NATIONAL MARINE FISHERIES SERVICE
ENDANGERED SPECIES ACT SECTION 7

BIOLOGICAL OPINION

Title: Environmental Protection Agency Approval of Cadmium and Selenium Water Quality Criteria to be Implemented by North Carolina

Consultation Conducted By: Endangered Species Act Interagency Cooperation Division, Office of Protected Resources, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce

Action Agency: United States Environmental Protection Agency

Publisher: Office of Protected Resources, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce

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Date: February 9, 2023

Consultation Tracking number: OPR-2022-02170

Digital Object Identifier (DOI): https://doi.org/10.25923/srcs-cy22

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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. Section 7(a)(2) of the ESA requires Federal agencies to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Federal agencies must do so in consultation with 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' 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 has insured is not likely to jeopardize ESA-listed species or destroy or adversely modify designated critical habitat. If NMFS determines that the action agency is unable to satisfy section 7(a)(2) of the ESA, NMFS provides a reasonable and prudent alternative that allows the action to proceed in compliance with section 7(a)(2). 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, 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 measures necessary to comply with section 101(A)(5) of the MMPA; 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 Incidental Take Statement be exceeded. Any incidental take which occurs in compliance with the terms and conditions in the Incidental Take Statement 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 4 (EPA). The EPA requested ESA section 7 consultation for the approval of Water Quality Standards (WQS) for cadmium and selenium in Waters of the United States located in the State of North Carolina under Section 303(c) of the Clean Water Act. The state agency that implements the criteria is the North Carolina Department of Environmental Quality (North Carolina DEQ).

Formal consultations result in NOAA Fisheries developing a biological opinion. The intent of a biological opinion is to ensure that the proposed project or action will not reduce the likelihood of survival and recovery of an ESA-listed species. A biological opinion usually also includes conservation recommendations that further the recovery of ESA-listed species. A biological opinion includes reasonable and prudent measures as needed to minimize any harmful effects, and may require monitoring and reporting to ensure that the project or action is implemented as described.

This consultation, its biological opinion (Opinion), and associated Incidental Take Statement 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 two days later on November 16, 2022. As a result, the 2019 regulations remain in effect, and we are applying the 2019 regulations here. For purposes of this consultation and in an abundance of caution, we considered whether the substantive analysis and conclusions articulated in the 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' Opinion on the effects of these actions on Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, Carolina, South Atlantic, New York Bight, Chesapeake, and Gulf of Maine Distinct Population Segments [DPS]); shortnose sturgeon (*Acipenser brevirostrum*); green (*Chelonia mydas,* North Atlantic DPS*)*, Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), and loggerhead (*Caretta caretta*, Northwest Atlantic Ocean DPS) sea turtles; North Atlantic right (*Eubalaena glacialis*), fin (*Balaenoptera physalus*), and sei (*Balaenoptera borealis*) whales..

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. Congressional findings and declaration of purposes and policy Pervaze et al. 2021). The WQS 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. The WQS 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 “WQSs” 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 that have a reasonable potential to cause an aquatic impairment for a given substance have permit limits and are required to monitor for that substance. Specifically at 40 CFR §122.44(d)(1) reads: “Limitations must control all pollutants or pollutant parameters (either conventional, nonconventional, or toxic pollutants) which the 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’ analysis determines whether adverse effects may result from exposure to the stressor within the limits of its criteria. Section 303(c)(2)(B) of the Clean Water Act 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 Section 304(a) of the Clean Water Act. Most of National Criteria were developed by EPA under the 1985 EPA Guidelines for Deriving Numerical National Water Quality Criteria (EPA Guidelines Stephen et al. 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.

Section 303(c) of the Clean Water Act requires that, at least once every three years, states, tribes, and territories review and, when necessary, modify their WQS or adopt new WQS to protect waters under their jurisdiction. Implementation of state, territory, or tribe WQS can also affect water quality in neighboring entities when rivers cross or delineate borders. As required by Section 303(c) of the Clean Water Act and 40 CFR 131, EPA reviews WQS proposed for adoption by a state, territory, or tribe, which 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 between EPA, NMFS, and U.S. Fish and Wildlife Service is to enhance coordination under the Clean Water Act and the ESA for section 7 consultations. The EPA consults with the Services on newly proposed and/or revised WQS to ensure that any adopted WQS are protective of ESA-listed species and critical habitats in waters under that state, territory, or tribe's jurisdiction and have a WQS description that includes the protection and propagation of fish, shellfish, and wildlife.

1.1.1 Prior Consultations

In June of 2020, NMFS issued a biological opinion and Incidental Take Statement on EPA Region 4's approval of Georgia's 2019 update to its aquatic life criteria to be consistent with EPA's recommended guidelines for cadmium. Incidental take was anticipated for this approval because NMFS' assessment determined that exposures of shortnose and Atlantic sturgeon to cadmium above background levels are most likely to occur in waters receiving urban and large volumes of roadway runoff or discharges from industries for which cadmium is a contaminant (i.e. kaolinite mining). Discharges at the city of Macon, Georgia were of particular concern. Macon, with an estimated population of 150,000 people and transected by interstates 75 and 16, lies at the fall line where the Ocmulgee River, tributary to the Altamaha River, enters the coastal plain. These are waters to which both shortnose and Atlantic sturgeon travel while spawning (Devries 2006, Ingram and Peterson 2016) so the potential for larval exposures in water affected by Macon runoff is high. The Altamaha River may contain the largest population of shortnose sturgeon south of the Delaware River (Devries 2006, Bahn et al. 2009). Given the greater abundance of sturgeon in this river, NMFS also expected some Atlantic sturgeon, including larvae, would likely be exposed to and affected by cadmium in runoff. These exposures were not expected to extirpate the population because they would be sporadic, affecting only those individuals present at the time of a storm event. Accordingly, the Georgia Opinion (OPR-2019-03141) included RPMs to minimize take by ensuring NMFS' review of, and opportunity to comment and provide technical assistance for, permitted discharges potentially affecting waters where ESA-listed sturgeon occur.

In February of 2021, NMFS issued a Letter of Concurrence (OPR-2021-00175) that EPA Region 4's approval of South Carolina's update of its aquatic life criteria for cadmium to be consistent with the EPA's 2016 recommended guidelines for cadmium was not likely to adversely affect ESA-listed species or critical habitat under NMFS' jurisdiction. The concurrence relied on two elements specific to EPA's approval of the South Carolina's adoption of the criteria:

1. Evidence that shortnose sturgeon and Atlantic sturgeon are extremely unlikely to be exposed to cadmium in South Carolina based on current monitoring data and absence of permitted discharges to waters where ESA-listed sturgeon are present; and
2. EPA's action incorporated NMFS' review of draft state-issued permits for discharges that may affect ESA-listed sturgeon species.

1.2 Preconsultation

On November 9, 2021, EPA Region 4 alerted NMFS of upcoming proposed Triennial changes to North Carolina's WQS to be implemented by the North Carolina DEQ.

On March 29, 2022, EPA Region 4 requested a species list from NMFS. A species list was transmitted to EPA Region 4 on April 11, 2022.

On May 9, 2022, EPA requested data summary spreadsheets for cadmium and selenium data replotted in EPA's ECOTOXicology Knowledgebase (ECOTOX). NMFS provided summary spreadsheets for ECOTOX data on July 6, 2022 and a revised cadmium spreadsheet on July 22, 2022 to correct an error in criteria calculations accompanying the ECOTOX data.

On July 19, 2022, EPA sent a draft biological evaluation (BE) for NMFS review and a revised BE on August 2, 2022.

1.3 Consultation History

On August 17, 2022, EPA Region 4 transmitted a letter requesting concurrence with EPA's not likely to adversely affect determination for North Carolina's proposed cadmium and selenium criteria. The rational for the determination was provided in an accompanying BE.

On September 8, 2022, NMFS informed EPA Region 4 via e-mail that a formal consultation would be required due to the presence of early life stage sturgeon in North Carolina waters and the likely to adversely affect determinations NMFS arrived at in prior opinions due to expected effects in vulnerable life stages exposed to cadmium within the chronic cadmium criterion limit.

On September 27, 2022, NMFS transmitted a nonconcurrence letter to EPA Region 4 for North Carolina's proposed cadmium and selenium criteria.

On September 29, 2022, EPA Region 4 met with NMFS via conference call to discuss nonconcurrence. NMFS requested that EPA seek any available permitting and monitoring data for cadmium and selenium from the state.

On October 6, 2022, EPA transmitted a request for formal consultation for North Carolina's proposed cadmium and selenium criteria to NMFS.

On October 17, 2022, EPA transmitted surface water monitoring data to NMFS for review.

On December 7, 2022 NFMS sent EPA draft RPMs for review.

On December 12, 2022 NFMS alerted EPA to concerns regarding accuracy of permitting data.

On December 15, 2022, EPA transmitted selenium tissue monitoring data to NMFS for review and edits for RPMs.

On December 28, 2022, NMFS alerted EPA to inconsistencies between the standards posted on the state website and the BE.

On January 2, 2023, EPA clarified that the information in the BE was the accurate description of their intended action.

On January 4, 2023, EPA and NMFS finalized RPMs.

On January 19, 2023, NMFS consolidated RPM 3 and RPM 1 after agreement with EPA because both RPMs were requirements of EPA working within its authority.

On February 2, 2023, EPA requested changes to RPMs.

On February 3, 2023, EPA and NMFS finalized RPMs.

2 THE ASSESSMENT FRAMEWORK

Section 7(a)(2) of the ESA requires Federal agencies, in consultation with NMFS, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species; or adversely modify or destroy their 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 insure 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 ad Designated Critical Habitat (Section 5): We identify the ESA-listed species and critical habitat that are likely to co-occur with the potential stressors cause by the action in space and time and evaluate the status of those species and habitat. At this stage, we assess how the modifications to land, water, and air affect the species and critical habitat in the action area to determine which of these potential stressors may affect listed species and critical habitat in the action area. In section 5.1, we identify 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 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).

Effects of the Action (Section 7): refers to 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 (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, North Carolina DEQ may issue National Pollution Discharge Elimination System (NPDES) permits for discharges of these pollutants and may 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.

Because this action involves two independently implemented criteria, the analysis is provided as two independent effects analyses in order to maintain focus on one determination at a time. The structure of the effects of the action subsections for cadmium or selenium, each “stressor X” in this Opinion is as follows:

> *Section 7.x Stressor X*: Introduces stressor “X” (i.e., cadmium or selenium), summarizing uses, sources, environmental fate, mechanism(s) of effect, the BE analysis, and the criteria.
>
> *Section 7.x.1 Exposure to Stressor X within the Action Area*: Identifies sources within the action area and evaluates monitoring and permitting data for stressor X to *chara*cterize 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 stressor X.
>
> *Section 7.x.2 Responses to Stressor X 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 X within criteria limits. This section also evaluates responses of forage species exposed within criteria limits.
>
> *Section 7.x.3 Risk Analysis*: The risk analysis for those likely to adversely affect determinations identified in section 8.x.2 lays out the evidence supporting the determination then evaluates the consequences of effects to individuals for the populations those individuals represent, and the species those populations comprise. Where effects to critical habitat are

expected, the risk analysis also considers the impacts of the proposed action on the physical or biological features and conservation value of designated 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 designated critical habitat for conservation of an ESA-listed species. The applicable risk hypotheses for direct stressors like toxic substances are straightforward, EPA's approval is 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 designated 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 nonfederal 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 proposed action are not considered because they must satisfy the requirements of section 7(a)(2) of the ESA.

Integration and Synthesis (Section 9): In this section, we integrate the analyses of Effects of the Action (Section 7), the Environmental Baseline (Section 6), and the Cumulative Effects (Section 8) 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 diminish the value of designated critical habitat as a whole for the conservation of a listed species.

Conclusion (Section 10): With full consideration of the status of the species and the designated critical habitat, we consider the effects of the action within the action area on populations or subpopulations and on essential habitat features when added to the environmental baseline and the cumulative effects to determine whether the action could reasonably be expected to:

- Reduce appreciably the likelihood of both the survival and recovery of ESA-listed species in the wild by reducing its numbers, reproduction, or distribution, and state our conclusion as to whether the action is likely to jeopardize the continued existence of such species; or
- Appreciably diminish the value of designated critical habitat as a whole for the conservation of an ESA-listed species, and state our conclusion as to whether the action is likely to destroy or adversely modify designated critical habitat.

If, in completing the last step in the analysis, we determine that the action under consultation is likely to jeopardize the continued existence of ESA-listed species or destroy or adversely modify designated critical habitat, then we must identify reasonable and prudent alternative(s) to the action, if any, or indicate that to the best of our knowledge there are no reasonable and prudent alternatives. See 50 CFR §402.02 and 402.14.

Incidental Take Statement (Section 11): If we determine EPA has satisfied section 7(a)(2) of the ESA or identify a reasonable and prudent alternative, we include an Incidental Take Statement 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)). We also provide discretionary Conservation Recommendations that may be implemented by the action agency (50 CFR §402.14(j)). Finally, we identify the circumstances in which Reinitiation of Consultation (Section 12) is required (50 CFR 402.16).

> *Note: Discovery of information, either found or newly generated, indicating that an ESA-listed species' exposure or response within a criterion's limit is no longer discountable or insignificant could be considered "new information" and could trigger reinitiation of consultation (Section 12) for EPA's approval of that criterion.*

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 that EPA used to evaluate whether the proposed criteria may result in effects to ESA-listed species and designated critical habitat. Our assessment considers these summaries, but also considers other data found in EPA's ECOTOX database, 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 made 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;
- Water quality monitoring data from the National Water Quality Monitoring Council's Water Quality Portal;
- Government databases, including ECOTOX, EPA's Enforcement and Compliance History Online Database (ECHO) and the National Water Quality Monitoring Council's Water Quality Portal 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.

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

2.2 Numeric Criteria for the Protection of Aquatic Life

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. Criteria for concentrations of substances in water were derived with the objective of protecting aquatic life from short and long-term adverse effects. They are derived from laboratory toxicity test data following the EPA Guidelines.

The EPA Guidelines are designed to arrive at criteria that, when applied as discharge limits, monitoring thresholds, and restoration goals, will achieve water quality that provides for the protection and propagation of fish, shellfish, and wildlife and provide for recreation in and on the water. As stated in Section 1.1 of the document:

> *"Because aquatic ecosystems can tolerate some stress and occasional adverse effects, protection of all species at all times and places it is not deemed necessary for the derivation of a standard. ...[given adequate data]... a reasonable level of protection will probably be provided if all except a small fraction of the taxa are protected, unless a commercially or recreationally important species is very sensitive."*

Relying on toxicity tests conducted in a laboratory for our understanding of toxic effects requires us to assume that laboratory conditions are representative of environmentally relevant conditions and that “domesticated” cultures of test animals will produce similar effects, as would exposure to the same substance on the same, or closely related, wild species. The assumption that effects in laboratory tests are reasonable predictors of effects to individuals in the wild is dependent upon the specific factor being considered. While it is generally reasonable to interpret effects from laboratory tests as being applicable to field situations where a water quality criterion is applied to a particular waterbody, there is risk that laboratory tests underpredict effects in wild animals under natural conditions. In nature, the abundance and quality of food and aquatic chemistry (e.g., pH, dissolved oxygen [DO], temperature, organic matter, ion composition) are variable, individuals are subject to predation, competition, parasitism and disease, and vulnerabilities differ among life stages and during life history events (e.g., migration, spawning). Considering this, arriving at a firm conclusion based on extrapolations from the lab to the field is challenging. It may be that the best overall conclusion is the same as that reached by Chapman (1983) that “when appropriate test parameters are chosen, the response of laboratory organisms is a reasonable index of the response of naturally occurring organisms.” His conclusion in turn contributed to one of the most fundamental assumptions of EPA Guidelines, that is, “these National Guidelines have been developed on the theory that effects which occur on a species in appropriate laboratory tests will generally occur on the same species in comparable field situations.” Even so, when test species and ESA-listed species have comparable sensitivities, the loss of an individual from an imperiled population has greater consequences than the loss of an individual from healthy populations.

2.2.1 Criteria Duration and Frequency for Ambient Exposures

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

The Guidelines specifying a four-day averaging period for chronic criteria was selected for use by EPA with the chronic criterion for two reasons. First, “chronic” responses with some substances and species may not really be due to long-term stress or accumulation, but rather the test was simply long enough that a briefly occurring sensitive stage of development was included in the exposure (e.g., Chapman 1978a, Barata and Baird 2000, De Schamphelaere and Janssen 2004, Grosell et al. 2006, Mebane et al. 2008b). Second, a much longer averaging period, such as one month, would allow for substantial fluctuations above the chronic criterion.

The Guideline’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 (Yount and Niemi 1990, Detenbeck et al. 1992). In most cases, once the cause of the disturbance ceased, recovery of populations and communities occurred on a timeframe of less than three 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 addressed mostly less severe disturbances that were 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 2012b, 2014).

2.2.2 Toxicity Test Data

Most criteria are developed consistent with Guidelines using endpoints identified through toxicity tests exposing laboratory-reared organisms to toxicants over a range of concentrations. The EPA applies restrictions to the types of data that may be used in deriving criteria. The data must meet very specific and stringent requirements; thus, laboratory conditions are tightly controlled, which is quite different from variability in natural systems the criteria are expected to protect. This level of control is necessary to attribute the response to the exposure. Data requirements also limit the types of responses and how those responses are reported. This ensures consistency among data to allow aggregation of information on the responses of multiple species from multiple studies (i.e., meta-analysis) to derive criteria. Data that are not acceptable for criteria derivation include tests that: lack a control, have too few exposure concentrations, have unacceptable mortality or disease in controls, report atypical responses (e.g., behavior) or measures of response (e.g., time to death), have exposures of the wrong duration, or used species that do not have reproducing wild populations in North American waters. The endpoints that may be used in criteria derivation include the following:

- concentration at which half of the exposed organisms die (lethal concentration for 50% of organisms, LC50);
- 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 ten 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% 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 life stages 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 one type of response, such as growth, and as the LOEC for another, such as reproduction.

