304(a), for surface water conditions. States may adopt guidelines as criteria as recommended with EPA approval, they may be modified with EPA approval, or a scientifically defensible alternative to the guidelines may be adopted with EPA approval under §303(c). When necessary, under §303(c)(4) EPA may promulgate standards for a State, Tribe, or territory to implement. EPA's action is approval of Virginia's adoption of water quality guidelines for aluminum in freshwater as criteria. Implementation is a reasonably certain to occur consequence of adoption. Under the Clean Water Act, EPA exerts oversight for setting State water quality standards and their implementation through:

- Approval or disapproval and promulgation of state water quality assessments and identification of aquatic impairments under §305(b) and §303(d) – referred to as Integrated Reports;

- Approval or disapproval and promulgation of state pollutant load allocations to restore impaired waters under §303(d) – referred to as Total Maximum Daily Loads[3] (TMDL);
- Approval, under §402(b), or withdrawal, under §402(c), of a state pollutant discharge permitting program;
- Objection, under 402(b)(5), of state pollutant discharge permits that are not protective and/or are inconsistent with the Clean Water Act;
- Federalizing a state pollutant discharge permit under §402(d)(4) if EPA's objections are not adequately addressed; and
- Enforcement for state pollutant discharge permit violations under §402(i).

While the Clean Water Act provides for these interventions by EPA, cooperation and collaboration is EPA's priority when working with the states in implementing the Act.

3.2 Aluminum in the Environment

Aluminum is the third most abundant element and the most common metal in the Earth's crust. It is typically complexed with oxygen (as oxides) and silica (as silicates). It is present in both industrial and nonpoint discharges associated with the manufacturing process and the environmental wear and tear of aluminum-containing objects (e.g., boats, vehicles, trash) and use and disposal of aluminum containing products (e.g., kitchenware, household and personal care products). Nonpoint sources also include atmospheric deposition, acid mine drainage, forestry, urban stormwater, and agriculture. Point sources among discharge permits with aluminum limits include coal ash storage, manufacturing, and recycling (USEPA 2018). While none of the publically owned treatment works in Virginia have aluminum limits, drinking water and sewage treatment facilities may use alum (potassium aluminum sulfate) as a coagulant. Dredging and disposal operations can also result in substantial suspension and resuspension of particulates in the water column, including those contaminated with aluminum, from disturbance of contaminated sediment. While the proposed aluminum criteria are for freshwater only, river discharges contribute to aluminum in coastal waters (Botté et al. 2022).

Aluminum speciation and solubility is strongly correlated with pH (Cardwell et al. 2018). The toxicity of aluminum appears to be lowest at neutral pH, with toxicity generally increasing with either an increase or decrease in pH. Below a pH value of 5, ionoregulatory effects dominate due to blockage of sodium uptake (Playle and Wood 1989). In moderately acidic water, with pH values less than 6.5, aluminum can accumulate on the gill surface, physically coating the gill surface and reducing gas exchange (Gensemer and Playle 1999). In alkaline conditions (pH > 8),

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[3] A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.

the negatively charged aluminate ion dominates, and, although it does not bind to the negatively charged gill surface, it can cause necrosis of the epithelial cells.

Aquatic organisms can accumulate metals from both aqueous and dietary exposure routes. Aluminum adsorbs rapidly to the gill surface from the surrounding water, but cellular uptake is slow and accumulation by the internal organs is gradual (Dussault 2001). Total uptake generally depends on the environmental aluminum concentration, exposure route and the duration of exposure (McGeer et al. 2003). Bioaccumulation and toxicity via the diet are considered highly unlikely based on studies by Handy (1993) and Poston (1991), and also supported by the lack of any biomagnification within freshwater invertebrates that are likely to be prey of fish in acidic, aluminum-rich rivers (Herrmann and Frick 1995; Otto and Svensson 1983; Wren and Stephenson 1991). The opposite phenomena, trophic dilution up the food chain, has been suggested based on the lowest aluminum accumulation exhibited by fish predators (perch) and highest by the phytoplankton that their zooplankton prey were consuming (King et al. 1992).

Aluminum sorbs to organic matter, thus aluminum is less bioavailable in waters with higher concentrations of suspended solids and dissolved organic carbon (Wilson 2012). Gensemer and Playle (1999) provide a review of studies demonstrating how dissolved organic carbon reduces aluminum toxicity. The ameliorating effect of dissolved organic carbon may be more pronounced in higher pH waters than in low pH where hydrogen ions compete for binding sites on fish gills (Parkhurst et al. 1990).

Hardness also has an effect on the toxicity of aluminum. Gundersen et al. (1994) demonstrated that increased water hardness (i.e., calcium concentrations) increased the survival of rainbow trout in both short (96 hour) and longer (16 days) exposures. However, at elevated pH conditions (e.g., pH 8) the protectiveness of hardness is reduced (Deforest et al. 2018; Gensemer et al. 2018).

3.3 EPA's Aluminum Guidelines

For stressors that cause toxic effects due to exposures in ambient water, such as aluminum, the concentration, duration, and frequency of exposure typically determines whether effects occur and, if so, the severity of the effects. For this reason, the EPA Guidelines for aluminum are expressed as exposure concentrations over a specified duration and frequency at and below which ecologically relevant effects are not expected to occur (Table 1). These duration and frequency limits are used in determining discharge permit limits to prevent aquatic impairments and waterbody pollutant load limits needed to restore impaired waters. Guideline limits are also used by states for monitoring and identification of impaired waters (see Section 3.4.2).

The one-hour and 4-day duration and averaging periods for the chronic and acute criteria, respectively, were based upon judgments by the EPA Guidelines' authors that included considerations of the relative toxicity of chemicals in fluctuating or constant exposures. The EPA Guidelines considered an averaging period of 1 hour most appropriate to use with the CMC because high concentrations of some materials could cause death in 1-3 hours. The few known studies that tested for latent toxicity following short-term exposures demonstrated delayed mortality following exposures on the order of 3-6 hours (Diamond et al. 2006; Marr et al. 1995; Meyer et al. 2007; Zhao and Newman 2004; Zhao and Newman 2006). Observations or predictions of appreciable mortality resulting from metals exposures on the order of only 3-6 hours supports the Guidelines recommendation that the appropriate averaging periods for the CMC is on the order of 1 hour.

EPA's Guidelines specify a 4-day averaging period for chronic criteria that was selected for use by EPA with the CCC for 2 reasons. First, "chronic" responses with some substances and species may not be due to long-term stress or accumulation, but due to the test being long enough that a briefly occurring sensitive stage of development was included in the exposure (e.g., Barata and Baird 2000; Chapman 1978; De Schamphelaere and Janssen 2004; Grosell et al. 2006; Mebane et al. 2008). Second, a much longer averaging period, such as 1 month, would allow for substantial fluctuations above the CCC.

EPA's once-per-three-years allowable exceedance policy was based on a review of case studies of recovery times of aquatic populations and communities from locally severe disturbances such as spills, fish eradication attempts, or habitat disturbances (Detenbeck et al. 1992; Yount and Niemi 1990). In most cases, once the cause of the disturbance was removed, recovery of populations and communities occurred on a timeframe of less than 3 years. The EPA has further evaluated the issue of allowable frequency of exceedances through extensive mathematical simulations of chemical exposures and population recovery. Unlike the case studies, these simulations largely addressed less severe disturbances considered more likely to occur without violating criteria (Delos 2008). Unless the magnitude of disturbance was extreme or persistent, this three-year period seemed reasonably supported or at least was not contradicted by the information NMFS reviewed (NMFS 2012; NMFS 2014).

The EPA Aquatic Life Ambient Water Quality Criteria for Aluminum (Aluminum Guideline USEPA 2018) are for total recoverable aluminum based on multiple linear regression modeling of the 3 major aquatic chemistry determinants of aluminum bioavailability: pH, dissolved organic carbon, and total hardness (USEPA 2018). If aluminum criteria were based on dissolved concentrations, toxicity will be underestimated, because the contribution of aluminum hydroxide precipitates to toxicity would not be measured (USEPA 2018).

Table 1. Range in Aluminum Water Quality Guidelines for the Protection of Aquatic Life

Basis	Freshwater Acute (1 hour)	Freshwater Chronic (4-day)
Criteria concentrations are determined by a water body’s pH, hardness and dissolved organic carbon content. Total recoverable values not to be exceeded more than once every 3 years, on average	1 - 4,800 µg/L	0.63 - 3,200 µg/L

The criterion maximum concentration, also called the CMC or acute criterion, is the highest acceptable aquatic exposure concentration of a chemical in water that is not expected to cause severe effects in aquatic organisms during short-term (i.e., acute) exposure. The acute criterion concentration is calculated from an assemblage of data for various laboratory species exposed in 4-day toxicity tests. The acute criterion is one-half the concentration that is hazardous to 5 percent of those species. This relies on the assumption that a concentration that is half the LC50 would be a no effect or LC01 (Stephen 1985). The acute criterion is intended to protect aquatic life from acute adverse effects on survival. It is not intended to protect aquatic life from the sublethal effects such as to growth/development and reproduction, which are expected to occur over chronic exposure timeframes. Behavioral responses are not used in criteria derivation, but behavior changes caused by effects on external receptors such as olfactory and lateral line receptors are acute responses and occur over short periods.

The criterion continuous concentration, also called the CCC or chronic criterion, is the highest acceptable aquatic exposure concentration of a chemical in water that is not expected to cause adverse effects on survival, growth/development, and reproduction over indefinite (i.e., chronic) exposures. The acute criterion duration and frequency limit for aluminum is a one-hour average not to be exceeded more than once in 3 years and the chronic criterion duration and frequency limit is a 4-day average not to be exceeded more than once in 3 years. It is not practical to conduct monitoring that precisely matches these durations and times, so states infer compliance with criteria from monitoring strategies they are able to implement.

The 2 models, 1 for vertebrate data and 1 for invertebrate data, are based on studies characterizing the bioavailability and toxicity of aluminum to fathead minnow or *Ceriodaphnia dubia* in aquatic systems under varying pH, total dissolved organic carbon, and total hardness (Deforest et al. 2018; Deforest et al. 2020; OSU 2018a; OSU 2018b; OSU 2018c).

The models were used to convert LC50 concentrations from toxicity tests for other species to standard conditions: pH of 7, dissolved organic carbon of 1 mg/L, and total hardness of 100 mg/L calcium carbonate. Once standardized, results for multiple species could be used to derive acute and chronic water quality criteria for total recoverable aluminum that is protective of 95 percent of species per the HC05/2[4] approach specified in the 1985 Guidelines.

The models reflect the aquatic conditions from the data used to derive them. As a result, they are not applicable to aquatic chemistry conditions at higher or lower values than reported with the modeled data. The model-specific limits are as follows: pH within 5.0-10.5 standard units, total hardness within 0.01-430 mg/L as calcium carbonate, and dissolved organic carbon within 0.08-12.0 mg/L. When water chemistry conditions outside these recommended conditions are encountered, EPA's criteria calculations substitute the applicable upper or lower limit, as appropriate, into the calculation.

In EPA's draft 2021 technical support document, EPA recommends that the criteria for each site be derived in a way that will protect aquatic life throughout the range of seasonal and flow conditions at a site, including those conditions of pH, total hardness, and dissolved organic carbon, when aluminum is most bioavailable (hence, toxic effects are greatest). To accomplish this, EPA recommends a State use 1 of 3 methods and clearly describe how the method will be applied in their water quality standards or other legally binding document.

Method 1: Identify protective criteria values by selecting 1 or more individual Criteria Calculator outputs based upon spatially and temporally representative data for inputs. Method 1 can be used where input datasets are more robust and inputs are measured frequently enough to statistically represent changes in the toxicity of aluminum, including water chemistry conditions under which aluminum is most toxic. In this case, the criteria values could be determined by selecting 1 or more individual outputs that will be protective of aquatic life under the full range of ambient conditions, including conditions of high aluminum toxicity. Method 1 could also be used to establish criteria values to apply on a seasonal basis where the data are sufficient.

Method 2: Generate protective criteria values from the lowest tenth percentile of the distribution of individual Criteria Calculator outputs, based upon spatially and temporally representative data from a site. Although the tenth percentile of outputs should be sufficiently protective in most cases, certain circumstances may warrant use of a different output (e.g., consideration of threatened or endangered species). For example, the state of Massachusetts applies the aluminum criterion from the lowest fifth percentile for waters where ESA-listed species occur.

It is difficult to say whether criteria based on data from multiple stations within a watershed protect aquatic life from aluminum toxicity over 95 percent of the watershed or 95 percent of the time because monitoring stations are not evenly distributed within a watershed. Sufficient data to characterize the appropriate distribution of outputs are necessary to derive a protective percentile so that any site is protected under conditions where aluminum is most bioavailable.

Method 3: Select the lowest Criteria Calculator outputs calculated from available input data. This could include assessment of individual data points (sometimes referred to as a "point-by-point"

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[4] The HC05/2 is one-1 half the estimated LC50 concentration below which 5 percent of species exposed are affected. This is the concentration at and below which aquatic life is expected to be protected.

approach). Under this method, the lowest values for the acute and chronic criteria would represent the most toxic conditions known at a site. EPA recommends Method 3 be used where few outputs are available (e.g., ten or fewer), due to the higher probability that a sample from a small dataset does not appropriately represent actual variability. NMFS considers this method to be high risk because the available data are as likely as not to be collected under conditions when aluminum is most toxic.

3.3.1 Metals Aquatic Life Criteria and Chemistry Map

EPA developed the *Metals Aquatic Life Criteria and Chemistry Map (MetALiCC-MAP)* to support States, Tribes, and stakeholders in identifying protective water quality criteria for those metals with criteria calculated using aquatic chemistry data. MetALiCC-MAP criteria are estimated using aquatic chemistry interpolated from USGS data collected over the entire continental United States (Figure 1, panels A through C). These are the best available data at this time. Specifically, where data were judged sufficient, EPA provides acute and chronic aluminum and copper criteria estimates for Level 3 Ecoregion stream orders[5] first through third, fourth through sixth (chronic criteria shown in Figure 1, panel D), and seventh through tenth. Sufficient data are not available for all stream orders and estimates for ecoregions are not evenly distributed. For example, the estimate for 7-10 order rivers in the Ridge and Valley Ecoregion is based on 46 samples from 2 stations while the Southeastern Plains estimate is based on 1,236 samples from 24 stations. The data tables downloaded from the MetALiCC-MAP do not identify whether these samples were collected during different seasons.

Interpolated criteria at the fifth and tenth percentile for ecoregions in Virginia are summarized in Table 2. The freshwater portions of Sturgeon Waters to which VADEQ will apply the aluminum criteria are only within in the Southeastern Plains ecoregion. These waters were identified based on the station salinity designation in VADEQs *2022 Final Water Quality Assessment Monitoring Stations* dataset. Virginia ecoregion chronic criteria at the fifth percentile range from 12.09 µg/L for first through third order streams in the Southeastern Plains ecoregion to more than 500 µg/L in fourth through sixth order streams in the Northern Piedmont. Sturgeon are not expected to enter third order and smaller streams. The fifth percentile chronic aluminum criterion in fourth through sixth order streams of the Southeastern Plains where sturgeon occur was reported at 109.27 µg/L and, for seventh through tenth order streams, at 422.54 µg/L. Although we cannot confirm that seasonality is represented among the 1,236 samples, these criteria estimates have greater confidence, given the larger sample size, than criteria estimates for Virginia ecoregions where early lifestage sturgeon do not occur.

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[5] Stream orders are hierarchical classifications indicating the position of a stream within its drainage, with first order streams as tributaries to second order streams and so on until draining to the river main stem.

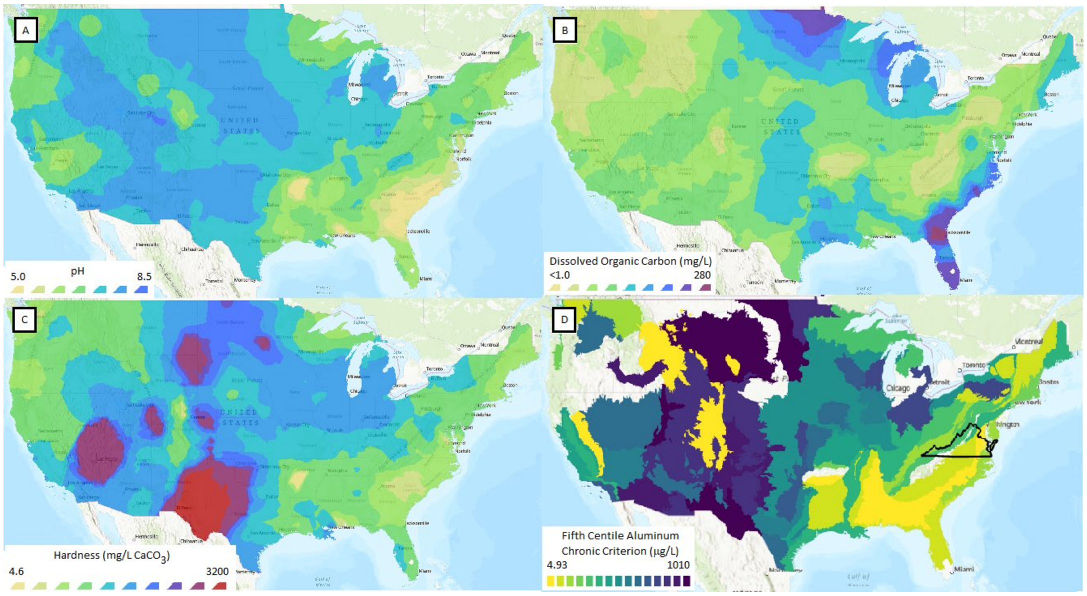

Figure 1. MetALiCC-MAP Interpolated Water Chemistry Across the Continental United States (Panels A through C) and Level 3 Ecoregion Fifth Percentile Chronic Aluminum Criteria Calculated for Stream Orders 4 through 6 (Panel D)

Table 2. MetALiCC-MAP Available Acute and Chronic Aluminum Criteria Derived from Interpolated Aquatic Chemistry Monitoring Data from Virginia Ecoregions

Ecoregion	Stream Order	Number of Samples (stations)	Fifth Percentile (µg/L)		Tenth Percentile (µg/L)	
			Acute	Chronic	Acute	Chronic
Middle Atlantic Coastal Plain	1-3	119 (3)	183.73	122.17	343.29	211.14
	4-6	514 (6)	335.84	211.56	453.19	273.70
Southeastern Plains	1-3	385 (16)	19.32	12.09	41.03	25.67
	4-6	1,236 (24)	169.78	109.27	347.24	217.84
	7-10	324 (4)	985.34	422.54	1202.47	499.92
Piedmont	1-3	852 (22)	102.09	67.81	185.73	112.69
	4-6	272 (5)	229.69	131.69	340.34	186.45
Northern Piedmont	1-3	218 (6)	1499.55	548.20	1703.31	586.02
	4-6	225 (6)	1377.16	512.71	1662.34	542.81
	7-10	539 (2)	1584.98	548.52	1787.21	649.03
Ridge and Valley	1-3	239 (8)	1542.60	621.39	1728.13	728.85
	4-6	550 (20)	870.31	380.74	1152.01	516.41
	7-10	46 (2)	1255.60	477.96	1480.43	563.13
Blue Ridge		no data				
Central Appalachians	1-3	102 (1)	1189.31	464.35	1275.18	521.97
	4-6	270 (1)	279.54	158.09	607.33	253.05

3.4 Virginia’s Adoption of EPA’s Aluminum Guidelines

VADEQ is proposing that acute and chronic freshwater aluminum criteria values for a site be calculated using the 2018 Aluminum Criteria Calculator (Aluminum Criteria Calculator V.2.0.xlsx), or a calculator in R or other software package using the same calculation approach and underlying model equations as in the Aluminum Criteria Calculator V.2.0.xlsx, as defined in EPA's Final Aquatic Life Ambient Water Quality Criteria for Aluminum. (EPA-822-R-18- 001, 2018). Virginia is adopting EPA’s recommendations that the acute criterion duration for aluminum is a one-hour average concentration, and the chronic criterion is a 4-day average concentration not to be exceeded more than once every 3 years on average.

3.4.1 Example: Criteria Calculated from Individual Sampling Events

VADEQ is not specifying any data sufficiency requirements or implementation strategy for setting criteria for a given discharge or waterway, but is expected to follow an approach outlined EPA’s draft 2021 technical support document (USEPA 2021). NMFS evaluated existing monitoring data reported in the National Water Quality Monitoring Council’s Water Quality Portal for Virginia[6] to determine which of these 3 methods are implementable at this time. The samples providing concurrent records for pH, dissolved organic carbon, and hardness (i.e., sampling events) were collected from 171 United States Geological Survey (USGS) stations. Only 4 of these stations are within catchment associated with Sturgeon Waters. Data were available for 1978 sampling events at these stations between 1972 and 2023.

MetALiCC-MAP interpolated fifth percentile chronic criteria for fourth-order and larger streams range from 109.27-422.54 µg/L and the acute criteria range from 169.78-985.34 µg/L. Among the Water Quality Portal sampling events at the 171 USGS stations, only 19 stations had more than ten sampling events, 18 had data from all 4 seasons, and only 5 stations had data collected during low, normal, and high stage conditions. Evaluation data within sub-basins could not detect seasonal or hydrological influences. While all but 1 of the 28 sub-basins had more than 10 sampling events, 15 had data from all 4 seasons, and only 6 had data collected during low, normal, and high flood stage conditions.

Among the 4 stations within catchments adjacent to Sturgeon Waters, the station in the James River at Boulevard Bridge in Richmond was sampled over 150 times during all seasons and under falling, peak, rising, and stable, normal hydrological stages. Variation among the calculated chronic criteria for this urban station, regardless of season and hydrological condition, is small, with a coefficient of variation[7] of 6%. The fifth percentile chronic criterion concentration for these data is 815 µg/L. The calculated acute criteria concentrations are more variable, with a coefficient of variation of 20%, but an analysis of variance did not suggest that

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[6] https://www.waterqualitydata.us/ accessed May 24, 2023

[7] The coefficient of variation, or CV, is a measure of consistency among data. A low CV indicates the observations do not differ substantially from the mean. It is calculated as the mean of an array of data divided by its standard deviation.

season or hydrological condition was responsible for variance among calculated acute criteria. The fifth percentile acute criterion for this station is 1,850 µg/L. Only a single sampling event was available for each of the other 3 stations within Sturgeon Waters-adjacent catchments: Gambo Creek at Tisdale Road at Dahlgren (acute=1,100 µg/L, chronic=450 µg/L), Black Marsh Near Mouth near Dahlgren (acute=1,200 µg/L, chronic=460 µg/L), and James River at Jamestown Ferry Pier (acute=2,400 µg/L, chronic=1,200 µg/L). The difference between the Richmond, Dahlgren, and Jamestown Ferry sites demonstrates the importance of collecting actual site-specific data.

3.4.2 Virginia's Implementation of Aluminum Criteria

While the BE states that Virginia did not have existing criteria for aluminum, EPA's Enforcement Compliance History Online database[8] includes 369 records for dischargers in Virginia with permit limits for aluminum, 11 of these permits are administratively continued, having expired since 2018. Among effective permits, 355 will expire in 2024, so the revised criteria will inform limits applied to renewed permits and any sources have the reasonable potential to contribute to an aluminum impairment.

Virginia's implementation of criteria for the purposes of identifying impaired waters are described in its water quality monitoring strategy document (VADEQ 2022). The current integrated report does not include aluminum monitoring data. Once adopted, the aluminum criteria will be integrated into the state monitoring programs that provide data to:

- Calculate permit limits,
- Detect and document water quality impairments and/or to evaluate permit adequacy;
- Define the cause, severity and geographic extension of impaired waters;
- Support TMDL model development and validation; and
- Evaluate the implementation of TMDLs and other best management practices.

Depending on regional monitoring run schedules, ambient watershed monitoring stations may be sampled bimonthly over 2 consecutive years or monthly for a one-year period. For trend monitoring, all water quality monitoring stations that are used for assessment purposes, and the resultant 305(b) Report, are sampled bimonthly (six times per year), at a minimum. This provides an adequate sample size (number of observations) for short-term (2- to 6-year) assessment purposes and is generally adequate for mid- to long-term trend analyses as well. More frequent sampling may be performed, if necessary, and certain parameters that demonstrate more stability in their values, or that are extremely expensive to collect and analyze, may be sampled with reduced frequencies.

The draft 2024 Water Quality Assessment Guidance Manual describes how criteria are to be used in assessing water quality impairments (VADEQ 2023). For toxic pollutant assessments, both chronic and acute criteria for the protection of aquatic live can be assessed whenever

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[8] Accessed May 15, 2023

sufficient data are available. Chronic criteria are to be assessed when multiple grab samples are collected within 2 separate 4-day periods within a three-year period, or when there are 2 or more separate 30-day passive sampler deployments[9] within a 3-year period. Two samples, either grab or using a passive sampler device, taken within 3 consecutive years are sufficient to assess acute criteria. Waters where there are 2 or more exceedances of the same aquatic life criterion in most of the 3-year periods for which there are a sufficient number of samples within a 6-year assessment window are considered impaired for the aquatic life use.

4 ACTION AREA

The action area is defined in 50 CFR §402.02 as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action." The extent and location of the marine and anadromous action area is defined as:

1. Virginia's coastal zone, including bays and waters, Chesapeake Bay; the Appomattox River, James River, Mattaponi River, Pamunkey River, Pocomoke River, Potomac River, Rappahannock River, and York River and their contributing tributaries for the Atlantic Sturgeon, including the critical habitat for the Atlantic sturgeon (Figure 2);
2. Virginia's coastal zone, including coastal bays and waters, Chesapeake Bay; the James River, Potomac River, and Rappahannock River and their contributing tributaries for the shortnose sturgeon;
3. Virginia and surrounding coastal waters and estuaries, and their contributing tributaries, where consequences of the action may be expose the green, Kemp's, leatherback, and loggerhead sea turtles; and
4. Virginia's coastal waters and any surrounding areas, and their contributing tributaries, where consequences of the action may be experienced by the North Atlantic right whale, fin, and sperm whales.

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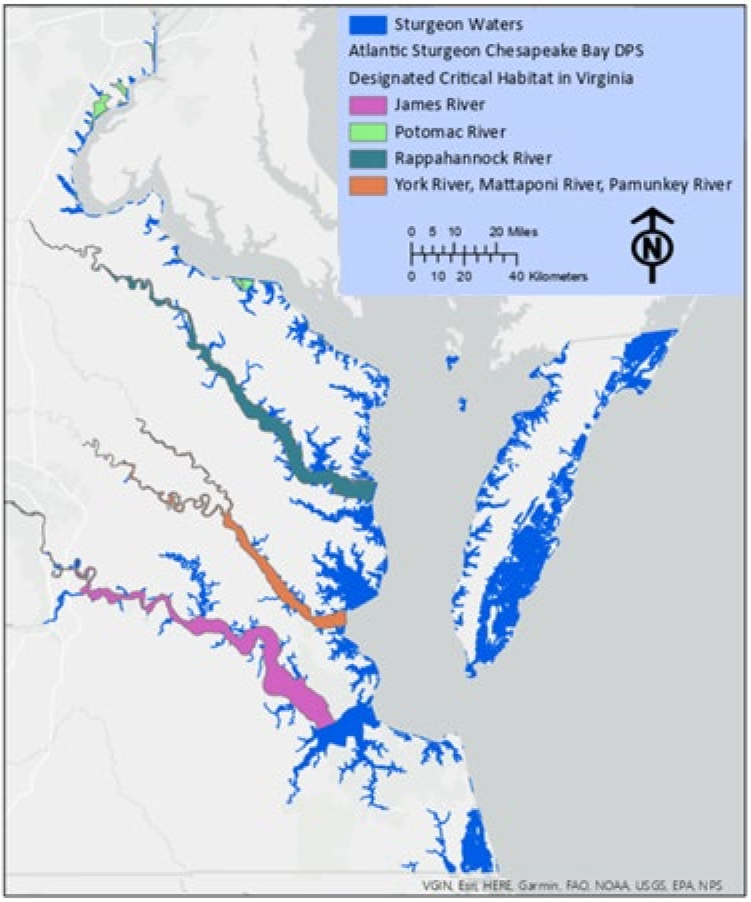
[9] Passive sampling using semipermeable membrane devices absorb lipophilic organic pollutants such as polychlorinated biphenyls from the water column to approximate pollutant exposure through the gills of organisms living in the water.



VGIN, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS

Figure 2. Surgeon Waters and Designated Critical Habitat for the Chesapeake Bay DPS of Atlantic Sturgeon

The Commonwealth of Virginia defines the boundaries of its marine and estuarine waters, for each river-estuarine system, based on Tidewater Virginia, as defined by the Code of Virginia § 28.2-100 (Figure 3).