SCREENING DATA FOR USE IN THIS OPINION

The screened datasets for NMFS' analysis include data that were not used in criteria derivation (e.g., LC10, IC50) because our purpose is to determine whether there is any indication that ESA-listed species under NMFS' jurisdiction are likely to be adversely affected by exposures within criteria limits. In light of that purpose, data for all available organism-level endpoint effect data are considered. This includes important but less commonly studied effects, such as altered behavior (e.g., prey strikes) or responses that affect behavior (e.g., acetylcholinesterase inhibition). Data for species that do not have reproducing populations in the United States were also included among data considered in this evaluation. When multiple effects were reported for a single endpoint, the effect was reassigned to a single type of response, favoring reproduction over growth, and growth over survival (i.e., effective mortality, mortality) when those options are among the effects reported.

In addition to extracting data from EPA's ECOTOX database, the analysis examined original sources to verify critical data and identify any important details not included in ECOTOX. Information from recently published literature in the Web of Science and Google Scholar was also collected. Queries of EPA's ECOTOX excluded records identified as having unacceptable controls. Data reported as formulations (e.g., a pesticide plus another active ingredient) were excluded to ensure the response was the result of exposure to the active ingredient. NMFS determined that data did not need to be adjusted for purity because, among those records reporting purity of the test substance, all reported values of 98% or greater pure. NMFS expects that a level of impurity of two percent impurity is insignificant relative to typical confidence intervals among analytical data. Data were excluded if test organisms were pre-exposed (i.e., acclimation studies) or if test organisms were collected from polluted waters. Endpoints with effect magnitudes greater than 50% (e.g., EC75, LC90) were excluded because there is no way to place these in context of a criterion's protectiveness (see section 2.2.3 below). Only records reporting mean exposure concentrations or concentration ranges where the maximum was less than two-fold the minimum were retained because a definitive effect threshold (i.e., the exposure concentration at which a response is altered) is needed for assessing the protectiveness of a criterion. When an effect threshold was reported as a range, NMFS' analysis used the minimum reported concentration. Studies reporting nominal rather than measured exposure concentrations were retained when this aspect did not influence the overall consistency among records.

Criteria for cadmium are calculated using data for hardness, an aquatic chemistry parameter that influences the biological availability of cadmium. Consequently, data lacking the hardness data could not be included in the evaluation. Where necessary, reported cadmium concentrations were corrected to dissolved form using EPA's recommended conversion factor. We also excluded data for metals toxicity where only the free ion (i.e., labile) concentration was reported because the metals criteria are based on the dissolved fraction of the metal (i.e., the sample fraction that will pass through a 0.45-micron filter) and there is no standard approach to converting labile metal to dissolved metal.

CONSIDERING FLOW-THROUGH, RENEWAL, OR STATIC EXPOSURE TEST DESIGNS

Test organisms are typically exposed to test solutions through one of three methods. In "static" tests, organisms are in the same test solution for the duration of the test. In "renewal" tests, fresh test solution is replaced once every 24 or 48 hours. In "flow-through" tests, steady-state exposure is achieved by continuously providing fresh test solution throughout the test (ASTM 1997). A flow-through test does not create a current; it just means that test solution is introduced as a once-through, nearly continuous delivery of test solution. Historically, flow-through toxicity tests were thought to provide a better estimate of toxicity than static or renewal toxicity tests because they provide a greater control of toxicant concentrations, minimize changes in water quality, and reduce accumulation of the organism's waste products in test exposure waters (Rand et al. 1995).

While EPA Guidelines instruct that, when there are data for flow-through tests, any static or renewal test data for that species are to be discounted (Stephen et al. 1985), an important consideration is that natural flowing waters should not be assumed to be in chemical equilibria. Tributary inputs, hyporheic exchanges, stormwater and snowmelt, and daily and seasonal fluxes in pH, carbon, light penetration, and temperature cycles will influence the bioavailability of aquatic pollutants (Stumm and Morgan 1996) (Stumm and Morgan 1996) and the physiology of aquatic organisms (Heath 1995, McCormick and Leino 1999).

Static exposure studies can yield LC50 values substantially higher than values obtained with flow-through tests or tests in which actual concentrations of contaminants in the system during the experiment are measured. For example, for DDT, LC50 values for static tests have been determined to be approximately 20 times higher than LC50s from flow-through tests (Earnest and Benville 1972). Mercury toxicity testing of trout embryos indicated that effects concentration-based endpoints (e.g., ECXX, or the effects concentration that cause a specified percent reduction in a particular response) could be as much as one to two orders of magnitude[1]

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[1] An order of magnitude expresses data in terms of factors of 10. For example, 78 is an order of magnitude larger than 7.8. It is calculated as Log_{10}([endpoint]/[criterion]) rounded to 0 decimal places.

lower in flow-through than static tests (Birge et al. 1979, Birge et al. 1981). Static tests also resulted in higher endpoint estimates for endosulfan when compared with data from flow-through tests (Naqvi and Vaishnavi 1993). Several additional studies with a variety of compounds report static exposures under estimating toxicity (i.e., providing higher endpoint estimates. (e.g., Burke and Ferguson 1969, Vernberg et al. 1977, Hedtke and Puglisi 1982, Randall et al. 1983, Erickson et al. 1998). There are a number of reasons static conditions can underestimate the true exposure concentration in a test. Fish will deplete the concentration in solution over time, causing a lack of steady-state exposure. Some toxicants may transform during the test or volatilize from the test chamber. Other toxicants can adsorb to the walls of the exposure chamber or to accumulating organic matter within the exposure chamber.

With metals, renewal tests can also produce higher EC50 concentrations than flow-through tests (i.e., metals were less toxic). This has been attributed to the adsorption to accumulated organic matter (Erickson et al. 1996, Erickson et al. 1998, Welsh et al. 2008). However, in contrast to earlier EPA and American Society for Testing and Materials (ASTM) recommendations favoring flow-through testing, Santore et al. (2001) suggested that flow-through tests were biased low because typical flow-through exposure systems allowed insufficient hydraulic residence time for complete copper-organic carbon complexation to occur. Copper complexation with organic carbon reduces acute toxicity, but is not instantaneous. Davies and Brinkman (1994) similarly found that cadmium and carbonate complexation was incomplete in typical flow-through designs, although they reported the opposite effect of copper studies, with cadmium in aged, equilibrated waters being more toxic.

When comparing data across different tests, it appears that other factors, such as testing the most sensitive-sized organisms or number of organisms per liter of test water, may be much more important than flow-through or renewal techniques. For instance, a Pickering and Gast (1972) study with fathead minnows and cadmium produced flow-through LC50 concentrations that were lower than comparable static LC50 values (~ 4,500 to 11,000 micrograms per liter [µg/L] for flow-through tests vs. ~30,000 µg/L for static tests). The fish used in the static tests were described as “immature,” weighing about two grams. The size of the fish used in their flow-through acute tests was not given, but is assumed to have been similar. By contrast, using modern protocols and newly hatched fry weighing about 1/1000th of the fish used by Pickering and Gast (1972), cadmium LC50 concentrations for fathead minnows tend to be around 50 µg/L, with no obvious bias for test exposure (USEPA 2002). Studies examining exposure of brook trout to cadmium report dramatically different results using flow-through and static exposures on different life stages. NMFS identified two brook trout studies, one using flow-through and one using static acute tests, both conducted in waters of similar hardness (41 to 47 milligrams per liter, mg/L). The LC50 of the static test which used fry was <1.5 µg/L whereas the LC50 of the flow-through test using yearlings was >5,000 µg/L(Carroll et al. 1979, Holcombe et al. 1983).

When all other factors are equal, it appears that renewal tests may indicate chemicals are somewhat less toxic (e.g., higher LC50 values), but there is no clear consensus whether this indicates that renewal tests are biased toward lower toxicity than is "accurate" or whether conventional flow-through tests are biased toward higher toxicity. Comparisons with data across studies suggest that other factors, in particular the life stage of exposures (e.g., Pickering and Gast 1972, Carroll et al. 1979, Holcombe et al. 1983), can dwarf the influence of flow-through or renewal methods for the acute toxicity of, at least, metals. For this reason, data were not excluded on the basis of test design.

MIXTURE TOXICITY

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. Whether the toxicity of chemicals in mixtures is likely greater or less than that expected of the same concentrations of the chemicals singly is a complex and difficult problem. While long recognized, the "mixture toxicity" problem is far from being resolved. Even the terminology for describing mixture toxicity is dense and inconsistently used (e.g., Sprague 1970, Marking 1985, Vijver et al. 2010). One scheme for describing the toxicity of chemicals in mixtures is whether the substances show additive, less than additive, or more than additive toxicity. The latter terms are roughly similar to the terms "antagonism" and "synergism" that are commonly, but inconsistently, used in the technical literature.

Relatively few toxicity studies have addressed this issue, and some studies have indicated conflicting results due to complex interactions that vary with the combination(s) and concentrations involved (Sorensen 1991). However, a number of studies have determined conclusively that adverse effects due to additive or synergistic toxicity mechanisms occur when one or more metals are near or equal to acute criteria concentrations (e.g., EIFAC 1969, Alabaster and Lloyd 1982, Spehar and Fiandt 1986, Enserink et al. 1991, Sorensen 1991). Spehar and Fiandt (1986) exposed rainbow trout and *Ceriodaphnia dubia*, simultaneously, to a mixture of arsenic, cadmium, chromium, copper, mercury, and lead, each at their acute criterion, which by definition were intended to be protective. Nearly 100% of all the organisms died. In chronic tests, the authors determined that rainbow trout embryo survival and growth were not reduced when exposed to combinations of these metals at their chronic criteria concentrations. However, adverse effects were observed at mixture concentrations of one-half to one-third the approximate chronic toxicity threshold of fathead minnows and daphnids, respectively, suggesting that components of mixtures at or below NOEC concentrations may contribute significantly to the toxicity of a mixture on a chronic basis (Spehar and Fiandt 1986). Combinations of organic pollutants also have been shown to result in different toxic responses, as have combinations of organic and metals contaminants.

For both metals and organic contaminants that have similar mechanisms of toxicity (e.g., different metals, different chlorinated phenols), assuming chemical mixtures to have additive toxicity has been considered reasonable and usually protective (Alabaster and Lloyd 1982, Norwood et al. 2003, Meador 2006). The EPA water quality guidelines were developed for toxicants singly, as if the toxicant was the only chemical present. However, in the real world, chemicals always occur in mixtures. As a result, criteria and discharge permits based upon them may afford less protection than intended.

2.2.3 Interpreting the Median Lethal Concentration (LC50)

Toxicity is most commonly expressed in terms of LC50s. The acute criterion are derived through a meta-analysis that ranks LC50 data among species to form a "sensitivity distribution" that is used to identify the concentration that is hazardous to five percent of species. The acute criterion is set at one-half the concentration that is hazardous to five percent of species exposed to the toxicant for four days. While LC50 data are abundant, an exposure in which half of exposed organisms die or are otherwise affected (e.g. an EC50 for immobilization) is clearly not an insignificant effect. When the original toxicity test data[2] are not provided, it is not possible to calculate the magnitude of response at the criterion concentration. In such cases, a comparison metric in some form is necessary to place endpoint data in context of the criterion. Comparison metrics used for this purpose are essentially ratio approaches that are described in more detail below.

Safety factors: Studies comparing the sensitivities of threatened and endangered species relative to species commonly used in laboratory toxicity tests suggest that multiplying the National Recommended Water Quality Guidelines, LC50s, or chronic response thresholds like inhibition concentrations (EC50, IC50) by a generic safety factor of about 0.5 provides an exposure concentration that would protect ESA-listed species. However, safety factors for the protection of ESA-listed species proposed in the open literature range from 0.3 to 0.63 (Dwyer et al. 2000, Sappington et al. 2001, Besser et al. 2005, Dwyer et al. 2005).

Risk Quotient: A risk or hazard quotient is the ratio of an anticipated exposure concentration to a reference concentration. When evaluating the protectiveness of a numeric water quality criterion, the anticipated exposure concentration is the criterion concentration and the reference concentration is the concentration at which a response, such as an EC10, LOEC, or LC50, was reported. When evaluating acute exposures for nontarget aquatic animals using LC50 data, EPA's Office of Pesticides Programs (OPP) considers a risk quotient greater than 0.5 as warranting concern. That is to say, exposures that are less than half an LC50 are expected to be safe. This is consistent with the assumption that half the LC50 is conceptually equivalent to an LC01 or to a no effect. However, for threatened and endangered aquatic animals, OPP's level of concern for acute exposures is an order of magnitude more protective, with risk quotients greater than 0.05 posing a concern (USEPA 2004). For chronic exposures, OPP bases risk on the lowest early life-stage or full life cycle NOEC for freshwater fish and invertebrates and

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[2] Toxicity test data consist of the response magnitude at each exposure concentration used in the test. Response magnitude at an exposure of interest, in this case the criterion concentration, may be calculated through regression for continuous responses like growth and number of eggs produced, or prohibit analysis for binary responses such as dead or alive and gravid or not gravid.

estuarine/saltwater fish and invertebrates, where a risk quotient greater than one is of concern for all aquatic species, regardless of ESA-listing status.

Adjustment factors: Adjustment factors are taxonomically aggregated data used in the same manner as a safety factor. Ideally, a Taxonomic Adjustment Factor (TAF) could be calculated using ratios from studies exposing species from the same taxonomic order as the ESA-listed species of interest. Calculation of a TAF ensures adequate representation among taxa by first calculating the geometric mean of ratios within species (SMAV), then the geometric mean of all SMAVs within each genus (GMAV), followed by the geometric mean of all GMAVs within each family, and finally as the geometric mean of all families within the order.

Extrapolation factors: EPA’s BE for this consultation used extrapolation factors. An extrapolation factor is applied to the species mean acute concentration (SMAC) based on taxonomic similarity between the test organism and with the ESA-listed species. There is an extrapolation factor of 1.0 times the SMAC if there are toxicity data using the ESA-listed species. The SMAC is discounted ten percent for each taxonomic “step” away from the ESA-listed species. For example, if the surrogate data are from a species within the same genus, a value that is 90% of the SMAC is used; if the surrogate data are from a species within the same taxonomic family, a value that is 80% of the SMAC is used, etc.

UTILITY OF “BRIGHT LINE” APPROACHES

While these ratio approaches offer straightforward derivation and a “bright line” for interpretation of median effect thresholds (i.e., LC50s, EC50s, IC50s), they do not reflect a plausible worst case scenario, or capture the variation around individual endpoint estimates or the abundance and overarching depth and quality of available data. As demonstrated in prior NMFS’ Opinions for EPA approval of Oregon and Idaho WQS (NMFS 2012a, 2014, 2020b), the validity of the assumption that one half an LC50 is a safe exposure is reliant on the slope of the exposure-response relationship (Figure 1), with shallow exposure-response curves indicating up to 20% mortality at one-half the reported LC50.

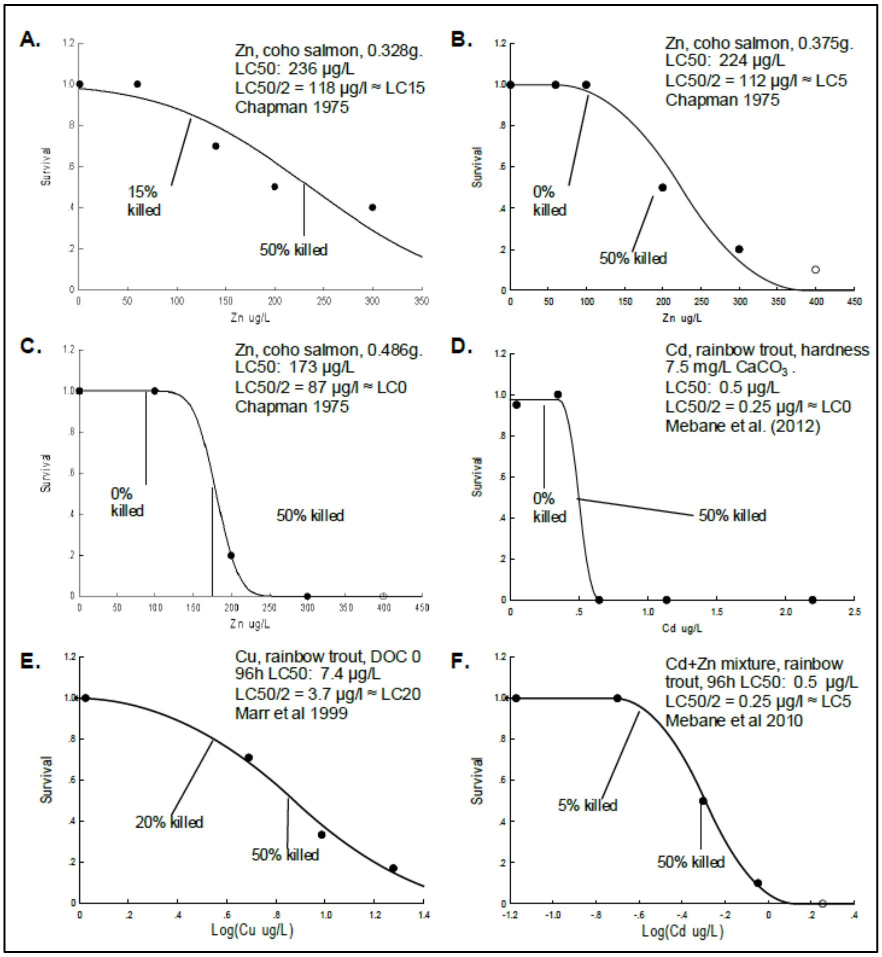

Figure 1. Plots Showing Proportion of Coho Salmon or Rainbow Trout Killed at One-Half Their LC50 Concentrations with Cadmium, Copper, and Zinc (NMFS 2014)

A more common pattern with metals data analyzed for a previous water quality consultation was that half an LC50 concentration would probably result in about a five percent death rate in salmon (NMFS 2012a). Testing with cutthroat trout and cadmium, lead, and zinc singly and in mixtures, Dillon and Mebane (2002) found that the LC50/2 concentration corresponded with death rates ranging from 0% to 15%.

A study by Spehar and Fiandt (1986) included effect-by-concentration information on the acute toxicity of chemical mixtures. Rainbow trout and *Ceriodaphnia dubia* were exposed for 96 and 48 hours, respectively, to a mixture of six metals, each at their presumptively "safe" acute criterion. In combination, the acute criterion concentrations killed 100% of rainbow trout and *Ceriodaphnia*, but 50% of the acute criterion concentrations killed none (Spehar and Fiandt 1986). This gives support to the assumption that dividing a lethal exposure by two would usually kill few, if any, fish, although it conflicts with arguments that criteria are protective for mixtures of metals at their respective acute criterion.

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

2.3 NMFS' Evaluation of Water Quality Criteria in this Opinion

Deriving criteria is a very different goal from evaluating criteria for protectiveness of imperiled species. Our purpose is to determine whether there is any indication that ESA-listed species or designated critical habitat under NMFS' jurisdiction are likely to be affected by exposures within criteria limits. This is actually a two-step analysis, first determining whether exposures are expected to occur followed by determining whether exposures within criteria limits may result in adverse effects.

For this Opinion, NMFS evaluates monitoring and toxicity data in terms of risk quotients because quotients place the data directly in the context of the applicable criterion. 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.[3] The use of risk quotients allows simultaneous presentation of the entirety of the data landscape and transparently identifies responses that occurred at concentrations one 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, four times) or within a "gray area" that demands more careful consideration.

For the evaluation of the acute and chronic cadmium criteria, NMFS used the hardness values reported with toxicity data to calculate toxicity test-specific criteria using the equations published in EPA's biological evaluation. NMFS then used the test-specific criteria to calculate risk quotients: the test-specific criterion, as the presumed exposure concentration, divided by the endpoint effect concentration (e.g., LOEC, NOEC, EC50, LC50, etc.). Considering the scale of uncertainty associated with interspecies and lab-to-field extrapolation, NMFS conservatively applied the acute criterion, which is implemented as a one-hour average, for toxicity test exposures that were four days or less and applied the chronic criterion, which is implemented as a four-day average, to longer exposures.

The selenium freshwater water column criterion is not hardness dependent, so adjustment of toxicity test data was not necessary. NMFS calculated risk quotients using the water column criterion as the presumed exposure concentration divided by the endpoint effect concentration (e.g., LOEC, NOEC, EC50, LC50, etc.). Considering the scale of uncertainty associated with

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[3] The analysis does not convert toxicity test data to "standard conditions" such as 100 mg/L hardness because that is not how the criteria will be applied in regulatory practice. Further, discussing data in terms of concentrations suggests a level of precision and certainty that is not translatable to real-world exposures.

interspecies and lab-to-field extrapolation, NMFS conservatively applied the water column selenium criterion, which is implemented as a 30 day average, for toxicity test exposures that were ten days or greater.

Risk quotients for all available endpoint effect data from the screened datasets are plotted in the context of reference values representing the applicable criterion concentration and one-half that criterion concentration. The toxicity data figures in this Opinion (Figures 8 through 11, and Figures 18 and 19) present test-specific risk quotients plotted in the context of reference lines representing a risk quotient of one (purple) for exposures at the criterion concentration and a risk quotient of 0.5 (orange) representing exposures at one-half the criterion concentration. Risk quotients plotted to the right of the purple reference line indicate responses occurring at an exposure concentration below the 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.

Less common endpoint types are defined in NMFS' analysis when they are represented in a dataset at concentrations suggesting adverse effects for exposures within criteria limits. Endpoints are sometimes reported with "<" and ">" to indicate studies in which only one exposure concentration was used or in which responses for that effect either occurred below the lowest exposure concentration, represented by the less than sign "<", or above the highest exposure concentration used in that study, represented by the greater than sign ">". This analysis excludes data reported with a greater than sign because they indicate that the response occurred at some unknown higher concentration than indicated and does not inform whether effects occur at concentrations within or below criterion limits.

Considering the slope of exposure-response relationships reported for a vast majority of toxicants, for the reasons described below, we expect that ESA-listed species are extremely unlikely to respond to exposures within criterion limits if the criterion concentration is orders of magnitude lower (i.e., by ten or 100-fold or more) than the lowest reported acute lethal effect (e.g., LC50s or EC50s) or the lowest chronic exposure-response threshold (e.g., LOEC). Interpreting criteria when the minimum exposures resulting in toxic response (i.e., LC50s, LOECs, and MATCs) are not one or more orders of magnitude greater than the criteria is somewhat more complicated. The magnitude of response at the applicable criterion concentration may be at some lower, but still unacceptable, level from the standpoint of effects to ESA-listed species.

For the evaluation of the selenium tissue based water quality criteria, NMFS assembled data reporting effects in fish alongside data for selenium concentration in tissues as well as data for effects reslting from dietary exposures to selenium in whole fish.

2.3.1 Evaluating Criteria Protectiveness for ESA-listed Species

Because the criteria developed using the EPA Guidelines are not expected to protect all species under all circumstances, waters compliant with the criteria may result in pollutant exposures that cause adverse effects in threatened and endangered 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. The underlying assumptions in the methods used to arrive at criteria affect how well ESA-listed species and designated critical habitat are protected. These assumptions include:

- Effects that occur on a species exposed to a toxicant in laboratory tests will generally be the same for the same species exposed to that toxicant under field conditions (i.e., effects are not influenced by predation, competition, disease, exposure to other stressors in the field, and fluctuations in natural water quality parameters).
- Collections of single-species laboratory toxicity test data used to derive criteria reflect communities in natural ecosystems.
- Data on severely toxic effects from short-term "acute" toxicity tests used to derive acute criterion can be extrapolated to less severe effects that would be expected to occur in long-term "chronic" exposures to derive chronic criterion.
- Loss of a small number of species will not affect the propagation of fish, shellfish, and wildlife.
- Loss of a small number of species will not result in incidental loss of any “economically or recreationally valuable species” for which data were not available.
- Sensitive species and life stages are adequately represented such that criteria are not biased.
- Derivation of criterion for a single chemical in isolation without regard to the potential for additive toxicity or other chemical or biological interactions is acceptable despite chemicals typically occur in mixtures in the environment.
- When applied to NPDES permits, unless the waters are already identified as impaired by a particular pollutant, the waters are free of that pollutant (i.e., the baseline concentration of that pollutant in the receiving water is zero).
- Accumulation of chemicals in tissues and along the food web does not result in ecologically significant latent toxicity or toxic exposures for predators.

There are also concerns about the underlying data used in the derivation of criteria including:

- Data sets for sublethal responses are usually small and have gaps such that sensitive species and life stages are under-represented.
- Variability within and among species used in calculating a hazardous concentration to five percent of species may be substantial, but this variability is not reflected in the final estimate used to derive an acute criterion.

For an ESA section 7 consultation, NMFS and Federal action agencies are required to use "the best scientific and commercial data available" (ESA section 7 (a)(2); 50 CFR §402.14(d)). It is important to note that EPA's use of data for criteria derivation and associated regulatory actions is not the same as NMFS' use of data for this consultation. For example, the requirement that EPA only use data for species that are native to waters of the United States means data on effects to sturgeon of the same genus as ESA-listed sturgeon that occur only in foreign waters would be excluded. This consultation is vetting the criteria. It is not necessary to create reference values or extrapolation factors. This would require restricting data. NMFS considers all data meeting the screening criteria discussed in the following section. This is consistent with the EPA Guidelines, as it discussed the use of "Other Data" as follows:

> *"Pertinent information that could not be used in earlier sections might be available concerning adverse effects on aquatic organisms and their uses. The most important of these are data on cumulative and delayed toxicity, flavor impairment, reduction in survival, growth, or reproduction, or any other adverse effect that has been shown to be biologically important. Especially important are data for species for which no other data are available. Data from behavioral, biochemical, physiological, microcosm, and field studies might also be available. Data might be available from tests conducted in unusual dilution water (see IV.D and VI.D), from chronic tests in which the concentrations were not measured (see VI.B), from tests with previously exposed organisms (see II.F), and from tests on formulated mixtures or emulsifiable concentrates (see II.D). Such data might affect a criterion if the data were obtained with an important species, the test concentrations were measured, and the endpoint was biologically important."*

2.3.2 Extrapolating Data from Other Species to Shortnose and Atlantic Sturgeon

Ideally, quantitative exposure-response data for shortnose and Atlantic sturgeon are available for exposures at the applicable criteria concentrations. Toxicity tests are rarely conducted on threatened and endangered species or species that are not easily cultured in the lab. Those data that are available for shortnose and Atlantic sturgeon demonstrate that taxonomic relatedness is not always a good predictor for toxicity and that rainbow trout, which have abundant toxicity data, are not "excessively sensitive" to toxicants relative to shortnose and Atlantic sturgeon, and can be a suitable surrogate when data for sturgeon are absent.

Dwyer et al. (2005) compared the relative toxicity of five chemicals to 18 fish species, including shortnose sturgeon, Atlantic sturgeon, and rainbow trout. Responses for all three species were similar for copper, suggesting rainbow trout are a good surrogate for metal exposures. A copper LC50 of 80 µg/L was reported for both shortnose sturgeon and rainbow trout while the LC50 for Atlantic sturgeon was only slightly lower, at 60 mg/L. Information supporting rainbow trout suitability as a surrogate for exposure to organic chemicals is mixed. Sturgeon were sometimes more sensitive. Shortnose sturgeon, Atlantic sturgeon, and rainbow trout 4-nonylphenol LC50s were 80, 50, and 190 µg/L, respectively. The pentachlorophenol LC50 was less than 40 µg/L for

Atlantic sturgeon and the LC50 for shortnose sturgeon was 70 µg/L while the rainbow trout LC50 was more than twice that, at 160 µg/L. Permethrin LC50s for both shortnose and Atlantic sturgeon were less than 1.2 µg/L while the LC50 for rainbow trout was 3.31 µg/L. The shortnose sturgeon LC50 for carbaryl was comparable to that of rainbow trout, at 1810 and 1880 µg/L, respectively, while the carbaryl LC50 for Atlantic sturgeon was less than 800 µg/L. In this case, taxonomic relatedness did not ensure similar sensitivity. Chambers et al. (2012) reported a four-fold within-genus difference in sensitivity for early-life-stage effects of polychlorinated biphenyl-126 in Atlantic sturgeon in comparison with shortnose sturgeon. The Chambers et al. (2012) study did not evaluate effects in rainbow trout.

To summarize, rainbow trout had similar sensitivity to copper as shortnose and Atlantic sturgeon, was less sensitive than either sturgeon to 4-nonylphenol, pentachlorophenol, and permethrin, was similarly sensitive to carbaryl as shortnose sturgeon, but not Atlantic sturgeon. Finally, shortnose sturgeon were less sensitive to PCB-126 than Atlantic sturgeon. Taken together, in terms of sensitivity to toxicants, these data suggest that rainbow trout are just as suitable a surrogate species for shortnose and Atlantic sturgeon as species within the same genus or family. The similarity in sensitivity to copper of rainbow trout, shortnose sturgeon, and Atlantic sturgeon suggests they are particularly good surrogates for metal toxicity.

Allometric differences (e.g., body size, membrane area, organ size) are factors to be considered when evaluating toxicity data. A smaller individual generally succumbs to toxic effects more rapidly than a larger individual does because it takes a longer time for exposures to reach critical concentrations within the tissues of the larger individual. Therefore, higher exposure concentrations would be expected to elicit the same response over a similar exposure period. While adult sturgeon are much larger than adult rainbow trout, one year old sturgeon captured in the Connecticut River ranged in length from 9 to 25 inches (Savoy et al. 2017) while a one year old rainbow trout is about seven to nine inches (Kebus et al. 1992). Rainbow trout hatchlings are reported to be 10 to 18 mm long (Réalis-Doyelle et al. 2016) while shortnose and Atlantic sturgeon hatchlings are 7 to 11 mm long (Smith et al. 1980, COSEWIC 2005). While not identically sized, this similarity suggests greater confidence when using data for rainbow trout as a surrogate species to assess impacts on early-life-stage sturgeon.

In the absence of data for shortnose and Atlantic sturgeon, this Opinion prioritizes data from surrogate species as follows: other sturgeon species and rainbow trout > other salmonids > other fish species. Where the analysis must rely on other fish species, this Opinion applies a comprehensive perspective that considers all fish data in context of differences reported among sturgeon sensitivities to other toxicants, and the need to be protective of ESA-listed sturgeon. This perspective is based on the expectation that mechanisms of effect in tested fish species are generally similar to mechanisms in the ESA-listed fish species based on fundamental physiological functions (e.g., osmoregulation, ion exchange, antioxidant defense, nerve function). This approach uses a high-level review of ECOTOX data, data from government reports, and peer-reviewed literature, to focus on observations suggesting whether adverse effects could occur within criteria limits. This review takes into consideration dataset characteristics, such as the diversity of species represented, outliers, life stage effects, allometric influences, how responses were documented by researchers, the number and quality of the available toxicity studies, and the magnitude and types of effects reported.

2.3.3 Evaluating Criteria Implementation

NMFS' assessment addresses criteria that are likely to be implemented. Examples of criteria that are not likely to be implemented include those for non-persistent pesticides with no registered uses in the state, territory, or tribe adopting the criteria and substances that are not expected to occur in the water column because they are no longer in domestic or industrial use. Because the criteria set the exposure conditions for each stressor, each analysis determines whether adverse effects may result from exposure to the stressor within the limits of its acute and chronic criteria. If NMFS' analysis determines that exposures and/or responses to a stressor within a criterion's limits are insignificant or extremely unlikely to occur for ESA-listed species under NMFS' jurisdiction, NMFS may make a not likely to adversely affect determination for EPA's approval of the adoption and implementation of that criterion. If exposure is reasonably certain to occur and adverse effects are expected in individuals of ESA-listed species under NMFS' jurisdiction exposed within criteria limits, NMFS proceeds with a risk analysis to estimate the implications for the population of affected individuals.

Because implementation of the criteria is an effect of EPA's approval, NMFS' exposure assessment evaluates monitoring and regulatory data to identify the pollutant's sources, determine whether the criteria are likely to be implemented, and whether implementation is expected to be successful. For example, some water quality monitoring occurs and uses "sufficiently sensitive analytical methods" as defined in the 122.44(i)(1)(iv) of the Clean Water Act and existing sources of wastewater discharges submit discharge monitoring reports.

Given limited monitoring data for the state North Carolina, this consultation considered whether "sufficiently sensitive analytical methods" are adequate to identify exposures that may result in adverse effects. The EPA has established that an EPA-approved test method is "sufficiently sensitive" in different situations using three different criteria:

- The method minimum level is at or below the level of the applicable water quality criterion or permit limitation for the measured pollutant or pollutant parameter; or
- The method minimum level is above the applicable water quality criterion, but the amount of the pollutant or pollutant parameter in the discharge is high enough that the method detects and quantifies the level of the pollutant or pollutant parameter in the discharge; or
- The method has the lowest minimum level of the EPA-approved analytical methods.

In other words, where none of the EPA-approved methods for a specific pollutant are able to "achieve the minimum levels necessary to assess reasonable potential or to monitor compliance with a permit limit," the method with the lowest minimum level of all methods approved by the EPA for the pollutant meets the "sufficiently sensitive" requirement. Because the acceptable detection limit is determined by North Carolina DEQ on a case-by-case basis, the only opportunity to assess such decisions for the protection of potentially affected ESA-listed species is for NMFS technical assistance review of permits discharging to Sturgeon Waters.

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 4's approval of the water quality criteria proposed for adoption by the state of North Carolina under Section 303(c) of the Clean Water Act. The EPA proposes to approve the adoption of National Recommended Water Quality Guidelines as numeric water quality criteria for implementation of the Clean Water Act in the state of North Carolina (Table 1).

The purpose of the criteria is to maintain or restore water quality conditions that support aquatic life. For North Carolina, EPA proposes to approve water hardness-specific freshwater acute criteria for cadmium in "trout waters" and "warm waters", freshwater chronic cadmium criteria, saltwater acute and chronic cadmium criteria, and freshwater chronic selenium egg/ovary, whole body, and water column criteria in lotic (flowing river and stream) and lentic (pond, lake, and reservoir) systems.

Table 1. National Recommended Water Quality Guidelines for the Protection of Aquatic Life that EPA Proposes to Approve for Implementation by North Carolina

Criteria	Acute	Chronic
Cadmium, freshwater (μg/L[a] at 25 mg/L $CaCO_3$ hardness[b])	0.75	0.25
Cadmium, freshwater-trout waters (μg/L[a] at 25 mg/L CaCO3 hardness[b])	0.49	--
Cadmium, saltwater (μg/L)	33	7.9
Selenium, freshwater egg/ovary (mg/kg[c])	--	15.1
Selenium, freshwater whole body/muscle (mg/kg)	--	8.5/11.3
Selenium, freshwater water column continuous for lentic systems (ponds, lakes and reserviors, μg/L)		1.5
Selenium, freshwater water column continuous for lotic systems (flowing rivers and streams μg/L)	--	3.1

[a] microgram per liter

[b] milligrams $CaCO_3$ per liter

[c] milligrams per kilogram

North Carolina chose to develop two different acute freshwater cadmium criteria, a trout-waters criterion for “cold” water habitats in the western portion of the state above the fall line[4] where trout occur and a less conservative criterion, calculated without data from trout toxicity tests, for “warm water” freshwater habitats where trout do not occur. The ESA-listed species under NMFS’ jurisdiction that occur in North Carolina freshwaters are the Atlantic sturgeon, primarily the Carolina DPS, and the shortnose sturgeon. The trout-waters criterion is the same as the EPA recommended acute guideline for cadmium, but will not be implemented in waters where ESA-listed sturgeon occur because sturgeon do not access waters above the fall line. On a similar note, ESA-listed species under NMFS’ jurisdiction do not occur in ponds, lakes, or reservoirs of North Carolina, so the water column lentic criterion for selenium would not be implemented in waters where ESA-listed sturgeon. Because these criteria will not be implemented in fresh waters where ESA-listed sturgeon occur, EPA’s approval of the trout waters acute cadmium criterion and the water column criterion for selenium in lentic waters will have no effect on shortnose sturgeon or Atlantic sturgeon.

For stressors that cause toxic effects due to exposures in ambient water, such as cadmium, 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 are usually expressed as exposure concentrations over a specified duration and frequency at and below which ecologically relevant effects are not expected to occur. 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 four-day toxicity tests. The acute criterion is one-half the concentration that is hazardous to five 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 et al. 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 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 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 cadmium is a one-hour average not to be exceeded more than once in three years and the chronic criterion duration and frequency limit is a four-day average not to be exceeded more than once in three years.

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[4] The fall line is a 900-mile (1,400 km) escarpment where the Piedmont and Atlantic coastal plain meet, is often described as "the point at which boats traveling upriver usually cannot continue any further" and is generally an impediment to river travel due to river rapids and waterfalls (Bleakley and Lin 2012).