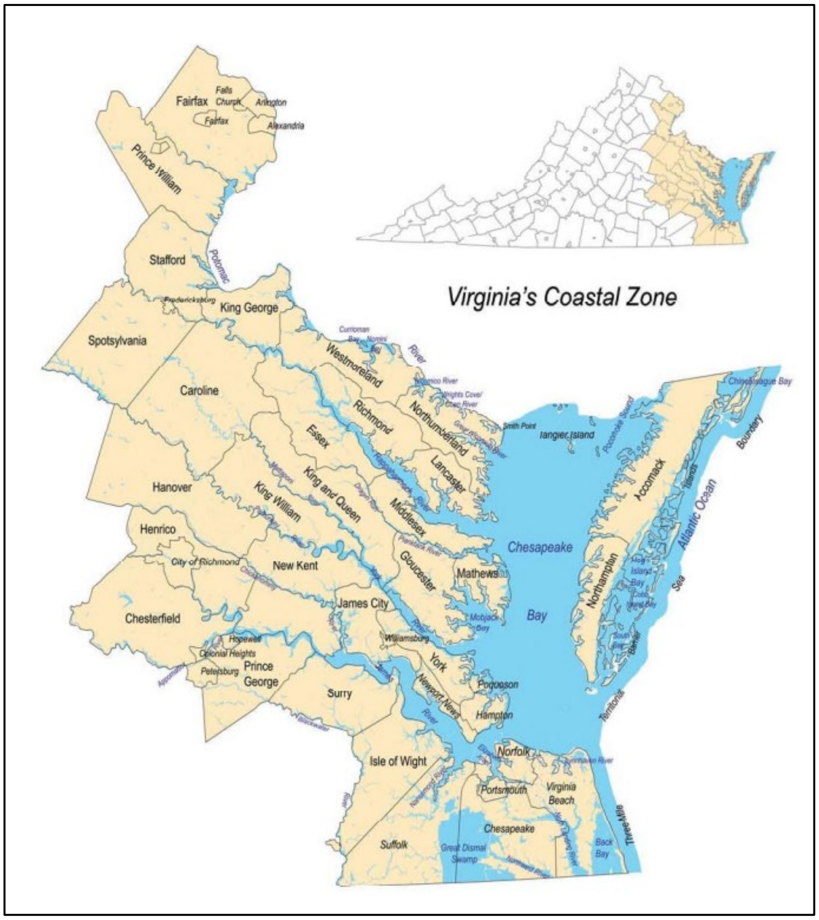


Figure 3. Virginia's coastal zone[10]

EPA's approval of water quality criteria affects conditions in all waters to which the criteria are applied and any waters affected by the water quality condition of those waters. For freshwater criteria, this includes brackish waters, salt waters, and water bodies across state lines to which freshwaters flow. The aluminum criteria applied to freshwater portions of Sturgeon Waters (Figure 4) may indirectly affect the water quality of downstream reaches of the estuary and coastal zone. This opinion therefore considers Virginia's coastal zone to be the action area for this consultation.

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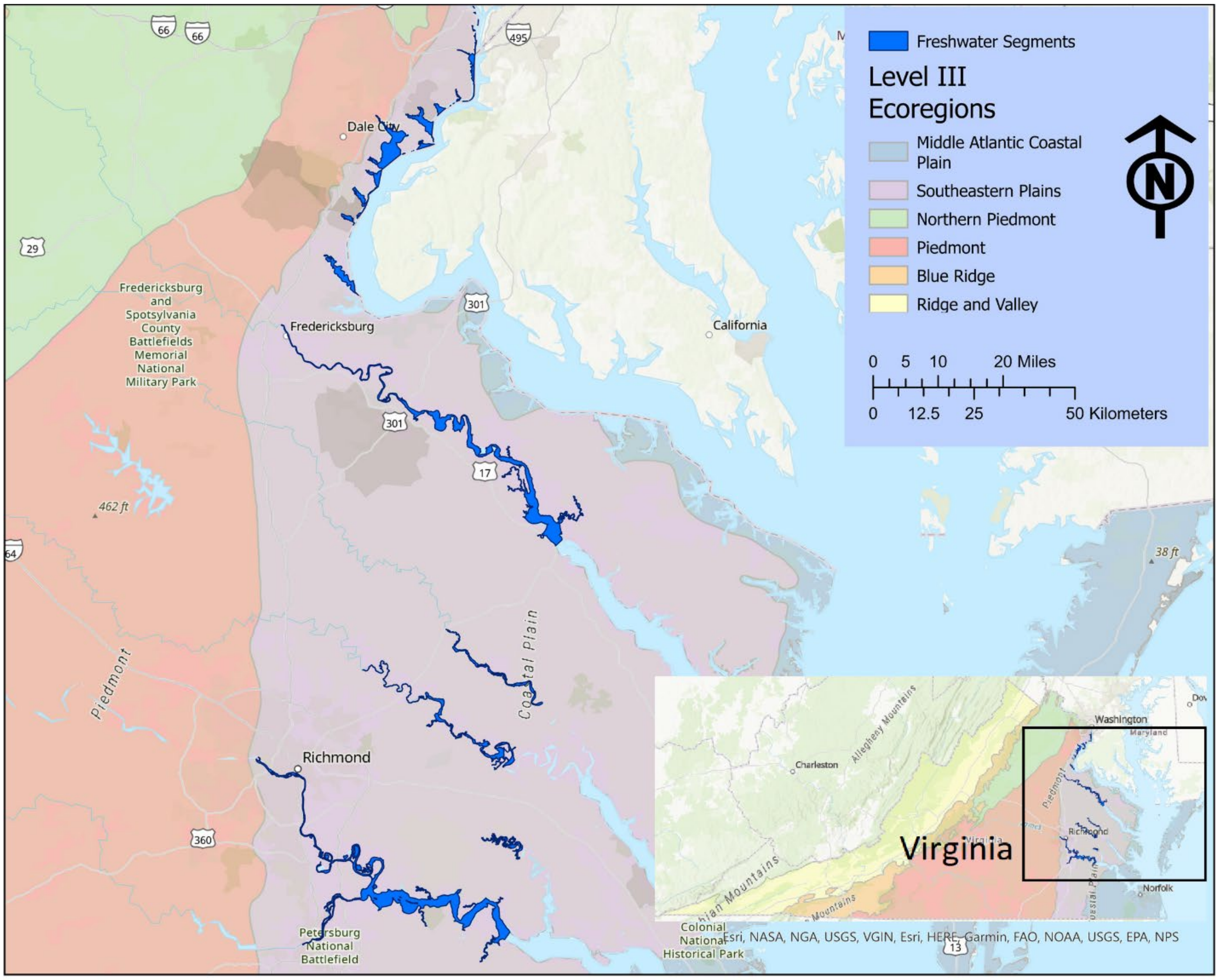
[10] https://www.deq.Virginia.gov/home/showpublisheddocument/4078/637461463603670000



Esri, NASA, NGA, USGS, VGIN, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS

Figure 4. Portions of Sturgeon Waters where Freshwater Aluminum Criteria may be Implemented

5 ESA-LISTED SPECIES AND CRITICAL HABITAT

Table 3 identifies the ESA-listed species (including DPSs) that occur in the action area and are under NMFS's jurisdiction.

Table 3. Endangered and Threatened Species and Critical Habitat within the Action Area and Under NMFS's Jurisdiction

Species	Federal Register Listing	Critical habitat
Fin Whale (endangered, *Balaenoptera physalus*)	35 FR 18319	--
North Atlantic Right Whale (endangered, *Eubalaena glacialis*)	73 FR 12024	81 FR 4837
Green Sea Turtle (threatened, *Chelonia mydas*), North Atlantic DPS	81 FR 20057	
Kemp's Ridley Sea Turtle (endangered, *Lepidochelys kempii*)	35 FR 18319	--
Leatherback Sea Turtle (endangered, *Dermochelys coriacea*)	35 FR 8491	Critical habitat is not in action area
Hawksbill Sea Turtle (endangered, *Eretmochelys imbricata*)	35 FR 8491	Critical habitat is not in action area
Loggerhead Sea Turtle (threatened, *Caretta caretta*), Northwest Atlantic Ocean DPS	76 FR 58868	Critical habitat is not in action area
Atlantic sturgeon (endangered, *Acipenser oxyrinchus oxyrinchus*) Chesapeake DPS, Migrating and foraging New York Bight, Carolina, South Atlantic DPSs (endangered), and Gulf of Maine DPS (threatened)	77 FR 5879 77 FR 5913	82 FR 39160
Shortnose Sturgeon (endangered, *Acipenser brevirostrum*)	32 FR 4001	--

The executive summary of the EPA's BE stated that it evaluated the potential effects of its action on the Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and its designated critical habitat, shortnose sturgeon (*A. brevirostrum*), green sea turtle (*Chelonia mydas*), Kemp's Ridley sea turtle (*Lepidochelys kempii*), leatherback sea turtle (*Dermochelys coriacea*), loggerhead sea turtle (*Caretta caretta*), North Atlantic right whale (*Eubalaena glacialis*), fin whale (*Balaenoptera physalus*), and sperm whale (*Physeter macrocephalus*). The BE later identifies the 2 sturgeon species and 4 sea turtle species, North Atlantic right whale, and fin whale, but lists the sei whale (*Balaenoptera physalus*) instead of the sperm whale as a species addressed in the BE. Meanwhile, the table listing species in the BE includes the sturgeon, sea turtles, and the North Atlantic right whale and fin whale. The Greater Atlantic Region ESA Section 7 Mapper indicates that the North Atlantic right whale and fin whale occur in Virginia's coastal zone while sperm, sei, and blue whales occur further out to sea, off the continental shelf (Figure 5), so this opinion addresses exposures and effects of Virginia's freshwater aluminum criteria on North Atlantic right whales and fin whales. EPA is in agreement with this decision.

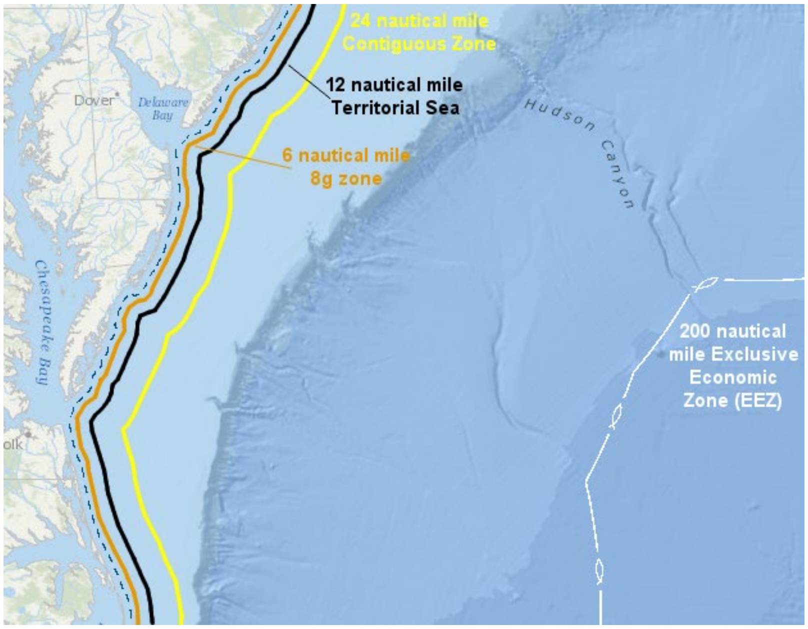


Figure 5. Map Indicating the Continental Shelf (Light Blue) and the Major Nautical Boundaries Off the Coast Of Virginia

5.1 ESA-Listed Species and Critical Habitat Not Likely To Be Adversely Affected

NMFS uses 2 criteria to identify the ESA-listed species or critical habitat that are not likely to be adversely affected by the action. The first criterion is exposure, or some reasonable expectation of a co-occurrence, between 1 or more potential stressors associated with the proposed activities and ESA-listed species or critical habitat. If we conclude that an ESA-listed species or critical habitat is not likely to be exposed to the proposed activities, we must also conclude that the species or critical habitat is not likely to be adversely affected by those activities.

The second criterion is the probability of a response given exposure. An ESA-listed species or critical habitat that is exposed to a potential stressor but is likely to be unaffected by the exposure is also not likely to be adversely affected by the proposed action.

An action warrants a "may affect, not likely to be adversely affected" finding when its effects are *wholly beneficial, insignificant* or *discountable*. *Beneficial* effects have an immediate positive effect without any adverse effects to the species or habitat. Beneficial effects are usually discussed when the project has a clear link to the ESA-listed species or its specific habitat needs, and consultation is required because the species may be affected.

Insignificant effects relate to the size or severity of the impact and include those responses that are undetectable, not measurable, or so minor that they cannot be meaningfully evaluated. Insignificant is the appropriate effect conclusion when species or critical habitat will be exposed to stressors, but the response will not be detectable outside of normal behaviors.

Discountable effects are those that are extremely unlikely to occur. For an effect to be discountable, the exposure of the listed species or critical habitat to the stressor is extremely unlikely to occur.

Prior consultations concurred that implementation of water quality criteria for aquatic toxicants are not likely to adversely affect ESA-listed sea turtles and baleen whales because, as air breathing species, their exposures to aquatic pollutants are expected to be far less than that of the gilled fish and aquatic invertebrates the criteria were derived to protect. Fish and aquatic invertebrates are exposed to aquatic toxicants as water continuously passes over their gill filaments where mineral and gas exchange regulates ion balance and oxygenates blood. The folded, feather-like structure of gills maximizes contact between water and respiratory epithelia for this exchange but also maximizes exposure to aquatic toxicants. Saltwater and estuarine fish exposures also occur through ingestion because saltwater fish "osmoregulate" by continuously drinking seawater and excreting solute in order to maintain a lower concentration of solutes in their body fluids than saltwater (Larsen et al. 2011). Both sea turtles and whales are highly migratory, only spending a portion of their annual travels in Virginia waters. Further, certain whale species do not frequent nearshore waters. Thus, exposures of sea turtles and whales to water quality conditions resulting from implementation of freshwater criteria would either be discountable due to a species pelagic lifestyle or insignificant because effects attributable to implementation of the criteria could not be meaningfully measured, detected, or evaluated (FPR-2017-9229, OPR-2019-03141, OPR-2021-00175, OPR-2022-00203, OPR-2022-02170, and OPR-2022-03042).

5.1.1 Whales

Aluminum criteria are proposed only for freshwater, so EPA's approval of Virginia's adoption and implementation of aluminum criteria will not result in direct exposures of ESA-listed marine mammal species such as fin whales and North Atlantic right whales. The aforementioned species occur offshore of the Virginia coastline, with the North Atlantic right frequenting nearshore waters of the action area.

Fin whales are highly migratory species and are associated with deep offshore habitats. Fin whales are centered along the 100-meter isobath and are common past United States Atlantic Exclusive Economic Zone north of Cape Hatteras, North Carolina throughout the year (Hayes 2022). Feeding areas for fin whales are located north near Massachusetts as well as the east end of Long Island, New York. They are considered rare in near coastal waters of Virginia. Potential calving area may occur offshore, and overwintering has been known to occur offshore of New Jersey. In contrast to fin whales, North Atlantic right whales will frequent nearshore waters. Most individuals migrate northward to Canada during the summer and fall months.

Aquatic toxicants are not readily absorbed through mammalian skin, so any exposure of these whales is primarily direct uptake from the water column through membranes that are in contact with ambient water or indirect uptake through ingesting organisms that have accumulated pollutants. However, North Atlantic right whale do not forage in Virginia waters. The pathway for direct exposure, and subsequent response, of whales to aquatic pollutants is further limited because whales do not drink seawater. Whale osmoregulation employs physiological and allometric adaptations such as increased filtration rates, urine volume, and kidney size along with tolerance of high solute levels in urine and plasma (Birukawa 2005; Kjeld 2003).

While both North Atlantic right whales and occasionally fin whales migrate through the waters offshore of Virginia, exposures to water quality conditions resulting from implementation of Virginia’s water quality criteria for aluminum in freshwater are expected to be insignificant because it would not be possible to meaningfully measure, detect, or evaluate marine exposures to aluminum originating from freshwaters where the criteria would be applied. Further, whales breathe air, do not drink seawater, and do not forage while in these waters. Therefore, NMFS concurs that EPA’s approval of Virginia’s adoption of freshwater aluminum criteria may affect, but is not likely to adversely affect North Atlantic right whale and fin whales.

5.1.2 Sea Turtles

As stated above, aluminum criteria are proposed only for freshwater, so EPA’s approval of Virginia’s adoption and implementation of aluminum criteria will not result in direct exposures of ESA-listed marine species such as North Atlantic DPS of green sea turtle, Kemp’s ridley sea turtle, leatherback sea turtle, and the Northwest Atlantic Ocean DPS of loggerhead sea turtle. Because ESA-listed sea turtles breathe air and do not have gills, their only direct exposures to aquatic toxicants would be through drinking seawater and limited absorption through exposed membranes. Sea turtles do not typically nest on the beaches of Virginia and are temporary residents to coastal waters, undergoing long migrations between breeding and foraging habitats. While metals and persistent organic pollutants can accumulate in sea turtles through their diet, sea turtles primarily consume lower trophic-level food species and are unlikely to ingest food with toxic levels of bioaccumulated pollutants (Figgener et al. 2019). The presence of a contaminant in tissues does not necessarily indicate adverse effects on survival, reproduction, or growth and development. Contaminant burdens in tissues reflect exposures integrated over the lifetime and entire foraging area of these long-lived, highly migratory species and cannot be directly attributable to exposures within an action area that comprises only a fraction of an individual’s range.

Exposures of ESA-listed North Atlantic DPS of green sea turtle, Kemp’s ridley sea turtle, leatherback sea turtle, and the Northwest Atlantic Ocean DPS of loggerhead sea turtle to water quality conditions resulting from implementation of Virginia’s water quality criteria for aluminum in freshwaters is expected to be insignificant because it would not be possible to meaningfully measure, detect, or evaluate marine exposures to aluminum originating from freshwaters where the criteria would be applied. Further, their only direct exposures would be through drinking seawater and limited absorption through exposed membranes. This contrasts continuous ingestion and respiratory epithelial exposures of gilled freshwater species the criteria are meant to protect. Therefore, NMFS concurs that EPA’s approval of Virginia’s adoption of freshwater aluminum criteria, is not likely to adversely affect North Atlantic DPS of green sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, and the Northwest Atlantic Ocean DPS of loggerhead sea turtle.

5.1.3 Conclusion

The action is not likely to adversely affect fin whale, North Atlantic right whale, green sea turtle (North Atlantic DPS), Kemp's ridley sea turtle, leatherback sea turtle, or loggerhead sea turtle (Northwest Atlantic Ocean DPS), or critical habitat designated for the Chesapeake DPS of Atlantic sturgeon.

5.2 Status of Species Likely to be Adversely Affected

The ESA-listed species that are likely to be adversely affected by EPA's approval of freshwater aluminum water quality criteria proposed for Virginia are the shortnose sturgeon and the Chesapeake Bay, Gulf of Maine, New York Bight, Carolina, and South Atlantic DPSs of Atlantic sturgeon. All lifestages from the Chesapeake Bay DPS occur in the Virginia rivers where the freshwater aluminum criteria will be applied. Upon hatching in freshwater, larvae drift downstream but remain above the salt front in the 0.0-0.5 parts per trillion salinity range where they forage and grow for 1 to 5 years before moving into nearshore coastal waters (Hilton et al. 2016). Adults and juveniles from the Gulf of Maine, New York Bight, Carolina, and South Atlantic DPSs of Atlantic sturgeon migrate and forage in the action area and may be exposed to water quality affected by implementation of the freshwater aluminum criteria as they may forage in tidal freshwaters. It is possible that individuals from these DPSs may spawn in Virginia rivers. Recent data indicate that Atlantic sturgeon spawning in the Connecticut River were more closely related to the Carolina and South Atlantic DPSs of Atlantic sturgeon than the New York Bight DPS (Savoy et al. 2017). Waters identified for potential shortnose sturgeon presence include Virginia's coastal zone, including bays and waters, the Chesapeake Bay, the James River, Potomac River, the York/Mattaponi/Pamunkey Rivers, and Rappahannock River and their contributing tributaries. Throughout this opinion, waters where sturgeon occur are referred to as "Sturgeon Waters."

Sturgeon Waters and associated catchments within the action area, as identified in Figure 3, above, include:

- James River;
- Potomac River;
- Chesapeake Bay;
- York, Mattaponi, and Pamunkey Rivers; and
- Rappahannock River.

Table 4 describes the sturgeon lifestages and their behaviors in the James River, the Potomac River, the Chesapeake Bay, the York/Mattaponi/Pamunkey Rivers, and Rappahannock River while Table 5 compares historical and current spawning and presence data in Virginia for shortnose sturgeon. Definitive historical and current spawning data are not available for Atlantic sturgeon.

Table 4. Lifestages and Behaviors of Shortnose Sturgeon and Atlantic Sturgeon in the Waters of Virginia

Body of Water (State)	Lifestages Present	Use of the Watershed
Atlantic Sturgeon		
James River (VA) including the Appomattoc and Chickahominy River tributaries (VA)	Adults, subadults, juveniles, year of young, larvae, eggs	Staging, spawning, rearing, and foraging
Potomac River (MD/VA)	Adults, subadults, and juveniles. Potentially eggs, larvae and year of young	Spawning, rearing and foraging
York/Mattaponi/Pamunkey Rivers (VA)	Adults, subadults, juveniles, eggs, larvae, year of young	Migrating, foraging, spawning and rearing
Chesapeake Bay (MD/VA)	Adults, Juvenile, Sub-adult	Migrating and foraging
Rappahannock River (VA)	Subadults and adults. Potentially eggs, larvae, year of young and juveniles	Spawning, rearing and foraging
Shortnose Sturgeon		
James River (VA) including the Appomattoc and Chickahominy River tributaries (VA)	Potentially adult	Migrating and foraging
Potomac River (MD/VA)	Adults, Juvenile	Migrating, foraging, overwintering
York/Mattaponi/Pamunkey Rivers (VA)	Adults	Foraging
Rappahannock River (VA)	Adults	Foraging
Chesapeake Bay (MD/VA)	Adults	Migrating, Foraging and overwintering

*Spawning occurs upriver in New Jersey and Pennsylvania

Table 5. Shortnose and Atlantic Sturgeon Historic and Current Presence and Spawning Location within Virginia Rivers

Body of Water	Historic Presence?	Historic Spawning Location	Current Presence?	Current Spawning?	Spawning Location
Shortnose Sturgeon					
Rappahannock River	Unknown	Unknown	Yes	Unlikely	NA
York River	Unknown	No Records	Yes	Unlikely	NA
James River	Unknown	Unknown	Yes	Potentially	Spawning area unknown
Chesapeake Bay	Yes	Unknown	Yes	Unknown	Potential spawning in tributaries
Potomac	Yes	Yes	Yes	No Records	Current spawning not documented but assumed based on presence of pre-spawning females and suitable habitat at river mile 115-116 (river kilometer 185-187)
Atlantic Sturgeon					
Chesapeake Bay	Yes	Yes	Yes	No	Historically and currently spawn in all major tributaries of the Bay, but none within the bay itself
Rappahannock River	Yes	Yes	Yes	Yes	Spawning potentially occurs
James River	Yes	Yes	Yes	Yes	Upper tidal freshwater reaches of the James River, northwest of Turkey Island
York River	Yes	Yes	Yes	Yes	Upriver during the fall, potentially in the Pamunkey River
Potomac River	Yes	Yes	Yes	Yes	Potentially occurs in upper tidal sections of the Potomac

This opinion examines the status of each species that are likely to be adversely affected by the action. The evaluation of adverse effects in this opinion begins by summarizing the biology and ecology of those species that are likely to be adversely affected and what is known about their life histories. The status is determined by the level of risk that the ESA-listed species face based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This helps to inform the description of the species' current "reproduction, numbers or distribution" that is part of the jeopardy determination as defined at 50 CFR §402.02. More detailed information on the status and trends of these ESA-listed species, and their biology and ecology is in the listing regulations and critical habitat designations published in the Federal Register, status reviews, recovery plans, and on the NMFS website: https://www.fisheries.NOAA.gov/species-directory/threatened-endangered.

5.2.1 Threats Common to Shortnose and Atlantic Sturgeon

The viability of sturgeon populations is highly sensitive to juvenile mortality resulting in lower numbers of sub-adults available to recruit into the adult breeding population. The significant threats to ESA-listed sturgeon include dams that block access to spawning areas or lower parts of rivers, poor water quality, dredging, vessel strikes, water withdrawals from rivers, and unintended bycatch in some commercial fisheries. Recent reviews also identify climate change as a threat to ESA-listed sturgeon (ASSRT 2022b; ASSRT 2022c; SSSRT 2010).

5.2.1.1 DAMS

Archaeological records indicate that, prior to the construction of dams in the 1950s and 60s, sturgeon swam further upriver to spawn than is possible today, leading experts to believe that dams severely impacted the natural breeding habits of the Atlantic and shortnose sturgeon (ASSRT 2007; Fernandes 2010; SSSRT 2010). Dams impede fish passage, fragmenting populations through eliminating or impeding access to historical habitat. Hydropower turbines, spillways, and fish passage devices can injure or kill fish attempting to migrate or turbines may entrain fish. Dams also modify natural hydrology, altering downstream flows and water temperatures, affecting dissolved oxygen, channel morphology, nutrient cycling, stratification, community structure, and sediment regime, which can include redistribution of sediment-associated toxicants (Cooke 2004; Jager 2001; Secor 2002a). Short-term negative impacts of dam removal include the influx of sediments into the stream, which embeds spawning substrates and negatively affects water, habitat and food quality. These effects are usually temporary. Several studies have demonstrated that after dam removal, sediments were flushed from river channels and natural sediment transport conditions resumed (American Rivers 2002).

5.2.1.2 IMPINGEMENT AND ENTRAINMENT

Depending on lifestage and size, sturgeon are susceptible to impingement on or entrainment from cooling water intake screens at power plants. Impingement and entrainment are also risks during dredging operations. Other effects of dredging include burial of benthic communities, turbidity, siltation of spawning habitats, redistribution of sediment-associated toxicants, noise/disturbance, modified hydrology, and overall loss of habitat (ASSRT 1998; Chytalo 1996; NMFS 2018; Smith 1997; Winger et al. 2000).

5.2.1.3 BYCATCH

Atlantic sturgeon bycatch mortality is now considered a primary threat affecting the recovery of all 5 DPSs of Atlantic sturgeon (ASSRT 2022b; ASSRT 2022c). The precise level of bycatch and poaching of shortnose sturgeon is mostly unknown, but modeling suggests that bycatch could have a substantial impact on the status of shortnose sturgeon, especially in populations with small numbers (SSSRT 2010). Commercial bycatch was ranked as the highest stressor in the York River for Atlantic sturgeon.

5.2.1.4 CONTAMINANTS

Life history of sturgeon species (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; NMFS 1998). However, there has been little work on the effects of contaminants on sturgeon to date. Shortnose sturgeon collected from the Delaware and Kennebec Rivers had total toxicity equivalent concentrations of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), DDE, aluminum, cadmium, and copper all above adverse effect concentration levels reported in the literature (Brundage III and O'Herron II 2009).

Adequate water quality is necessary for Atlantic sturgeon to carry out their life functions. Low dissolved oxygen (DO) and the presence of contaminants modify the quality of Atlantic sturgeon habitat and in some cases, restrict the extent of suitable habitat for life functions. Secor (1995) noted a correlation between low abundances of sturgeon during this century and decreasing water quality caused by increased nutrient loading and increased spatial and temporal frequency of hypoxic (low oxygen) conditions. Using a multivariate bioenergetics and survival model, Niklitschek (2005) demonstrated that, within the Chesapeake Bay, a combination of low DO, water temperature, and salinity restricts available Atlantic sturgeon habitat to 0-35 percent of the Bay's modeled surface area during the summer. Pulp mill, silviculture, agriculture, and sewer discharge can elevate temperatures and/or increase biological oxygen demand resulting in reduced DO levels that can be stressful to aquatic life. Niklitschek and Secor (2009) also simulated the effects of achieving EPA's DO-criteria for the Chesapeake Bay and water temperature effects on available habitat. The EPA adjusted their open water minimum DO-criteria for the Chesapeake Bay (increased from ~2 ppm to 3.5 ppm) to provide protection specifically for sturgeon species, which require higher levels of DO compared to other species. This study found that EPA's new DO-criteria would increase Atlantic sturgeon habitat by 13 percent per year, while an increase in water temperature by 1 degree Celsius would reduce available habitat by 65 percent. Similar trends in low DO have been observed in the lower portion of the Potomac River (ASSRT 1998).

The 2010 status review for shortnose sturgeon reviewed contaminant risks applicable to all sturgeon species. The life history characteristics of amphidromous sturgeon predispose these species to long-term and repeated exposure to environmental contamination and potential bioaccumulation of heavy metals and other toxicants (Dadswell 1979; NMFS 1998). Chemicals and metals such as chlordane, dichlorodiphenyl dichloroethylene (DDE), Dichlorodiphenyltrichloroethane (DDT), dieldrin, PCBs, cadmium, mercury, and selenium settle to the river bottom and are consumed by benthic feeders, such as macroinvertebrates, and then work their way higher into the food web, including to sturgeon. Some of these compounds may affect physiological processes and impede a fish's ability to withstand stress, while simultaneously increasing the stress of the surrounding environment by reducing DO, altering pH, and altering other physical properties of the water body.