Selenium causes deleterious effects when biologically accumulated in an organism's tissues and exposures to selenium are primarily dietary and primarily through transfer to the eggs and subsequent reproductive effects. Accordingly, EPA's National Criteria for selenium are expressed as instantaneous freshwater chronic egg/ovary concentrations in fish, whole body/muscle concentrations in fish, or 30-day average water column criterion. The criterion applied is dependent on the data available, with egg/ovary criterion taking priority over the whole body/muscle criterion and whole body/muscle criterion taking priority over water column criteria.

4 ACTION AREA

The action area for EPA's approval includes all waters the criteria will be applied to within the state of North Carolina and any waters in other states affected by water quality due to the application of the criteria to North Carolina waters. Like most coastal states, North Carolina has jurisdiction over coastal waters extending to three nautical miles from mean high water mark. The action area includes approximately 1,939 km (1,205 miles) of rivers designated as occupied critical habitat for the Carolina DPS of Atlantic sturgeon in the Roanoke, Tar-Pamlico, Neuse, Cape Fear, Northeast Cape Fear, Waccamaw, and Pee Dee Rivers.

5 ESA-LISTED SPECIES AND DESIGNATED CRITICAL HABITAT

Table 2 identifies the ESA-listed species (including DPSs) that occur in the action area and are under NMFS' jurisdiction that may be affected by the proposed action.

Table 2. Endangered and Threatened Species and Designated Critical Habitat within the Action Area and Under NMFS' Jurisdiction

Species	Federal Register Listing	Designated Critical Habitat
Fin Whale (endangered, *Balaenoptera physalus*)	35 FR 18319	--
North Atlantic Right Whale (endangered, *Eubalaena glacialis*)	73 FR 12024	81 FR 4837
Sei Whale (endangered, *Balaenoptera borealis*)	35 FR 18319	--
Green Sea turtle (threatened, *Chelonia mydas*), North Atlantic DPS	81 FR 20057	Does not occur in action area
Kemp's Ridley Sea turtle (endangered, *Lepidochelys kempii*)	35 FR 18319	--
Leatherback Sea turtle (endangered, *Dermochelys coriacea*)	35 FR 8491	Does not occur in action area
Hawksbill Sea Turtle (endangered, *Eretmochelys imbricata*)	35 FR 8491	Does not occur in action area
Loggerhead Sea turtle (threatened, *Caretta caretta*), Northwest Atlantic Ocean DPS	76 FR 58868	Does not occur in action area
Atlantic sturgeon (endangered, *Acipenser oxyrinchus oxyrinchus*) Carolina DPS, Migrating and foraging New York	77 FR 5879	82 FR 39160

Bight, Chesapeake, South Atlantic DPSs (endangered), and Gulf of Maine DPS (threatened)	77 FR 5913	
shortnose sturgeon (endangered, *Acipenser brevirostrum*)	32 FR 4001	--

Although EPA made a "may affect, not likely to adversely affect" determination for designated critical habitat in the action area, NMFS concludes that the action will not affect designated critical habitat. Designated critical habitat PBFs must explicity identify pollutant conditions (e.g., water free from harmful concentrations of pollutants) or a biological component that would respond to toxicant exposures (e.g., forage species) in order for EPA's approval of water quality criteria to have an effect. Designated critical habitat for the Atlantic sturgeon does not include biological features and the biological feature of designated critical habitat for North Atlantic right whale, *Calanus finmarchicus*, does not occur in water affected by North Carolina DEQ implementation of water quality criteria. Neither critical habitat designation specifies pollutant conditions.

5.1 ESA-Listed Species Not Likely To Be Adversely Affected

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

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

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 to the stressor is extremely unlikely to occur.

Prior consultations determined that implementation of EPA's Water Quality Guidelines for aquatic toxicants are not likely to adversely affect ESA-listed sea turtles and baleen whales because their exposures to aquatic pollutants are expected to be far less than that of the fish and aquatic invertebrates the criteria were derived to protect (NMFS 2015, 2018a, 2020a). 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. 2014).

5.1.1 Whales

Selenium criteria are proposed only for freshwater habitats, so EPA's approval of the North Carolina adoption and implementation of freshwater selenium criteria will not result in exposures of ESA-listed marine species, including fin, sei and North Atlantic right whales. The only criteria proposed for implementation by North Carolina that are applied to marine waters are acute and chronic criteria for cadmium. Fin and sei whales are highly migratory species and are associated with deep offshore habitats. Sei whales prefer deep waters off the continental slope (Horwood 1987). Sei whales are very rare in North Carolina waters. Fin whales are rare to uncommon in North Carolina waters. The North Carolina Department of Parks reports that strandings that have occurred were in the months from January to May with the highest frequency in January, suggestive of the peak of occurrence in NC waters. This species is typically seen in waters offshore of North Carolina, though can be within a few miles of the coast.

In contrast to fin and sei whales, the North Atlantic right whale 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 whales do not forage in North Carolina 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 (Kjeld 2003, Birukawa et al. 2005).

Exposures of fin and sei whales to water quality conditions resulting from implementation of North Carolina's water quality criteria for cadmium are expected to be insignificant because of their long migrations and affinity for deeper offshore waters, resulting in infrequent and short duration presence in North Carolina waters. Therefore, NMFS concludes that EPA's approval of

North Carolina's adoption of saltwater cadmium criteria may affect, but is not likely to adversely affect, fin and sei whales.

While North Atlantic right whales calve in waters off of Cape Fear, North Carolina, their exposures to water quality conditions resulting from implementation of North Carolina's water quality criteria for cadmium are expected to be insignificant because they breathe air, do not drink seawater, and do not forage while in North Carolina waters. Therefore, NMFS concludes that EPA's approval of North Carolina's adoption of saltwater cadmium criteria may affect, but is not likely to adversely affect North Atlantic right whales.

5.1.2 Sea Turtles

Selenium criteria are proposed only for freshwater, so EPA's approval of the North Carolina adoption and implementation of selenium criteria will not result in exposures of ESA-listed marine species, including the 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. The only criteria proposed for implementation by North Carolina that are applied to marine waters are acute and chronic criteria for cadmium. Because ESA-listed sea turtles breathe air and do not have gills, their only direct exposure to aquatic toxicants, would be through drinking seawater and limited absorption through exposed membranes. Even though some species nest on North Carolina beaches, sea turtles are temporary residents to North Carolina 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 are unlikely to accumulate a significant amount of persistent pollutants because they primarily consume lower trophic-level food species (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 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 North Carolina's water quality criteria are expected to be insignificant because their only direct exposures to aquatic toxicants would be through drinking seawater and limited absorption through exposed membranes. This contrasts with the continuous ingestion and respiratory epithelial exposures of gilled saltwater species the criteria are meant to protect. Therefore, NMFS concludes that EPA's approval of North Carolina's adoption of saltwater cadmium 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.

5.2 Status of Species Likely to be Adversely Affected

Section 5.1 above set forth the rationale for determining that EPA's approval of cadmium and selenium water quality criteria proposed by North Carolina are not likely to adversely affect ESA-listed whales (Section 5.1.1) and sea turtles (Section 5.1.2). The ESA-listed species that may be adversely affected by EPA's approval of cadmium and selenium water quality criteria proposed for North Carolina are the shortnose sturgeon and the Carolina DPS and migrating and foraging Gulf of Maine, New York Bight, Chesapeake, and South Atlantic DPSs of Atlantic sturgeon. Waters identified for potential shortnose sturgeon presence include North Albemarle Sound, Albemarle Sound, Chowan, Roanoke, Tar-Pamlico, Neuse, New River, Cape Fear, Waccamaw, and Pee Dee Rivers. The Gulf of Maine, New York Bight, Chesapeake, and South Atlantic DPSs of Atlantic sturgeon may migrate and forage along the North Carolina coast and estuary. Throughout this Opinion, these waters are referred to as "Sturgeon Waters."

This Opinion examines the status of each species and critical habitat that may 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 and the condition of designated critical habitat within the applicable critical habitat unit and in the action area. The status is determined by the level of risk that the ESA-listed species and designated critical habitat 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 described in 50 CFR§402.02. More detailed information on the status and trends of these ESA-listed species, and their biology and ecology can be found in the listing regulations and critical habitat designations published in the Federal Register, status reviews, recovery plans, and on the NMFS Web site: [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 catch in some commercial fisheries. Recent reviews also identify climate change as a threat to ESA-listed sturgeon (SSSRT 2010, NMFS 2022a, b).

DAMS

Dams impede fish passage, fragmenting populations through eliminating or impeding access to historic habitat. Hydropower turbines, spillways, and fish passage devices can injure or kill fish attempting to migrate or are entrained in turbines. Dams also modify natural hydrology, altering downstream flows and water temperatures, affecting DO, channel morphology, nutrient cycling, stratification, community structure, and sediment regime, which can include redistribution of sediment-associated toxicants (Jager et al. 2001, Secor et al. 2002, Cooke and Leach 2004). Short-term negative impacts of dam removal include the influx of sediments into the stream flow, which can embed spawning substrates and negatively affect water, habitat and food quality. These effects are usually temporary. Several studies have demonstrated that after dam removal, sediments were flushed from river channels, natural sediment transport conditions resumed (American Rivers 2002).

IMPINGEMENT AND ENTRAINMENT

Depending on life stage and size, sturgeon are susceptible to impingement on or entrainment through cooling water intake screens at power plants. Impingement and entrainment is also a risk 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 (Chytalo 1996, Smith and Clugston 1997, NMFS 1998b, Winger et al. 2000, NMFS 2018b).

BYCATCH

At this time, Atlantic sturgeon bycatch mortality is now considered a primary threat affecting the recovery of all five DPSs of Atlantic sturgeon (NMFS 2022a, b). The 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 of small numbers (SSSRT 2010).

CONTAMINANTS

The 2010 status review for shortnose sturgeon reviewed contaminant risks applicable to all sturgeon species. The life history characteristics of amphidromous sturgeon (i.e., long lifespan, extended residence in estuarine habitats, benthic foraging) predispose these species to long-term and repeated exposure to environmental contamination and potential bioaccumulation of heavy metals and other toxicants (Dadswell 1979, NMFS 1998a). Chemicals and metals such as chlordane, dichlorodiphenyl dichloroethylene (DDE), DDT, dieldrin, PCBs, cadmium, mercury, and selenium settle to the river bottom and are later consumed by benthic feeders, such as macroinvertebrates, and then work their way higher into the food web, 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 dissolved oxygen, altering pH, and altering other physical properties of the water body.

General Effects of Contaminant Exposures and Tissue Burdens in Fish

Pesticide exposure in fishes may affect anti-predator and homing behavior, reproductive function, physiological development, and swimming speed and distance (Beauvais et al. 2000, Scholz et al. 2000, Moore and Waring 2001, Waring and Moore 2004). Sensitivity to environmental contaminants also varies across life stage. Early-life-stages of fishes appear to be more susceptible to environmental and pollutant stress than older life stages (Rosenthal and

Alderdice 1976). The presence of a contaminant in the tissues of an organism indicates exposure, but does not always mean these tissues residues are causing adverse effects. Elevated levels of contaminants in fish have been associated with reproductive impairment (Giesy et al. 1986, Mac and Edsall 1991, Cameron et al. 1992, Longwell et al. 1992, Matta et al. 1997, Billsson 1998, Hammerschmidt et al. 2002)), reduced larval survival (Berlin et al. 1981, Giesy et al. 1986), delayed maturity (Jørgensen et al. 2004) and posterior malformations (Billsson 1998).

TISSUE BURDENS REPORTED IN STURGEON

Shortnose sturgeon collected from the Delaware and Kennebec Rivers had total toxicity equivalent concentrations of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), PCBs, DDE, aluminum, cadmium, and copper above adverse effect concentration levels reported in the literature (ERC 2002, 2003). 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 (TCDD) concentrations > 50 ppt, a level which can adversely affect the development of sturgeon fry (NOAA, Damage Assessment Center, Silver Spring, MD, unpublished data).

Dadswell (1975) reported mercury concentrations averaging 0.29 (0.06 – 1.38) milligrams per kilogram (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 some 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). Kootenai River white sturgeon exhibited organochlorine levels that could potentially affect reproduction or other physiological functions (Kruse and Scarnecchia 2002). Aldrin, 4,4-DDE, α-HCH, copper, and selenium were the most frequently detected contaminants in the plasma of green sturgeon from Washington coastal estuaries, with the highest concentrations in fish collected from more urbanized areas, but few fish had plasma contaminant levels at toxic thresholds (Layshock et al. 2022). The liver and gonads of white sturgeon from the San Francisco Bay Estuary had high concentrations of arsenic, barium, cadmium, copper, chromium, lead, mercury, nickel, selenium, and zinc. The concentrations of arsenic, cadmium, copper, selenium, mercury and selenium were at levels known to impair fish health (Gundersen et al. 2017). Selenium in the ovaries and liver of vitellogenic San Francisco Bay Delta white sturgeon was measured at levels demonstrated to cause reproductive impairment in laboratory studies (Linares-Casenave et al. 2015).

EFFECTS ASSOCIATED WITH EXPOSURE IN THE WILD

Male Columbia River white sturgeon growth and reproductive impacts were observed along with a negative correlation between plasma androgens and gonad size with DDT, pesticides, and PCBs (Feist et al. 2005). Mercury concentrations of white sturgeon captured from the Columbia River was correlated with suppressed circulating sex steroids, decreased condition factor and relative weight, and a lower gonadosomatic index in immature males. A significant positive linear relationship was observed between age and liver mercury concentrations (Webb et al. 2006). Poly- and perfluorinated compounds accumulated in the tissues and eggs of wild 17 to 25 year old female Chinese sturgeon, but accumulations in eggs did not reach estimated concentrations that would impair reproduction (Peng et al. 2010). The condition of wild caught stellate sturgeon was negatively correlated with liver and muscle concentrations of cadmium and lead (Heydari et al. 2011).

5.2.2 Shortnose Sturgeon

Shortnose sturgeon was first listed under the Endangered Species Preservation Act on October 15, 1966 (32 FR 4001). When the ESA was signed into law in 1973, replacing the Endangered Species Preservation Act, shortnose sturgeon remained listed as endangered. Shortnose sturgeon occur along the Atlantic Coast of North America 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. (A metapopulation is a group of separate but interacting populations such that there is gene flow occurring among the populations.) In the southern metapopulation, shortnose sturgeon are currently found in the Great Pee Dee, Waccamaw, Edisto, Cooper, Altamaha, Ogeechee, and Savannah rivers. They may also be found in the Black, Sampit, Ashley, Santee, Roanoke, and Cape Fear rivers, as well as Albemarle Sound and Pamlico Sound. Among these waters, Albemarle Sound, Pamlico Sound, the Waccamaw River, Roanoke River, the Cape Fear River and its tributary the Black River, and the headwaters of the Pee Dee River, are within the state of North Carolina.

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.

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 (Welsh et al. 2002, Finney et al. 2006, Fernandes et al. 2010, Dionne et al. 2013). Non-spawning movements include rapid, directed post-spawning movements to downstream feeding areas in the spring, and localized, wandering movements in the summer and winter (Dadswell 1984, Buckley and Kynard 1985). In the northern extent of their range, shortnose sturgeon exhibit three distinct movement patterns. These migratory movements are associated with spawning, feeding and overwintering activities. In the spring, as water temperatures reach between 7.0 and 9.7 ºC, pre-spawning shortnose sturgeon move from overwintering grounds to spawning areas.

Spawning times for shortnose sturgeon range geographically due to a specific water temperatures needed for spawning (44.6-50 degrees F). In areas between South Carolina and New England, males reach sexual maturity at age three while females reach sexual maturity by age seven (SSSRT 2010).Shortnose sturgeon spawning migrations are characterized by rapid, directed and often extensive upstream movement (NMFS 1998a). Once males begin spawning, one to two years after reaching sexual maturity, they will spawn every other year or annually depending on the river they inhabit and females will begin spawning five years after reaching sexual maturity and continue to do so every three year (Dadswell 1979, NMFS 1998a). 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 1998a). Spawning occurs over channel habitats containing gravel, rubble, or rock-cobble substrates (Dadswell 1979, NMFS 1998a). Additional environmental conditions associated with spawning activity include decreasing river discharge following the peak spring freshet, water temperatures ranging from 6.5 to 18ºC, and bottom water velocities of 0.4 to 0.8 m/sec (Dadswell 1979, Hall et al.

1991, Kieffer and Kynard 1996, NMFS 1998a). Adult shortnose sturgeon typically leave the spawning grounds shortly after spawning. At this time, there is insufficient data to determine if and where spawning occurs for shortnose sturgeon in North Carolina.

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

Shortnose sturgeon are benthic omnivores that feed on crustaceans, insect larvae, worms, mollusks (Moser and Ross 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 (Dadswell 1979, Bain 1997).

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' 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 1998a). Both mtDNA and nDNA analyses indicate effective (with spawning) coastal migrations are occurring between adjacent rivers in some areas, particularly within the Gulf of Maine and the Southeast (King et al. 2014).

The distribution of shortnose sturgeon is disjointed across their range, with northern populations separated from southern populations by a distance of about 400 km near their geographic center in Virginia. Genetic components of sturgeon in rivers separated by more than 400 km appear to be connected by very little migration, while rivers separated by less than 20 km would experience high migration rates. At the northern end of the species' distribution, the highest rate of gene flow (which suggests migration) occurs between the Kennebec, Penobscot, and Androscoggin Rivers (Wirgin et al. 2005).

STATUS

According to the 2010 status review (SSSRT 2010), water quality represents a major threat to one shortnose sturgeon population (Potomac River), a moderately high threat to six populations, a moderate threat to 13 populations, and a moderately low threat to one population. Specific sources of water quality degradation affecting shortnose sturgeon include coal tar, (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, polychlorinated biphenyl [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 two shortnose sturgeon populations (Delaware and Potomac).

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

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 to 2,122 individuals) over a 7-year period in the Altamaha River. Bahr and Peterson (2017) estimated the adult shortnose population in the Savannah River was 1,865 in 2013, 1,564 in 2014, and 940 in 2015. Their estimates of juvenile shortnose sturgeon ranged from 81-270 age 1 fish and 123-486 age 2+ 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).