Pesticide exposure in fishes may affect anti-predator and homing behavior, reproductive function, physiological development, and swimming speed and distance (Beauvais et al. 2000; Moore and Waring 2001; Scholz et al. 2000; Waring 2004). Sensitivity to environmental contaminants also varies across lifestage. Early-life-stages of fishes appear to be more susceptible to environmental and pollutant stress than older lifestages (Rosenthal and Alderdice 1976). The presence of a contaminant in the tissues of an organism indicates exposure, but does not always mean these tissue residues are causing adverse effects. Elevated levels of contaminants in fish have been associated with reproductive impairment (Billsson 1998; Cameron et al. 1992; Giesy et al. 1986; Hammerschmidt et al. 2002; Longwell et al. 1992; Mac and Edsall 1991; Matta et al. 1997), reduced larval survival (Berlin et al. 1981; Giesy et al. 1986), delayed maturity (Jørgensen et al. 2004), and posterior malformations (Billsson 1998).

With the exception of a few studies (Cope et al. 2011; Dwyer et al. 2000; Dwyer et al. 2005; Dwyer 2005; Kocan 1996), data on the effects of contaminants and tissue burdens in shortnose and Atlantic sturgeon pre-date listing, are from accidental sampling mortalities, or are from fish found dead.

Exposures of shortnose sturgeon embryos and larvae to weathered coal tar sediment from the Connecticut River near Holyoke, Massachusetts was >95 percent lethal (Kocan 1996). A study evaluating the suitability of the Roanoke River for shortnose sturgeon placed caged juvenile shortnose sturgeon and the common laboratory species, fathead minnow, in the river for 28 days. Shortnose sturgeon survival at the end of 28 days was 0 percent while fathead minnow survival was greater than 90 percent. Histopathology analysis determined that the mortality among the river-deployed shortnose sturgeon was likely due to liver and kidney lesions from 1 or more unknown agents because effects did not correlate well with exposures to those pollutants analyzed for in the study (Cope et al. 2011).

Accidental mortalities occurred during 2 gill netting surveys of shortnose sturgeon in the Delaware (N=2) and Kennebec Rivers (N=1). The fish had total toxicity equivalent concentrations of PCDDs, PCDFs, PCBs, DDE, aluminum, cadmium, and copper above adverse effect concentration levels reported in the literature (ERC 2002; ERC 2003).

Between June and August 2006 2 Atlantic sturgeon and 3 shortnose sturgeon died during scientific sampling activities in the Penobscot River in Maine and 1 shortnose sturgeon was collected after being killed by a seal. In the summer of 2009, 3 additional shortnose sturgeon were recovered on the Kennebec River after a red tide event and 2 more seal-killed shortnose sturgeon were recovered further north in the river (Mierzykowski 2012). Tissues from these fish were analyzed for 21 organochlorine compounds including PCBs, Polybrominated Diphenyl Ethers (PBDEs), and DDT, and 19 trace metals including mercury. Total PCB in sturgeon muscle tissue ranged from below the detection limit of 5.00 micrograms per kilogram (µg/kg) to 1,900.00 µg/kg wet weight. Five shortnose sturgeon had PCB muscle concentrations that would exceed suggested criteria for protecting fish-eating wildlife (120 µg/kg) and aquatic life (400 µg/kg). Total PBDE in muscle tissue from 5 shortnose sturgeon ranged from 4.4 µ to 39.1 µg/kg. The PBDE concentration range in Kennebec sturgeon was similar to a study that measured PBDE levels in wild-caught fish sold in fish markets and large-chain supermarkets (0.04-38 µg/kg). DDT metabolites and isomers were detected in all sturgeon samples, but at low levels compared to toxicity threshold levels and consumption action levels. Other organochlorine compounds in fillet samples were below detection limits or detected at low concentrations (~ 5 µg/kg). Mercury in muscle tissue of shortnose sturgeon from the Penobscot and Kennebec Rivers (mean 0.49 milligrams per kilogram [mg/kg]; range: 0.19-1.00 mg/Kg wet weight) were elevated compared to freshwater regional and national fish tissue bio-monitoring programs. Mercury levels in both Atlantic sturgeon muscle tissue were 0.18 mg/kg. A suggested tissue threshold-effect concentration for mercury in whole-body fish is 0.20 mg/kg. Concentrations of 18 other trace metals in sturgeon tissue samples appeared consistent with levels reported in other sturgeon studies. The only exception was selenium at 2.40 mg/kg wet weight in muscle tissue from a Kennebec River shortnose sturgeon. The suggested tissue effect threshold for selenium is slightly lower, at 2 mg/kg.

Congeners[11] of PCB, PCDDs and PCDFs in Hudson River shortnose and Atlantic sturgeon obtained from museum archives and sampling between 2014 and 2016 indicated higher liver burdens in archived shortnose sturgeon than in more recently collected fish, with PCDFs at levels potentially impairing recruitment of juveniles into reproducing adults. Hepatic concentrations of 9 out of 11 PCB congeners were greater than 5 times higher in shortnose sturgeon than in Atlantic sturgeon collected contemporaneously during 2014-2016 (pre-print, Wirgin and Chambers 2022).

Dioxin and furans were detected in ovarian tissue from shortnose sturgeon caught in the Sampit River/Winyah Bay ecosystem, South Carolina. Results showed that 4 out of 7 fish tissues analyzed contained tetrachlorodibenzo-p-dioxin concentrations > 50 ppt, a level that can adversely affect the development of sturgeon fry (NOAA, Damage Assessment Center, Silver Spring, MD, unpublished data).

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[11] Variations within a chemical group named for the quantity and position of key atoms such as chlorine, or nitrogen or structures such as phenyl rings.

Dadswell (1976) reported mercury concentrations averaging 0.29 (0.06 – 1.38) mg/kg wet weight in 30 juvenile Atlantic sturgeon collected in the Saint John River estuary, New Brunswick. Rehwoldt et al. (1978) analyzed cadmium, mercury, and lead in tissues from freshly captured Atlantic sturgeon from the Hudson River in 1976 and 1977 and found no chronological relationship when compared to preserved reference samples collected between 1924 and 1953. The 1976-1977 average cadmium, mercury, and lead tissue concentrations were 0.02, 0.09, and 0.16 µg/g wet weight, respectively.

Twenty juvenile Gulf sturgeon, a subspecies of Atlantic sturgeon, exhibited an increase in metal body burdens with an increase in fish length (Alam et al. 2000). Gulf sturgeon collected from a number of rivers between 1985 and 1991 had arsenic, mercury, DDT metabolites, toxaphene, polycyclic aromatic hydrocarbons (PAHs), and aliphatic hydrocarbons at concentrations that were sufficiently high to warrant concern (Bateman and Brim 1994).

5.2.1.5 DREDGING

The direct effects of dredging on Atlantic or shortnose sturgeon occur at the time of the dredging activity and/or indirectly from modifications to their foraging habitat. Dredging activities have occurred in the James River and Chesapeake Bay. Most of these projects are routine and ongoing.

5.2.1.6 CLIMATE CHANGE

Sturgeon are ranked as very vulnerable to climate change. Secor and Gunderson (1998) found that Atlantic sturgeon juvenile metabolism and survival were impacted by increasing hypoxia in combination with increasing temperature. Niklitschek and Secor (2005) used a multivariable bioenergetics and survival model to generate spatially explicit maps of potential production in the Chesapeake Bay; a 1 degree Celsius temperature increase reduced productivity by 65 percent (Niklitschek 2005). A population viability analysis for shortnose sturgeon at the southern end of their range found that saltwater intrusion and decreases in summer dissolved oxygen could reduce population productivity (Jager et al. 2013). In the Hudson River, Woodland and Secor (2007) found that flow volume and water temperature in the fall months preceding shortnose sturgeon spawning were significantly correlated with subsequent year-class strength. Habitat models coupled with global climate models for the congener, European Atlantic Sturgeon (*Acipenser sturio*), indicate strong climate effects throughout the range, especially in the southern portions of the range (Lassalle et al. 2010).

5.2.2 Shortnose Sturgeon

Shortnose sturgeon were first listed under the ESA’s predecessor, the Endangered Species Preservation Act on October 15,1966 (32 FR 4001). No critical habitat has been designated for the shortnose sturgeon. Shortnose sturgeon occur along the Atlantic Coast from the Saint John River in Canada to the Saint Johns River in Florida. While shortnose sturgeon spawning has been documented in several rivers across its range, status for many other rivers remain unknown. Currently, shortnose sturgeon can be found in 41 bays and rivers along the East Coast, but their distribution across this range is broken up, with a large gap of about 250 miles separating the northern and mid-Atlantic metapopulations from the southern metapopulation[12]. In the northern and mid-Atlantic metapopulation, shortnose sturgeon are currently found in the Saint John (Canada), Penobscot, Kennecbec, Androscoggin, Piscataqua Merrimack, Connecticut, Hudson, Delaware, and Potomac Rivers. They are known to occur in the Chesapeake Bay, but these fish may be transients from the Delaware River via the Chesapeake and Delaware Canal (Welsh et al. 2002) or remnants of a population in the Potomac River. They have also been frequently spotted opportunistically foraging and transiting in the St. George, Medomak, Damariscotta, Sheepscot, Saco, Deerfield, East, and Susquehanna Rivers. On rare occasions, they have been seen in the Narraguagus, Presumpscot, Westfield, Housatonic, Schuylkill, Rappahannock, and James rivers. Within the state of Virginia, there are 5 main river systems where shortnose sturgeon may occur: the James River, the Potomac River, the Chesapeake Bay, the York River and the Rappahannock River.

5.2.2.1 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 remain within freshwater habitats.

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). 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 (Dionne et al. 2013; Fernandes 2010; Finney et al. 2006; Welsh 2002). 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 (Buckley and Kynard 1985; Dadswell 1984). In the northern extent of their range, shortnose sturgeon exhibit 3 distinct movement patterns. These migratory movements are

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[12] A metapopulation is a group of separate but interacting populations such that there is gene flow occurring among the populations.

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.

Spawning times for shortnose sturgeon range geographically due to the specific water temperatures needed for spawning (7-10 degrees Celsius). In areas between South Carolina and New England, males reach sexual maturity at age 3 while females reach sexual maturity by age 7 (SSSRT 2010). Shortnose sturgeon spawning migrations are characterized by rapid, directed and often extensive upstream movement (NMFS 1998). Once males begin spawning, 1-2 years after reaching sexual maturity, they will spawn every other year or annually depending on the river they inhabit, and females will begin spawning 5 years after reaching sexual maturity and continue to do so every 3 years (Dadswell 1979; NMFS 1998). Spawning is estimated to last from a few days to several weeks. Shortnose sturgeon are believed to spawn at discrete sites within their natal river (Kieffer and Kynard 1996), typically at the farthest upstream reach of the river, if access is not obstructed by dams (Kieffer and Kynard 1996; NMFS 1998). Spawning occurs over channel habitats containing gravel, rubble, or rock-cobble substrates (Dadswell 1979; NMFS 1998). Additional environmental conditions associated with spawning activity include decreasing river discharge following the peak spring freshet, water temperatures ranging from 6.5-18 degrees Celsius, and bottom water velocities of 0.4-0.8 m/sec (Dadswell 1979; Hall et al. 1991; Kieffer and Kynard 1996; NMFS 1998). Adult shortnose sturgeon typically leave the spawning grounds shortly after spawning.

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 range from 27,000-208,000 eggs/female, with a mean of 11,568 eggs/kg body weight (Dadswell 1984). At hatching, shortnose sturgeon are 7-11 millimeters (mm) long and resemble tadpoles (Buckley and Kynard 1981). In 9-12 days, the yolk sac is absorbed and the sturgeon develops into larvae which are about 15 millimeters total length (Buckley and Kynard 1981). Sturgeon larvae are believed to begin downstream migrations at about 20 millimeters total length.

Shortnose sturgeon are benthic omnivores that feed on crustaceans, insect larvae, worms, mollusks (Moser 1995; Savoy and Benway 2004), oligochaete worms (Dadswell 1979) and off plant surfaces (Dadswell 1984). Sub adults feed indiscriminately, consuming aquatic insects, isopods, and amphipods along with large amounts of mud, stones, and plant material (Bain 1997; Dadswell 1979).

5.2.2.2 POPULATION DYNAMICS

Historically, shortnose sturgeon are believed to have inhabited nearly all major rivers and estuaries along the entire east coast of North America. NMFS's shortnose sturgeon Recovery Plan identifies 19 populations based on the fish's strong fidelity to natal rivers and the premise that populations in adjacent river systems did not interbreed with any regularity (NMFS 1998). 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 currently available genetic information suggests that shortnose sturgeon can be separated into smaller groupings that form regional clusters across their geographic range (SSSRT 2010). Differences in life history and ecology further support these genetic groupings or clusters. Both regional populations and metpopulation structures may exist according to genetic analyses and dispersal and migration patterns (King et al. 2014).

The Shortnose Sturgeon Review Team (SSSRT) concluded shortnose sturgeon across their geographic range include 5 genetically distinct groupings each of which have geographic ecological adaptations: 1) Gulf of Mexico; 2) Connecticut and Housatonic rivers; 3) Hudson River; 4) Delaware River and Chesapeake Bay; and 5) Southeast (SSSRT 2010). Very few shortnose sturgeon have been captured in the Chesapeake Bay since the species was listed (40 in the Potomac, 1 at the mouth of the Rappahonock and 1 in the James River), and those fish moved back and forth to the Delaware estuary, which is why it is grouped with the Delaware population. Although these populations are geographically isolated, genetic analyses suggest individual shortnose sturgeon move between some of these populations each generation (Quattro et al. 2002; Wirgin et al. 2005; Wirgin et al. 2010).

The 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).

5.2.2.3 STATUS

According to the 2010 status review (SSSRT 2010), water quality represents a *high risk* threat to 1 shortnose sturgeon population (Potomac River), a moderately high threat to 6 populations, a moderate threat to 13 populations, and a moderately low threat to 1 population. Specific sources of water quality degradation affecting shortnose sturgeon include coal tar, (a potential source of metal exposure, Gao et al. 2016), wastewater treatment plants, fish hatcheries, industrial waste, pulp mills, sewage outflows, industrial farms, water withdrawals, and nonpoint sources. These sources contribute to the following conditions that may have adverse effects on shortnose sturgeon: nutrient loading, low DO, algal blooms, increased sedimentation, elevated contaminant levels (mercury, PCBs, dioxin, polycyclic aromatic hydrocarbons [PAHs], endocrine disrupting chemicals, cadmium), and low pH levels. Impingement/entrainment at power plants and treatment plants was rated as a moderate threat to 2 shortnose sturgeon populations (Delaware and Potomac) and dredging was rated as a moderately high threat for the Chesapeake. The SSSRT also found a negative correlation between population health and stressors for both the Chesapeake and Potomac, meaning the population stressors far exceed the population health scores. The shortnose sturgeon status review team (SSSRT 2010) reported results of an age-structured population model using software from Applied Biomathematics (Akçakaya and Root

2007) to estimate shortnose sturgeon extinction probabilities for 3 river systems: Hudson, Cooper, and Altamaha. The estimated probability of extinction was zero for all 3 populations under the default assumptions, despite the long (100-year) horizon and the relatively high year-to-year variability in fertility and survival rates. The estimated probability of a 50 percent decline was relatively high (Hudson 0.65, Cooper 0.32, Altamaha 0.73), whereas the probability of an 80 percent decline was low (Hudson 0.09, Cooper 0.01, Altamaha 0.23; SSSRT 2010).

The largest shortnose sturgeon adult populations are found in the Northeastern rivers: Hudson 56,708 adults (Bain et al. 2007); Delaware 12,047 (ERC 2002); and Saint Johns > 18,000 adults (Dadswell 1979). Shortnose sturgeon populations in southern rivers are considerably smaller by comparison. Peterson and Bednarski (2013) documented a three-fold variation in adult abundance (707-2,122 individuals) over a 7-year period in the Altamaha River. Bahr and Peterson (2017) estimated the adult shortnose population in the Savannah River was 1,865 in 2013, 1,564 in 2014, and 940 in 2015. Their estimates of juvenile shortnose sturgeon ranged from 81-270 age 1 fish and 123-486 age 2+ fish over the course of the three-year (2013-2015) study period. This study suggests that the Savannah River population is likely the second largest within the South Atlantic (Bahr and Peterson 2017).

5.2.2.4 STATUS WITHIN THE ACTION AREA

The James River (Appomattox, Chickahominy Tributaries)

One adult shortnose sturgeon was captured in the James River in March 2016 (Balazik 2017), as well as 1 gravid female just downstream of the Hog island discharge in February 2018. These are the only records of shortnose sturgeon captures in the southwestern portion of the Chesapeake Bay. Modeling by Niklitschek (2001) indicates that suitable habitats for shortnose sturgeon were very restricted during the summer months with favorable foraging habitat limited to upper tidal portions of the James River.

In 1823, the Bosher Dam was constructed on the James River, which impeded upstream diadromous fish migration until a vertical slot fish passagewas installed in 1999. Despite the added fishway, no Atlantic or shortnose sturgeon have been observed to pass through the fishway (Bushnoe et al. 2005).

Chesapeake Bay

The first published account of shortnose sturgeon in the Chesapeake system was from a specimen collected in 1876 from the Potomac River as reported in a general list of the fishes of Maryland (SSSRT 2010). There is evidence that, in years past, both Atlantic and shortnose sturgeon were prolific in the Potomac River, but it is generally accepted that at the turn of the 20th century shortnose sturgeon were essentially extirpated from the Potomac and rarely seen in the Chesapeake Bay (Hildebrand and Schroeder 1928).

The current distribution of shortnose sturgeon in the Chesapeake Bay is unknown as there is limited data regarding their distribution (SSSRT 2010). There is no information indicating that shortnose sturgeon are currently spawning in the Chesapeake Bay. Anecdotal reports from waterfolk indicate shortnose sturgeon presence in Gunpowder Falls, which enters the Gunpowder River in Baltimore County, MD, although there has not been any documentation of spawning activity here nor in any of the tributaries leading to the Chesapeake Bay. Similarly, there is no information available for shortnose sturgeon foraging areas in the Chesapeake Bay. A study by Niklitschek (2001) indicated via modeling that suitable habitats were very restricted during the summer months with favorable foraging habitat limited to the upper tidal portions of the upper Bay, the Potomac, and the James rivers.

Tagging data from shortnose sturgeon in the upper Chesapeake Bay and Delaware River suggest movements through the Chesapeake and Delaware Canal (SSSRT 2010). Outside of tagged data, there is no information regarding movements to foraging or overwintering areas. Additionally, no information is available for shortnose sturgeon overwintering areas in the Chesapeake Bay or its tributaries.

Potomac River

Four documents dated between 1876 and 1929 state that shortnose sturgeon inhabited the Potomac River. Twelve shortnose sturgeon have been captured in the Potomac River between 1996 and 2010. Eleven of these captures were documented during the ongoing reward program sponsored by USFWS to compensate commercial anglers who report captures of Atlantic sturgeon in the Chesapeake Bay system (SSSRT 2010). Since 2010, only 1 shortnose sturgeon has been caught in the Potomac, which occurred in April of 2021 (Blankenship 2021).

The Potomac River is considered to be tidally influenced up to the Chain Bridge that lies just 2 km upstream of the suspected spawning area at Fletcher's Marina. Two late-stage females were captured and tracked within the Potomac, however only 1 was observed to make an apparent spawning migration in the spring (2005 – 2007, SSSRT 2010). Annual movements of shortnose sturgeon in the Potomac River seem typical of north-central adults. Both tracked female sturgeon remained in freshwater for at least 1 year with pre-spawning migration occurring in spring. Shortnose sturgeon that are found within the Chesapeake Bay may be migrants from the Delaware River.

Historically, shortnose sturgeon spawning habitat on the Potomac River likely occurred below Little Falls Dam. Little Falls Dam was built in 1959 and hindered diadromous fish from moving upstream to spawn. Prior to the dam's erection, McAtee and Weed observed 2 species of sturgeon ascend to Little Falls but no further. A passageway for fish was completed in 2000 at the Little Falls Dam, which resulted in 10 miles of historic spawning habitat becoming available to migratory fish.

The York River

There is limited information available for shortnose sturgeon presence and status within the York River. Commercial landings data from the 1880s demonstrate historical presence of sturgeon within the York River. Modeling done by Niklitschek (2005) demonstrated habitat availability for juvenile Atlantic sturgeon which indicated that the cumulative stresses of hypoxia and high temperatures during summer months caused large reductions in potential habitats and carrying capacity during the 1993-2002 time period. The modeling showed a similar summertime habitat squeeze for shortnose sturgeon. Similar trends in low DO concentration during the summer months have been observed in the lower portions of the York River (ASSRT 2007). The York River is presumed to be too salty for spawning.

The Rappahannock River

Observations of shortnose sturgeon and their status within the Rappahannock River is limited. Commercial landings data during the 1880s are available for the Rappahannock which provides historic evidence of sturgeon presence in the river. Additionally, incidental capture of shortnose sturgeon has been reported to the USFWS Reward Program in the Rappahannock River in May of 1998 (Spells 1998).

Table 6. Risk Assessment Scores for Shortnose Sturgeon in Virginia Rivers (SSSRT 2010).

River	Abundance Score	Population Health Score[1]	Overall Stressor Score[2]
Potomac River	1.12	2.12	7.65
Chesapeake Bay	2.23	3.23	7.70

[1] The population health score represents shortnose sturgeon viability at a riverine scale and considers the number of individuals, demographics, and abundance trends as defined below. A population health score of 12 is the total possible.

[2] Sum of scores for each criterion to calculate the total population health score.

Currently, data supports some presence of shortnose sturgeon with the rivers of Virginia, however the extent to which is unknown. As of 2010, 78 shortnose sturgeon have been reported within the Chesapeake Bay, most of which have been adults, and 13 have been captured in the Potomac River. Abundance estimates in the York, Rappahannock and James River are unknown.

5.2.2.5 RECOVERY GOALS

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 1998a). 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.

If the distance to rivers that could support a reproducing population exceeds the migration distance for sturgeon inhabiting the Southeast or Delaware River/Chesapeake Bay metapopulations. King et al. (2014) recommends supplementation as a plausible restoration strategy. Accordingly, to ensure the long-term survival of populations, conservation actions should be based on available habitat and structural isolation. Many recovery tasks for shortnose sturgeon in Chesapeake Bay lack priority rankings because very little is known about the status of these population segments. Documentation of distribution and mapping of sturgeon concentration areas is ongoing and determination of the abundance, age structure, and recruitment is the highest prioritized task.

5.2.3 Atlantic Sturgeon

Five DPSs of Atlantic sturgeon were listed under the ESA in 2012. The Gulf of Mexico DPS is listed as threatened while the New York Bight, Chesapeake Bay, Carolina, and south Atlantic DPSs are listed as endangered. Critical habitat was proposed by NMFS for each DPS on June 3, 2016.

The Atlantic sturgeon is a long-lived (approximately 60 years), late maturing, iteroparous, estuarine dependent species (ASSRT 2007). They are anadromous, spawning in freshwater but spending most of their subadult and adult life in the marine environment. The appearance of Atlantic sturgeon is similar to that of the sympatric shortnose sturgeon. Atlantic sturgeon are generally larger, have a smaller mouth, have a different shaped snout, and different scutes, which are lacking in the shortnose sturgeon (SSSRT 2010). They are bluish-black or olive brown dorsally (on their back) with paler sides, a white belly, have 5 major rows of dermal scutes, can grow to approximately 14 feet (4.3 meters) long, and weigh up to 800 pounds (370 kilograms).

5.2.3.1 LIFE HISTORY

Hager et al. (2020) reports return rates for fish spawning in the York River system of once every 1.13 years for males and once every 2.13 years for females. Fecundity increases with age and body size (ranging from 400, 000 – 8 million eggs, Dadswell 2006; Smith et al. 1982; Van Eenennaam 1998). The average age at which 50 percent of maximum lifetime egg production is achieved is 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. Smith (1985) reported that the timing of the arrival of mature adults into estuaries was temperature dependent and varied with latitude: February in Florida, Georgia, and South Carolina; April in the Delaware and Chesapeake Bay systems; and May-June in the GOM and Gulf of St. Lawrence systems. Traditionally, it was believed that spawning within all populations occurred during the spring and early summer months. More recent studies, however, suggest that spawning occurs from late summer to early autumn in 2 tributaries of the Chesapeake Bay (James River and York River, Virginia) and in the Altamaha River, Georgia (Balazik et al. 2012; Hager et al. 2014). A recent study by Balazik and Musick (2015) indicates that 2 cohorts of Atlantic sturgeon repeatedly spawn during 2 different times (spring and fall) and places in the James River, and possibly the groups have become genetically distinct from each other. Based on a combination of telemetry data and historical documentation Balazik et al. hypothesize that a dual spawning strategy likely occurs in various degrees throughout the Atlantic sturgeon's range. Smith et al. (2015) identified fall spawning in the Roanoke River. These studies suggest that adult Atlantic sturgeon that show up in the southern estuaries spend the summer in the estuary before making a spawning run in the fall. Farrae et al. (2017) found genetically distinct fall- and spring-spawned Atlantic sturgeon in the Edisto River.

Sturgeon eggs are highly adhesive and are deposited in freshwater or tidal freshwater reaches of rivers on the bottom substrate, usually on hard surfaces such as cobble (Gilbert 1989; Smith 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 – 12 day period (Kynard 2002). During the daytime, larvae use benthic structure (e.g., gravel matrix) as refugia (Kynard 2002). Juvenile sturgeon continue to move further downstream into waters ranging from zero to up to ten parts per thousand salinity. 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 (Boreman 1997; Schueller 2010; Smith 1985).

Atlantic sturgeon feed primarily on soft-bodied benthic invertebrates like polychaetes, isopods, and amphipods in the saltwater environment, while in fresh water, they feed on oligochaetes, gammarids, mollusks, insects, and chironomids (Brosse 2002; Collins 2008; Guilbard 2007; Haley 1998; Haley 1999; Johnson 1997; Moser 1995; Savoy 2007). Diets vary latitudinally and seasonally, though universally researchers have found that polychaetes constitute a major portion of Atlantic sturgeon diets. In North Carolina, Moser (1995) determined Atlantic sturgeon fed on 32 percent polychaetes, 28 percent isopods, 12 percent mollusks, and then other items. The directed movement of subadult and adult Atlantic sturgeon in the spring is from saltwater waters to river estuaries. River estuaries provide foraging opportunities for subadult and adult Atlantic sturgeon in addition to providing access to spawning habitat. The directed movement of subadult and adult Atlantic sturgeon reverses in the fall as the fish move back into saltwater waters for the winter. In the saltwater environment, sub adults and adults typically occur within the 50-m depth contour.

5.2.3.2 POPULATION DYNAMICS

The Chesapeake Bay DPS is comprised of all Atlantic sturgeon spawned in the watersheds that drain into the Chesapeake Bay and into coastal waters from Delaware-Maryland border on Fenwich Island to Cape Henry, Virginia (ASSRT 2022a). Within this range, and depending on the information used to determine historical spawning, Atlantic sturgeon likely spawned in the Susquehanna, Choptank, Nanticoke, Wicomico and Pocomoke Rivers as well as the Potomac, Rappahannok, York River system and James river (ASSRT 2022a).

Historically, Atlantic sturgeon were common throughout the Chesapeake Bay and its tributaries (ASSRT 1998). Several newspapers report large sturgeon in the lower reaches of the Susquehanna River from 1765-1895, indicating that at 1 time, Atlantic sturgeon may have spawned there. Historical harvests were also reported in the Patuxent, Potomac, Choptank, Nanticoke, and Wicomico/Pocomoke rivers. Secor (2002b), using U.S. Fish Commission landings, Secor (2002b) estimated approximately 20,000 adult females inhabited the Chesapeake Bay and its tributaries prior to 1890, when a sturgeon fishery began.

A Virginia Institute of Marine Science trawl survey was initiated in 1955 to investigate finfish dynamics within the Chesapeake Bay; the survey was standardized in 1979. Since 1955, 40 Atlantic sturgeon have been captured, 16 of which were captured since 1990, and 2 of these collections may have been young-of-year based on size. No fish were captured between 1990 and 1996; however, 7 were captured in 1998. In subsequent years, catch declined ranging between zero and 3 fish per year. The Maryland reward tagging has resulted in the capture of 1,700 Atlantic sturgeon (ASSRT 1998). The capture data indicates that some of the Chesapeake Bay tributaries may continue to support spawning populations as evidence by young-of-year captures (James River) and carcasses of mature adults being found occasionally within the Bay during the spawning season.

5.2.3.3 STATUS

Information on the status of Atlantic sturgeon populations is not as detailed as that for shortnose sturgeon. Atlantic sturgeon were once abundant across their range but are currently estimated to be at 3 percent of their historical levels, especially in the southern portion of their range. There is not sufficient information on the status of Atlantic sturgeon DPSs within the action area to place these populations in context of the range-wide status of the species. With limited data available to establish quantitative metrics to determine stock status, it was necessary for the Atlantic States Marine Fisheries Commission to consider qualitative criteria such as the appearance of Atlantic sturgeon in rivers where they had not been documented in recent years, discovery of spawning adults in rivers they had not been documented in before, and increases in anecdotal interactions. In some cases, qualitative metrics may be the result of increased research and attention, not a true increase in abundance (ASMFC 2017a; ASMFC 2017b).

The 1998 Atlantic sturgeon status review determined that the species did not warrant listing at the time since direct fishing pressure was essentially removed by a coast-wide moratorium on the fishery and water quality had improved substantially since the early 1990s (ASSRT 1998). The 1998 status review team, also determined that bycatch of Atlantic sturgeon in other fisheries was unsubstantial and did not pose a threat to the viability of species. The 2007 status review concluded that only a few subpopulations seem to be increasing or stabilizing since 1998, with the majority of subpopulations showing no signs of recovery (ASSRT 2007). New information also suggested that stressors such as bycatch, ship strike, and water quality were resulting in substantial impacts on subpopulations. The Atlantic sturgeon remained low, with the lack of recovery attributed to habitat degradation, ship strike, bycatch and damns. In 2012 NMFS listed the New York Bight and Chesapeake Bay DPSs as endangered. Historically, each of these DPSs likely supported more than 10,000 spawning adults (ASSRT 2007; MSPO 1993; Secor 2002b). The best available data indicate that current numbers of spawning adults for each DPS are 1-2 orders of magnitude smaller (e.g., hundreds to low thousands) than historical levels (ASSRT 2007; Kahnle et al. 2007).

The Carolina and South Atlantic DPSs were estimated to have declined to less than 3 and 6 percent of their historical population sizes, respectively (ASSRT 2007). Both of these DPSs were listed as endangered due to a combination of habitat curtailment and alteration, bycatch in commercial fisheries, and inadequacy of regulatory mechanisms in ameliorating these impacts and threats.

Lacking complete estimates of population abundance across the distribution of Atlantic sturgeon, the NMFS Northeast Fishery Science Center developed a virtual population analysis model with the goal of estimating bounds of Atlantic sturgeon ocean abundance (Kocik 2013). The Atlantic Sturgeon Production Index (ASPI) was developed to characterize uncertainty in abundance estimates arising from multiple sources of observation and process error, and to complement future efforts to conduct a more comprehensive stock assessment. Model inputs include empirical estimates of post-capture survivors and natural survival, probability estimates of recapture using tagging data from the USFWS sturgeon tagging (PIT and T-bar tags) database, and Federal fishery discard estimates from 2006-2010.

Based on the ASPI, estimated mean abundance from 2006-2011 was 417,934 fish, with a 95 percent confidence interval of 165,381-744,597 fish. This estimate does not include juvenile Atlantic sturgeon that reside year-round in rivers and estuaries. Kocik et al. (2013) partitioned the coast-wide ASPI estimate across DPSs using a Mixed Stock Analysis developed by (Wirgin et al. 2015) based on genetic data (n=173 fish) from bycatch in Atlantic coast commercial Federal fisheries. The DPS proportions and ocean population estimates are as follows: GOM (11 percent) 45,973 fish; New York Bight (49 percent) 204,788; Chesapeake Bay (14 percent) 58,511; Carolina (4 percent) 16,717; and South Atlantic (20 percent) 83,587 (note: remaining 2 percent partitioned to Canada).

Kocik et al. (2013) produced an alternative Atlantic sturgeon ocean population estimate by dividing the observed total discards by the five-year moving average exploitation rate derived from the ASPI tagging model (139,935 fish; coefficient of variation 21%). This estimate, which is based on more conservative assumptions, is considerably smaller than the ASPI model estimate. Partitioning this more conservative ocean population estimate by Atlantic sturgeon DPS results in the following: GOM 15,393 fish; New York Bight 68,568; Chesapeake Bay 19,590; Carolina 5,597; and South Atlantic 27,987.

An Atlantic sturgeon population abundance estimate was also derived from Northeast Area Monitoring and Assessment Program (NEAMAP) trawl survey data from 2007-2012. The NEAMAP estimates were based on sampling in a large portion of the marine range of the 5 DPSs (Cape Cod, Massachusetts to Cape Hatteras, North Carolina) in known sturgeon coastal migration areas, and during times of year that sturgeon are expected to be migrating north and south. The Atlantic sturgeon population estimates from fall surveys range from 6,980-42,160 fish (with coefficients of variation between 0.02 and 0.57), and the estimates from spring surveys range from 25,540-52,990 fish (with coefficients of variation between 0.27 and 0.65). These are considered minimum population estimates because the calculation makes the assumptions that the gear will capture all of the sturgeon in the water column along the tow path (i.e., 100 percent net efficiency) and that all sturgeon are within the sampling domain of the survey. Since the NEAMAP survey does not sample in rivers, these estimates will not include river resident young-of-year or juvenile Atlantic sturgeon. The NEAMAP derived estimates only include those subadults that are of a size vulnerable to capture in commercial sink gillnet and otter trawl gear and are present in the marine environment, which is only a fraction of the total number of subadults. Additionally, NEAMAP surveys are not conducted in the GOM or south of Cape Hatteras, NC. Atlantic sturgeon population abundance estimates based on NEAMAP data for catchabilities of 10 percent, 50 percent, and 100 percent are shown in Table 7, along with ASPI estimates for comparison. Partitioned the NEAMAP based estimate a conservative 50 percent efficiency across DPSs, using the proportions developed by Wirgin et al. (2015), results in the following: GOM 7,455 fish; New York Bight 33,210; Chesapeake Bay 9,489; Carolina 2,711; and South Atlantic 13,555.

Table 7. Comparison of Estimated Atlantic Sturgeon Abundance and 95 Percent Confidence Intervals Based on 2 Population Models

Model	Model Years	95 % low	Mean	95 % high
ASPI	2006-2010	165,381	417,934	744,597
NEAMAP Survey, swept area assuming 100 percent efficiency	2007-2012	8,921	33,888	58,856
NEAMAP Survey, swept area assuming 50 percent efficiency	2007-2012	13,962	67,776	105,984
NEAMAP Survey, swept area assuming 10 percent efficiency	2007-2012	89,206	338,882	588,558

All DPSs of Atlantic sturgeon are thought to be highly vulnerable to climate change due to their low likelihood to change distribution in response to current global climate change stressors. This includes changes in estuarine habitat such as changes in the occurrence and abundance of prey species in currently identified key foraging areas (ASSRT 2022a; ASSRT 2022b; ASSRT 2022c).The 2017 stock assessment compared the 1998 and 2015 relative abundance index values and found that the Gulf of Maine and Chesapeake Bay DPSs were below their 1998 values while the New York Bight and Carolina DPSs, as well as the coastwide stock, were above their 1998 values. The South Atlantic DPS could not be evaluated due to lack of adequate data to estimate a relative abundance index. All of the DPSs showed qualitative signs of improving populations such as increased presence, including in rivers where species interactions had not been reported in recent years, and the discovery of spawning in rivers where it had not been previously documented (ASMFC 2017a; ASMFC 2017b).

5.2.3.4 STATUS WITHIN THE ACTION AREA

While all 5 DPS may occur in the action area, the Chesapeake DPS, listed as endangered in 2012, is expected to be dominant. There have been minimal updates on reproduction in the Chesapeake Bay DPS. Fall spawning activity has been documented in the Pamunkey River, a tributary of the York River, and in Marshyhope Creek, a tributary of the Nanticoke River (Hager et al. 2014; Kahn et al. 2014; Richardson and Secor 2016; Secor et al. 2022). The James River is currently the only river of the Chesapeake Bay DPS where evidence suggests there is both spring and fall spawning with separate spawning populations.

York and James Rivers

Monitoring in the York River reveals that males return to spawn every 1.13 years and females every 2.19 years (Hager et al. 2020). Hager et al. (2020) show spawning in the York River occurs on decending temperatures from 25.1°C to 21.5°C. This narrow temperature window is bounded by increased egg mortality at 25°C and peak bioenergetics growth around 22°C. Sex ratios when spawning range from approximately 64-75% male in the York River, though the overall population appears to be approximately 51% male (95% CL, 43-58%: Kahn et al. 2021).

A recent assessment of relatedness of all Atlantic sturgeon populations showed that, when all populations along the coast are grouped, the James River (spring and fall runs) is most closely related to rivers in the northeast, while the York River is most closely related to rivers in the Southeast (White et al. 2021). The York River population was distinct when compared to those southeastern rivers; the James River, meanwhile, when compared to northeastern rivers, remains closely related to a group of rivers in Canada and Maine but is differentiated from the Hudson and Delaware Rivers. At this point in the analysis, Program COLONY, which was used to estimate closeness of relationships, could have identified 3 clusters (James spring and fall, Hudson and Delaware, and Maine/Canada), but did not. When compared only with rivers from Maine and Canada (White et al. 2021), the James River spring and fall runs both appear to be unique but can be further separated from each other when compared to 1 another (Balazik et al. 2017; White et al. 2021). This analysis shows that the York River population (and Nanticoke River population, which appear to form an upper Chesapeake Bay metapopulation [J. Kahn, unpublished data]) is significantly different from the 2 James River populations at the most basic level of comparison.

The Chesapeake Bay DPS's risk of extinction is "High" because of its low productivity (e.g., relatively few adults compared to historical levels and irregular spawning success), low abundance (e.g., only 3 known spawning populations and low DPS abundance, overall), and limited spatial distribution (e.g., limited spawning habitat within each of the few known rivers that support spawning). Genetic bottlenecks and low levels of inbreeding are also indicated. Based on U.S. Fish Commission landings data, approximately 20,000 adult female Atlantic sturgeon inhabited the Chesapeake Bay and its tributaries prior to development of a commercial fishery in 1890 (Secor 2002b). Chesapeake Bay rivers once supported at least 6 historical spawning subpopulations (ASSRT 2007), but today reproducing populations are only known to occur in the James, York, and Nanticoke rivers. Estimates of James River effective population size from separate studies and based on different age classes are similar, ranging from 32-62 sturgeon (ASSRT 2022a). Balazik et al. (2012) reported empirical evidence that James River Atlantic sturgeon spawn in the fall, and a more recent study indicates that Atlantic sturgeon also spawn in the spring in the James River (i.e., dual spawning races) (Balazik and Musick 2015). In 2007, the Atlantic Sturgeon Status Review Team concluded that the James River had a moderately high risk (greater than 50 percent chance) of becoming endangered in the next 20 years, due to anticipated impacts from commercial bycatch (ASSRT 2007). (Kahn et al. 2019) estimated a spawning run size of up to 222 adults (but with yearly variability) in the Pamunkey River, a tributary of the York River in Virginia, based on captures of tagged adults from 2013-2018. The highest ranked stressor for the York River was commercial bycatch, which received a moderate risk rank (ASSRT 2007). New information for the Nanticoke River system suggests a small adult population based on a small total number of captures (i.e., 26 sturgeon) and the high rate of recapture across several years of study (Secor et al. 2022). At the DPS level, the Chesapeake Bay DPS is estimated to have an apparent annual survival of approximately 88 percent (95 percent CL, 46-99 percent, ASMFC 2017b). A recent estimate for adult York River Atlantic sturgeon by Kahn et al. (In Press) shows much higher survival than other estimates with an annual apparent survival of 99.2 percent (97.9-99.7 percent).

5.2.3.5 CRITICAL HABITAT

Critical habitat for the Atlantic sturgeon Chesapeake Bay DPS was designated in 2017 (82 FR 39160, Figure 6). Critical habitat boundaries of the Chesapeake Bay DPS include the Potomac River, the Rappahannock River from U.S. Highway 1 Bridge, downstream to the mouth of the Chesapeake Bay, the York river from its confluence with the Mattaponi and Pamunkey rivers downstream to where the main stem river discharges at the mouth of the Chesapeake Bay, the James River and the Nanticoke River. Only the Potomac River, Rappahannock River, York/Mattaponi/Pamunkey Rivers, and James fall within the action area and are in Chesapeake.

The PBFs identified as essential components of the critical habitat to conserve the Atlantic sturgeon include:

1. Hard bottom substrate (e.g., rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (i.e., 0.0-0.5 parts per thousand range) for settlement of fertilized eggs and refuge, growth, and development of early lifestages.
2. Aquatic habitat with a gradual downstream salinity gradient of 0.5 up to as high as 30 ppt and soft substrate (e.g., sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development;
3. Water of appropriate depth and absent physical barriers to passage (e.g., locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support (i) Unimpeded movement of adults to and from spawning sites, (ii) Seasonal and physiologically dependent movement of juvenile
4. Water, between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support: Spawning; annual and interannual adult, subadult, larval, and juvenile survival; and larval, juvenile, and subadult growth, development, and recruitment (e.g., 13 degrees

Celsius to 26 degrees Celsius for spawning habitat and no more than 30 degrees Celsius for juvenile rearing habitat, and 6 mg/L or greater DO for juvenile rearing habitat).

5. Appropriate salinity zones within the river estuary; and (iii) staging, resting, or holding of subadults or spawning condition adults. Water depths in main river channels must also be deep enough (at least 1.2 meters) to ensure continuous flow in the main channel at all times when any sturgeon lifestage would be in the river.

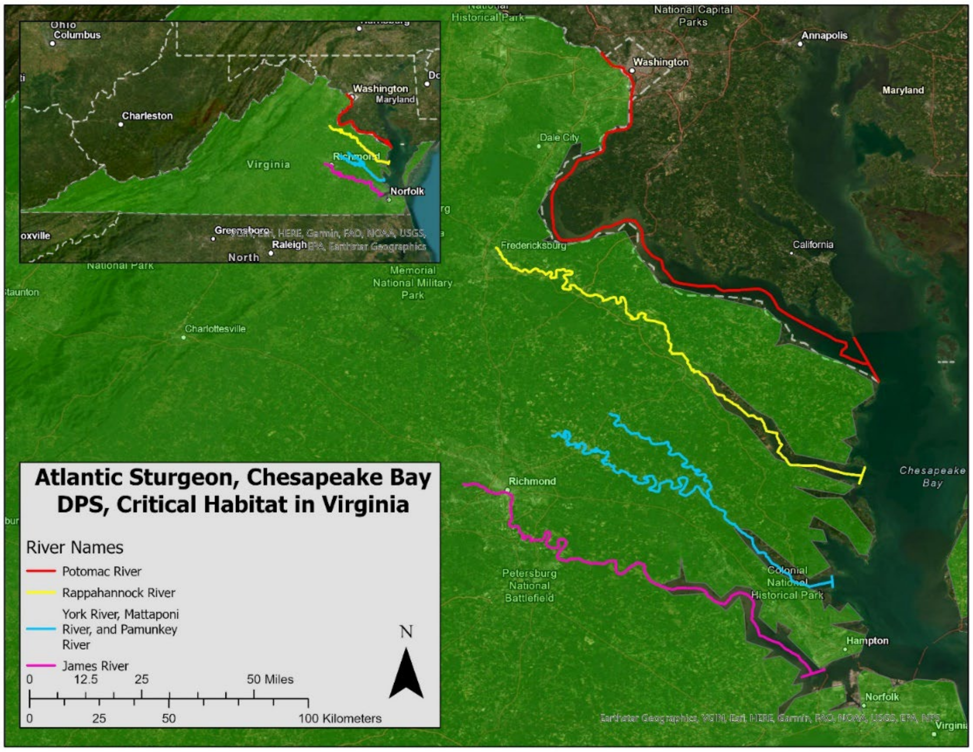

Figure 6. Critical Habitat for Atlantic Sturgeon Chesapeake Bay DPS within Virginia (82 FR 39160; August 17, 2017)

5.2.3.6 RECOVERY GOALS

A recovery plan has not been completed for the listed Atlantic sturgeon DPSs. However, a recovery outline has been prepared (NMFS 2018). A recovery outline is an interim guidance to guide recovery efforts until a full recovery plan is developed and approved. NMFS's vision, explained in the recovery outline, is that subpopulations of all 5 Atlantic sturgeon DPSs must be present across the historical range. These subpopulations must be of sufficient size and genetic diversity to support successful reproduction and recovery from mortality events. The recruitment of juveniles to the sub-adult and adult lifestages must also increase and must be maintained over many years. Recovery of these DPSs will require conservation of the riverine and marine habitats used for spawning, development, foraging, and growth by abating threats to ensure a high probability of survival into the future. The outline includes a recovery action to implement region-wide initiatives to improve water quality in sturgeon spawning rivers, with specific focus on eliminating or minimizing human-caused anoxic zones.

6 ENVIRONMENTAL BASELINE

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 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 CFR §402.02). This includes discharges and activities authorized by the EPA's Construction General Permit, and other activities authorized by the EPA (e.g., NPDES permits, cooling water intake, air emissions, and the cleanup and management of hazardous waste).

Like most of the U.S. Atlantic coast, the Virginia coastline has 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.

Water quality in riverine and estuarine systems is affected by human activities conducted in the riparian zones of the Appomattox River, James River, Mattaponi River, Pamunkey River, Pocomoke River, Potomac River, Rappahannock River, and York River, as well as those conducted more remotely in the upland portion of the Potomac, Lower Chesapeake, Albemarle-Chowan, and James basins. 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, run-off 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.

6.1 Existing Permitted Sources

In Virginia, EPA has authorized VADEQ to issue permits through its VPDES program. The agency issues permits for all point source discharges to surface waters, dischargers of stormwater from Municipal Separate Storm Sewer Systems (MS4s), and dischargers of stormwater from industrial activities. Additionally, the agency issues Virginia Stormwater Management Program permits to dischargers of stormwater from construction and industrial activities.

There are 2 types of VPDES permits: Individual Permits and General Permits. VADEQ issues individual permits to both municipal and industrial facilities. As of May 10, 2023 there are 5, 809 current VPDES active permits. General permits are written for a general class of dischargers and adopted as regulations. General permits are available for concrete products, small MS4s, Noncontact cooling water, domestic sewage, nonmetallic mineral mining, nutrient trading, petroleum, potable water treatment plants, seafood, stormwater industrial activities, and vehicle wash. Unlike general permits issued by EPA, the VADEQ general permits do not include consideration of the presence of state or Federally protected species. Many permits require monitoring for pollutants and characteristics such as nutrients, biological oxygen demand, organic solvents, and other metals. At the time of this writing, there are 369 discharges with permit limits for aluminum under VPDES permits. Presently, in the absence of aluminum criteria, there are no records for violations of aluminum limits or receiving water bodies impaired by aluminum. Permit limit violations are reported for 49 pollutants or pollutant indicators.[13] The top 5 commonly violated permit limits are total suspended solids, ammonia, *Escherichia coli*, biological oxygen demand, and pH. Zinc and copper limits rank 10th and 11th among violated permit limits.

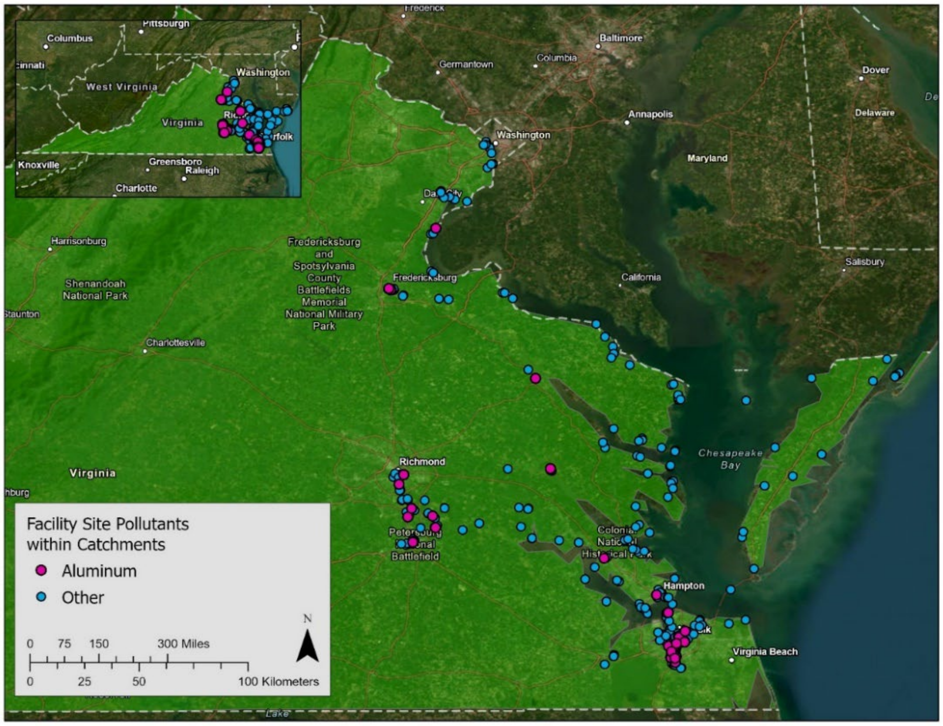

Figure 7. Virginia Discharges in Catchments Adjacent to Sturgeon Waters

6.2 Mixtures and Impairments

As noted above in Section 3.1.3, in point or nonpoint source pollution, chemicals occur together in mixtures, but criteria for those chemicals are developed in isolation, without consideration of additive toxicity or other chemical or biological interactions. Most importantly, a number of studies have determined conclusively that adverse effects due to additive or synergistic toxicity

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[13] Pollutant indicators are responsed to pollutants such as microbes, toxicity, or oxygen demand.

mechanisms occur when 1 or more metals are near or equal to acute criteria concentrations (e.g., Marking 1985; Sprague 1970; Vijver et al. 2010)

The Clean Water Act requires states and territories to assess water quality every 2 years under 305(b) and identify waters that are impaired under 303(d) and in need of restoration. Impairments may be based on a single or multiple stressors within the system. One stressor may mask the effects of other stressors that are also adversely affecting aquatic life. Restoration is achieved by establishing the maximum amount of an impairing pollutant allowed in a waterbody, or TMDL. These assessments are sent as an integrated report every even numbered year to EPA, which must approve of each impaired waters' listing. As a result, many recent state assessments are not finalized until the following year or later.

The EPA approved Virginia's most recent 303(d) list via the 2022 Final Integrated Report on October 21, 2022. The report revealed that bacteria remains a common impairment in Virginia's rivers, and mercury and PCBs remain a major cause of impairments in fish tissue. However, there were no major changes to riverine assessments between the 2020 and the 2022 Integrated Reports. Similarly, low dissolved oxygen, insufficient submerged aquatic vegetation, mercury and PCBs in fish tissue remain the major cause of impairments in Virginia's estuaries designated for aquatic life. The majority of these impairments are being addressed by the Chesapeake Bay TMDL. There are 42 approved TMDL reports for the Chesapeake Bay Basin, 38 in the Potomac River Basin, 29 in the Rappahannock River Basin, 9 in the Upper James River, and 1 in the York River Basin. Significant causes of designated use impairments for Sturgeon Waters in Virginia are listed by river basin and by water body type in Tables 8-10.

Table 8. Significant Causes Of Designated Use Impairments for the Chesapeake Bay/Atlantic Ocean and Small Coastal Basins by Waterbody Type, Ranked by Percentage of Impaired Water Size

Rivers		Estuaries	
Bacteria	56%	Impaired Aquatic Plants	100%
Impaired Benthic Community	28%	PCBs in Fish Tissue	99%
Mercury in Fish Tissue	26%	Dissolved Oxygen	85%
Dissolved Oxygen	18%	Bacteria	3%
pH	8%	Impaired Benthic Community	2%
--	--	Mercury in Fish Tissue	<1%

Table 9. Significant Causes of Designated Use Impairments for the James River Basin and the Potomac River Basin by Waterbody Type, Ranked by Percentage of Impaired Water Size

James River Basin				Shenandoah Potomac River Basin			
Rivers		**Estuaries**		**Rivers**		**Estuaries**	
Bacteria	79%	PCBs in Fish Tissue	94%	Bacteria	87%	Dissolved Oxygen	100%
Impaired Benthic Community	20%	Impaired Benthic Community	74%	Impaired Benthic Community	16%	PCBs in Fish Tissue	92%
PCBs in Fish Tissue	9%	Impaired Aquatic Plants	71%	pH	15%	Impaired Aquatic Plants	78%
Dissolved Oxygen	8%	Chlorophyll-a	27%	Dissolved Oxygen	8%	Impaired Benthic Community	73%
pH	7%	Bacteria	14%	PCBs in Fish Tissue	8%	Bacteria	22%
Temperature	4%	Dissolved Oxygen	8%	Mercury in Fish Tissue	6%	Mercury in Fish Tissue	21%

Table 10. Significant Causes of Designated Use Impairments for the Rappahannock River Basin and the York River Basin by Waterbody Type, Ranked by Percentage of Impaired Water Size

Rappahannock River Basin				York River Basin			
Rivers		**Estuaries**		**Rivers**		**Estuaries**	
Bacteria	92%	Dissolved Oxygen	95%	Bacteria	85%	PCBs in Fish Tissue	62%
Impaired Benthics	14%	PCBs in Fish Tissue	84%	Impaired Benthic Community	34%	Impaired Aquatic Plants	59%
pH	9%	Impaired Benthic Community	82%	pH	8%	Dissolved Oxygen	32%
Dissolved Oxygen	5%	Bacteria	21%	Mercury in Fish Tissue	7%	Bacteria	20%
PCBs in Fish Tissue	4%	Impaired Aquatic Plants	6%	PCBs in Fish Tissue	5%	Impaired Benthic Community	4%
Temperature	2%	Chloride	3%	Temperature	3%	pH	2%

6.3 Municipal Separate Storm Sewer Systems

Stormwater Municipal Separate Storm Sewer Systems (MS4s) permits regulate discharges on a system or jurisdiction-wide basis and must effectively prohibit non-stormwater discharges into the sewer system. Stormwater discharges regulated under an MS4 permit represent a baseline stormwater impact to which other regulated discharges are added. While aluminum is ubiquitous and occurs as a stormwater pollutant, aluminum sulfate or alum, is sometimes used as a flocculant to remove turbidity (Kazaz et al. 2022; Xu et al. 2020) and other pollutants (Adhikari et al. 2016; Monira et al. 2021) from stormwater. None of Virginia's 101 permitted MS4s are required to monitor for aluminum. There are few monitoring data for aluminum concentrations in samples taken during stormwater events. Dissolved aluminum ranged from 7.5-430 in 17 samples collected during precipitation events between 1990 and 2014.

6.4 Climate Change

Climate change, despite being a global phenomenon, is discussed in this section and in the cumulative effects section (Section 8), because it is a current and ongoing effect that influences environmental quality now and in the future in the action area. NMFS's policy guidance with respect to climate change when evaluating an agency's action is to project climate effects over the timeframe of the action's consequences. The EPA's approval and subsequent implementation of water quality criteria will be in effect indefinitely. Since Atlantic sturgeon can migrate widely, some aspects of global climate change are important to consider.

Climate change has the potential to influence species abundance, geographic distribution, migration patterns, and susceptibility to disease and contaminants, as well as the timing of seasonal activities and community composition and structure (Evans and Bjørge 2013; IPCC 2014; Kintisch and Buckheit 2006; Macleod 2009; Mcmahon 2006; Robinson et al. 2008). The loss of habitat because of climate change could be accelerated due to a combination of other environmental and oceanographic changes such as an increase in the frequency of storms and/or changes in prevailing currents (Antonelis et al. 2006; Baker 2006).

Changes in the saltwater ecosystem caused by climate change (e.g., ocean acidification, salinity, oceanic currents, DO levels, nutrient distribution) could influence the distribution and abundance of lower trophic levels (e.g., phytoplankton, zooplankton, submerged aquatic vegetation, crustaceans, mollusks, forage fish), ultimately affecting primary foraging areas of ESA-listed species. Saltwater species ranges are expected to shift as they align their distributions to match their physiological tolerances under changing environmental conditions (Doney 2012). Similarly, climate-related changes in important prey species populations are likely to affect predator populations. Changes in core habitat area means some species are predicted to experience gains in available core habitat and some are predicted to experience losses (Hazen 2012).

As stated in Section 5.2.1.6, ESA-listed sturgeon are highly vulnerable to climate change. While it is speculated that future climate change may affect sturgeon, it is difficult to predict the magnitude and scope of those potential impacts. Sturgeon could be affected by changes in river ecology resulting from increases in precipitation and changes in water temperature, which, in turn, may affect recruitment and distribution in these rivers. The effects of increased water temperature and decreased water availability are likely to have a more immediate effect on Atlantic sturgeon populations that migrate and spawn in river systems with existing water temperatures that are at or near the maximum for the species, including the South Atlantic and Carolina DPSs. Atlantic sturgeon prefer water temperatures up to approximately 28 degrees

Celsius; these temperatures are experienced naturally in some areas of rivers during the summer months. If river temperatures rise and temperatures above 28 degrees Celsius are experienced in larger areas, sturgeon may be excluded from some habitats. The increased rainfall predicted by some models in some areas may increase runoff and scour spawning areas, while flooding events could cause temporary decreases in water quality. Rising temperatures predicted for all of the U.S. could exacerbate existing water quality problems with changes in dissolved oxygen and temperature.