STATUS WITHIN THE ACTION AREA

Few surveys have been conducted in the rivers and bays along the North Carolina coast so the presence of a reproducing population of shortnose sturgeon is uncertain (SSSRT 2010). NMFS' 2010 Biological Assessment indicates that shortnose sturgeon were historically present in the Roanoke, Chowan, and Cape Fear Rivers and the Winyah Bay System/Pee Dee River (Table 14, SSSRT 2010). Most historical commercial sturgeon landings records were from Albemarle sound, however records did not differentiate between Atlantic and shortnose sturgeon (SSSRT 2010). Historical use of the New River, Neuse River, and Tar-Pamlico System are unknown, but there are relatively recent anecdotal reports from commercial fishers.

Only two records of shortnose sturgeon exist in the Albemarle Sound watershed: a juvenile in 1881 from Salmon Creek and an adult in 1998 in western Batchelor Bay near the mouth of Roanoke River (Armstrong and Hightower 1999). This individual was likely either spawned in the Roanoke or the Chowan River (Armstrong and Hightower 1999). The 1998 capture prompted

NMFS to include an Albemarle Sound population in the shortnose sturgeon recovery plan (63 FR 69613; December 17, 1998).

Cape Fear estuary likely serves as a migration or staging corridor for spawning, perhaps in Brunswick River. Evidence of a reproducing population in the Cape Fear River was provided by a gillnet survey conducted in the early 1990s. Three gravid female shortnose were captured in the Brunswick River reach of the Cape Fear estuary during the months of January and February in 1989, 1990, 1991 and 1992 (Moser and Ross 1995). The survey used sonic tracking to document the distribution and movements of adult shortnose sturgeons and juvenile Atlantic sturgeons in the lower Cape Fear River. While only eight fish were captured during the study, the presence of gravid females and observations of rapid upstream migrations provided evidence of shortnose sturgeon spawning in this system. The most current estimate for shortnose sturgeon in the Cape Fear River system was fewer than 50 fish in 1996 (NMFS 2004).

The most recent status review for shortnose sturgeon was written in 2010 (SSSRT 2010). This review developed cumulative shortnose sturgeon population health scores, ranked stressors occurring to shortnose sturgeon within each river, and compared population health to stressors. Population health scores were based on number of individuals (one to five), demographics (three points per life stage present) and abundance trends (zero for unknown or no estimate to three for increasing trend). Stressor impact scores were ranked from one (low or no risk) to five (high risk).

Currently, a majority of rivers in North Carolina do not support shortnose sturgeon populations, despite historical records indicating their presence (VanDerwarker 2001). The most recent population estimate of shortnose sturgeon in the Cape Fear River is 50, based on a study that concluded in 1995 (NMFS 1998a). Within North Carolina, shortnose sturgeon only inhabit the Cape Fear River, the Waccamaw/Pee Dee/Black Rivers, and the Albemarle Sound. Within North Carolina, shortnose sturgeon are listed as a priority species and as State Endangered.

Table 3. Risk Assessment Scores for Shortnose Sturgeon in North Carolina Rivers

River	Abundance Score	Population Health Score	Overall Stressor Score
Roanoke	0	1	6.3
Tar-Pamlico River	0	0	5.65
Cape Fear	1.12	3.12	10
Pee Dee	NA	NA	NA
Neuse	0	0	7.2
Albemarle	NA	NA	NA
Onslow Bay	NA	NA	NA

CRITICAL HABITAT

Under the ESA, critical habitat designation, or a determination that such designation is not prudent, is only required for species listed since the ESA was enacted. As stated previously, the shortnose sturgeon was first listed under the Endangered Species Preservation Act which was superseded by the ESA. A critical habitat designation for shortnose sturgeon has not been made.
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 North Carolina rivers (or elsewhere) that could support a reproducing population exceeds the migration distance for sturgeon inhabiting the southeast or Delaware River/Chesapeake Bay metapopulations, supplementation may be a plausible restoration strategy. Accordingly, to ensure the long-term survival of populations, conservation actions should be based on available habitat and structural isolation. In this era of rapid environmental change and sea-level rise, this may be especially pertinent for the shortnose sturgeon that requires upstream migration through freshwater or species at their range margins.

5.2.1 Atlantic Sturgeon

The appearance of Atlantic sturgeon is similar to that of the sympatric shortnose sturgeon. Atlantic sturgeon are generally larger, have a smaller mouth, 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 five major rows of dermal scutes, can grow to approximately 4.3 meters [m]) long, and weigh up to 370 kg.

LIFE HISTORY

The general life history pattern of Atlantic sturgeon is that of a long lived, late-maturing, iteroparous, anadromous species. Spawning intervals range from once every one to five years for males (Smith 1985, Bain 1997, Collins et al. 2000, Schueller and Peterson 2010) and three to five years for females (Vladykov and Greeley 1963, Bain 1997, Stevenson and Secor 1999, Schueller and Peterson 2010). Fecundity increases with age and body size (ranging from 400,000 – 8 million eggs, Smith et al. 1982, Van Eenennaam and Doroshov 1998, Dadswell 2006). 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).

Spawning adults swim upriver in late winter to spring, depending on the population; in the south, migration occurs between February and March, in the mid-Atlantic, migration occurs between April and May, and in Canada, migration occurs between May and June. A small spawning migration may also take place in the fall, again depending on the population (ASSRT 2007). Spawning occurs in flowing water between the salt wedge and fall line of large rivers. Spawning intervals, or the amount of time between spawning events for an individual fish, is estimated to be 1 to 5 years for males and 2 to 5 years for females. The number of eggs laid by a female Atlantic sturgeon is dependent on age and body size and can be between 400,000 and 8 million eggs.

Sturgeon eggs are highly adhesive and are deposited in freshwater or tidal freshwater reaches of rivers on the bottom substrate, usually on hard surfaces such as cobble (Gilbert 1989, Smith and Clugston 1997). Hatching occurs approximately 94-140 hours after egg deposition, and larvae assume a bottom-dwelling existence (Smith et al. 1980). The yolk sac larval stage is completed in about 8-12 days, during which time larvae move downstream to rearing grounds over a 6 – 12 day period (Kynard and Horgan 2002). During the daytime, larvae use benthic structure (e.g., gravel matrix) as refugia (Kynard and Horgan 2002). Juvenile sturgeon continue to move further downstream into waters ranging from zero to up to 10 parts per thousand salinity. Older juveniles are more tolerant of higher salinities as juveniles typically spend at least two years and sometimes as many as five years in freshwater before eventually becoming coastal residents as sub-adults (Smith 1985, Boreman 1997, Schueller and Peterson 2010).

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 (Moser and Ross 1995, Johnson et al. 1997, Haley 1998, Haley 1999, Brosse et al. 2002, Guilbard et al. 2007, Savoy 2007, Collins et al. 2008). Diets vary latitudinally and seasonally, though universally researchers have found that polychaetes constitute a major portion of Atlantic sturgeon diets. . In North Carolina, Moser and Ross (1995) determined Atlantic sturgeon fed on 32% polychaetes, 28% isopods, 12% 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.

POPULATION DYNAMICS

Atlantic sturgeon are thought to have historically spawned within the Roanoke, Tar-Pamlico, Neuse, and Cape Fear Rivers. Currently, the Roanoke River is the only North Carolina river with a known spawning population. Evidence of spawning in other rivers includes adult sturgeon, fitted with radio-telemetry tags, potentially making a spawning run within the Cape Fear and

Northeast Cape Fear Rivers and the presence of young of year fish in other North Carolina rivers.

Atlantic sturgeon at various life stages are found within most estuarine waters of North Carolina throughout the entire year. Age at which Atlantic sturgeon reach sexual maturity is unknown for specimens in North Carolina, but other fish within the Carolina and South Atlantic DPSs mature as early as 5 to 13 years for males and 7 to 19 years for females. Research conducted in South Carolina show spawning intervals of one to five years for males and three to five years for females.

The Atlantic States Marine Fisheries Commission completed a benchmark assessment on Atlantic sturgeon in July 2017 (ASMFC 2017b). The assessment addressed the limited available data by employing a number of approaches including Mann-Kendall test, Autoregressive Integrated Moving Average (ARIMA) model, and power, cluster, dynamic factor, and population viability analyses for the coastwide stock and by DPS. While some methods did not indicate trends, both the Mann-Kendall and population viability analysis detected a significant increasing trend of young of year and juvenile abundance in North Carolina's Albemarle Sound Independent Gill Net Survey. Results also indicated a coast-wide population structure rather than a DPS-structured stock. The ARIMA analysis indicated the time series had no significant trend or an increasing trend when using all available years of data for all indices and the terminal year index values were all credibly above the 25th percentile for their unique time series. Coast-wide abundance values are not available; however, stock reduction analysis indicated that the population declined to a low but stable level in the early 1900's but began to increase from the late 1990's onwards. In addition, estimates of coast-wide total mortality were below the Z 50% eggs per recruit threshold, suggesting current levels of total mortality (Z) are sustainable. However, Z estimates for the New York Bight, Chesapeake, and South Atlantic DPS had less than 50% chance that Z was above the threshold while the Maine and Carolina DPSs had greater than 70% chance that Z was above the threshold, indicating that mortality is too high within these DPSs.

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 three 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 rivers 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 Saltwater 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 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 2017b). All DPSs of Atlantic sturgeon are considered depleted. All DPSs of Atlantic sturgeon are highly vulnerable to climate change due to their low likelihood to change distribution in response to current climate change stressors. This includes changes in the occurrence and abundance of prey species in currently identified key foraging areas (NMFS 2022b, a).

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 coastwise 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 of Atlantic sturgeon, 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 2017b).

There are multiple lines of evidence to indicate the mixing of several DPSs of Atlantic sturgeon in NC waters. For example, along with the presence of the Carolina DPS, acoustic detection data from Albemarle Sound have included sub-adults and adults from Cape Fear River, James River, Virginia, and areas of Connecticut, Delaware, South Carolina, and Georgia (Post et al. 2014). Genetic data from Atlantic sturgeon sampled from NC also demonstrated the presence of several DPSs (ASMFC 2017b, Kazyak et al. 2021). This mixing makes determination of the DPS assignment in real time challenging for any sampled Atlantic Sturgeon. Purported DPS can be assigned for some individuals based on lengths.

Status within the Action Area

Atlantic sturgeon are considered in danger of extinction in North Carolina and the NC Division of Marine Fisheries implemented a statewide moratorium on the possession of sturgeon in 1991 (MFC Rule 15A NCAC 03M.0508). Five DPSs of Atlantic sturgeon were listed under the ESA in 2012. The Gulf of Maine DPS is listed as threatened while the New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs are listed as endangered (50 CFR §224.101). The Carolina DPS habitats include rivers from the Albemarle Sound drainage that originate in southern Virginia, south to rivers of the Charleston Harbor area north of the Edisto River. There is evidence of spawning in the Roanoke, Tar-Pamlico, Cape Fear, Waccamaw, and Great Pee Dee Rivers (ASSRT 2007).

The Pamlico Sound (Tar and Neuse Rivers) Atlantic sturgeon population is speculated to be small compared to other populations (Albemarle Sound, Cape Fear Estuary) in North Carolina (Oakley 2003, ASSRT 2007). There is no documented spawning activity of Atlantic sturgeon in Wake or Johnston counties, with all records from the basin being further downriver. Additionally, there is no documentation of spawning activity in the Neuse River, however, juveniles are well documented in the Middle and Lower sections of the Neuse River (Hassler and

Hill 1974, Hoff 1980, Oakley 2003, ASSRT 2007). Oakley (2003) and Hassler (1974) captured juveniles as far upriver as river kilometer (RKM) 80. Given that juveniles remain in their natal rivers, it is a logical assumption that the individuals captured in the river were spawned upstream. NMFS used this life history attribute, along with the presence of suitable spawning habitat features and lack of physical barriers, to justify designating critical habitat up to RKM 328 (Milburnie Dam). The Quaker Neck Dam on the Neuse River at RKM 225 was a known impediment for spawning migrations of other anadromous species, American Shad (*Alsoa sapidissima*) and Striped Bass (*Morone saxitilis*). Following removal of the dam in 1999, spawning runs of both species were documented up to the Milburnie Dam at RKM 328 (Beasley and Hightower 2000, Bowman and Hightower 2001). Most of the recent information for Atlantic sturgeon in North Carolina estuarine waters is from the Cape Fear River and the Albemarle Sound and its tributaries. Acoustically tagged subadult fish captured in the Cape Fear River made seasonal movements between freshwater habitats in the upper estuary to the river mouth at the ocean (Post et al. 2014). Emigration out of the river and into the ocean starts in September and continues through January, with a peak in October when temperatures fall below 15 degrees Celsius. Subadult fish return to the river system between February and May with peak immigration occurring in April when temperatures were greater than 10 degrees Celsius. Acoustically tagged adults were shown to enter the Cape Fear River system beginning in February and make upriver migrations to freshwater staging and spawning areas. Adults remained in these areas until migrating downriver and returning to the ocean in April and May (Post et al. 2014).

In the Albemarle Sound system, acoustic telemetry data indicated that Atlantic sturgeon were present in the system throughout the year (Loeffler 2018). Smaller juvenile fish occurred in western Albemarle Sound where salinities were low. Tagged subadult Atlantic sturgeon from Albemarle Sound demonstrated seasonal migration patterns, with fish moving from low salinity waters in the western sound during warm water temperatures to higher salinity waters in the eastern sound during cooler water temperatures. Adult Atlantic sturgeon entered the Albemarle Sound in late spring, moved into western Albemarle Sound in the summer months and resided there until October and early November when temperatures fell to 20 degrees Celsius (Post et al. 2014, Smith et al. 2015, Loeffler 2018). Smith et al. (2015) confirmed fall spawning in the Roanoke River through the collection of eggs in the vicinity of Weldon, NC. After spawning the adults exited the river and immediately moved to the ocean, many traveling through Oregon Inlet (Loeffler 2018).

CRITICAL HABITAT

Critical habitat for the Atlantic sturgeon Carolina DPS was designated in 2017 (82 FR 39160, see Figure 2). The Carolina DPS is under the jurisdiction of the NOAA Fisheries Service, Southeast Region and fall under Carolina Unit 3. Carolina Unit 3 includes the Neuse River main stem from the Milburnie Dam downstream to RKM 0. The Neuse River, one of two major tributaries to Pamlico Sound, is dammed.

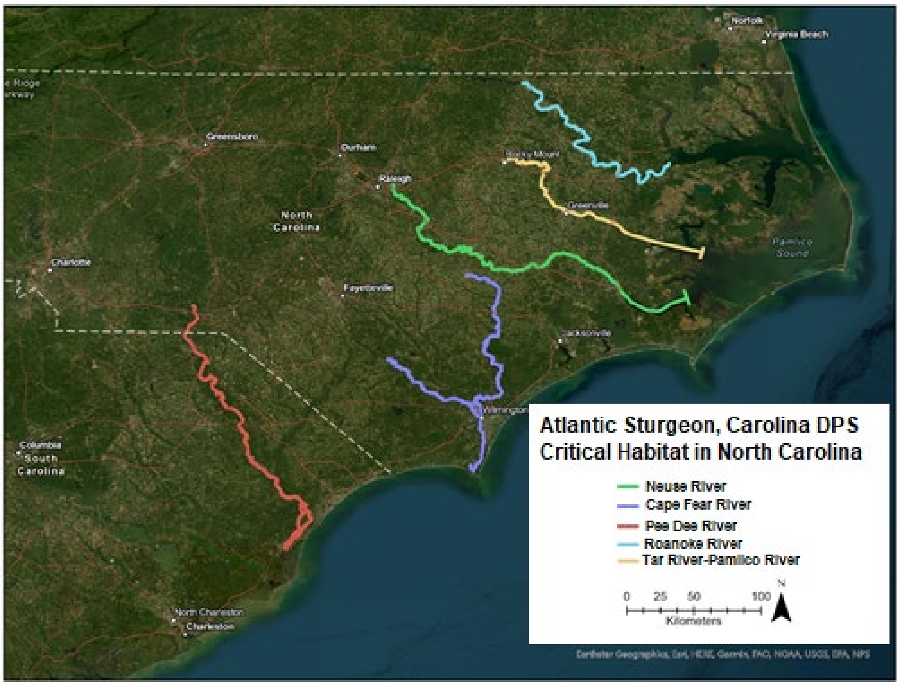

Figure 2. Designated Critical Habitat for Atlantic Sturgeon Carolina DPS (82 FR 39160; August 17, 2017)

The PBFs identified as essential components of the designated 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 life stages.
2. Transitional salinity zones inclusive of waters with a gradual downstream gradient of 0.5 up to as high as 30 parts per thousand and soft substrate (e.g., sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development.
3. Water of appropriate depth and absent physical barriers to passage (e.g., locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support (i) Unimpeded movement of adults to and from spawning sites, (ii) Seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary; and (iii) Staging, resting, or holding of subadults or spawning condition adults. Water depths in main river channels must also be deep enough (at least 1.2 meters) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river.
4. Water quality conditions, especially in the bottom meter of the water column, with temperature and oxygen values that support (i) Spawning; (ii) Annual and inter-annual adult, subadult, larval, and juvenile survival; and (iii) Larval, juvenile, and subadult growth, development, and recruitment.

RECOVERY GOALS

A recovery plan has not been completed for the listed Atlantic sturgeon DPSs. However, a recovery outline has been prepared. A recovery outline is an interim guidance to guide recovery efforts until a full recovery plan is developed and approved. NMFS' vision, stated in the recovery outline, is that subpopulations of all five 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 life stages must also increase and that increased recruitment 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" means "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 administratively continued 2017 Construction General Permit, and other activities authorized by the EPA (e.g., NPDES permits, cooling water intake, and the cleanup and management of hazardous waste) or other Federal agencies that have undergone or are in the process of completing ESA section 7 consultations. The purpose of the environmental baseline is to describe the condition of the ESA-listed species in the action area without the consequences caused by the proposed action. The scope of the environmental baseline is largely focused on Sturgeon Waters and associated catchments within the action area, as identified in Figure 2and include:

- The Neuse River
- The Cape Fear River extending into the Northeast Cape Fear River
- The Pee Dee River, which extends into South Carolina
- The Roanoke River
- The Tar-Pamlico River

Table 4 describes the sturgeon life stages and their behaviors in these waters, while Table 5 compares historical and current spawning and presence data in North Carolina for shortnose sturgeon. Definitive historical and current spawning was not available for Atlantic sturgeon.