Increased droughts (and water withdrawal for human use) predicted by some models in some areas may cause loss of habitat including loss of access to spawning habitat. Drought conditions in the spring may also expose eggs and larvae in rearing habitats. If a river becomes too shallow or flows become intermittent, all lifestages, including adults, may become susceptible to strandings or habitat restriction. Low flow and drought conditions are also expected to cause additional water quality issues. Any of the conditions associated with climate change are likely to disrupt river ecology causing shifts in community structure and the type and abundance of prey. Additionally, cues for spawning migration and spawning could occur earlier in the season causing a mismatch in prey that are currently available to developing sturgeon in rearing habitat.

Changes in oceanic conditions could also affect the marine distribution of sturgeon or their marine and estuarine prey resources. Rising sea level may result in the salt wedge moving upstream in affected rivers. Sturgeon spawning occurs in fresh water reaches of rivers because early lifestages have little to no tolerance for salinity. In river systems with dams or natural falls that are impassable by sturgeon, movement of the salt wedge further upstream would further restrict spawning and rearing habitat. The effects of climate change on ESA-listed sturgeon will not occur independently from other stressors. Rather, the anthropogenic stressors already affecting the fitness and survival of sturgeon – including bycatch, loss of migratory habitat from dams, contamination of riverine habitat and overall decreased water quality – will be compounded by the anticipated effects of climate change.

6.4.1 Climate Change in Virginia

Since the beginning of the 20th century, temperatures in Virginia have risen more than 1.5 °F and historically unprecedented warming is projected during the 21st century due to higher emissions. Higher temperatures will increase evaporation rates, accelerating soil moisture loss and adversely affecting agriculture and intensifying naturally occurring droughts. Extreme heat and extreme precipitation events are projected to increase throughout the 21st century (Runkle et al. 2022). Virginia’s diverse geographic elements (e.g., Appalachian and Blue Ridge Mountains in the west, the Atlantic coastal region to the east) shows substantial regional variation in climate which heavily influence temperature and precipitation patterns. The west generally sees lower rainfall and cooler temperatures than the east.

Total annual precipitation in Virginia show a small upward trend since the 1990s. The wettest years on record occurred in the late 1970s and recently in the late 2010s. The wettest year on record occurred in 2018 (total of 63.5 inches (161.29 cm)), and 2020 was the third wettest (61.4

inches [155.96 cm]). Virginia is prone to hazardous weather, including severe thunderstorms, tornadoes, winter storms, hurricanes, droughts, and heat waves. Virginia was affected by 82 of the 290 U.S. billion dollar disaster events between 1980 and 2020 (Runkle et al. 2022).

The Chesapeake Bay specifically is especially vulnerable to sea level rise, precipitation extremes, increased water temperatures, and potential acidification (ocean and biological). The Chesapeake Bay area is perceived to be the third most vulnerable area in the United States to sea level rise behind Louisiana and South Florida. Tidal gauge records show that sea level in the Chesapeake Bay have been increasing at an average rate of 3.3-3.8 centimeters per decade over the past 100 years. Additionally, increasing urban development, excess pollution levels, and changes in water temperature and salinity have affected some plant and animal species, affecting the Chesapeake Bay area ecosystems. (Runkle et al. 2022).

Along the coast, concerns for seal level rise grow with increasing temperatures. Since 1900, the global average sea level has risen by 7-8 inches (17.78 – 20.32 cm), however, along the Virginia coast, sea level has risen to about 17 inches (43.18 cm) between 1927 and 2020. This in turn has caused an increase in tidal flooding events associated with nuisance-level impacts, causing infrastructure damage and road closures (Runkle et al. 2022). Virginia's coastlines have also seen an increase in the number of tidal flood days annually (any day exceeding the nuisance-level), with the greatest number (15 days) occurring in 2009.

6.5 Impervious Cover

The oldest available impervious cover data from the National Land Cover Dataset is from 2001 and the most recent is from 2019. Table 11summarizes the change in impervious cover between 2001 and 2019 for catchments immediately adjacent to Sturgeon Waters and catchments abutting water-adjacent catchments. Data for Virginia are divided into the *major* river basins within the states (Figure 8). To place impervious cover for these states in context: Arnold and Gibbons (1996) demonstrated that runoff doubles in forested catchments that are 10-20 percent impervious, triples between 35 and 50 percent and increases more than five-fold at above 75 percent impervious. Catchments that shifted from below ten percent impervious cover in 2001-greater than ten percent impervious in 2019 are typically adjacent to existing areas of increased impervious cover. These are highlighted in Figure 9 using an aqua-to-fuchsia color scale to illustrate the degree of impervious cover change. For example, impervious cover at 5 percent in 2001 and 6.5 percent in 2019 is a 30 percent increase in impervious cover.

Overall, Virginia has seen a slight increase in impervious cover throughout the state for catchment areas near Sturgeon Waters. Catchment areas within the James River basin saw largest increase in impervious cover, Figure 5 shows the proportional change from 2001-2019. Since 2010, Virginia's population grew 8 percent with an estimated 0.6% increase between April, 2020 and July 2022. Loudoun County, along the Potomac, has seen the highest increase in population with an increase of 45.23 percent since the 2010 census (U. S. Census Bureau 2020). Virginia's population is increasing at a rate of 1.15 percent.

Table 11. Summary of Impervious Cover and Proportion of Region, for Catchments Adjacent to Sturgeon Waters

River Basin	Catchment area (km^2)	2001 catchment area already >10% impervious cover	Catchment area increased to >10% impervious cover by 2019	2019 catchment area still <10% impervious cover
Potomac River	1739.93	600.76 (34.5%)	22.83 (1.3%)	1110.26 (63.8%)
York River	2337.23	339.60 (14.5%)	28.78 (1.2%)	1968.85 (84.2%)
Rappahannock River	2073.53	165.42 (8.0%)	10.15 (0.5%)	1897.96 (91.5%)
James River	3563.38	1413.42 (39.7%)	139.36 (3.9%)	2010.17 (56.4%)

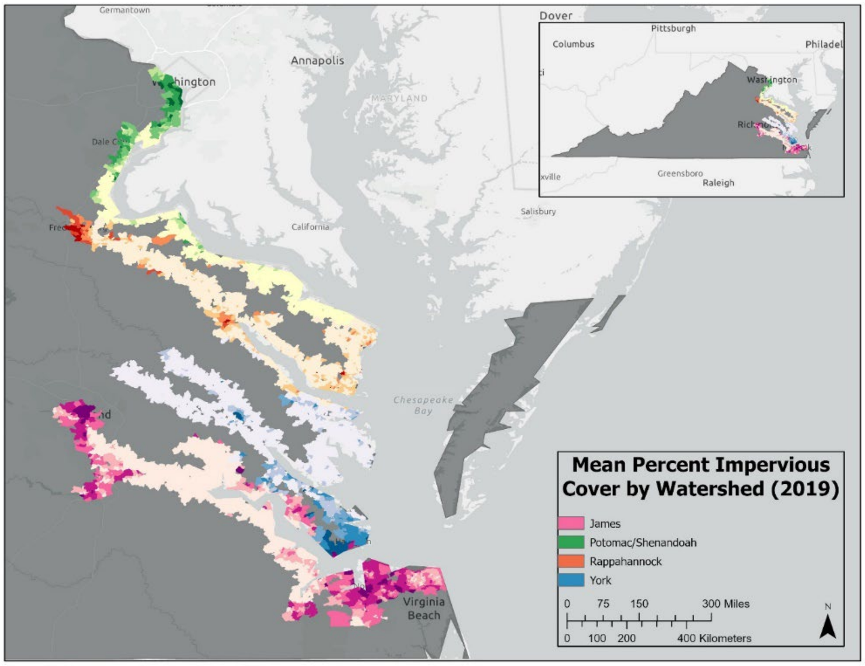

Figure 8. Relative Impervious Cover within Virginia Catchments Associated with Sturgeon Waters (Darker Shades = Highly Impervious)

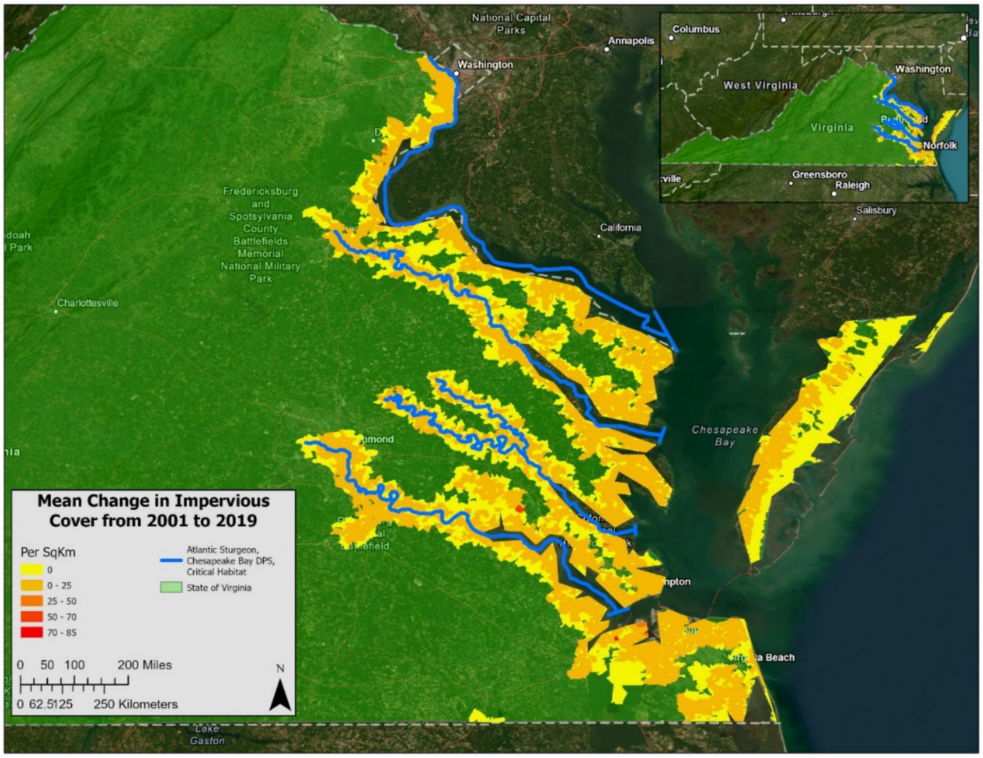

Figure 9. Change in Impervious Cover within Virginia Catchments Associated With Sturgeon Waters between 2001 and 2019

6.6 Climate Change and the Built Environment

The aggregate effects of an increasingly built environment affecting watersheds where species and critical habitat under NMFS's jurisdiction occur interacts with climate change-driven shifts in precipitation to result in a continually shifting baseline of the Potomac, Lower Chesapeake, Albemarle-Chowan, and James basins. Aggregate impacts include:

- time-crowded perturbations (i.e., repeated occurrence of 1 type of impact in the same area) or perturbations that are so close in time that the effects of 1 perturbation do not dissipate before a subsequent perturbation occurs;
- space-crowded perturbations (i.e., a concentration of a number of different impacts in the same area) or perturbations that are so close in space that their effects overlap;
- interactions or perturbations that have qualitatively and quantitatively different consequences for the ecosystems, ecological communities, populations, or individuals exposed to them because of synergism (when stressors produce fundamentally different effects in combination than they do individually), additivity, magnification (when a combination of stressors have effects that are more than additive), or antagonism (i.e., when 2 or more stressors have less effect in combination than they do individually); and
- nibbling (e.g., the gradual disturbance and loss of land and habitat) or incremental and decremental effects are often, but not always, involved in each of the preceding 3 categories (NRC 1986).

Climate change influences on precipitation frequency and intensity interacting with increasing impervious cover intensifies risk to surface water quality through increased pollutant transport and erosive flow. Further, changes in plant cover and soil structure under climate change will influence infiltration potential (Lal 2015).

7 EFFECTS OF THE ACTION

Under the ESA, "effects of the action" means "all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action" (see 50 CFR §§ 402.02 and 402.17). This analysis focuses on any data that indicate exposures within criterion limit may result in short or long-term adverse effects to ESA listed shortnose and Atlantic sturgeon or result in reduction in the quantity or quality of available prey, as described through risk hypotheses identified in the Assessment Framework of this opinion (Section 2) repeated below:

- Reduced survival of individuals through direct mortality or effects favoring predation (e.g., immobility, reduced predator detection);
- Reduced growth of individuals through direct effects of toxicity or effects impairing foraging (e.g., swimming, development, prey detection, strike success);
- Reduced fecundity through direct effects of toxicity (e.g., reduced hatch, egg mass, egg counts) or effects impairing reproduction (e.g., impaired nest tending, gonads mass), and
- Reduced survival, growth, and/or fecundity due to reduced quantity or quality of forage due to toxic effects on forage species abundance or toxic effects of body burdens of the stressor in forage species.

As discussed in Section 2.2 and 3.1 of the prior opinion for EPA approvals of criteria for Delaware and Maryland (NMFS 2023), the criteria developed using the EPA Guidelines are not expected to protect all species under all circumstances, so waters compliant with the criteria may result in pollutant exposures that cause adverse effects in some species. When assessing risk to an ESA-listed species, the vulnerability of an imperiled population of that species to the loss of an individual, or key individuals, amplifies the fundamental threat posed by a toxic pollutant. There are also concerns about the underlying data used in the derivation of criteria. Further, aluminum does not exist alone in effluents or natural waters. The toxicity of mixtures is dependent upon many factors, such as which chemicals are most abundant, their concentration ratios, differing factors affecting bioavailability, and organism differences. Because of this complexity, accurate predictions of the combined effects of chemicals in mixtures in every case where the criteria assessed in this opinion are applied is not current practice. The work of Spehar and Fiandt (1986) showed 100 percent mortality in rainbow trout and *Ceriodaphnia dubia* exposed to a mixture of 6 metals at their acute criterion concentrations suggests severe effects result from exposure to compliant discharges and within "unimpaired" waters.

7.1 Exposure to Aluminum in the Action Area

Current monitoring and permitting data indicate that all lifestages of ESA-listed shortnose and Atlantic sturgeon are certain to be exposed to waters where the aluminum criteria will be implemented. Data for stations within rivers occupied by ESA-listed sturgeon from the National Water Quality Monitoring Council Water Quality Portal identify dissolved or total aluminum concentrations in all rivers occupied by shortnose and Atlantic sturgeon. In natural waters, dissolved metals are a fraction of the total recoverable metal. Aluminum criteria are expressed as total recoverable metal. Total aluminum[14] detections from 18 stations sampled within Sturgeon Waters between 2000 and 2022 included 27 observations ranging from 95-664 µg/L. Only 2 detections were below the MetALiCC-MAP fifth percentile chronic aluminum criterion for fourth through sixth-order freshwater streams in the Southeastern Plains Ecoregion where ESA-listed sturgeon would be exposed (Figure 10. orange line). Four detections were above the fifth percentile chronic aluminum criterion for seventh through tenth-order freshwater streams (Figure 10, purple line).

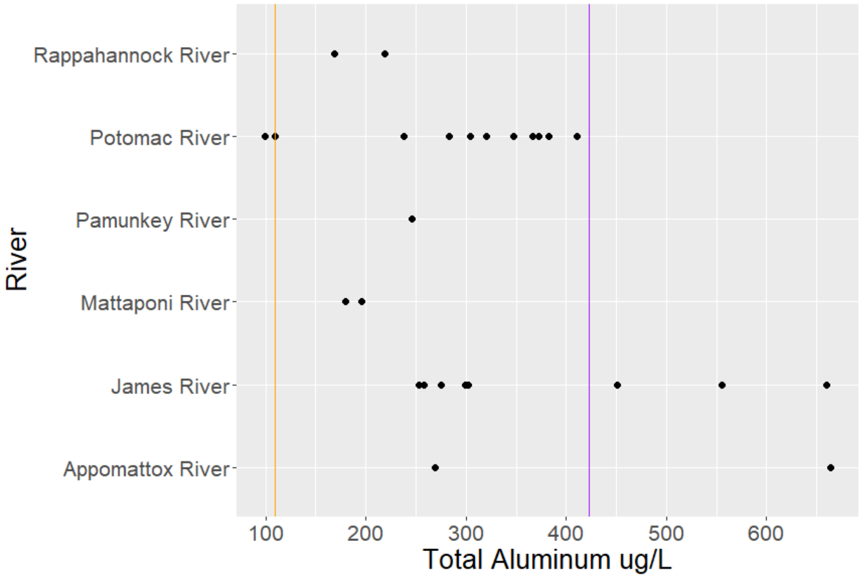

Figure 10. Monitoring Data in Context of Fifth Percentile Chronic Criteria for Fourth through Sixth Order Streams (Orange Line) and Seventh through Tenth Order Streams (Purple Line) in the Southern Plains Ecoregion

The environmental baseline section of this opinion established that permitted sources required to monitor for aluminum discharge to Sturgeon Waters, including designated critical habitat, but in the absence of aluminum criteria, these permits do not have limits on the amount of aluminum discharged and receiving waters cannot be evaluated for aluminum impairment. The permit monitoring data indicate average aluminum detections ranging from 0.024-61,000 µg/L.

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[14] Identified in the Water Quality Portal as the total, total recoverable, recoverable or unfiltered sample fraction.

7.2 Responses to Aluminum Exposures within Criteria Limits

NMFS's screened ECOTOX dataset for aluminum had fewer records that included data for pH, organic carbon, and total hardness than the dataset used by EPA for its BE. The BE relied on data provided in the 2018 Aluminum Guideline (USEPA 2018). In preparing the Aluminum Guideline EPA obtained the unpublished water chemistry data for toxicity test conditions from the researchers or used values reported by other studies using the same or similar water for the toxicity tests. Where only data for dissolved organic carbon was lacking, default values from several different dilution waters were applied using a methodology documented in the 2007 freshwater Copper Guideline document (USEPA 2007). These values were determined from empirical data obtained for each source water. The data in EPA's document includes observations on behavior that were not used in criteria development, but are important to NMFS's analysis. The unpublished water chemistry data in the Aluminum Guideline are thus the best available data. The dataset for 13 species of fish exposed to aluminum includes responses for behavior, development, growth, and survival. There are also data for 18 species of invertebrates describing aluminum effects on development, growth, population, reproduction, and survival.

Toxicology data are expressed in terms of endpoints identified through toxicity tests exposing laboratory-reared organisms to toxicants over a range of concentrations. The most commonly reported endpoints include the following:

- Lethal concentration (LC) at which a certain proportion of the exposed organisms die (LC## such as LC50 = concentration at which 50 percent of test organisms die);
- lowest test exposure at which a given effect or response did not differ from controls (no observed effects concentration, NOEC);
- lowest test exposure at which the effect or response differed significantly from controls (lowest observed effects concentration, LOEC);
- effect concentration (EC) at which a certain proportion of an effect was observed (EC##, such as EC10 = concentration at which 10 percent of test organisms show an adverse response); and
- maximum acceptable toxic concentration (MATC), which is typically the geometric mean of the LOEC and NOEC, but other calculations have been used.

There are other less common endpoints such as IC## for proportion inhibition and LETC for lethality threshold. It is important to note that LOEC and NOEC data are influenced by study design (e.g., distribution and number of concentrations tested). Depending on exposures tested and underlying variability in responses, the LOEC may actually result in a 30 percent difference in response from controls. Data are not equally available for all types of endpoints or responses and can vary widely due to differences in the lifestages of the organisms used and the study design (e.g., exposure duration, flow through versus static exposures). In addition, the same exposure concentration may be reported as the NOEC for 1 type of response, such as growth, and as the LOEC for another, such as reproduction.

7.2.1 EPA's Effects Analysis

EPA BE analyses for 303(c) section 7 consultations estimate protective thresholds. Many of the available LC## and EC## are reported without the toxicity test exposure-response data used to calculate them. As a result, theoretical "low effect" thresholds, such as LC05 or EC05 cannot be calculated for those exposures. EPA estimates the LC05 or EC05 for such data by using exposure-response data that are available to calculate an adjustment factor that is then applied to those endpoints lacking exposure-response data. For the BE analysis, EPA used the web-based Interspecies Correlation Estimation (web-ICE) program to identify a representative acute toxicity value for shortnose sturgeon, based on rainbow trout data, and derive adjustment factors from those exposure-response data that were available and used those to adjust other data to LC05 and EC05 concentrations.

Because the aluminum criteria are based on MLR models using different vertebrate and invertebrate slopes to model aluminum toxicity across water chemistry, the criterion and species sensitivity do not always change proportionally across all water chemistries. Consequently, comparing aluminum criteria to species sensitivity in reference water chemistry does not produce results that are broadly applicable to all water chemistries. To explore this, for each set of water quality data, the BE calculated normalized LC05 effect concentration and compared this to the applicable criterion. Individual renormalized acute low effect concentrations were compared to aluminum acute criterion for each sample to determine the number and percentage of samples for which the aluminum criterion exceeded the LC05 (Table 4.3). The aluminum acute criterion was greater than the sturgeon LC05 in 13.2- 35.6% of the water quality observations across the 4 watersheds with sturgeon habitat (Table 12). It is not clear from the BE how data were screened to only include freshwater stations. The parameter summary table of the BE (Table 3-2) does include values that are well outside of model limits. Maximum hardness values above 430 mg/L calcium carbonate suggests that some brackish and saltwater samples were included in the analysis. Otherwise, these data suggest that acute exposure to aluminum within acute criteria limits is likely to result in adverse effects in the James, Mattaponi, and Pamunkey Rivers.

Table 12. Frequency and Proportion of Site Specific Calculated Aluminum Criteria Above Response Thresholds for Rivers where Shortnose and Atlantic Sturgeon Occur.

Watershed	Count of samples	Acute		Chronic	
	with calculated criteria	count of criteria above LC05	%	count of criteria above EC05	%
Rappahannock	526	0	0%	0	0%
Mattaponi	117	20	17%	1	0.85%
Pamunkey	190	86	45%	0	0%
James	810	197	24%	0	0%

However, the LC05 and EC05 response thresholds are treated as bright line decision points in this table: only evaluating whether the criterion is above or below the response threshold.

Response thresholds are estimates derived from the central tendency of exposure concentration-response relationships calculated from multiple replicate exposures over a concentration gradient. Variability in responses among toxicity test replicates are important to consider. The comparisons in Table 12 do not take into account the confidence intervals around the LC05s and ECO5s.

NMFS appreciates that estimating a "low effect" threshold is thought to be necessary when assessing risk, and given the variance around any estimate, the concentration 1 standard deviation below an LC05 or EC05 could conceptually encompass an LC00 or EC00, but larger response magnitudes would occur at the LC05 plus 1 standard deviation. As such, NMFS does not consider LC05s or EC05s to be bright line decision points that, above and below which, determines "safe" from "not safe." Rather, when NMFS encounters these estimates they are viewed as context for potential effects to ESA-listed species.

7.2.2 This Opinion's Effects Analysis Examining all Available Data

For this biological opinion, NMFS includes data that EPA does not normally consider in its analyses because the study design and other factors do not meet the standard conditions that allow aggregation of data from disparate into a meta-analysis. The analysis does not convert toxicity test data to "standard conditions" because that is not how the criteria are applied in regulatory practice. Discussing data in terms of concentrations suggests a level of precision and certainty that is not translatable to real-world exposures. For these reasons, NMFS evaluates toxicity data in terms of risk quotients because quotients place the data directly in context of the applicable criterion by using the response thresholds in the denominator and corresponding criteria as the exposure in the numerator. The term "applicable criterion" refers to a criterion calculated to match the aquatic chemistry reported for a monitoring event or toxicity test. The term "test-specific criterion" is also used to identify a criterion calculated to match aquatic chemistry conditions of the test.[15] The use of risk quotients allows simultaneous presentation of the entirety of the data landscape and transparently identifies responses that occurred at concentrations 1 or more orders of magnitude above or below the criterion (i.e., factors of ten), at concentrations that are multiples of the criterion (e.g., twice, 4 times) or within a "gray area" that demands more careful consideration.

This opinion addresses existing toxicity data at face value. Toxicity tests with hardness, dissolved organic carbon, and pH within model limits were used to calculate toxicity test-specific criteria using EPA's Aluminum Criteria Calculator. Each test-specific criterion was then divided by the reported endpoint threshold concentrations (LOEC, NOEC, EC50, LC50 etc.) to obtain test-specific risk quotients. Risk quotients for all available endpoint effect data from the screened datasets are plotted in context of reference values representing the applicable criterion (orange) concentration and one-half that criterion concentration (purple). Risk quotients plotted to the right of a reference line indicate responses occurring at an exposure concentration below the

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[15]

applicable criterion (i.e., higher risk). Risk quotients are plotted on a log scale to enhance resolution. Those few data reported in with "<" operators are presented as hollow icons (i.e., □, Δ, □) to indicate that the response is expected to occur at a concentration less than the reported concentration. This typically happens when a response is observed at the lowest concentration tested in the study. Risk quotients for all available endpoint effect data are aggregated in Figure 11.

The only acute exposure toxicity data proximate to the orange and purple reference lines are behavioral responses indicating that fish would avoid waters with aluminum within the acute criterion limit. Gunn and Noakes (1986) reported an EC50 for avoidance behavior by brook trout exposed to a steep aluminum gradient concentration. The test design counted the number of individuals that moved to uncontaminated water within 15 minutes after introduction of aluminum-contaminated water. The sudden, sharp exposure gradient represented by this study would be more similar to a discharge pulse than a mixing zone interface. At a risk quotient of 0.57, this response represents an exposure that is above the test-specific acute criterion, but we cannot be certain that exposure at the acute criterion would not result in an EC20 or EC35-scale response. The confidence intervals for this EC50 estimate are broad, representing about 25 percent of the mean. In the control, fish spent 47 +/- 15.7 percent of the 15-minute observation period in the un-dosed side of the tank. At 100 µg/L fish spent 62.8+/- 15.5 percent of that 15 minutes in the un-dosed side of the tank, but avoidance behavior was not statistically significant until, at 500 µg, /L fish spent 80.7+/-13.1 percent of the time in the un-dosed side of the tank.

The rainbow trout behavior LOEC risk quotient of 1.62 is for increased frequency of gill flushing (i.e. "cough") over a 24-hour exposure period (Ogilvie and Stechey 1983). While this response is typically associated with clearance of particulate matter, it is not an unexpected response to aluminum exposure because aluminum hydroxide precipitates contribute to effects (USEPA 2018). The magnitude of response at the LOEC was twice that of the control and the NOEC. Interpreting the ecological significance of this response is complex. In the wild, this may result in avoidance if there are refugia. In the absence of refugia, an increased cough rate might interfere with feeding, predator avoidance, and be associated other energetically demanding stress responses like mucous production. Relocation to refugia also has implications. Relocation requires energy expenditure and can increase visibility to predators (Nunes et al. 2019). Refugia may be otherwise suboptimal habitat or be occupied by competitors (reviewed by Magoulick and Kobza 2003).

Most concerning among the data for chronic exposures are the risk quotients representing a 16-day rainbow trout mortality LC50 and 28-day EC20s for growth and development (Birge 1978; Birge et al. 1978; Birge et al. 2000). These studies were not included in criteria derivation due to the duration of the exposures. The risk quotient indicating an LC50 below its test-specific chronic criterion is for embryo-larval exposures of rainbow trout (Birge et al. 2000). Although not found in ECOTOX, the study also reported an LC10 indicating early-life-stage mortality could occur at nearly one-third the test-specific chronic criterion concentration. The EC20s and

EC50 reported in Birge et al. (1978) represent gross morphological impairments to the vertebrae in rainbow trout surviving the test. A brook trout growth EC20 used in criterion derivation had a risk quotient of 1.09, indicating visibly toxic effects occurring at the test-specific chronic criterion and suggesting detrimental effects occurring at and below the chronic criterion limit (Cleveland et al. 1986). Original data from the study providing an Atlantic salmon EC20 (McKee et al. 1989) that was also used in chronic criterion derivation suggested a exposure-response relationship with reductions in growth below the test-specific chronic criterion, but the effect was not statistically significant until growth was reduced, on average, by 36 percent.