Table 4. Life Stages and Behaviors of Shortnose Sturgeon and Atlantic Sturgeon in the Waters of North Carolina

Body of Water (State)	Life Stages Present	Use of the Watershed
Atlantic Sturgeon		
Roanoke River/Albemarle Sound	Adults, juveniles	Upstream migration
Cape Fear River	Adults, juveniles	Upstream migration
Neuse River	Adults, young juveniles	Spawning, Upstream Migration
Tar-Pamlico River	Adults, young juveniles	Spawning, Upstream Migration
Brunswick	Adult	Upstream migration
Pee Dee River	Adult, juveniles	
shortnose sturgeon		
Cape Fear River	Adult	Spawning migrations
Waccamaw, Pee Dee and Black Rivers	Adults, sub-adults, juveniles	Spawning migration
Albemarle Sound	Adults, sub-adults, juveniles	

Table 5. Shortnose Sturgeon Historic and Current Presence and Spawning Location

Body of Water (State)	Historic Presence?	Historic Spawning	Present?	Spawning?	Current Spawning Location
shortnose sturgeon					
Roanoke River	Yes	Unknown	Yes	Unknown	Unknown
Tar-Pamlico River	Unknown	Unknown	Unknown	Unknown	Unknown
Neuse River	Unknown	Unknown	Unknown	Unknown	Unknown
Cape Fear River	Yes	Unknown	Yes	Unlikely	Cape Fear estuary (likely migration or staging, perhaps Brunswick River)
Pee Dee River	Yes	Unknown	Yes	Yes	Great Pee Dee at rkm (river kilometer) 206.5, other sites

Atlantic sturgeon rely on a variety of water quality parameters to successfully carry out their life functions. Low 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. Of particular concern is the high occurrence of low DO coupled with high temperatures in the river systems throughout the range of the Carolina and South Atlantic DPSs in the Southeast. Sturgeon are more highly sensitive to low DO than other fish species (Niklitschek and Secor 2009) and low DO in combination with high temperature is particularly problematic for Atlantic Sturgeon. Studies have shown that juvenile Atlantic sturgeon experience lethal and sublethal (metabolic, growth, feeding) effects as DO drops and temperatures rise (Secor and Gunderson 1998, Niklitschek and Secor 2005, Niklitschek and Secor 2009). In the Neuse River, Oakley (2003) recorded prolonged periods of low DO in many sections of the river, and found that a juvenile Atlantic sturgeon that was tracked via radio telemetry tagging tended to avoid hypoxic river reaches.

Sturgeon are inherently susceptible to effects from exposure to toxicants in the substrate, such as heavy metals, given their benthic foraging behavior and long-lived traits (ASSRT 2007). Heavy industrial development and concentrated animal feed lots have degraded water quality in the Cape Fear River. Water quality in the Waccamaw and Yadkin-Pee Dee Rivers has been affected by industrialization and riverine sediment samples contain high levels of various toxins, including dioxins.

6.1 Existing Permitted Sources

Under the Clean Water Act, NPDES permits are renewed every five years. At the time of this writing, there are three permitted discharges for cadmium and one for selenium under North Carolina NPDES permits. The National Recommended Water Quality Criteria these discharges are currently subject to are listed in Table 6. The locations of these facilities are illustrated in Figure 3.

Table 6. Existing Water Quality Criteria Compared with Proposed Criteria

Pollutant	Fresh Water			Salt Water	
	Acute	Chronic	Acute, Trout Waters	Acute	Chronic
Cadmium (µg/L, dissolved, Hardness at 25 mg/L calcium carbonate, $CaCO_3$)					
2022	0.75	0.25	0.49	33	7.9
2021	0.82	0.15	0.51	40	8.8
2016	0.82	0.15	0.51	40	8.8
Selenium (µg/L, total recoverable)					
2022	NA		NA	NA	71
2021	NA	5	NA	NA	71
2016	NA	5	NA	NA	71

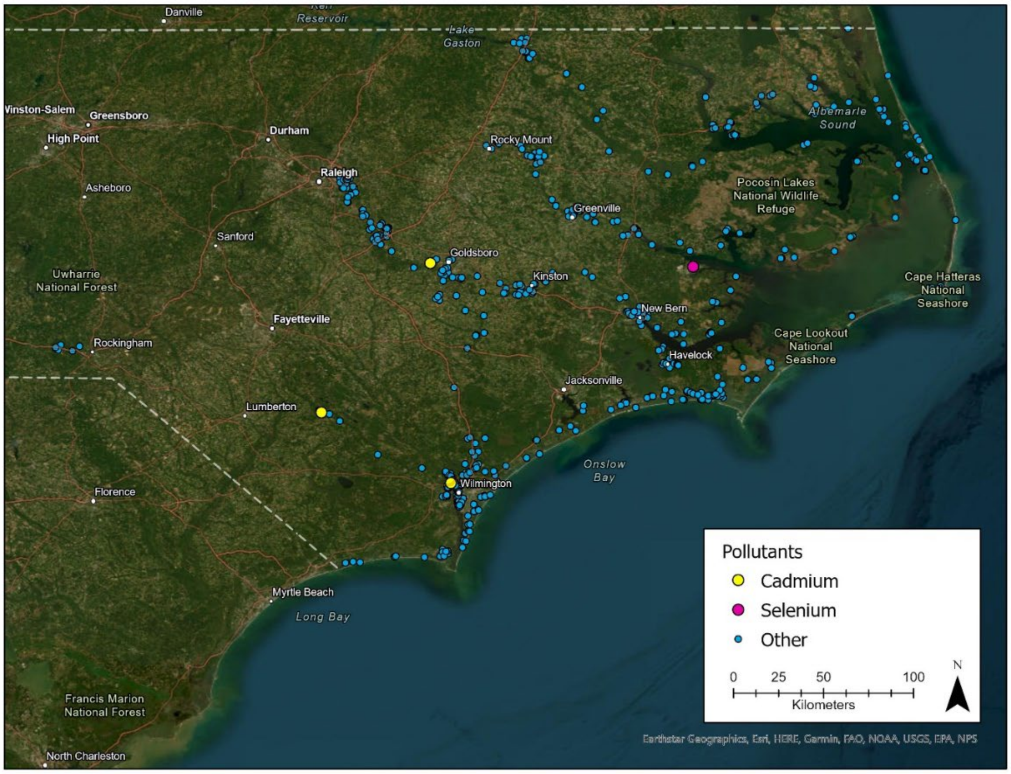

Figure 3. Locations of Permitted Discharges with Permit Limits for Pollutants Considered in this Opinion

6.2 Mixtures and Impairments

As noted above in Section 2.2.2, 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 mechanisms occur when one or more metals are near or equal to acute criteria concentrations (e.g., Sprague 1970, Marking 1985, Vijver et al. 2010). Among the available monitoring data for North Carolina Sturgeon Waters, three quarters report detections of more than one metal, and more than half report the presence of three or more metals. The most commonly co-occurring metals are cadmium with copper followed by cadmium with mercury. Among the 51 NPDES Permits required to monitor for metals in discharges to Sturgeon Waters, 20 are monitoring for two or more metals. Those required to monitor for cadmium also monitor for aluminum, arsenic, chromium, copper, lead, mercury, nickel, and silver.

The Clean Water Act requires states and territories to assess water quality every two 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 spressors 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 Total Maximum Daily Load[5] (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.

Table 7. Impairments within Sturgeon Waters with Approved TMDLs

Basin/Impairment	Square Miles Impaired
Lumber	
Fecal Coliform	206
Neuse	
Benthos	11.6
Nitrogen	6063
Nitrogen, Phosphorus	771
PCB Fish Tissue Advisory, Fish Community	45.9
Roanoke	
Dioxin	304
Low Dissolved Oxygen	501
Tar	
Fecal Coliform	64
Nitrogen, Phosphorus	6148
White Oak	
Fecal Coliform	365
Nitrogen	17.4

The EPA approved North Carolina's most recent 303(d) list for freshwaters in April of 2022. The Cape Fear River basin remains impaired due to benthic and fish community imbalance and low DO. Four rivers and creeks within the basin, New Hope Creek, UT at Cross Creek Publicly Owned Treatment Works (POTW), Rocky River, and Little Cross Creek, were down listed. New Hope Creek and UT at Cross Creek POTW were reclassifies as from category 5 (exceeds criteria) to category 3a (data are insufficient to determine if a parameter is meeting or exceeding criteria) because new data indicated improvements in turbidity and DO levels, respectively. Rocky River was reclassified as category 1 (unimpaired) because data indicated DO levels were consistently within criteria limits. Little Cross Creek was delisted because the benthic community assessment used data collected from the wrong station. Two segments of the Cape Fear River Basin, UT to Stagg Creek and Neills Creek, were newly listed as a category 5 impairments for benthos and turbidity, respectively. TMDLs for nutrients are in development for the Middle Cape Fear River and approved TMDLs for cadmium in Little Troublesome Creek and for Selenium in South Buffalo Creek have been in place since 1997.

For the Neuse River, impairments include turbidity, chlorophyll a, impaired benthic biological criteria, and pH. Two creeks were down listed from a category 5 to category 3a (Pigeon House

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[5] 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.

Branch) and to a category 1 (Little Creek) for new data regarding improvements in DO and benthic biological criteria. The larger Neuse River (from Falls Lake below normal pool elevation) was added as a new listing due to exceeding turbidity criteria. The Neuse River Estuary has had approved TMDLs since 2002 for total nitrogen.

Similarly, the Yadkin-Pee Dee River Basin remains heavily impaired by chlorophyll a, pH, zinc, turbidity, low impaired benthic biological criteria and fish community criteria, fecal coliform, copper, PCBs, arsenic, DO, and water temperature. The Pee Dee River was downlisted from a category 5 to 3a as a result of new data on pH showing improved pH levels. Several creeks were also added to the 303(d) list for exceeding the following criteria: turbidity, benthic community criteria, copper, zinc, PCBs, and chlorophyll a. TMDLs exist for various creeks within the Yadkin-Pee Dee River Basin and approved TMDLs for fecal coliform are in place for Roaring River (2011) and Rocky River (2002).

Listed impairments to the Roanoke River basin include poor benthic biological criteria and fish community criteria, turbidity, water temperature, copper dissolved chronic criteria, chlorophyll a, and DO. Two creeks within the basin were down listed from a category 5 to a category 3a (Country Line Creek) and to a category 1 (Nutbush Creek) for new data regarding improvements in benthic community criteria and chlorophyll a. Two additional creeks (Island Creek and Rattlesnake Creek) were added to the list of impaired waters for North Carolina due to impaired benthic biological criteria and fish community criteria. Approved TMDLs for Roanoke River were approved in 1996 for dioxin and DO as well as for the Tar River in 1995 for nutrient and DO.

The Tar-Pamlico River Basin remains impaired by pH, chlorophyll a, turbidity, DO, benthic biological criteria, zinc, copper, shellfish growth capabilities, enterococcus, and fish community criteria. Segments of the Pamlico River were down listed from a category 5 to category 3a for improved DO levels as a result of new data, and from a category 5 to a 1 for improvements towards enterococcus criteria also as a result of new data. One segment of the Pamlico River was added to the impaired list for exceeding chlorophyll a criteria in addition to two creeks for exceeding turbidity criteria (UT to Deep Creek) and DO criteria (Town Creek). TMDLs for the Tar River were approved in 1995 for nutrients and DO levels.

6.3 Municipal Separate Storm Sewer Systems

Municipal Separate Storm Sewer Systems (MS4s) are conveyances or a system of conveyances that are:

- owned by a state, city, town, village, or other public entity that discharges to Waters of the United States,
- designed or used to collect or convey stormwater (e.g., storm drains, pipes, ditches),
- not a combined sewer, and
- not part of a sewage treatment plant, or publicly owned treatment works

The Clean Water Act Section 402(p)(3)(B) states that permits for MS4 discharges may be issued 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.

In North Carolina all MS4 dischargers are required to register for a permit. NPDES permits may be issued in one of two types: individual and general. General NPDES wastewater permits currently exist for non-contact cooling water discharges, petroleum-based groundwater remediation, sand dredging, seafood packaging, and domestic discharges from single-family residences (e.g., pesticides, conjunctive water uses). Individual permits are issued on a case-by-case basis for activities not covered under the general permits.[6] General permits, on the other hand, cover discharges with similar operations and types of discharges that are applicable statewide. The requirements of a general permit are defined and known by the permittee. In general, an individual permit will take longer to be issued than a general permit.

There are currently 122 permitted MS4 entities in North Carolina and there are currently 109 active NPDES MS4 permits. The North Carolina DEQ issues individual NPDES MS4 Permits for a five-year permit term and does not currently offer a general permit option.

6.4 Climate Change

Climate change is discussed both here in the environmental baseline section of this Opinion and in the cumulative effects section (Section 8), because it is a current and ongoing circumstance that, for the most part, is not subject to consultation, yet influences environmental quality and the effects of the action, currently and in the future. NMFS' 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 is an example of an action that will be in effect indefinitely.

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

In order to evaluate the implications of different climate outcomes and associated impacts throughout the 21st century, many factors have to be considered with greenhouse gas emissions and the potential variability in emissions serving as a key variable. Developments in technology,

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[6] Individual permits are further divided into two classes: major and minor. Major discharges are permitted to discharge one million gallons per day or greater. Minor discharges are permitted to discharge less than one million gallons per day.

changes in energy generation and land use, global and regional economic circumstances, and population growth must also be considered.

A set of four scenarios was developed by the Intergovernmental Panel on Climate Change (IPCC) to ensure that starting conditions, historical data, and projections are employed consistently across the various branches of climate science. The scenarios are referred to as representative concentration pathways (RCPs), which capture a range of potential greenhouse gas emissions pathways and associated atmospheric concentration levels through 2100 (IPCC 2014). The RCP scenarios drive climate model projections for temperature, precipitation, sea level, and other variables: RCP2.6 is a stringent mitigation scenario; RCP4.5 and RCP6.0 are intermediate scenarios; and RCP8.5 is a scenario with no mitigation or reduction in the use of fossil fuels. IPCC future global climate predictions (IPCC 2014, 2018) and national and regional climate predictions included in the Fourth National Climate Assessment for U.S. states and territories (USGCRP 2018) use the RCP scenarios.

The 2022 AR6 (Sixth Assessment Report) Work Group II on impacts, adaptation, and vulnerability has a section on Key Developments since AR5 (Fifth Assessment Report). It states that AR6 report emphasizes at three broad themes: (1) risk and solution frameworks, (2) social justice/equity, and (3) role of transformation in meeting societal goals (IPCC 2022). The AR6 report also identified the following overarching conclusions from the whole of the assessment of Intergovernmental Panel on Climate Change (IPCC) Work Group II:

1. The magnitude of observed impacts and projected climate risks indicate the scale of decision-making, funding and investment needed over the next decade if climate resilient development is to be achieved.
2. Since AR5, climate risks are appearing faster and will get more severe sooner (high confidence). Impacts cascade through natural and human systems, often compounding with the impacts from other human activities. Feasible, integrated mitigation and adaptation solutions can be tailored to specific locations and monitored for their effectiveness while avoiding conflict with sustainable development objectives and managing risks and tradeoffs (high confidence).
3. Available evidence on projected climate risks indicates that opportunities for adaptation to many climate risks will likely become constrained and have reduced effectiveness should 1.5 degree Celsius global warming be exceeded and that, for many locations on Earth, capacity for adaptation is already significantly limited. The maintenance and recovery of natural and human systems will require the achievement of mitigation targets.

The recent assessment concluded that the substantial damages, and increasingly irreversible losses, in terrestrial, freshwater and coastal and open ocean marine ecosystems are larger than estimated in previous assessments. The report indicates that widespread deterioration of ecosystem structure and function, resilience and natural adaptive capacity, and shifts in seasonal timing is occurring under climate change. Approximately half of the species assessed globally have shifted poleward or, on land, also to higher elevations. Hydrological changes resulting from the retreat of glaciers, or the changes in ecosystems driven by permafrost thaw are approaching irreversibility.

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

The globally-averaged combined land and ocean surface temperature data, as calculated by a linear trend, show a warming of approximately 1.0 degrees Celsius from 1901 through 2016 (Hayhoe et al. 2018). The IPCC Special Report on the Impacts of Global Warming (IPCC 2018) noted that human-induced warming reached temperatures between 0.8 and 1.2 degrees Celsius above pre-industrial levels in 2017, likely increasing between 0.1 and 0.3 degrees Celsius per decade. Warming greater than the global average has already been experienced in many regions and seasons, with most land regions experiencing greater warming than over the ocean (Allen et al. 2018). Annual average temperatures have increased by 1.8 degrees Celsius across the contiguous U.S. since the beginning of the 20th century with Alaska warming faster than any other state and twice as fast as the global average since the mid-20th century (Jay et al. 2018). Global warming has led to more frequent heatwaves in most land regions and an increase in the frequency and duration of saltwater heatwaves (Hoegh-Guldberg et al. 2018). Average global warming up to 1.5 degrees Celsius as compared to pre-industrial levels is expected to lead to regional changes in extreme temperatures, and increases in the frequency and intensity of precipitation and drought (Hoegh-Guldberg et al. 2018).

The Atlantic Ocean appears to be warming faster than all other ocean basins except perhaps the southern oceans (Cheng et al. 2017). In the western North Atlantic Ocean, surface temperatures have been unusually warm in recent years (Blunden and Arndt 2016). A study by Polyakov et al. (2010) suggests that the North Atlantic Ocean overall has been experiencing a general warming trend over the last 80 years of 0.031±0.0006 degrees Celsius per decade in the upper 2,000 m of the ocean. Additional consequences of climate change include increased ocean stratification, decreased sea-ice extent, altered patterns of ocean circulation, and decreased ocean oxygen levels (Doney et al. 2012). Since the early 1980s, the annual minimum sea ice extent (observed in September each year) in the Arctic Ocean has decreased at a rate of 11 to 16% per decade (Jay et al. 2018). Further, ocean acidity has increased by 26% since the beginning of the industrial era (IPCC 2014) and this rise has been linked to climate change. Climate change is also expected to increase the frequency of extreme weather and climate events including, but not limited to, cyclones, tropical storms, heat waves, and droughts (IPCC 2014).

Climate change has the potential to 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 (Kintisch and Buckheit 2006, Mcmahon and Hays 2006, Robinson et al. 2008, Macleod 2009, Evans and Bjørge 2013, IPCC 2014). 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 et al. 2006).