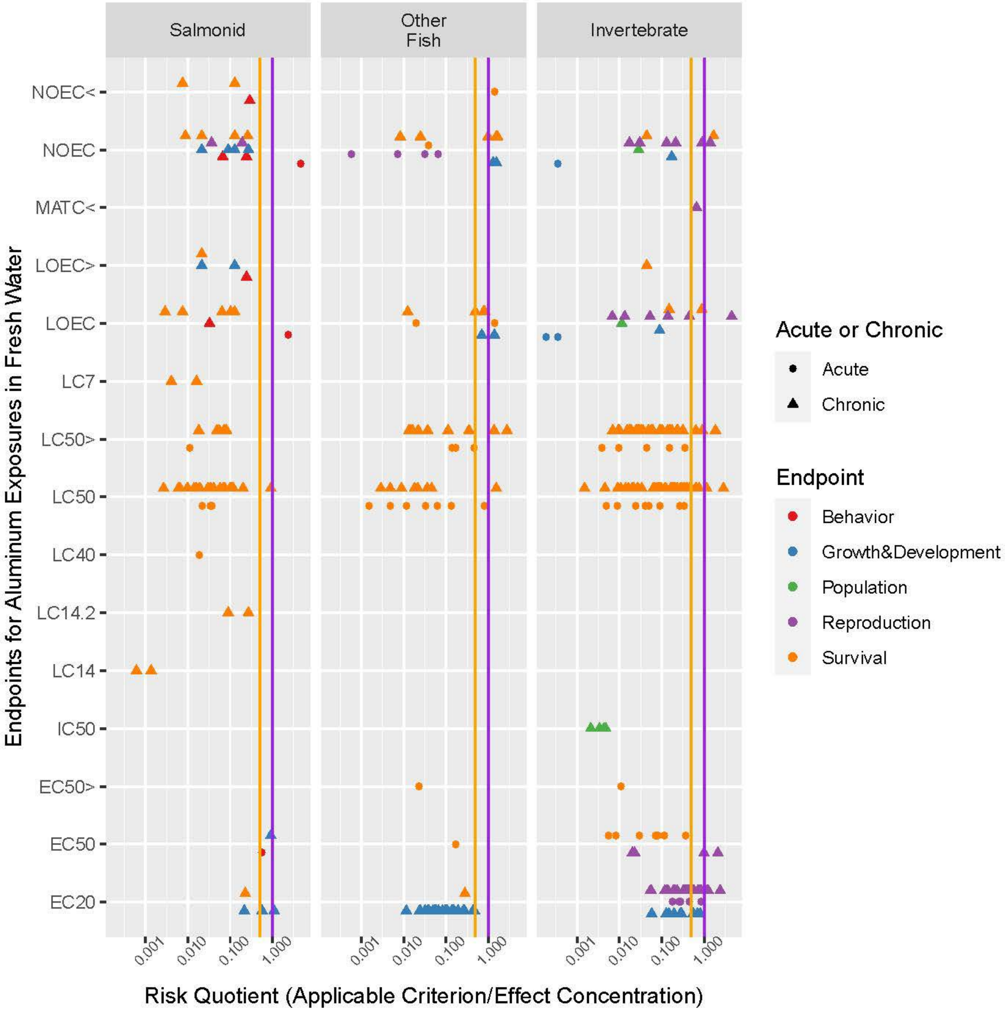

Figure 11. Distribution of Risk Quotients for Freshwater Exposures to Aluminum in Context of Reference Lines Representing the Applicable Criterion (Purple) and One-Half the Applicable Criterion (Orange)

The plotted risk quotients for invertebrates include data for growth, reproduction, ecosystem productivity, and mortality among 29 species. While the bulk of the data indicate responses occurring above the criterion limit, the plots draw attention to risk quotients representing chronic reproduction EC50s and EC20s for *Ceriodaphnia dubia* ranging from 0.12-2.4 (ENSR Consulting and Engineering 1992; European Al Association 2010; Gensemer et al. 2018;

McCauley et al. 1986; OSU 2018a) and risk quotients representing chronic LC50s below their test-specific chronic criterions for *Ceriodaphnia dubia* and *Daphnia magna* (European Al Association 2009; European Al Association 2010).

7.3 Risk of Aluminum Exposures within Criteria Limits in Waters Regulated by VADEQ

NMFS OPR's biological opinion, Section 2.2.2.1 (NMFS 2023), on EPA Region 3's approval of Delaware and Maryland's adoption of aluminum criteria establishes rainbow trout as a suitable surrogate species in the absence of data for effects on sturgeon. The attendant uncertainties when extrapolating across species can lead to underestimation or over estimation of effects. Taken with the discussion of lab-to-field extrapolation in Sections 2.2.2 and 2.2.3 of that opinion and response magnitudes associated with the endpoints used in deriving the aluminum chronic criterion, NMFS relies on the best available scientific data to be protective of ESA-listed species.

7.3.1 Survival

NMFS's 2020 opinion on EPA's promulgation of freshwater aquatic life criteria for aluminum in Oregon (NMFS 2020) relied on data reported by Gundersen et al. (1994) for its likely to adversely affect determination. NMFS's 2020 opinion concluded that the application of EPA's "low effect" adjustment factor to the lower LC50 estimates reported by Gundersen et al. (1994) for rainbow trout provided an LC05 estimate that was less than the acute criterion, indicating mortality in fish is likely to occur due to exposures within acute criterion limit. The lower normalized LC50s ranged from 1,680-2,180 µg/L and were for exposures with pH values at 8.3 while the normalized LC50s that were reported at >5,164->7,216 µg/L in the same study were for exposures at pH 7.6. This is an important distinction because waters of the Southeastern Planes ecoregion trend towards more neutral to acidic conditions whereas the Columbia River Basin action area for NMFS's 2020 opinion, which includes the Coast Range, Willamette Valley, West Cascades, East Cascades, and Columbia Plateau ecoregions, is relatively alkaline, with pH values around 8.3 (Little 2012). This opinion, therefore, does not replicate the basis for the determination of NMFS's 2020 opinion because the exposure conditions within the Commonwealth of Virginia are not expected to result in mortality at or below the acute criterion limit.

While EPA's assessment methodology suggests that the chronic criterion is generally protective against mortality, the rainbow trout embryo-larval LC50 represented by a risk quotient of 0.91 (Birge et al. 2000) indicates that early-life-stage mortality would occur at and below the chronic criterion limit. The other rainbow trout LC50s were for exposures of alevins (Hickie et al. 1993; Holtze 1983), fingerlings (Call et al. 1984), and juveniles (Gundersen et al. 1994).

Taken together, these data suggest direct adverse effects on survival are likely to occur in ESA-listed shortnose sturgeon and early lifestage Chesapeake Bay Atlantic sturgeon due to exposures within the aluminum chronic criterion limit, but not the acute criterion limit. Reduced survival of early lifestage sturgeon will influence the number of fish reaching the juvenile lifestage. While there are no data for population viability analysis, the viability of ESA-listed sturgeon populations in Virginia's waters is highly sensitive to juvenile mortality resulting in lower numbers of sub-adults recruiting into the adult breeding population (ASSRT 2007; NMFS 1998).

7.3.2 Behavior Effect within Acute Criterion Limits

The acute aluminum exposure data analyzed in this opinion are not direct effects on survival. Behavioral studies reporting avoidance and doubling of cough frequency in salmonids suggest behavioral effects may occur within the acute criterion concentration limits (Gunn and Noakes 1986; Ogilvie and Stechey 1983). For such responses to be considered take under the ESA, it would need to be found to significantly impair or disrupt normal behavioral patterns. To place this response in context, Hughes (1975) reported that rainbow trout cough frequency generally doubled at 100 mg/L total suspended sediment and study report that rainbow trout avoided waters with 100 mg/L suspended sediment (Suchanek et al. 1984, after Newcombe and Jensen, 1996). Taken together these studies provide evidence that a doubling of cough frequency would result in avoidance by rainbow trout. While the acute criterion is implemented as a one-hour average, the cough and avoidance responses occurred within 15-minutes. Aluminum exposures within the acute criterion limit may not result in mortality, but given the magnitude and acuteness of behavioral responses in surrogate fish species, we expect exposures within the acute criterion limit would cause ESA-listed sturgeon to leave otherwise suitable habitat. In the absence of data indicating fish would return to an area one hour after adverse conditions abate or whether gill damage, delayed mortality, or increased predation vulnerability would occur subsequent to the avoidance response, NMFS will exercise its professional judgment and use the best available scientific data to be protective of ESA-listed species.

7.3.3 Growth

Growth is an important determinant of survival and maturation, and thus recruitment into the adult population (Anderson 1988; Poletto et al. 2018)Early-life-stage studies for salmonids include a 28-day EC50 risk quotient of 0.93 for death and deformity in rainbow trout (Birge 1978; Birge et al. 1978) and an EC20 of 1.09 for reduced biomass in brook trout exposed for greater than 30 days (Cleveland 1989). These data suggest that growth and development in early life-stage shortnose sturgeon and Chesapeake Bay DPS of Atlantic sturgeon would occur within chronic criterion limits.

7.3.4 Reproduction

Available data for the effects of aluminum on reproduction in fish were NOECs for rainbow trout fertilization (Everhart and Freeman 1973) and striped bass hatch success (Buckler et al. 1995). The Everhart and Freeman (1973) study reported no effects on successful fertilization at concentrations as high as 5,200 µg/L. The Buckler et al. (1995) study reported hatch success to be unaffected by aluminum exposures ranging up to 300 µg/L at a pH value of 5.5. The corresponding chronic criterion under test conditions for this study is 36 µg/L. These data do not suggest that water quality conditions consistent with the chronic aluminum criterion would influence reproduction in ESA-listed shortnose sturgeon and the Chesapeake Bay DPS (or any DPS) of Atlantic sturgeon.

7.3.5 Abundance and Quality of Forage Species

Examination of the data behind the risk quotients presented in Figure 11 indicates that adverse effects will occur in invertebrates exposed to aluminum within the chronic criterion, but not acute criterion limit. While the diets of larval shortnose and Atlantic sturgeon have not yet been characterized, there are studies of larval green sturgeon (Zarri and Palkovacs 2019) and larval white sturgeon (Muir et al. 2000) diets. While diets are likely location-specific based on availability, larval stages of both green and white sturgeon were reported to rely on zooplankton species such as copepods, amphipods, and dipterans. An assessment of effects for listed species must address any evidence indicating adverse effects may occur to an individual of that species, and when assessing effects to forage species, it is the abundance and quality of forage species that is of concern. With respect to the quality of forage species, NMFS does not expect that EPA's approval of the aluminum acute criterion and chronic criterion will affect the quality of forage species because, as discussed previously, aluminum does not bioaccumulate in the food chain (see Section 3).

Among the 44 zooplankton risk quotients representing LC50s (0.30+/-0.46), 5 indicated adverse effects on survival within criterion limit (ENSR Consulting and Engineering 1992; European Al Association 2009). Among 36 zooplankton risk quotients representing EC20s for reproduction, 4 indicate adverse effects within criterion limit (CECM 2014; ENSR Consulting and Engineering 1992; European Al Association 2009; Gensemer et al. 2018). Risk quotients for the types of species more likely to occur in the diet of adult sturgeon, worms and mollusks, ranged from 0.0045 representing an LC50 for the red-rimmed melania snail (foreign Shuhaimi-Othman et al. 2013) to 0.55 representing an EC20 for fat mucket mussel growth (Wang et al. 2016). The implications of these effects on the abundance and quality of forage species for shortnose and Atlantic sturgeon is attenuated by the majority of risk quotients representing LC50s and EC20s indicating adverse effects would not occur within criterion limit and the wide variety of forage species sturgeon consume. A reduction in the abundance of 1 benthic species is likely to be compensated for by an increase in other species (Wesolek et al. 2010). NMFS does not expect that aluminum exposures within chronic criterion or acute criterion limit are likely to affect the abundance or quality of forage for shortnose sturgeon and the Chesapeake Bay and migrating and foraging DPSs of Atlantic sturgeon.

7.4 Likely to Adversely Affect Determination for EPA Approval of VADEQ Adoption of Freshwater Aluminum Criteria

NMFS concludes that EPA's approval of VADEQ adoption and implementation of the recommended National Recommended Water Quality Criteria for aluminum is likely to adversely affect shortnose sturgeon and the Chesapeake Bay DPS of Atlantic sturgeon because:

1) Permitting and monitoring of VADEQ-regulated waters indicate that exposures to aluminum will occur.
2) Although EPA's analysis may have included some saltwater data (e.g., hardness values exceeding 400 mg/L calcium carbonate), the data suggest that adverse effects will occur for acute exposures within criteria limits for the Mattaponi, Pamunkey, and James Rivers (Table 12).
3) VDEQ has not specified data sufficiency requirements or an implementation strategy for setting criteria for a given discharge or waterway, so it is not yet known whether implementation of the criteria will satisfactorily accommodate seasonal influences (e.g., litterfall, snowmelt) or climatic factors (e.g., drought) affecting aluminum bioavailablility.
4) The toxicity of aluminum in surrogate species indicate that exposures within criteria limits will likely result in adverse effects on behavior and growth at the juvenile and pre-juvenile lifestages that are expected to influence juvenile survival.
5) The viability of ESA-listed sturgeon populations in Virginia's waters are highly sensitive to juvenile mortality, resulting in lower numbers of sub-adults recruiting into the adult breeding population (ASSRT 2007; NMFS 1998).

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 area of the Federal action subject to consultation (50 CFR §402.02). Future Federal actions that are unrelated to the action under consultation are not considered in this section because they require separate consultations pursuant to section 7 of the ESA.

The future intensity of specific non-Federal activities in the action area is influenced by the difficult-to-predict future economy, funding levels for restoration activities, and individual investment decisions. In addition, the need for communities to adapt to climate change and recover from severe climatic events will influence how wetlands, inland surface waters, and coastal areas are managed. Due to their additive and long-lasting nature, the adverse effects of non-Federal activities that are stimulated by general resource demands and driven by changes in human population density and standards of living, are likely to compound in the future. Specific human activities that may contribute to declines in the abundance, range, and habitats of ESA-listed species in the action area include the following: urban and suburban development, shipping, infrastructure development, water withdrawals and diversion, recreation (including off-road vehicles and boating), and expansion of agricultural and grazing activities (including alteration or clearing of native habitats for domestic animals or crops), and introduction of non-native species which can alter native habitats, out-compete or prey upon native species.

Activities that degrade water quality will continue into the future. These include conversion of natural lands, land use changes from low impact to high impact activities, increases in impervious cover (e.g., Section 6), water withdrawals, effluent discharges, the progression of climate change, the introduction of nonnative invasive species, and the introduction of contaminants and pesticides. In particular, many nonpoint sources of pollution, which are not subject to Clean Water Act NPDES permit and regulatory requirements, have proven difficult for states to monitor and regulate. Nonpoint source pollution has been linked to loss of aquatic species' diversity and abundance, fish kills, seagrass bed declines, and toxic algal blooms (Gittings 2013). Nonpoint sources of pollution are expected to increase as the human population continues to grow. Given the challenges of monitoring and controlling nonpoint source pollution and accounting for all the potential stressors and effects on listed species, chronic stormwater discharges will continue to result in aggregate impacts.

8.1 Climate Change

Climate change is discussed in both the environmental baseline section of this opinion and in the cumulative effects because it is a current and ongoing circumstance that, for the most part, is not subject to consultation, yet influences environmental quality in the action area currently and in the future. As climate change proceeds, precipitation rates are following a small upward trend in Virginia. The number and intensity of extreme precipitation events are also projected to increase. The Chesapeake Bay area is the third most vulnerable area of the United States to sea level rise, behind Louisiana and South Florida (Runkle et al. 2022). The foremost impacts of sea level rise includes more frequent and severe coastal flood events, increased shore erosion, resulting in unmanaged pollutant discharges and redistribution of legacy pollutants in sediments, inundation of wetlands and low-lying lands, and saltwater intrusion into groundwater (Runkle et al. 2022).

9 INTEGRATION AND SYNTHESIS

The *Integration and Synthesis* section is the final step in our assessment of the risk posed to species and critical habitat because of implementing the action. In this section, we add the *Effects of the Action* (Section 7) to the *Environmental Baseline* (Section 6) and the *Cumulative Effects* (Section 9) to formulate the agency's biological opinion as to whether the action is likely to reduce appreciably the likelihood of both the survival and recovery of a ESA-listed species in the wild by reducing its numbers, reproduction, or distribution. This assessment is made in full consideration of the *Status of the Species Likely to be Adversely Affected by the Action* (Section 5.2). Populations that occur in the Sturgeon Waters within Virginia are of primary concern for this action.

Some ESA-listed species and critical habitat are located within the action area but the effects of the action on these ESA resources were determined to be insignificant or discountable and thus not likely to adversely affect these resources. Some exposures and responses evaluated individually (e.g., exposure of Fin whale to affected waters, absence of biological features for Atlantic sturgeon critical habitat) were determined to have insignificant effects or discountable effects and thus to be not likely to adversely affect some ESA-listed species and critical habitat (Section 5.1).

The following discussions provide an overview of the findings of this opinion and a Jeopardy Analysis that summarizes the probable risks the action poses to shortnose surgeon and the Atlantic sturgeon Chesapeake Bay DPSs and migrating and foraging New York Bight, Gulf of Maine, Carolina, and South Atlantic DPSs. These summaries integrate the exposure profiles presented previously with the results of our response and risk analyses (Section 7.3) for each of the water quality criteria considered further in this opinion.

9.1 Overview

This opinion concludes that EPA approval of VADEQ’s adoption and implementation of Nationally Recommended Freshwater Criteria for aluminum is likely to adversely affect early lifestage and young of year shortnose sturgeon and the Chesapeake DPS of Atlantic sturgeon that may spawn within Virginia rivers. The viability of ESA-listed sturgeon populations in Virginia waters is highly sensitive to juvenile mortality resulting in lower numbers of sub-adults recruiting into the adult breeding population (NMFS 1998a, ASSRT 2007).

For example, poor water quality in these rivers contributes to the stressor scores for shortnose sturgeon (Section 5.2.2). If sufficient up to date monitoring data in Sturgeon Waters were available, it could indicate whether baseline conditions attenuate the concern that the criteria concentrations are not sufficiently protective. When revised criteria are more protective than those currently applied to discharge permits, and rigorous monitoring information indicates that baseline instream concentrations are below effects thresholds, then it is reasonable to expect more stringent criteria applied to permits would not result in exposures above those thresholds.

Current water quality impairments with TMDLS in sturgeon waters are attributed to indicators of eutrophication (e.g. low dissolved oxygen, aquatic vegetation), persistent biomagnifying chemicals in biota (i.e., mercury and PCBs), pH, temperature and bacteria (Section 6.2). Given available water quality and discharge monitoring data, exposures of shortnose and Atlantic sturgeon to aluminum are likely to occur through stormwater runoff and discharges from facilities that use either these metals or treat waste containing these metals. Under section 402 of the Clean Water Act, a discharge permit will includes discharge limits for substances if there is a reasonable potential that the discharge would result in pollutant levels that would impair the designated use of the receiving water (40 CFR 122.44(d)(1)). Permitting decisions are made on an individual basis and aggregate impacts of discharge authorizations, TMDLs, are only considered when an impairment is identified.

Once EPA approves the criteria, they will be implemented by VADEQ’s VPDES programs. The authority to implement the VPDES program is accompanied by a Memorandum of Agreement with EPA. However, unlike other states, the memorandum between EPA and Virginia does not incorporate measures that satisfy EPA’s obligations under the ESA such as allowing for the Services’ review of NPDES permits. Nevertheless, NMFS OPR does receive some permits from the state for review. Those state memoranda of agreement with EPA that include ESA measures only provide for review of individual permits potentially affecting ESA-listed species as they are drafted. Yet, criteria are in place indefinitely and are applied to multiple sources within a watershed. Thus, there is an aggregate impact to EPA's approval, and subsequent implementation of criteria under 303(c) of the Clean Water Act that is not addressed by 303(c) consultation and permit review.

In the absence of rigorous monitoring information, water quality data collected *after* implementation of revised criteria may or may not indicate whether actual instream concentrations are below effects thresholds. It is reasonable that the constituents monitored for are selected based on what is likely to be present given local land usage and industries. For example, if sampling in the Everglades, 1 might monitor for nutrients and sugarcane pesticides, but not industrial chemicals. Aluminum, however, is a ubiquitous pollutant such that current VPDES permits require monitoring for aluminum even though, in the absence of criteria, permit limits cannot be applied.

The analyses in Section 7 of this opinion establish that early-life-stage shortnose sturgeon and Atlantic sturgeon are likely to be exposed to aluminum in Virginia Sturgeon Waters and that adverse effects are expected to occur in early-life-stage individuals exposed within respective criteria limits.

9.2 Jeopardy Analysis

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 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 CFR §402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species, by focusing on effects to reproduction, numbers, and distribution.

9.2.1 Shortnose Sturgeon

Whether the potential effects to reproductive output would appreciably reduce the likelihood of survival of shortnose sturgeon in the wild depends on the probable effect the changes in reproductive output would have relative to current population sizes and trends. The most recent population estimates available for the species indicate that the largest shortnose sturgeon adult populations are found in the northeastern rivers.

The current distribution of shortnose sturgeon in the Chesapeake Bay is unknown as there is limited data regarding their distribution (SSSRT 2010), and there is no information available for shortnose sturgeon foraging areas in the Chesapeake Bay. A study by Niklitschek (2001) indicated via modeling that suitable foraging habitat during the summer months is limited to the upper tidal portions of the upper Bay, the Potomac, and the James rivers. The Potomac River is considered to be tidally influenced up to the Chain Bridge which lies just 2 km upstream of the suspected spawning area at Fletcher's Marina. Two late-stage females were captured and tracked within the Potomac, however only 1 was observed to make an apparent spawning migration in the spring (2005 – 2007, SSSRT 2010). Annual movements of shortnose sturgeon in the Potomac River seem typical of north-central adults. Both of the tracked female sturgeon remained in freshwater for at least 1 year with pre-spawning migration occurring in spring. Shortnose sturgeon that are found within the Chesapeake Bay may be migrants from the Delaware River.

One adult shortnose sturgeon has been captured in the James River in March 2016 (Balazik 2017), as well as 1 gravid female just downstream of the Hog Island discharge in February 2018. These are the only records of shortnose sturgeon captures in the southwestern portion of the Chesapeake Bay. Modeling by Niklitschek (2001) indicates that suitable habitats for shortnose sturgeon were very restricted during the summer months with favorable foraging habitat limited to upper tidal portions of the James River.

The 1998 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). Even though shortnose sturgeon were listed under the ESA over 50 years ago, population dynamics and distribution data are lacking for many population segments. A range-wide genetic assessment and reliable estimates of population size, age structure, and recruitment are needed to review the status of each population segment. The recovery tasks for the Delaware River shortnose sturgeon population segment that are relevant to the impacts of the action include analyzing contaminant loads in sturgeon tissue and habitat, determining effects of contaminants on sturgeon fitness, and identifying contaminant sources and reducing contaminant loading. These are classified as Priority 2 tasks, which are actions "that must be taken to prevent a significant decline in population numbers, habitat quality, or other significant negative impacts short of extinction" (NMFS 1998). These tasks for the Chesapeake Bay population segment lack priority rankings because very little is known about its status. Documentation of distribution and mapping of sturgeon concentration areas is ongoing and determination of the abundance, age structure, and recruitment is the highest prioritized task.

Section 7.2 and Section 7.3 address the responses of individuals to exposures within criteria limits and the risks those responses pose to the populations to which those individuals belong. Effects of exposures to aluminum within acute criterion limits is not expected to reduce numbers through direct toxicity, but may temporarily affect habitat use. Exposures within the freshwater chronic criterion limit are not expected to affect fish fertilization or hatch success, but may cause avoidance and influence early lifestage growth. It is important to consider that young sturgeon drift towards the estuary and remain above the salt wedge for 1-5 years so exposures would occur along the river length and in rearing habitat. While avoidance is a rapid response that would occur well within the acute aluminum criterion limit, we expect there will be few instances of shortnose sturgeon occurring in the same place at the same time as an acute pulse of aluminum.

Exposures to aluminum within aquatic chemistry-adjusted chronic criteria limits is not expected to affect reproduction. The studies reporting an EC50 and an EC20 for effects on growth and development from sustained exposures at or near the criterion concentration over 28 and more than 30-day exposures, respectively, suggest significant effects on early life stage sturgeon. A sustained exposure leaves no opportunity for clearance and recovery of gill tissues (Lyndon and

Houlihan 1998). Yolk sac larvae spend the first 8-12 days near the spawning site; thereafter they begin drifting towards the estuary, settling above the salt wedge at about 40 days. Due to diurnal fluctuations in pH and other aquatic chemistry parameters, along with varying aquatic chemistry due to catchment land use and geology (Bourg and Bertin 1996; Hamid et al. 2019; Scholefield et al. 2005), exposures to a sustained concentration of aluminum at the criterion concentration along this migration route is unlikely in unimpaired waters.

Based on the available evidence, including that described in the Environmental Baseline, Effects of the Action, and Cumulative Effects sections of this opinion, effects resulting from EPA approval of the freshwater aluminum criterion would not be expected to appreciably reduce the likelihood of the survival of shortnose sturgeon in the wild by reducing the reproduction, numbers, or distribution of these populations. We also conclude that effects from EPA's approval of the aluminum criterion would not be expected, directly or indirectly, to appreciably reduce the likelihood of recovery of shortnose sturgeon in the wild by reducing the reproduction, numbers, or distribution of these populations.

9.2.2 Atlantic Sturgeon

Whether the potential effects to reproductive output would appreciably reduce the likelihood of survival of the Chesapeake Bay DPS of Atlantic sturgeon in the wild depends on the probable effect the changes in reproductive output would have relative to current population sizes and trends.

In the absence of quantitative population estimates of Atlantic sturgeon DPSs, the Atlantic States Marine Fisheries Commission considers qualitative criteria such as the appearance of Atlantic sturgeon in rivers where they were not documented in recent years, discovery of spawning adults in rivers they had not been documented in before, and increases in anecdotal interactions. Kahn et al. (2019) proposed the following ranking of qualitative evidence of Atlantic sturgeon spawning:

Confirmed spawning:

1. Recently spawned-out female still releasing nonviable eggs in freshwater in the presence of milting males;
2. Spawning female (actively releasing viable eggs in freshwater in the presence of milting males);
3. Presence of eggs to 180 d post-hatch fish.

Near certain spawning;

1. Juveniles under 400 millimeters FL in fresh- water or low-salinity areas;
2. Gravid female in upstream freshwater (at least 15 km upstream of the freshwater/ saltwater interface).

Possible Spawning;

1. Milting male in upstream freshwater.

Uncertain spawning;

1. Capture of adult in any condition in lower freshwater (near salinity interface);
2. Telemetry detection of adult female in unknown reproductive stage in freshwater.

Uninformative Evidence;

1. Telemetry detection of adult male in unknown sexual condition in upstream or lower freshwater.

Qualitative metrics can be the result of increased research and attention, not a true increase in abundance (ASMFC 2017a). Both the New York Bight and Chesapeake Bay DPSs of Atlantic sturgeon are considered depleted and are highly vulnerable to climate change due to their low likelihood to change distribution in response to current global climate change. They will also be exposed to effects of climate change on estuarine habitat such as changes in the occurrence and abundance of prey species in currently identified key foraging areas (ASSRT 2022a; ASSRT 2022c).

Atlantic sturgeon are considered in danger of extinction in Virginia. The Chesapeake Bay DPS's risk of extinction is "High" because of its low productivity (e.g., relatively few adults compared to historical levels and irregular spawning success), low abundance (e.g., only 3 known spawning populations and low DPS abundance, overall), and limited spatial distribution (e.g., limited spawning habitat within each of the few known rivers that support spawning). There is also new information indicating genetic bottlenecks as well as low levels of inbreeding.

NMFS's vision, explained in the recovery outline, is that subpopulations of all 5 Atlantic sturgeon DPSs must be present across the historical range. These subpopulations must be of sufficient size and genetic diversity to support successful reproduction and recovery from mortality events. The recruitment of juveniles to the sub-adult and adult lifestages must also increase and must be maintained over many years. Recovery of these DPSs will require conservation of the riverine and marine habitats used for spawning, development, foraging, and growth by abating threats to ensure a high probability of survival into the future. The outline includes a recovery action to implement region-wide initiatives to improve water quality in sturgeon spawning rivers, with specific focus on eliminating or minimizing human-caused anoxic zones.

Section 7.2 and Section 7.3 address the responses of individuals to exposures within criteria limits and the risks those responses pose to the populations those individuals belong to. Effects of exposures to aluminum within acute criterion limits is not expected to reduce numbers through direct toxicity, but may temporarily affect habitat use. Exposures within the freshwater chronic criterion limits is not expected to affect fish fertilization or hatch success, but may cause avoidance and influence early lifestage growth. It is important to consider that young sturgeon drift towards the estuary remain above the salt wedge for 1-5 years so exposures would occur along the river length and in rearing habitat. While avoidance is a rapid response that would occur well within the acute aluminum criterion limits, we expect there will be few instances of shortnose sturgeon occurring in the same place at the same time as an acute pulse of aluminum.

Exposures to aluminum within chronic criteria limits is not expected to affect reproduction. The studies reporting an EC50 and an EC20 for effects on growth and development from sustained exposures at or near the criterion concentration over 28 and more than 30-day exposures, respectively suggests significant effects on early lifestage sturgeon. A sustained exposure leaves no opportunity for clearance and recovery of gill tissues (Lyndon and Houlihan 1998). Yolk sac larvae spend the first 8-12 days near the spawning site; thereafter they begin drifting towards the estuary, settling above the salt wedge at about 40 days. Due to diurnal fluctuations in pH and other aquatic chemistry parameters, along with varying aquatic chemistry due to catchment land use and geology (Bourg and Bertin 1996; Hamid et al. 2019; Scholefield et al. 2005), exposures to a sustained concentration of aluminum at the criterion concentration along this migration route is unlikely in unimpaired waters.

Based on the available evidence, including that described in the Environmental Baseline, Effects of the Action, and Cumulative Effects sections of this opinion, effects resulting from EPA approval of the freshwater aluminum criteria would not be expected to appreciably reduce the likelihood of the survival of the Chesapeake Bay DPSs of Atlantic sturgeon in the wild by reducing the reproduction, numbers, or distribution of these populations. We also conclude that effects from EPA's approval of the aluminum criteria would not be expected, directly or indirectly, to appreciably reduce the likelihood of recovery of the Chesapeake Bay DPS of Atlantic sturgeon in the wild by reducing the reproduction, numbers, or distribution of these populations.

10 CONCLUSION

After reviewing the current status of the ESA-listed species, the environmental baseline within the action area, the effects of the action, and cumulative effects, it is NMFS's biological opinion that the action is likely to adversely affect, but is not likely to jeopardize the continued existence of shortnose sturgeon or the Chesapeake Bay DPS of Atlantic sturgeon.

11 INCIDENTAL TAKE STATEMENT

ESA section 9 of the ESA and Federal regulations pursuant to section 4(d) 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 (16 U.S.C. §1532(19)). 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 (see 50 CFR § 222.102).

Incidental take is defined as take that results from, but is not the purpose of, carrying out an otherwise lawful activity (see 50 CFR §402.02). Section 7(b)(4) of the ESA requires that when a proposed agency action is found to be consistent with section 7(a)(2) of the ESA and the proposed action may incidentally take individuals of ESA-listed species, NMFS will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. Sections 7(b)(4) and 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking if that action is performed in compliance with the terms and conditions of this incidental take statement.

Exposures of shortnose sturgeon and Chesapeake Bay DPS to aluminum within criteria limits in the action area is reasonably certain to result in incidental take due to the reductions in survival of early lifestage fish and fitness of these species.

11.1 Amount or Extent of Take

Section 7 regulations require NMFS to specify the impact of any incidental take of endangered or threatened species; that is, the amount or extent, of such incidental taking on the species (50 CFR §402.14(i)(1)(i)). The amount of take represents the number of individuals that are expected to be taken by the proposed action. The extent of take represents the "extent of land or marine area that may be affected by an action" and may be used if we cannot assign numerical limits for animals that could be incidentally taken during the course of an action (51 FR 19953).

Where it is not practical to quantify the number of individuals that are expected to be taken by the action, a surrogate (e.g. similarly affected species or habitat or ecological conditions) may be used to express the amount or extent of anticipated take (50 CFR §402.14(i)(1)(i)). To use a surrogate we must describe the causal link between the surrogate and take of the listed species, explain why it is not practical to express the amount or extent of anticipated take or to monitor take-related impacts in terms of individuals of the listed species, and set a clear standard for determining when the level of anticipated take has been exceeded

Incidental take under the aluminum criteria cannot be accurately quantified or monitored as a number of individuals because the action area includes all waters of Virginia. Data do not exist that would allow us to quantify how many individuals of each species and lifestage exist in affected waters, considering that the numbers of individuals vary with environmental conditions, and changes in population size due to recruitment and mortality, and in the case of Atlantic sturgeon, emigration from other populations. In addition, currently we have no means to detect or determine which impairments to reproduction, development, and growth are due to the water quality within criteria limits versus other natural and anthropogenic environmental stressors.

Further, NMFS cannot precisely predict the number of shortnose sturgeon and Atlantic sturgeon that are reasonably certain to demonstrate behavioral and injurious effects due to the presence of aluminum within criteria limits. Also, there is no feasible way to count, observe, or determine the number of individuals of each species that would be affected by exposures because the effects of the action will occur over a large geographic area and effects may occur in areas where animals are not likely to be observed due to water depth. Even if affected animals are observed, it is unlikely that the exact cause of injury, mortality or behavioral effects could be determined.

Because we cannot quantify the amount of take, we will use the regulatory application of the criteria in setting permitting and TMDL limits and identifying water quality impairments as a measure reflecting the potential for harmful exposures to aluminum for the extent of authorized take as a surrogate for the amount of authorized take. Take would be exceeded if receiving waters for sources discharging aluminum are found to be impaired by aluminum even though permitted sources are complying with discharge limits and the impairment cannot be attributed solely to nonpoint sources. This suggests that other permitted sources discharging to the water body should have been assigned permit limits for aluminum. Take may also be exceeded if aluminum within criteria limits is identified as a contributing causal agent for impairment of an aquatic assemblage in the sense of the findings of Spehar and Fiandt (1986).

For the reasons discussed above, the specified amount or extent of incidental take of ESA-listed shortnose and Atlantic sturgeon species requires that VADEQ's intended level of protection is met, as confirmed through the terms and conditions specified in this incidental take statement. The amount or extent of incidental take applies only to exposures when waters are monitored using sufficiently sensitive analytical methodology as defined in the 122.44(i)(1)(iv) of the Clean Water Act. Effects of the action could manifest later in time. Discharge limits are determined using sufficiently sensitive analytical methodology. If sufficiently sensitive analytical methodology is not applied, it will be not possible to confirm whether VADEQ's intended level of protection is met. NMFS expects that, upon identification, Virginia and EPA will address any noncompliance with 40 CFR 136. This reflects VADEQ and EPA's intended level of protection for aquatic life and ensures that exceedances will be detected and addressed, thereby minimizing take.

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 CFR 402.02). Section 7(b)(4) of the ESA requires that when an agency action is found to be consistent with section 7(a)(2) of the ESA and the action may incidentally take individuals of ESA-listed species, the U.S. Fish & Wildlife Service (USFWS) or National Marine Fisheries Service (NOAA Fisheries), collectively "the Services," will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. To minimize such impacts, reasonable and prudent measures (RPMs), and term and conditions to implement the measures, must be provided. Only incidental take resulting from the agency actions and any specified reasonable and prudent measures and terms and conditions identified in the incidental take statement are exempt from the taking prohibition of section 9(a), pursuant to section 7(o) of the ESA.

RPMs are defined by regulation as: "those actions the Director believes necessary or appropriate to minimize the impacts, i.e., amount or extent, of incidental take" (50 CFR 402.02). NMFS believes the RPMs described below, which were refined in cooperation with EPA, are necessary and appropriate to minimize the impacts of incidental take on threatened and endangered species resulting from exposure to aluminum within criteria limits:

1. EPA Region 3, Water Division will ensure that VADEQ is aware of the Aluminum TSD's[16] methods for applying the freshwater aluminum criteria site-specifically and the TSD's intent that threatened or endangered species be considered in such application.
2. EPA Region 3, Water Division will work within its authorities to ensure that the implementation of freshwater aluminum criteria adopted by Virginia minimize aggregate adverse effects to ESA-listed species and designated critical habitat under NOAA Fisheries' jurisdiction.
3. EPA Region 3 will ensure that persons applying EPA-approved standards in regulatory actions and those who are subject to regulations applying EPA-approved standards are aware of the prohibition of take of ESA-listed species under section 9 of the ESA and where ESA-listed species under NOAA Fisheries' jurisdiction occur.

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.

Terms and Conditions for RPM 1:

The EPA Region 3, Water Division shall achieve RPM 1 by reminding and encouraging VADEQ to be consistent with the aluminum TSD's intent that endangered or threatened species be considered when applying the freshwater aluminum criteria site-specifically. At the time of this Biological Opinion, VADEQ does not have seasonally and hydrologically representative data to allow the calculation of location-specific criteria using Aluminum TSD methods 1 or 2. Method 3: "Select the lowest Criteria Calculator outputs calculated from available input data" for Sturgeon Waters is expected to be applied until such time as VADEQ is able to use one or both of the other methods. This could result in a period of inadequate protection, given that data available for method 3 may not have been collected under conditions when aluminum was most biologically available (and therefore most toxic).

1) In its CWA 303(c) decision letter, EPA will strongly encourage VADEQ to be consistent with the aluminum TSD's intent that endangered or threatened species be considered when applying the freshwater aluminum criteria site-specifically.

Terms and Conditions for RPM 2:

The EPA Region 3, Water Division shall achieve RPM 2 by ensuring that criteria that protect species over the full range of water chemistry conditions, including during conditions when aluminum is most toxic, are applied in Virginia waters where endangered shortnose sturgeon and endangered Chesapeake Bay DPSs of Atlantic sturgeon may occur and where endangered

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[16] EPA, Draft Technical Support Document: Implementing the 2018 Recommended Aquatic Life Water Quality Criteria for Aluminum, EPA-800-D-21-001, 2021, https://www.epa.gov/system/files/documents/2021-11/aluminum-tsd-draft-2021.pdf

New York Bight, Carolina, and South Atlantic DPSs and the threatened Gulf of Maine DPS for Atlantic sturgeon may migrate and forage (Sturgeon Waters). EPA shall also provide guidance to VADEQ on the use of the revised criteria in VPDES permits for new sources and existing VPDES permits upon renewal, and participating in sustained attention[17] to water quality within waters where Atlantic and shortnose sturgeon occur. Specifically:

1) EPA will encourage VADEQ to develop implementation guidance for the application of Virginia's freshwater aluminum water quality criteria in Sturgeon Waters. As part of that coordination, EPA will strongly encourage VADEQ to consider and include the following in the implementation guidance, where appropriate:
    a. In the absence of sufficient data for Aluminum TSD methods 1 or 2, VADEQ should use the most recent stream order-specific fifth percentile MetALiCC-MAP criteria for Sturgeon Waters and adjacent catchments.
    b. When adequate seasonally and hydrologically representative data are available for calculating location-specific criteria, VADEQ should consider (1) establishing a default process that would use the fifth percentile of criteria outputs for VPDES permits discharging to Sturgeon Waters and adjacent catchments absent a showing that some other percentile of outputs would be adequately protective of sturgeon; and (2) apply a seasonally-specific fifth percentile of criteria outputs, where available, for Clean Water Act 305(b) assessments and 303(d) impairment listings.
2) EPA will request that VADEQ release the draft implementation guidance for Sturgeon Waters for public notice and comment.

   If VADEQ chooses to release the draft implementation guidance for comment, EPA will: (1) make best efforts to support VADEQ's release of draft implementation guidance for public comment within 18 months of this Biological Opinion, (2) notify NOAA Fisheries of the draft implementation guidance and request that NOAA Fisheries comment publicly, and (3) support VADEQ's finalization of implementation guidance within 6 months after the public comment period has closed.
3) While not binding, Section IX of the 2001 MOA establishes a framework for coordinating actions for permitting program activities under the CWA section 402. Specifically, EPA will remind VADEQ of its obligation pursuant to 40 C.F.R. §§ 124.10(c)(1)(iv) and (e) to provide notice and copies of draft permits and related documents to NOAA Fisheries. To the extent possible, EPA and NOAA Fisheries will follow the 9 coordination procedures regarding issuance of State permits specified in Section IX. A. of the 2001 MOA in a manner consistent with statutory and regulatory procedures. This provides for NOAA Fisheries' review of draft state-issued permits for

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[17] Consistent and continued vigilance for the purpose of early detection and mitigation of emerging problems

discharges that may affect ESA-listed sturgeon species for the purposes of technical assistance to ensure that permitted aluminum discharges minimize take.

4) As practical, EPA will, when reviewing permits under its regular permit review practices under CWA section 402(d) and 40 C.F.R. § 123.44, evaluate draft NPDES permits prepared by VADEQ for discharges into Sturgeon Waters, and consider whether the effluent limitations were developed using a sufficiently sensitive methodology in determining monitoring requirements and discharge limits.
5) The EPA will, when reviewing Virginia's list of waters pursuant to CWA section 303(d), consider whether Virginia has appropriately implemented its freshwater Aluminum criterion in a manner that minimizes take of ESA-listed sturgeon.
6) EPA will strongly encourage VADEQ to monitor aluminum in Sturgeon Waters.
7) If EPA becomes aware of new information that indicates revisions to criteria subject to this consultation may be necessary to protect threatened and endangered species, EPA will work with Virginia regulatory authorities to revise water quality standards or take other actions, as appropriate.
8) Baseline Water Quality Review
    a. Within 6 months of the signature of the Biological Opinion, EPA will collaborate with NOAA Fisheries on the development of a baseline water quality condition tool for those stressors addressed in this consultation in waters where Atlantic and shortnose sturgeon occur.
    b. Thereafter, EPA will meet with NOAA Fisheries at least biannually, for a period of 6 years, but not to exceed a period of 10 years, to review water quality conditions for those stressors addressed in this consultation potentially affecting Atlantic and shortnose sturgeon and discuss changes in water quality, gaps in information regarding water quality, and approaches to resolving those gaps.

Terms and conditions for RPM 3:

The EPA Region 3, Water Division shall achieve RPM 3 through supporting other EPA Region 3 branches applying EPA-approved criteria subject to this consultation.

1) The EPA Water Division will notify the VADEQ and EPA-Region 3 NPDES Permit Branch of: 1) updated freshwater water quality criteria for aluminum, and 2) the importance of compliance with permit limits based on such criteria in all NPDES permits, including general permits, to protect threatened and endangered species, including the Atlantic and shortnose sturgeon

2) EPA Region 3, Water Division will provide notice of EPA's obligations under the ESA in its communications, as appropriate, including, but not limited to, 303(c) decision letters, NPDES permit development and decisions, permit application materials, training, and/or informational websites. Such notice shall contain the following

a. Section 7(a)(2) of the ESA requires Federal agencies 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 and proposed critical habitat.

b. Take of ESA-listed endangered species is prohibited under section 9 of the ESA, and these prohibitions apply to all individuals, organizations, and agencies subject to United States jurisdiction. These take prohibitions have also been extended to the Chesapeake Bay DPS of Atlantic Sturgeon under section 4(d) of the ESA (50 CFR §223.211).

c. "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 16 U.S.C. 1532(19). "Harm" for purposes of the ESA is further defined by regulation to mean "an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including, breeding, spawning, rearing, migrating, feeding or sheltering" 50 CFR §222.102.

d. Endangered shortnose sturgeon, endangered Chesapeake Bay DPSs of Atlantic sturgeon may spawn, migrate, and forage within accessible inland rivers, estuaries, and coastal waters from Canada to Florida. Poor water quality is among the most significant threats to the species due to harm to offspring development. Sensitive early lifestages may occur in the following waters of Virginia: Potomac River, Rappahannock River, York River, Mattaponi River, Pamunkey River, James River and the Chesapeake Bay.

11.3 Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on ESA-listed species or critical habitat, to help implement recovery plans or develop information (50 CFR § 402.02).

1) Actions or measures that could also minimize or avoid adverse effects of adopted freshwater aluminum criteria on ESA-listed sturgeon species under NMFS's jurisdiction include:

   a) Consistent with the Memorandum of Agreement between the Environmental Protection Agency, Fish and Wildlife Service and National Marine Fisheries Service Regarding Enhanced Coordination Under the Clean Water Act and Endangered Species Act, revise the Memoranda of Agreement with the Commonwealth of Virginia to include measures that support EPA's obligations under the ESA.

   b) Coordinate with nationally recognized sturgeon experts from government and academic institutions to close gaps in our understanding of the effects of aluminum on the biology, ecology, and recovery of shortnose and Atlantic sturgeon.

   c) Coordinate with state and Federal agencies that carry out water quality monitoring in waters where sturgeon occur or could reestablish to sample and analyze for aluminum where significant sources occur or are suspected.

   d) Use information gained in items b) and c) above, along with up-to-date toxicity data, to determine whether sturgeon are at risk from exposure to aluminum.

   e) If the analysis in item d) above indicate species are currently at risk or may be at risk in the future, coordinate with private, state, and Federal stakeholders to develop and implement actions that minimize or prevent such risks.

2) EPA is increasingly developing aquatic chemistry-based guidelines. Actual implementation of such guidelines as regulatory criteria is complex. To support states in adopting these criteria, EPA should:

   a) Provide strategy and tools to assist states with implementation at the same time EPA issues a set of aquatic chemistry-based guidelines.

   b) Consider whether aquatic chemistry-based guidelines themselves should include "guardrails" to prevent misapplication. Establish guardrails where needed.

   c) Include strategies that address seasonality, climate, hydrology, and other factors that may influence variability or trends in aquatic chemistry bioavailability drivers.

   d) Provide advanced notice of the aquatic chemistry parameters and anticipated data requirements, including factors influencing variability, to states and the regulated community so that they can, if they choose, collect the necessary data to effectively implement the guidelines.

3) Aluminum does not exist alone in effluents or natural waters. The toxicity of mixtures is dependent upon many factors, such as which chemicals are most abundant, their concentration ratios, differing factors affecting bioavailability, and organism differences. Because of this complexity, accurate predictions of the combined effects of chemicals in mixtures in every case where the criteria assessed in this opinion are applied is not current practice. The work of Spehar and Fiandt (1986) showed 100 percent mortality in rainbow trout and *Ceriodaphnia dubia* exposed to a mixture of 6 metals at their CMC concentrations suggests severe effects could result from exposure to compliant discharges and within "unimpaired" waters. EPA OW could collaborate with NMFS on the development of a baseline water quality condition tool for all stressors in waters where Atlantic and shortnose sturgeon occur. EPA OW could then periodically review water quality conditions potentially affecting Atlantic and shortnose sturgeon and identify both positive and negative changes in

water quality, gaps in information regarding water quality, and approaches to resolving those gaps.

4) Engage in a Framework Programmatic consultation with NMFS to establish procedures to address information needs for Regional 303(c) consultations and the aggregate ESA implications of EPA's guidelines.
5) In order for the NMFS Office of Protected Resources ESA Interagency Cooperation Division to be kept informed of actions minimizing or avoiding adverse effects on, or benefiting, ESA-listed species or their critical habitat, EPA should notify the ESA Interagency Cooperation Division of any conservation recommendations they implement in their final action.

11.4 Reinitiation Notice

This concludes consultation on EPA approval of water quality standards proposed in 2023 by the state of Virginia. Consistent with 50 CFR §402.16(a), reinitiation of formal consultation is required and shall be requested by the Federal agency, where discretionary Federal involvement or control over the action has been retained or is authorized by law and:

1. The amount or extent of taking specified in the incidental take statement is exceeded;
2. New information reveals effects of the agency action that may affect ESA-listed species or critical habitat in a manner or to an extent not previously considered;
3. The identified action is subsequently modified in a manner that causes an effect to the ESA-listed species or critical habitat that was not considered in this opinion; or
4. A new species is listed or critical habitat designated under the ESA that may be affected by the action.

12 LITERATURE CITED

Adhikari, R. A., K. C. B. Krishna, and R. Sarukkalige. 2016. Evaluation of phosphorus adsorption capacity of various filter materials from aqueous solution. Adsorption Science & Technology 34(4-5):320-330.

Akçakaya, H. R., and W. T. Root. 2007. RAMAS Red List Professional: Spatial and Temporal Data Analysis for Threatened Species Classifications Under Uncertainty. Applied Biomathematics, Setauket, New York.

Alam, S. K., M. S. Brim, G. A. Carmody, and F. M. Parauka. 2000. Concentrations of heavy and trace metals in muscle and blood of juvenile Gulf sturgeon *(Acipenser oxyrinchus desotoi*) from the Suwannee River, Florida. Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering 35(5):645-660.

American Rivers. 2002. The Ecology of Dam Removal: A Summary of Benefits and Impacts, https://www.americanrivers.org/wp-content/uploads/2016/05/EcologyOfDamRemovalcf24.pdf.

Anderson, J. T. 1988. A Review of Size Dependant Survival During Pre-recruit Stages of Fishes in Relation to Recruitment. Journal of Northwest Atlantic Fishery Science 8:55-66.

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

ASMFC. 2017a. Atlantic States Marine Fisheries Commission Atlantic Sturgeon Benchmark Stock Assessment and Peer Review Report, Arlington, VA. 456 pp.

ASMFC. 2017b. Special Report to the ASMFC Atlantic Sturgeon Management Board: Estimation of Atlantic Sturgeon Bycatch in Coastal Atlantic Commercial Fisheries of New England and the Mid Atlantic Atlantic States Marine Fisheries Commission, Arlington, VA

ASSRT. 1998. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*).

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

ASSRT. 2022a. Chesapeake Bay Distinct Population Segment of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) - 5 Year Review: Summary and Evaluation. GARFO, editor, Gloucester, Massachusettes.

ASSRT. 2022b. Gulf of Maine Distinct Population Segment of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) 5-Year Review: Summary and Evaluation. Pages 34 pp *in*, Northeast Regional Office.

ASSRT. 2022c. New York Bight Distinct Population Segment of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) 5-Year Review: Summary and Evaluation. Pages 38 pp *in*, Northeast Regional Office.

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

Bain, M. B. 1997. Atlantic and shortnose sturgeons of the Hudson River: Common and divergent life history attributes. Environmental Biology of Fishes 48(42739):347-358.

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

Baker, J. D. L., C. L.;Johnston, D. W. . 2006. Potential effects of sea level rise on the terrestrial habitats of endangered and endemic megafauna in the Northwestern Hawaiian Islands. Endangered Species Research 4:42745.

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

Balazik, M. T., D. J. Farrae, T. L. Darden, and G. C. Garman. 2017. Genetic differentiation of spring spawning and fall spawning male Atlantic sturgeon in the James River, Virginia. PLoS One 12(7):e0179661.

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

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

Barata, C., and D. J. Baird. 2000. Determining the ecotoxicological mode of action of chemicals from measurements made on individuals: results from instar based tests with *Daphnia magna* Straus. Aquatic Toxicology 48(2-3):195-209.

Bateman, D. H., and M. S. Brim. 1994. Environmental contaminants in Gulf sturgeon of Northwest Florida 1985-1991. USFWS Publication Number PCFO-EC 94-09. Panama City, Florida. 23pp.

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(7):1875-1880.

Berlin, W. H., R. J. Hesselberg, and M. J. Mac. 1981. Chlorinated hydrocarbons as a factor in the reproduction and survival of Lake Trout (*Salvelinus namaycush*) in Lake Michigan. USFWS Technical Paper 105 42 pp.

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

Birge, W. J. 1978. Aquatic toxicology of trace elements of coal and fly ash. In: J.H. Thorp and J.W. Gibbons (Eds.), Dep. Energy Symp. Ser., Energy and Environmental Stress in Aquatic Systems, Augusta, GA, 219-240.

Birge, W. J., J. E. Hudson, J. A. Black, and A. G. Westerman. 1978. Embryo-larval bioassays on inorganic coal elements and in situ biomonitoring of coal-waste effluents. In: Symp., U.S. Fish Wildl. Serv., Dec. 3-6, 1978, Surface Mining Fish Wildlife Needs in Eastern U.S., WV, 97-104.

Birge, W. J., A. G. Westerman, and J. A. Spromberg. 2000. Comparative toxicology and risk assessment of amphibians. e. a. E. D.W. Sparling, editor. Ecotoxicology of Amphibians and Reptiles, Chapter 14A, SETAC Spec. Publ., 727-791.

Birukawa, N. A., H.;Goto, M.;Kanda, N.;Pastene, L. A.;Nakatsuji, H.;Hata, H.;Urano, A. . 2005. Plasma and urine levels of electrolytes, urea and steroid hormones involved in osmoregulation of cetaceans. Zoolog Sci 22(11):1245-57.

Blankenship, K. 2021. Anglers hook rare sturgeon in Potomac. Bay Journal.

Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Environmental Biology of Fishes 48(42739):399-405.

Botté, A., M. Zaidi, J. Guery, D. Fichet, and V. Leignel. 2022. Aluminium in aquatic environments: abundance and ecotoxicological impacts. Aquatic Ecology 56.

Bourg, A. C. M., and C. Bertin. 1996. Diurnal variations in the water chemistry of a river contaminated by heavy metals: natural biological cycling and anthropic influence. Water, Air, and Soil Pollution 86(1):101-116.

Brosse, L. D., P.;Lepage, M.;Rochard, E. . 2002. Evaluation of a gastric lavage method for sturgeons. North American Journal of Fisheries Management 22(3):955 - 960.

Brundage III, H. M., and J. C. O'Herron II. 2009. Investigations of Juvenile Shortnose And Atlantic Sturgeons in the Lower Tidal Delaware River. Bulletin: New Jersey Academy of Science 54(2).

Buckler, D. R., L. Cleveland, E. E. Little, and W. G. Brumbaugh. 1995. Survival, sublethal responses, and tissue residues of Atlantic salmon exposed to acidic pH and aluminum. Aquatic Toxicology 31(3):203-216.

Buckley, J., and B. Kynard. 1981. Spawning and rearing of shortnose sturgeon from the Connecticut River. The Progressive Fish-Culturist 43(2):74-76.

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

Bushnoe, T. M., J. A. Musick, and D. S. Ha. 2005. Essential spawning and nursery habitat of Atlantic sturgeon (Acipenser oxyrinchus) in Virginia. Draft Provided by Jack Musick, Virginia Institute of Marine Science, Gloucester Point, Virigina.

Call, D. J., and coauthors. 1984. Toxicity of aluminum to freshwater organisms in water of pH 6.5-8.5. Tech. Rep. Project No. 549-238-RT-WRD, Center for Lake Superior Environmental Studies, University of Wisconsin, Superior, WI.

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

Cardwell, A. S., and coauthors. 2018. Chronic toxicity of aluminum, at a pH of 6, to freshwater organisms: Empirical data for the development of international regulatory standards/criteria. Environmental Toxicology and Chemistry 37(1):36-48.

CECM. 2014. Studies on the effect of aluminium in the survival and reproduction of *Ceriodaphnia dubia* at different pHs and hardness. Center for the Ecotoxicology and Chemistry of Metals, Final Report, December 2014, Santiago, Chile. (Data summarized in Gensemer et al. 2018).

Chapman, G. A. 1978. Effects of continuous zinc exposure on sockeye salmon during adult to smolt freshwater residency. Transactions of the American Fisheries Society 107(6):828-836.

Chytalo, K. 1996. Summary of Long Island Sound dredging windows strategy workshop. In: Management of Atlantic Coastal Marine Fish Habitat: Proceedings of a Workshop for Habitat Managers. ASMFC Habitat Management Series #2.

Cleveland, L. 1989. Chronic no-observed-effect concentrations of aluminum for brook trout exposed in low-calcium, dilute acidic water. Environmental chemistry and toxicology of aluminum:229-246.

Cleveland, L., E. E. Little, S. J. Hamilton, D. R. Buckler, and J. B. Hunn. 1986. Interactive Toxicity of Aluminum and Acidity to Early Life Stages of Brook Trout. Transactions of the American Fisheries Society 115(4):610-620.

Collins, M. R. N., Corbett;Rourk, Angela. 2008. Shortnose and Atlantic sturgeon age growth, status, diet, and genetics (2006 0087 009): October 25, 2006 June 1, 2008 final report. South Carolina Department of Natural Resources.

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

Cope, W. G., and coauthors. 2011. Assessing water quality suitability for shortnose sturgeon in the Roanoke River, North Carolina, USA with an in situ bioassay approach. Journal of Applied Ichthyology 27(1):42747.

Dadswell, M. J. 1976. Mercury, DDT and PCB content of certain fishes from the Saint John River estuary, New Brunswick. Transactions of the Atlantic Chapter, Canadian Society of Environmental Biologists Annual Meeting. Fredericton, NB, November 1976.

Dadswell, M. J. 1979. Biology and population characteristics of the shortnose sturgeon *Acipenser brevirostrum* LeSueur 1818 (Osteichthyes: Acipenseridae), in the Saint John River Estuary, New Brunswick, Canada. Canadian Journal of Zoology 57(11):2186-2210.

Dadswell, M. J. 1984. Status of the shortnose sturgeon, *Acipenser brevirostrum*, in Canada. Canadian Field-Naturalist.

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

Dadswell, M. J., B. D. Taubert, T. S. Squiers, D. Marchette, and J. Buckley. 1984. Synopsis of biological data on shortnose sturgeon, *Acipenser brevirostrum* LeSueur 1818. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, NMFS 14, Silver Spring, Maryland.

De Schamphelaere, K. A. C., and C. R. Janssen. 2004. Bioavailability and Chronic Toxicity of Zinc to Juvenile Rainbow Trout (*Oncorhynchus mykiss*): Comparison with Other Fish Species and Development of a Biotic Ligand Model. Environmental Science & Technology 38(23):6201-6209.

Deforest, D. K., K. V. Brix, L. M. Tear, and W. J. Adams. 2018. Multiple linear regression models for predicting chronic aluminum toxicity to freshwater aquatic organisms and developing water quality guidelines. Environmental Toxicology and Chemistry 37(1):80-90.