Changes in the saltwater ecosystem caused by global 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 et al. 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 et al. 2012).

CLIMATE CHANGE IN NORTH CAROLINA

The following is a comprehensive summary of baseline climate change conditions in North Carolina as reported in the 2022 NOAA National Centers for Environmental Information,

State Climate Summaries (Frankson et al. 2022). Temperatures in North Carolina have increased steadily with winter average temperatures generally above average since 1990 and summer average temperatures the warmest on record for the last 16 years (2005–2020). Although North Carolina has not experienced an increase in the frequency of very hot days the last 11 years (2010–2020) have seen the largest number of very warm nights. There is no overall trend over time in annual precipitation.

Since 1900, global average sea level has risen by about 7–8 inches. This has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts. These events can damage infrastructure, cause road closures, and overwhelm storm drains. As sea level has risen along the North Carolina coastline, the number of days exceeding the nuisance-level threshold has also increased, with the greatest number (14) occurring at Wilmington in 2018. A large portion of North Carolina's coastline is extremely vulnerable to sea level rise due to its low elevation and to geological factors that are causing the land to sink in the northern Coastal Plain.

A storm at hurricane intensity reaches the North Carolina about once every 3 years; however, storms at less than hurricane intensity can also have major impacts. The late 1990s through the early 2000s and the late 2010s through 2020 were notably active hurricane periods. In 1999, Hurricane Floyd dropped 15 to 20 inches of rain in the eastern part of the state, which was still recovering from flooding caused by Hurricane Dennis several weeks earlier. Beginning on September 6, 2004, the remnants of Hurricane Frances dropped 6 to 10 inches of rain across much of western North Carolina over a 3-day period. Less than 2 weeks later, the remnants of Hurricane Ivan struck the same area, dropping 10 inches of rain and causing hundreds of landslides in the mountains. During October 7–9, 2016, Hurricane Matthew dumped torrential rain that caused major flooding in eastern North Carolina, with many locations receiving more than 10 inches and a few locations more than 18 inches. In September 2018, the most intense rainfall event on record occurred as Hurricane Florence dropped 20 to 36 inches in eastern North Carolina, causing widespread destruction and losses exceeding $20 billion, more than the combined losses from Floyd and Matthew. In addition to damage from high winds and flooding, hurricane strikes can produce tornadoes. Rainbands associated with Hurricane Frances spawned multiple tornadoes in the central and eastern portions of the state.

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 8 summarizes the change in impervious cover between 2001 and 2019 for catchments immediately adjacent to Sturgeon Waters and catchments abutting water-adjacent catchments.

Table 8. Summary of Impervious Cover and Proportion of Region, for Catchments Adjacent to Sturgeon Waters

Region	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
Onslow	3640.93	645.56 (17.7%)	276.87(7.6%)	2720.62 (74.7%)
Cape Fear	8434.46	364.82 (4.3%)	158.42 (1.9%)	7911.22 (93.8%)
Pee Dee	1748.04	181.61 (10.4%)	130.10 (7.4%)	1450.14 (83.0%)
Neuse	10,177.81	1228.35 (12.1%)	421.78 (4.1%)	8527.69 (83.8%)
Albemarle-Chowan	9594.26	274.04 (2.9%)	102.79 (1.1%)	9217.42 (96.1%)
Roanoke	3179.73	150.75 (3.6%)	27.79 (0.67%)	4001.18 (95.7%)
Pamlico	8959.08	595.83 (6.7%)	97.48 (1.1%)	8265.04 (92.3%)

Data for North Carolina are divided into the major river basins within the state Figure 4. According to Arnold and Gibbons (1996), runoff doubles in forested catchments that are 10 to 20% impervious, triples between 35 and 50% and increases more than five-fold at above 75% impervious. Catchments that shifted from below 10% impervious cover in 2001 to greater than 10% impervious in 2019 are typically adjacent to existing areas of increased impervious cover. These are highlighted in Figure 5 using an aqua-to-fuchsia color scale to illustrate the degree of impervious cover change. For example, impervious cover at 5% in 2001 and 6.5% in 2019 is a 30% increase in impervious cover. Overall, impervious cover has increased throughout the state of North Carolina. Figure 5 shows the proportional change from 2001 to 2019. The total population in North Carolina has increased 9.5% in the last decade, with the highest increase in population occurring in Johnston County (27.9%), Brunswick County (27.2%) and Cabarrus County (26.8%). Coastal Counties also saw an increase in population over the last decade ranging from a 1.8% increase to a 27.2% increase (U.S. Census Bureau 2020).

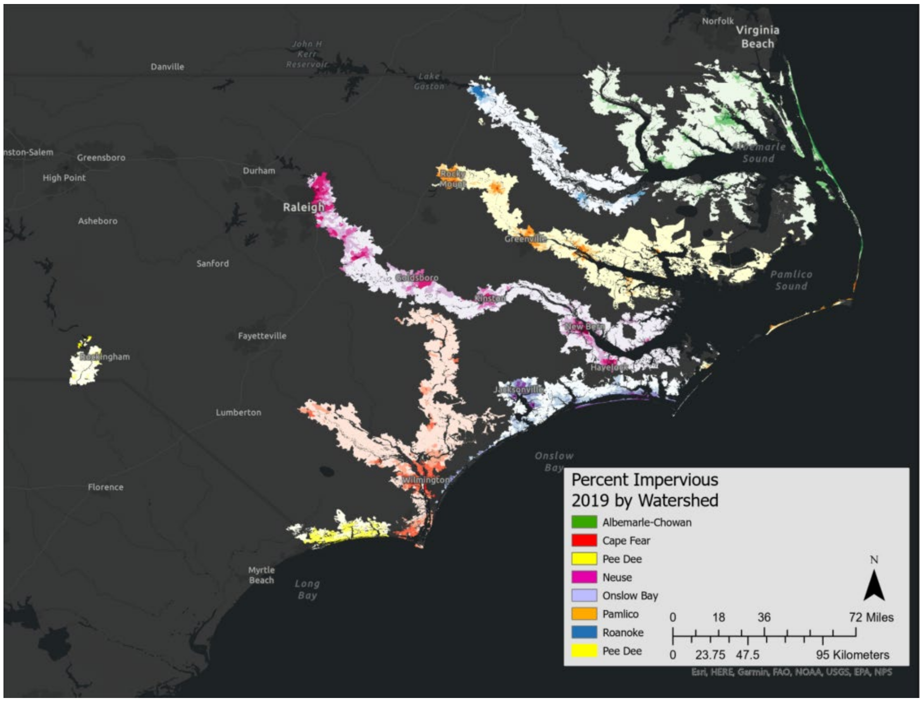

Figure 4. Relative Impervious Cover within North Carolina Catchments Associated with Sturgeon Waters (Darker Shades = Highly Impervious)

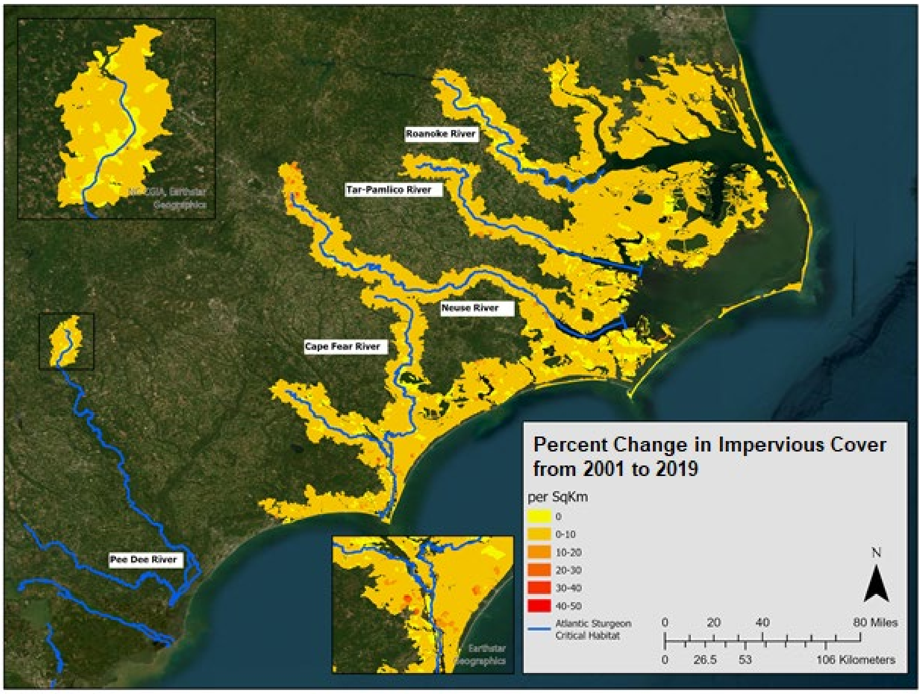

Figure 5. Change in Impervious Cover within North Carolina Catchments Associated With Sturgeon Waters between 2001 and 2019

6.6 Interaction between Climate Change and the Impervious Cover

The aggregate effects of an increasingly built environment affecting watersheds where species and designated critical habitat under NMFS' jurisdiction occur interacts with climate change-driven shifts in precipitation to result in a continually shifting baseline. Aggregate impacts include:

- time-crowded perturbations (i.e., repeated occurrence of one type of impact in the same area) or perturbations that are so close in time that the effects of one 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 two 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 three 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). There is no overall trend in precipitation with statewide total annual precipitation ranging from a low of 34.8 inches in 2007 to a high of 68.4 inches in 2018 (Frankson et al. 2022). North Carolina is projected to have significant increases in winter and spring precipitation of between 5 and 15%. Climate change models indicate a five to 10% increase in annual precipitation. Hurricane associated storm intensity and rainfall rates are projected to increase as the climate warms (Frankson et al. 2022). Extreme rainfall in North Carolina is expected to increase as a result from hurricanes (as experienced in recent years with Dorian, Florence, Matthew, and Michael), from Nor'easters (strong coastal storms with winds from the northeast), and from other weather systems like thunderstorms. Severe thunderstorms are also likely to increase with the warming climate, which can result in flash flooding, especially in urban areas (Kunkel et al. 2020).

The extent to which existing stormwater control technologies and best management practices will be effective under increasingly challenging stormwater conditions has yet to be proven. The increasing impervious area taken with anticipated increases in annual and seasonal precipitation is expected to result in more frequent and extreme uncontrolled stormwater discharges that, in turn, will likely to adversely affect water quality and aquatic life through erosive waters and contribution of land-sourced pollutants.

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" (50 CFR § 402.02). This analysis focuses on any data that indicate exposures within criteria limits 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)

- 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 of this Opinion, 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. The underlying assumptions in the methods used to arrive at criteria affect how well ESA-listed species and designated critical habitat are protected. Paramount among these are assumptions that:

- Effects that occur on a species exposed to a toxicant in laboratory tests will generally be the same for the same species exposed to that toxicant under field conditions (i.e., effects are not influenced by predation, competition, disease, exposure to other stressors in the field, and fluctuations in natural water quality parameters).
- Collections of single-species laboratory toxicity test data used to derive criteria reflect communities in natural ecosystems.
- Data on severely toxic effects from short-term "acute" toxicity tests used to derive acute criteria can be extrapolated to less severe effects that would be expected to occur in long-term "chronic" exposures to derive chronic criteria.
- Loss of a small number of species will not affect the propagation of fish, shellfish, and wildlife.
- Loss of a small number of species will not result in incidental loss of any “economically or recreationally valuable species” for which data were not available.
- Sensitive species and life stages are adequately represented such that criteria are not biased.
- Derivation of a criterion for a single chemical in isolation without regard to the potential for additive toxicity or other chemical or biological interactions is acceptable despite chemicals typically occurring in mixtures in the environment.
- When applied to NPDES permits, unless the waters are already identified as impaired by a pollutant, the waters are free from that pollutant.
- Accumulation of chemicals in tissues and along the food web does not result in ecologically significant latent toxicity or toxic exposures for predators.

There are also concerns about the underlying data used in the derivation of criteria including:

- Data sets for sublethal responses are usually small and have gaps such that sensitive species and life stages are under-represented.

- Variability within and among species used in calculating a hazardous concentration to 5% of species may be substantial, but this variability is not reflected in the final estimate used to derive an acute criterion.

These assumptions are repeated here to underscore the importance of the scale of uncertainty that accompanies lab-to-field extrapolation and the methods used to synthesize data for criteria derivation. Further, cadmium and selenium do 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% mortality in rainbow trout and *Ceriodaphnia dubia* exposed to a mixture of six metals at their acute criterion concentrations suggests severe effects result from exposure to compliant discharges and within “unimpaired” waters.

Because this action involves criteria for two parameters that will be implemented independently, the analysis is structured on a parameter-by-parameter basis under the Effects of the Action section in order to maintain focus on one parameter at a time.

7.1 Cadmium

Cadmium is a naturally occurring element in the earth’s crust that is most commonly associated with zinc ore as a small, but significant, impurity. Cadmium is used in batteries and pigments and in the manufacture of electronics and plastics. It is a component of fossil fuels, alloys, cement, and some fertilizers (ATSDR 2012). Given its abundant usage, cadmium is a common pollutant in stormwater. Shaver et al. (2007) reported the median cadmium concentration in urban runoff at 1.0 +/- 4.42 µg/L with highway runoff ranging from 0-40 µg/L and parking lot runoff ranging from 0.5-3.3 µg/L. Median dissolved cadmium concentrations in stormwater from commercial, industrial, and freeway land use areas were reported at 0.3, 0.6, and 0.7 µg/L, respectively.

The biological availability of cadmium in water is strongly influenced by aquatic chemistry: the abundance of ligand ions, organic acids, organic matter, and clay particles which may bind to cadmium. While complexation with substances in the water column results in precipitation and incorporation in bed sediments, bed sediment is not a static sink. Cadmium can return into the water column and become biologically available when sediments are disturbed and conditions, such as low pH, favor cadmium release in the free ion form (Cadmium Guideline USEPA 2016). Scenarios in which this might occur include storm events (Krein and Bierl 1999, Paus et al. 2014, Vidal-Dura et al. 2018) and re-inundation of exposed sediments after drought (Mosley et al. 2014).

Cadmium is a calcium analog that competes with calcium receptors at the gill. This disrupts calcium and ionic homeostasis in both freshwater and saltwater species (Adiele et al. 2010, Garcia-Santos et al. 2011, Onukwufor et al. 2015, Tang et al. 2016). Cadmium can accumulate at the gill, but is also transported throughout the body, accumulating to the highest extent in the organs with important roles in filtration and detoxification, the liver and anterior kidneys for fish and the hepatopancreas of arthropods and mollusks (Kouba et al. 2010, Paschoalini and Bazzoli 2021, Rodrigues et al. 2022). At the cellular level, cadmium induces oxidative stress, interfering with mitochondrial function and cellular repair that can lead to organ-level effects. If cellular injury is extensive, consequences for organ function will influence the survival and health of individuals (Paschoalini and Bazzoli 2021, Sun et al. 2022). A study by Mebane (2006) included a review of other data for cadmium dietary exposures and body burdens. Although there were not adequate data to establish acceptable tissue effect concentrations for aquatic life, Mebane (2006) concluded that cadmium is unlikely to accumulate in tissue to levels that would result in adverse effects to aquatic invertebrates or fish at calculated chronic criteria. In the Cadmium Guideline, EPA concluded that the evaluation of direct exposure effects to organisms via water is more applicable to the development of criteria for aquatic life than dietary exposure.

The EPA proposes to approve North Carolina DEQ adoption and implementation of the freshwater and saltwater cadmium National Recommended Criteria for the Protection of Aquatic Life. For fresh waters, these criteria are hardness-based values for the acute criterion and chronic criterion using state-specific equations. The saltwater acute criterion and chronic criterion concentrations are 33 and 7.9 µg/L, respectively (USEPA 2016). The acute criterion is a one-hour average and the chronic criterion is a four-day average not to be exceeded more than once in three years on average.

7.1.1 Exposure to Cadmium in the Action Area

Before addressing the potential for adverse effects from implementing the cadmium criteria, it is first necessary to identify natural and anthropogenic sources of cadmium that may contribute to aquatic impairments or be regulated under the criteria. Regarding natural sources, cadmium co–occurs with zinc ore and zinc ore is not among the mineral resources of North Carolina. Zinc occurs in stream sediments at concentrations of up to 50 mg/kg[7] (Figure 6). To place this in the context of concentrations at which effects may occur, the frequency of significant toxic effects reported for sediment exposures below 150 mg/kg zinc, three times the North Carolina stream baseline concentration, is about six percent (Long and Morgan 1991). This suggests that naturally occurring zinc, and any associated cadmium, are toxicologically insignificant. Because zinc ore and its associated cadmium is not naturally enriched in North Carolina soils, we would not expect cadmium to be redistributed to aquatic habitats through sediment and soil disturbing activities in areas without anthropogenic sources. In the absence of natural sources, any cadmium

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[7] Geochemical atlas of North Carolina accessed October 27, 2022. https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/mineral-resources/geochemical-atlas-of-nc#maps

reaching Sturgeon Waters would do so through permitted discharges and stormwater runoff from highways and urbanized areas.