Deforest, D. K., and coauthors. 2020. Updated Multiple Linear Regression Models for Predicting Chronic Aluminum Toxicity to Freshwater Aquatic Organisms and Developing Water Quality Guidelines. Environmental Toxicology and Chemistry 39(9):1724-1736.

Delos, C. G. 2008. Modeling framework applied to establishing an allowable frequency for exceeding aquatic life criteria. U.S. Environmental Protection Agency, Office of Water, 4304, Washington, D.C. 158 pp.

Detenbeck, N. E., P. W. DeVore, G. J. Niemi, and A. Lima. 1992. Recovery of temperate-stream fish communities from disturbance: A review of case studies and synthesis of theory. Environ Manage 16(1):33.

Diamond, J. M., S. J. Klaine, and J. B. Butcher. 2006. Implications of pulsed chemical exposures for aquatic life criteria and wastewater permit limits. Environmental Science & Technology 40(16):5132-5138.

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 *(Acipenser brevirostrum*). Canadian Journal of Fisheries and Aquatic Sciences 70(1):119-127.

Doney, S. C. R., Mary;Duffy, J. Emmett;Barry, James P.;Chan, Franci. S.;English, Chad A.;Galindo, Heather M.;Grebmeier, Jacqueline M.;Hollowed, Anne B.;Knowlton, Nancy. 2012. Climate change impacts on marine ecosystems. Marine Science 4.

Dussault, È. B. 2001. Effects of sublethal, acidic aluminum exposure on blood ions and metabolites, cardiac output, heart rate, and stroke volume of rainbow trout, *Oncorhynchus mykiss*. Fish Physiology and Biochemistry 25(4):347-357.

Dwyer, F., D. Hardesty, C. Ingersoll, J. Kunz, and D. Whites. 2000. Assessing Contaminant Sensitivity of American Shad, Atlantic Sturgeon and Shortnose Sturgeon.

Dwyer, F. J., and coauthors. 2005. Assessing contaminant sensitivity of endangered and threatened aquatic species: Part III. Effluent toxicity tests. Arch. Env. Cont. Toxicol. 48(2):174-183.

Dwyer, F. J. M., F. L.;Sappington, L. C.;Buckler, D. R.;Bridges, C. M.;Greer, I. E.;Hardesty, D. K.;Henke, C. E.;Ingersoll, C. G.;Kunz, J. L.;Whites, D. W.;Augspurger, T.;Mount, D. R.;Hattala, K.;Neuderfer, G. N. . 2005. Assessing contaminant sensitivity of endangered and threatened aquatic species: Part I. Acute toxicity of five chemicals. Arch. Env. Cont. Toxicol. 48(2):143-154.

ENSR Consulting and Engineering. 1992. Chronic toxicity of aluminum to *Ceriodaphnia dubia* under static renewal test conditions at four levels of water hardness. Doc. No. 8505-092-047, Prepared for Climax Metals Company, Golden, CO by ENSR Consulting and Engineering, Ft. Collins, CO, 122 pp.

ERC. 2002. Contaminant analysis of tissues from two shortnose sturgeon (*Acipenser brevirostrum*) collected in the Delaware River. Environmental Research and Consulting, Inc., National Marine Fisheries Service, Gloucester, Massachusetts.

ERC. 2003. Contaminant analysis of tissues from a shortnose sturgeon *(Acipenser brevirostrum*) from the Kennebec River, Maine. Environmental Research and Consulting, Inc., National Marine Fisheries Service, Gloucester, Massachusetts.

European Al Association. 2009. Systematic characterization of the relationship between BLM parameters and aluminum toxicity in *Daphnia magna*, *Ceriodaphnia dubia* and *Pseudokirchneriella subcapitata*. Draft of the Final Report, Chilean Mining and Metalurgy Research Center, Vitacura, Santiago, Chile.

European Al Association. 2010. Effect of different test media composition in Al acute and chronic toxicity. Draft Report, Chilean Mining and Metalurgy Research Center, Vitacura, Santiago, Chile.

Evans, P. G., and A. Bjørge. 2013. Impacts of climate change on marine mammals. MCCIP Science Review 2013:134-148.

Everhart, W. H., and R. A. Freeman. 1973. Effects of chemical variations in aquatic environments: Volume II, Toxic Effects of Aluminum to Rainbow Trout.

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

Fernandes, S. J. Z., Gayle Barbin;Zydlewski, Joseph. D.;Wippelhauser, Gail. S.;Kinnison, Michael T. . 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.

Figgener, C., J. Bernardo, and P. T. Plotkin. 2019. Beyond trophic morphology: stable isotopes reveal ubiquitous versatility in marine turtle trophic ecology. Biological Reviews 94(6):1947-1973.

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.

Gao, L. J., X. J. Zheng, Y. M. Zhu, and X. F. Zhao. 2016. Identification and Solvent Extraction-Sedimentation Removal of Metallic Elements in Coal Tar Pitch. Pages 815-818 *in* 3rd International Conference on Mechatronics and Information Technology (ICMIT), Shenzhen, PEOPLES R CHINA.

Gensemer, R. W., and coauthors. 2018. Evaluating the effects of pH, hardness, and dissolved organic carbon on the toxicity of aluminum to freshwater aquatic organisms under circumneutral conditions. Environmental Toxicology and Chemistry 37(1):49-60.

Gensemer, R. W., and R. C. Playle. 1999. The Bioavailability and Toxicity of Aluminum in Aquatic Environments. Critical Reviews in Environmental Science and Technology 29(4):315-450.

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

Gilbert, C. R. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Mid Atlantic Bight): Atlantic and shortnose sturgeons. U.S. Department of the Interior, Fish and Wildlife Service and U.S. Army Corps of Engineers, Waterways Experiment Station, Washington, D. C.

Gittings, S. T., M.;Broughton, K. . 2013. National Marine Sanctuary System Condition Report 2013, U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD.

Grosell, M., R. Gerdes, and K. V. Brix. 2006. Influence of Ca, humic acid and pH on lead accumulation and toxicity in the fathead minnow during prolonged water-borne lead exposure. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology 143(4):473-483.

Guilbard, F. M., Jean;Dumont, Pierre;Hatin, Daniel;Fortin, Rejean. 2007. Feeding ecology of Atlantic sturgeon and lake sturgeon co occurring in the St. Lawrence estuarine transition zone. American Fisheries Society Symposium 56:85.

Gundersen, D. T., S. Bustaman, W. K. Seim, and L. R. Curtis. 1994. pH, hardness, and humic acid influence aluminum toxicity to rainbow trout (*Oncorhynchus mykiss*) in weakly alkaline waters. Can. J. Fish. Aquat. Sci. 51: 1345-1355.

Gunn, J. M., and D. L. G. Noakes. 1986. Avoidance of low pH and elevated Al concentrations by brook charr (*Salvelinus fontinalis*) alevins in laboratory tests. Water, Air, and Soil Pollution 30(1):497-503.

Hager, C., J. Kahn, C. Watterson, J. Russo, and K. Hartman. 2014. Evidence of Atlantic Sturgeon spawning in the York River system. Transactions of the American Fisheries Society 143(5):1217-1219.

Hager, C. H., J. C. Watterson, and J. E. Kahn. 2020. Spawning Drivers and Frequency of Endangered Atlantic Sturgeon in the York River System. Transactions of the American Fisheries Society 149(4):474-485.

Haley, N. 1998. A gastric lavage technique for characterizing diets of sturgeons. North American Journal of Fisheries Management 18(4):978-981.

Haley, N. J. 1999. Habitat characteristics and resource use patterns of sympatric sturgeons in the Hudson River Estuary. University of Massachusetts Amherst.

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

Hamid, A., S. U. Bhat, and A. Jehangir. 2019. Local determinants influencing stream water quality. Applied Water Science 10(1):24.

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

Handy, R. D. 1993. The accumulation of dietary aluminium by rainbow trout, *Oncorhynchus mykiss*, at high exposure concentrations. Journal of Fish Biology 42(4):603-606.

Hayes, S. 2022. Fin whale (Balaenoptera physalus): Western North Atlantic Stock Assessment.

Hazen, E. L. J., Salvador;Rykaczewski, Ryan R.;Bograd, Steven J.;Foley, David G.;Jonsen, Ian D.;Shaffer, Scott A.;Dunne, John P.;Costa, Daniel P.;Crowder, L. Arry B.;Block, Barbara A. . 2012. Predicted habitat shifts of Pacific top predators in a changing climate. Nature Climate Change 3(3):234-238.

Herrmann, J., and K. Frick. 1995. Do stream invertebrates accumulate aluminium at low pH conditions? Water, Air, and Soil Pollution 85(2):407-412.

Hickie, B. E., N. J. Hutchinson, D. G. Dixon, and P. V. Hodson. 1993. Toxicity of Trace Metal Mixtures to Alevin Rainbow Trout (*Oncorhynchus mykiss*) and Larval Fathead Minnow (*Pimephales promelas*) in Soft, Acidic Water. Canadian Journal of Fisheries and Aquatic Sciences 50(7):1348-1355.

Hildebrand, S. F., and W. C. Schroeder. 1928. Fishes of chesapeake bay.

Hilton, E. J., B. Kynard, M. Balazik, A. Horodysky, and C. Dillman. 2016. Review of the biology, fisheries, and conservation status of the Atlantic Sturgeon,(Acipenser oxyrinchus oxyrinchus Mitchill, 1815). Journal of Applied Ichthyology 32:30-66.

Holtze, K. E. 1983. Effects of pH and ionic strength on aluminum toxicity to early developmental stages of rainbow trout (*Salmo gairdneri,* Richardson). Res. Rep., Ontario Ministry of the Environment, Rexdale, Ontario, Canada, 39 pp.

Hughes, G. M. 1975. Coughing in the rainbow trout *Salmo gairdneri* and the influence of pollutants. Revue suisse de zoologie. 82:47-64.

IPCC. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY.

Jager, H., I.;Chandler, J. A.;Lepla, K. B.;Van Winkle, W. . 2001. A theoretical study of river fragmentation by dams and its effects on white sturgeon populations. Environmental Biology of Fishes 60(4):347-361.

Jager, H. I., D. L. Peterson, D. Farrae, and M. S. Bevelhimer. 2013. A population model to assess influences on the viability of the shortnose sturgeon population in the Ogeechee River, Georgia. Transactions of the American Fisheries Society 142(3):731-746.

Johnson, J. H. D., D. S.;Warkentine, B. E.;R. Achlin, J. W.;Andrews, W. D. . 1997. Food habits of Atlantic sturgeon off the central New Jersey coast. Transactions of the American Fisheries Society 126(1):166-170.

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

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

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

Kahn, J. E., and coauthors. 2014. Atlantic Sturgeon annual spawning run estimate in the Pamunkey River, Virginia. Transactions of the American Fisheries Society 143(6):1508-1514.

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

Kazaz, B., M. A. Perez, W. N. Donald, X. Fang, and J. N. Shaw. 2022. Detection of Residual Flocculant Concentrations in Construction Stormwater Runoff. Transportation Research Record 2676(7):222-232.

Kieffer, M., and B. Kynard. 1996. Spawning of shortnose sturgeon in the Merrimack River, Massachusetts. Transactions of the American Fisheries Society 125:179-186.

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, S. O., C. E. Mach, and P. L. Brezonik. 1992. Changes in trace metal concentrations in lake water and biota during experimental acidification of Little Rock Lake, Wisconsin, USA. Environ Pollut 78(1-3):9-18.

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

Kintisch, E., and K. Buckheit. 2006. Along the road from Kyoto. American Association for the Advancement of Science.

Kjeld, M. 2003. Salt and water balance of modern baleen whales: Rate of urine production and food intake. Canadian Journal of Zoology 81(4):606-616.

Kocan, R. M. M., M. B.;Salazar, S. M. . 1996. Toxicity of weathered coal tar for shortnose sturgeon (*Acipenser brevirostrum*) embryos and larvae. Archives of Environmental Contamination and Toxicology 31(2):5.

Kocik, J. L., C.;Miller, T.;R. Ago, P.;Shepherd, G. . 2013. An Atlantic Sturgeon Population Index for ESA Management Analysis. National Marine Fisheries Service.

Kynard, B. H., Martin. 2002. Ontogenetic behavior and migration of Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus, and shortnose sturgeon, A. brevirostrum, with notes on social behavior. Environmental Biology of Fishes 63(2):137-150.

Lal, R. 2015. Restoring Soil Quality to Mitigate Soil Degradation. Sustainability 7(5):5875-5895.

Larsen, E. H., and coauthors. 2011. Osmoregulation and excretion. Comprehensive Physiology 4(2):405-573.

Lassalle, G., P. Crouzet, J. Gessner, and E. Rochard. 2010. Global warming impacts and conservation responses for the critically endangered European Atlantic sturgeon. Biological conservation 143(11):2441-2452.

Little, E. E. C., R. D.;Linder, G. . 2012. Toxicity of Copper to Early life Stage Kootenai River White Sturgeon, Columbia River White Sturgeon, and Rainbow Trout. Archives of Environmental Contamination and Toxicology 63(3):400-408.

Longwell, A. C., S. Chang, A. Hebert, J. B. Hughes, and D. Perry. 1992. Pollution and developmental abnormalities of Atlantic fishes. Environmental Biology of Fishes 35(1):1-21.

Lyndon, A. R., and D. F. Houlihan. 1998. Gill protein turnover: costs of adaptation. Comp Biochem Physiol A Mol Integr Physiol 119(1):27-34.

Mac, M. J., and C. C. Edsall. 1991. Environmental contaminants and the reproductive success of lake trout in the Great Lakes: an epidemiological approach. J Toxicol Environ Health 33(4):375-94.

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

Magoulick, D. D., and R. M. Kobza. 2003. The role of refugia for fishes during drought: a review and synthesis. Freshwater Biology 48(7):1186-1198.

Marking, L. L. 1985. Toxicity of chemical mixtures. Pages 164-176 in G. M. Rand, and S. R. Petrocelli, editors. Fundamentals of Aquatic Toxicology: Methods and Applications. Hemisphere Publishing, New York, NY.

Marr, J. C. A., and coauthors. 1995. Relative sensitivity of brown and rainbow trout to pulsed exposures of an acutely lethal mixture of metals typical of the Clark Fork River, Montana. Canadian Journal of Fisheries and Aquatic Sciences 52(9):2005-2015.

Matta, M. B., C. Cairncross, and R. M. Kocan. 1997. Effect of a Polychlorinated Biphenyl Metabolite on Early Life Stage Survival of Two Species of Trout. Bulletin of Environmental Contamination and Toxicology 59(1):146-151.

McCauley, D. J., L. T. Brooke, C. D.J., and L. C.A. 1986. Acute and chronic toxicity of aluminum to *Ceriodaphnia dubia* at various pH's. Center for Lake Superior Environmental Stud., Univ. Wisconsin-Superior, Superior, WI.

McGeer, J. C., and coauthors. 2003. Inverse relationship between bioconcentration factor and exposure concentration for metals: Implications for hazard assessment of metals in the aquatic environment. Environmental Toxicology and Chemistry 22(5):1017-1037.

McKee, M. J., C. O. Knowles, and D. R. Buckler. 1989. Effects of aluminum on the biochemical composition of Atlantic salmon. Archives of Environmental Contamination and Toxicology 18(1):243-248.

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

Mebane, C. A., D. P. Hennessy, and F. S. Dillon. 2008. Developing acute to chronic toxicity ratios for lead, cadmium, and zinc using rainbow trout, a mayfly, and a midge. Water Air and Soil Pollution 188(1-4):41-66.

Meyer, J. S., C. J. Boese, and J. M. Morris. 2007. Use of the biotic ligand model to predict pulse exposure toxicity of copper to fathead minnows (*Pimephales promelas*). Aquatic Toxicology 84(2):268-278.

Mierzykowski, S. E. 2012. Contaminants in Atlantic Sturgeon and Shortnose Sturgeon Recovered from the Penobscot and Kennebec Rivers, Maine. USFWS. Spec. Proj. Rep. FY09-MEFO-3-EC. Maine Field Office. Orono, ME. 50 pp.

Monira, S., M. A. Bhuiyan, N. Haque, and B. K. Pramanik. 2021. Assess the performance of chemical coagulation process for microplastics removal from stormwater. Process Safety and Environmental Protection 155:11-16.

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

Moser, M. L. R., S. W. . 1995. Habitat use and movements of shortnose and Atlantic sturgeons in the lower Cape Fear River, North Carolina. Transactions of the American Fisheries Society 124(2):225.

MSPO. 1993. Kennebec River Resource Management Plan. Maine State Planning Office Paper 78, http://digitalmaine.com/spo_docs/78.

Muir, W. D., J. McCabe, G. T., M. J. Parsley, and S. A. Hinton. 2000. Diet of first-feeding larval and young-of-the-year white sturgeon in the lower Columbia River. Northwest Science 74:25-33.

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

Niklitschek, E. J., and D. H. Secor. 2009. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: II. Model development and testing. J Exp Mar Bio Ecol 381:S161-S172.

Niklitschek, E. J. S., David H. . 2005. Modeling spatial and temporal variation of suitable nursery habitats for Atlantic sturgeon in the Chesapeake Bay. Estuarine, Coastal and Shelf Science 64(1):135-148.

NMFS. 1998. Final Recovery Plan for the Shortnose Sturgeon *Acipenser brevirostrum*. Pages 104 *in*, Prepared by the Shortnose Sturgeon Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland.

NMFS. 2012. Jeopardy and Destruction of Adverse Modification of Critical Habitat Endangered Species Act Biological Opinion for Environmental Protection Agency's Proposed Approval of Certain Oregon Administrative Rules related to Revised Water Quality Criteria for Toxic Pollutants. National Marine Fisheries Service, Northwest Region, Seattle, WA.

NMFS. 2014. Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for Water Quality Toxics Standards for Idaho.

NMFS. 2018. Recovery Outline for Atlantic sturgeon Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic Distinct Population Segments.

NMFS. 2020. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the proposed EPA promulgation of freshwater aquatic life criteria for aluminum in Oregon.

NMFS. 2023. Environmental Protection Agency approval of Delaware and Maryland’s adoption of criteria for ammonia in freshwater and cadmium in freshwater and saltwater and Delaware’s adoption of criteria for nonylphenol in freshwater and saltwater. OPR-2022-030402.

NMFS/USFWS. 1998. Endangered Species Act Consultation Handbook: Procedures for Conducting Section 7 Consultations and Conferences.

NRC. 1986. The special problem of cumulative effects. Pages 93-103 *in* Committee on the Applications of Ecological Theory to Environmental Problems, editor. Ecological Knowledge and Problem Solving: Concepts and Case Studies. National Academy Press, Washington, DC.

Nunes, J. A. C. C., and coauthors. 2019. Refuge choice specificity increases with predation risk in a rocky reef fish. J Exp Mar Bio Ecol 520:151207.

Ogilvie, D. M., and D. M. Stechey. 1983. Effects of aluminum on respiratory responses and spontaneous activity of rainbow trout, *Salmo gairdneri*. Environmental Toxicology and Chemistry 2(1):43-48.

OSU. 2018a. Chronic toxicity of aluminum to the cladoceran, *Ceriodaphnia dubia*: Expansion of the empirical database for bioavailability modeling. Prepared by Oregon State University Aquatic Toxicology Laboratory, Corvallis, OR, USA. Prepared for Aluminum Reach Consortium, Brussels, Belgium.

OSU. 2018b. Short-term chronic toxicity of aluminum to the fathead minnow, *Pimephales promelas*: Validation of aluminum bioavailability models (confirmatory studies). Prepared by Oregon State University Aquatic Toxicology Laboratory, Corvallis, OR, USA. Prepared for Aluminum Reach Consortium, Brussels, Belgium.

OSU. 2018c. Short-term chronic toxicty of aluminum to the fathead minnow, *Pimephales promelas*: Expansion of the empirical database for bioavailability modeling. Prepared by Oregon State University Aquatic Toxicology Laboratory, Corvallis, OR, USA. Prepared for Aluminum Reach Consortium, Brussels, Belgium.

Otto, C., and B. Svensson. 1983. Properties of acid brown water streams in South Sweden. Arch. Hydrobiol 99(1):15-36.

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

Playle, R. C., and C. M. Wood. 1989. Water chemistry changes in the gill micro-environment of rainbow trout: experimental observations and theory. Journal of Comparative Physiology B 159(5):527-537.

Poletto, J. B., and coauthors. 2018. Assessment of multiple stressors on the growth of larval green sturgeon *Acipenser medirostris:*: implications for recruitment of early life-history stages. Journal of Fish Biology 93(5):952-960.

Poston, H. A. 1991. Effects of Dietary Aluminum on Growth and Composition of Young Atlantic Salmon. The Progressive Fish-Culturist 53(1):7-10.

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

Rehwoldt, R. E., W. Mastrianni, E. Kelley, and J. Stall. 1978. Historical and current heavy metal residues in Hudson River fish. Bulletin of Environmental Contamination and Toxicology 19(1):335-339.

Richardson, B., and D. Secor. 2016. Assessment of critical habitats for recovering the Chesapeake Bay Atlantic Sturgeon distinct population segment. Final Report to the Maryland Department of Natural Resources, Stevenville, MD.

Robinson, R. A., and coauthors. 2008. Travelling through a warming world: climate change and migratory species. Endangered Species Research.

Rosenthal, H., and D. F. Alderdice. 1976. Sublethal effects of environmental stressors, natural and pollutional, on marine fish eggs and larvae. Journal.

Runkle, J., and coauthors. 2022. Virginia State Climate Summary 2022. NOAA Technical Report NESDIS 150-VA. NOAA/NESDIS, Silver Spring, MD, 5 pp.

Savoy, T. 2007. Prey eaten by Atlantic sturgeon in Connecticut waters. American Fisheries Society Symposium 56:157.

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

Savoy, T. F., and J. Benway. 2004. Food habits of shortnose sturgeon collected in the lower Connecticut River from 2000 through 2002. American Fisheries Society Monograph 9:353-360.

Scholefield, D., and coauthors. 2005. Concerted diurnal patterns in riverine nutrient concentrations and physical conditions. Science of The Total Environment 344(1):201-210.

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

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

Secor, D. A., P.;Webster, V. W.;Dixon, D. . 2002a. Can we study sturgeon to extinction? What we do and don't know about the conservation of North American sturgeon. American Fisheries Society Symposium 28:183-189.

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

Secor, D. H., and T. Gunderson. 1998. Effects of hypoxia and temperature on survival, growth, and respiration of juvenile Atlantic sturgeon, Acipenser *oxyrinchus*, volume 96.

Secor, D. H., and coauthors. 2022. Atlantic Sturgeon Status and Movement Ecology in an Extremely Small Spawning Habitat: The Nanticoke River-Marshyhope Creek, Chesapeake Bay. Reviews in Fisheries Science & Aquaculture 30(2):195-214.

Secor, D. R. 1995. Chesapeake Bay Atlantic sturgeon: current status and future recovery. Chesapeake Biological Laboratory. Solomons, MD, 10 p.

Shuhaimi-Othman, M., Y. Nadzifah, R. Nur-Amalina, and N. S. Umirah. 2013. Deriving freshwater quality criteria for copper, cadmium, aluminum and manganese for protection of aquatic life in Malaysia. Chemosphere 90(11):2631-6.

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

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

Smith, T., I. J.;Clugston, J. P. . 1997. Status and management of Atlantic sturgeon, *Acipenser oxyrinchus*, in North America. Environmental Biology of Fishes 48(42739):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., E. K. Dingley, and D. E. Marchette. 1980. Induced spawning and culture of Atlantic sturgeon. The Progressive Fish-Culturist 42(3):147-151.

Spehar, R. L., and J. T. Fiandt. 1986. Acute and chronic effects of water quality criteria based metal mixtures on three aquatic species. 5(10):917-931.

Spells, A. 1998. Atlantic sturgeon population evaluation utilizing a fishery dependent reward program in Virginia's major western shore tributaries to the Chesapeake Bay. US Fish and Wildlife Service, Charles City, Virginia.

Sprague, J. B. 1970. Measurement of pollutant toxicity to fish. II. Utilizing and applying bioassay results. Water Research 4(1):3-32.

SSSRT. 2010. Biological Assessment of shortnose sturgeon (*Acipenser brevirostrum*). Report to National Marine Fisheries Service, Northeast Regional Office.

Stephen, C. E. M., D, I.;Hansen, D. J.;Gentile, J. R.;Chapman, G. A.;Brungs, W. A. . 1985. Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. Pages 59 *in*, EPA ORD Environmental Research Laboratories.

Suchanek, P. M., R. L. Sundet, and M. N. Wenger. 1984, after Newcombe and Jensen, 1996. Resident Fish Habitat Studies. Alaska Department of Fish and Game.Susitna Hydro Aquatic Studies, 1984 Report 2, Part 6. Anchorage.

USEPA. 2007. Ambient Water Quality Criteria for Copper (revision), Office of Water, Office of Science and Technology, Health and Ecological Criteria Division, United States Environmental Protection Agency, Washington, D.C. EPA-820-R-16-002 721 p.

USEPA. 2018. Aquatic Life Ambient Water Quality Criteria for Aluminum, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division, United States Environmental Protection Agency, Washington, D.C. EPA-822-R-18-001 49 p.

USEPA. 2021. Draft Technical Support Document: Implementing the 2018 Recommended Aquatic Life Water Quality Criteria for Aluminum E.-.-D.-.-. Office of Water, editor.

VADEQ. 2022. Water Quality Monitoring Strategy.

VADEQ. 2023. 2024 Water Quality Assessment Guidance Manual, accessed October 4, 2023. W. P. Division, editor. Commonwealth of Virginia Department of Environmental Quality, Richmond, VA

Van Eenennaam, J. P. D., S, I. . 1998. Effects of age and body size on gonadal development of Atlantic sturgeon. Journal of Fish Biology 53(3):624-637.

Vijver, M. G., W. J. G. M. Peijnenburg, and G. R. De Snoo. 2010. Toxicological Mixture Models are Based on Inadequate Assumptions. Environmental Science & Technology 44(13):4841-4842.

Wang, N., and coauthors. 2016. Columbia Environmental Research Center (CERC) preliminary data summary for acute and chronic aluminum toxicity tests with freshwater mussels and amphipods. Memorandum to Diana Eignor. Dated January 14th. U.S. Geological Survey, CERC, Columbia, MO.

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

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

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

Wesolek, B. E., E. K. Genrich, J. M. Gunn, and K. M. Somers. 2010. Use of littoral benthic invertebrates to assess factors affecting biological recovery of acid- and metal-damaged lakes. Journal of the North American Benthological Society 29(2):572-585.

White, S. L., and coauthors. 2021. Establishment of a microsatellite genetic baseline for North American Atlantic sturgeon (Acipenser o. oxyrhinchus) and range-wide analysis of population genetics. Conservation Genetics 22(6):977-992.

Wilson, R. W. 2012. Chapter 2: Aluminum. In: C.M Wood, A.P. Farrel and C.J. Brauner (Eds.), Homeostasis and toxicology of non-essential metals: Volume 31B. Elsevier Inc.

Winger, P. V., P. J. Lasier, D. H. White, and J. T. Seginak. 2000. Effects of Contaminants in Dredge Material from the Lower Savannah River. Archives of Environmental Contamination and Toxicology 38(1):128-136.

Wirgin, I., and R. C. Chambers. 2022. Hepatic Burdens of PCB and PCDD/F Congeners in Federally Endangered Shortnose Sturgeon and Atlantic Sturgeon from the Hudson River, New York, USA: Burden Patterns and Potential Consequences in Offspring. Archives of Environmental Contamination and Toxicology 83(1):21-35.

Wirgin, I., and coauthors. 2005. Range wide population structure of shortnose sturgeon *Acipenser brevirostrum* based on sequence analysis of the mitochondrial DNA control region. Estuaries 28(3):406-421.

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

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

Woodland, R., and D. Secor. 2007. Year-Class Strength and Recovery of Endangered Shortnose Sturgeon in the Hudson River, New York. Transactions of the American Fisheries Society 136:72-81.

Wren, C. D., and G. L. Stephenson. 1991. The effect of acidification on the accumulation and toxicity of metals to freshwater invertebrates. Environ Pollut 71(2-4):205-41.

Xu, D., and coauthors. 2020. Water treatment residual: A critical review of its applications on pollutant removal from stormwater runoff and future perspectives. Journal of Environmental Management 259:12.

Yount, J. D., and G. J. Niemi. 1990. Recovery of lotic communities and ecosystems from disturbance—A narrative review of case studies. Environ Manage 14(5):547-569.

Zarri, L. J., and E. P. Palkovacs. 2019. Temperature, discharge and development shape the larval diets of threatened green sturgeon in a highly managed section of the Sacramento River. Ecology of Freshwater Fish 28(2):257-265.

Zhao, Y., and M. C. Newman. 2004. Shortcomings of the laboratory derived median lethal concentration for predicting mortality in field populations: Exposure duration and latent mortality. Environmental Toxicology and Chemistry 23(9):2147-2153.

Zhao, Y., and M. C. Newman. 2006. Effects of exposure duration and recovery time during pulsed exposures. Environmental Toxicology and Chemistry 25(5):1298.