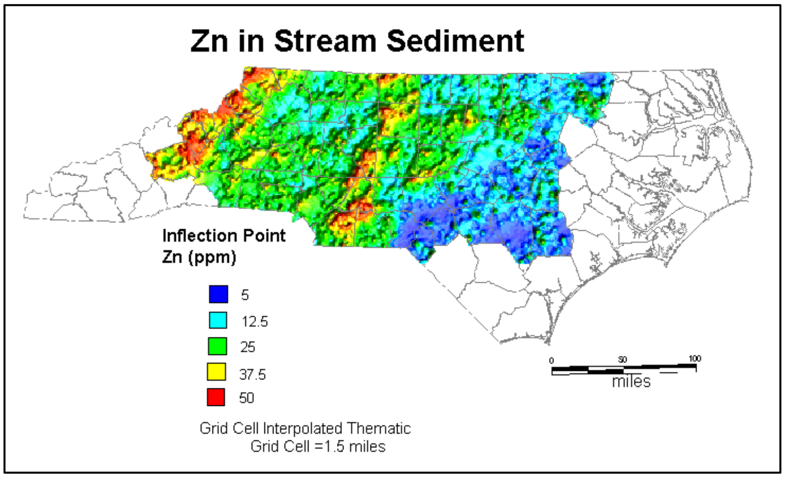

Figure 6. Distribution of Zinc in North Carolina Stream Sediments (Cadmium Frequently Occurs in Zinc Ore)

7.1.2 Permitted Discharges

Greater than 95% of the NPDES permits for facilities currently discharging to Sturgeon Waters or within catchments adjacent to Sturgeon Waters have been issued since EPA approved North Carolina DEQ initially adopting cadmium criteria for the protection of aquatic life in 2016. Due to the urgency in applying the criteria to multiple permit renewals for metal discharges, EPA wrote an ESA section 7(d) memo to file and notified the state that their approval was contingent on consultation with the Services.[8] The older permits are either expired or adminstratively continued. It is reasonable to expect that any cadmium discharger with the "reasonable potential" to cause a water quality impairment due to cadmium in effluent currently has cadmium limits in their permit. A review of EPA's ECHO database identified three permitted discharges within catchments adjacent to Sturgeon Waters that are required to monitor for cadmium. The Standard Industrial Classification (SIC) codes for these dischargers are SIC 3824, electromechanical counters and metering devices, and SIC 4911, electric services. There are seven other permits for SIC 4911 facilities and two for SIC 3824 facilities that are not required to monitor for cadmium, but may contribute cadmium below levels considered to have "reasonable potential." In addition to these sectors, due to the ubiquity of cadmium in various commonly used products, wastewater treatment plants are also likely to have some amount of cadmium in their discharges. In order to establish that a facility or surface water is in compliance with water quality criteria limits, it is critical that monitoring data are collected using methods and procedures with detection limits that allow quantification of pollutants below their respective criteria concentrations. Otherwise, a

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[8] NMFS received a BE for this approval, but consultation OPR-2016-00010 was closed because EPA Region 4 has approved the criteria but is reserving its authority pending ESA consultation, if NMFS ultimately finds that the criteria are likely to adversely affect ESA-listed species under NMFS' jurisdiction.

“non-detect” does not indicate whether or not pollutants are within regulatory limits. The EPA’s 2013 Permit Quality Review of North Carolina’s NPDES permits observed that data provided in application forms lacked detailed information regarding method detection limits; applications that contained “Non-Detect” in the field (versus an indication of method detection limit) were incorrectly considered complete. However, an indication of Non-Detect is insufficient to determine if sufficiently-sensitive analytical methods were employed to allow quantification of the pollutant with respect to compliance with the applicable water quality criterion. As a result, EPA recommended that North Carolina require use of “sufficiently sensitive analytical methods” and ensure method detection limits are documented in application forms. The EPA’s 2019 Permit Quality Review of North Carolina’s NPDES permits reported that North Carolina has implemented this recommendation.

Information on permit compliance status for North Carolina’s NPDES discharges is uncertain because, at the time of this writing, North Carolina is experiencing issues affecting the upload of data that may cause NPDES-permitted facilities to erroneously be displayed in ECHO as being noncompliant. Monitoring data reported for the cadmium-discharging facilities, accessed on November 9, 2022, identified few discharges above analytical detection limits, although there do appear to be data missing for cadmium. As described in Section 2, NPDES monitoring requires the use of sufficiently sensitive analytical methods. Yet sufficiently sensitive analytical methods can include a method with the lowest minimum detection limit for the pollutant that is still too high to “achieve the minimum levels necessary to assess reasonable potential or to monitor compliance with a permit limit.” The EPA standard methods for cadmium identify instrument and method detection limits ranging from 0.02 to 3.4 µg/L using Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES), Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), and Graphic Furnace Atomic Absorption (GF-AA) instrumentation Table 9. For cadmium in freshwaters, the adequacy of these methods depends on water hardness and analytical interferences.

Table 9. Instrument and Method Detection Limits for EPA Approved Clean Water Act Methods

Method	Mode	Instrument Detection Limit (µg/L)	Method Detection Limit* (µg/L)
200.7 Revision 4.4 ICP-AES	Total cadmium Recoverable cadmium	3.4 1	
200.8 Revision 5.4: ICP-MS	Scanning multiple analytes Cadmium-targeted	0.1 0.02	0.5 0.03
200.9 Revision 2.2: GF-AA			0.05

*Method detection limits are influenced by analytical interferences caused by the various components in the sample matrix (e.g., organic acids, salinity)

7.1.3 Stormwater

Precipitation either infiltrates into the ground, enters stormwater conveyance systems where it is potentially treated, or enters surface waters through overland flow. Factors such as the amount of dry deposition, storm intensity, rain acidity, inter-storm period, seasonality, and the physical properties and material composition of the surfaces contributing pollutants to the runoff event determine the constituents and their concentrations within the discharge. Added to this is the variability contributed by the receiving water itself and other stormwater sources and land uses within the watershed. For catchments with a large amount of impervious cover, stormwater pollutant data are strongly affected by the timing of sampling, with “first flush” samples collected early in the precipitation event containing the highest concentrations of pollutants.

This variability is shown in the broad ranges of cadmium concentrations in monitoring data. The National Stormwater Quality Database reported cadmium in greater than 80% of stormwater samples from freeways throughout the nation at concentrations ranging from 0.10 to 16.05 µg/L. Meanwhile cadmium was detected in 40% of stormwater samples from urban developed areas (commercial, residential, institutional) at concentrations ranging from 0.04 to 105 µg/L. Cadmium was detected in fewer than 20% of stormwater samples from undeveloped areas, however concentrations of up to 90 µg/L were reported (Pitt et al. 2018). Stormwater monitoring data available for North Carolina urban areas span the years 1992 through 2000 with cadmium concentrations ranging from 0.04 to 8.2 µg/L (Figure 7, Table 10). Table 10 summarizes cadmium observations for specific land use types within these urban areas.

Whether a given storm event results in exposures to cadmium at harmful levels depends on the mass of pollutant in the volume of stormwater discharge entering the receiving water (i.e. pollutant load), the extent of the mixing zone, dilution volume of the receiving water, any cadmium already present in the receiving water, and aquatic chemistry factors influencing cadmium bioavailability. The EPA’s cadmium criteria are calculated using water hardness because that was determined to be the most critical factor in influencing the bioavailability and, therefore, toxicity of cadmium in water. Hardness data were not included with the North Carolina stormwater data, so the applicable cadmium criteria for the specific stormwater discharges, or their receiving waters, could not be calculated. To place stormwater data in the context of waters receiving stormwater runoff, we rely on monitoring data reported in the National Water Quality Monitoring Council’s Water Quality Portal for Sturgeon Waters and associated tributaries within adjacent catchments in North Carolina. These data indicate greater than 90% of hardness values for these waters were below 50 mg/L $CaCO_3$ (1042 out of 1108 observations). Using reported hardness data, calculated North Carolina non-trout acute criteria for these waters range from 0.07 to 1.45 µg/L. The EPA Guideline’s acute freshwater criteria range, which applies to trout waters only, is 0.04 to 0.97 µg/L. Of course, stormwater would be diluted within the receiving water, but that dilution would not be instantaneous. Rather, there would be an impact zone surrounding points of discharge.

Table 10. Stormwater Cadmium Concentrations within North Carolina Urban Area Land Use Classes

Principle Land Use	Cadmium range (µg/L)	Detection Frequency
Commercial	0.04-5.1	51 out of 77 samples (66%)
Industrial	0.19-8.2	46 out of 72 samples (64%)
Institutional	0.5-1.5	3 out of 18 samples (17%)
Open Space	0.04-5	18 out of 31 samples (58%)
Residential	0.04-6	38 out of 117 samples (32%)

In order to identify pollutant contributors to water quality degradation, it is important for detection limits to be below concentrations at which adverse effects are expected to occur. Figure 7 includes cases where cadmium was analyzed for in stormwater, but not detected (Below Detection, ☒). These are plotted on Figure 7 at the detection limit for that specific analytical run. In most cases, detection limits were at or below 1 µg/L. However, Fayetteville's data includes seven instances where the detection limit was as high as 5 µg/L for samples collected in 1995 and 1997, and data for Charlotte included detection limits at 2 µg/L for 33 analytical runs conducted from 1992 through 1994.

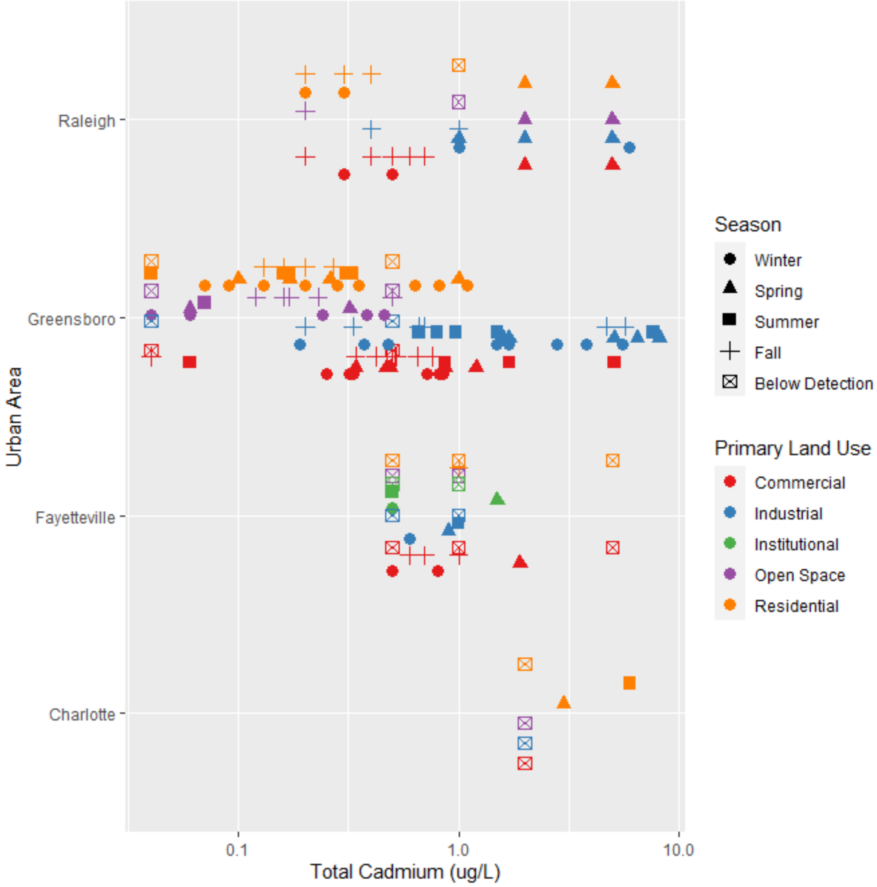

Figure 7. Cadmium Concentrations in Stormwater from North Carolina Urban Areas

7.1.4 Monitoring Data

Streams and rivers integrate the multiple point and nonpoint sources affecting water quality conditions, but unless monitored continuously or systematically, monitoring data are merely snapshots in time of the water chemistry and conditions at the time each a sample was taken. Cadmium concentrations from a creek receiving bridge-deck stormwater runoff ranged from 0.013 to 1.14 µg/L with an average of 0.22 µg/L. These data were reported by the United States Geological Survey's North Carolina Water Science Center in 2010. Two of the ten values were estimates because they were below the laboratory reporting level of 0.02 µg/L. The remaining North Carolina Water Quality Portal data had practical quantitation limits at 0.5 or 1 µg/L for samples collected between 2011 through 2020 (N=486). Cadmium was not detected in any sample. In all cases, there were no hardness data available to use to calculate applicable water quality criteria for these waters so it is uncertain whether detection limits of 0.5 or 1 µg/L are low enough to confirm whether cadmium was present within criteria limits.

Other sampling efforts in Sturgeon Waters that did not analyze for cadmium did measure water hardness. As stated in the preceding section on stormwater (Section 7.1.3), greater than 90% of hardness values for these waters were less than 50 mg/L $CaCO_3$ (1042 out of 1108 observations) and calculated acute criteria for Sturgeon Waters range from 0.07 to 1.45 µg/L. The state-wide chronic criteria range from 0.04 to 0.42 µg/L. This means that, under the current North Carolina DEQ practical quantitation limits, cadmium could not be detected within chronic criteria limits in greater than 90% of samples and could not be detected within acute criteria limits for at least 15% of samples from Sturgeon Waters.

Cadmium occurs in North Carolina Sturgeon Waters at concentrations within and greater than criteria limits. The extent to which cadmium occurs within or above criteria limits within Sturgeon Waters is uncertain because detection limits for monitoring data may not reliably identify the presence of cadmium, cadmium is not routinely monitored for in Sturgeon Waters, and, when cadmium is monitored for, the water hardness data needed to calculate applicable criteria limits are not collected concurrently.

7.1.5 Responses to Cadmium Exposures within Criteria Limits

As explained previously, risk quotients for all available endpoint effect data from screened ECOTOX data for the effects of cadmium and additional data from the open literature are plotted in Figures 8 through 11 in the context of reference lines representing a risk quotient of one (purple) for exposures at the criterion concentration and a risk quotient of 0.5 (orange) representing exposures at one-half the criterion concentration. Risk quotients that occur to the right of the purple reference line indicate responses occurring at an exposure concentration below the applicable criterion (i.e., higher risk). Risk quotients are plotted on a log scale to enhance resolution. Those few data reported 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.

7.1.6 Freshwater Cadmium Criteria Limits

The screened ECOTOX cadmium data for freshwater exposures included 1,113 toxicity tests from 127 studies exposing 52 species of fish from 21 taxonomic families. About half of the freshwater fish toxicity tests were for exposures of rainbow trout. Data for invertebrates, representing forage species, were obtained from 108 studies that conducted 707 toxicity tests evaluating the effects of cadmium on 87 invertebrate species from 46 taxonomic families. Nearly 60% of the invertebrate data are for exposures of *Daphnia* or *Hyallela*.

Risk quotients for acute exposure data apply North Carolina's recalculated acute criterion for fresh waters that do not contain trout. The acute freshwater cadmium criterion for trout waters in western North Carolina is the same as EPA's recommended guideline for the protection of aquatic life. The recalculated criterion is less protective than the EPA recommended guideline because the recalculation excluded data from trout toxicity tests.

While Figure 8 indicates that LC50s for white sturgeon are generally an order of magnitude higher than the test-specific criteria, the magnitude of responses at the LOECs from the same tests suggest adverse effects would occur within North Carolina's proposed acute criterion limit. Twenty percent of individuals exhibited loss of equilibrium and immobilization at a LOEC of 3.06 µg/L in an acute test reported by Calfee et al. (2014). With a test-specific criterion of 2.99 µg/L cadmium, the risk quotient for this LOEC is 0.98, which means the LOEC is essentially equivalent to the acute criterion. The four-day survival LOECs for fish exposed at age two days through 89 days post hatch had risk quotients ranging from 0.02 to 0.68, but the response magnitudes at these LOECs ranged from 20+/-11.55 percent to 95 +/-10 percent (Ingersoll et al. 2014).

Ingersoll et al. (2014) also reported a biomass LOEC for white sturgeon at 5.29 µg/L (RQ=0.15) for a chronic exposure that reduced fish mass by 25%, the EC10 calculated for this exposure was 2.4 µg/L with a confidence interval of 1.5 to 4.0 µg/L.

The EPA's BE acknowledged rainbow trout data indicating effects occurring at concentrations below North Carolina's acute and chronic criteria for cadmium, but dismissed these data due to uncertainty in using a coldwater fish as a surrogate to determine effects to anadromous sturgeon. However, the best available scientific data support the use of rainbow trout as a suitable surrogate for sturgeon. There is no coldwater/warmwater designation for Atlantic or shortnose sturgeon. The thermal optima for each species overlap considerably. For rainbow trout, the range is reported from 11.3 to 19 degrees Celsius while the range for shortnose and Atlantic sturgeon is between 7 and 26 degrees Celsius (McCauley et al. 1977, Myrick and Cech 2000, Niklitschek and Secor 2005, Niklitschek and Secor 2009, Niklitschek and Secor 2010, Rothermel et al. 2020). Considering that the fall line is often described as "the point at which boats traveling upriver usually cannot continue any further" and is generally an impediment to river travel

(Bleakley and Lin 2012), sturgeon size is most likely why they do not occur above the fall line in Western North Carolina.

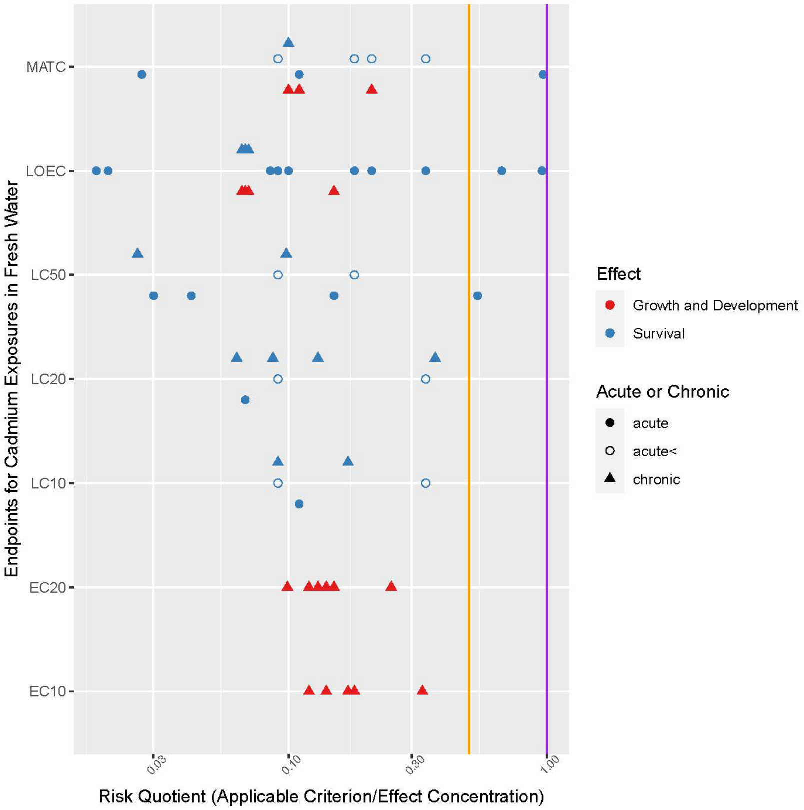

Figure 8. Distribution of Risk Quotients for Freshwater Exposures of White Sturgeon to Cadmium in Context of Reference Lines Representing the Applicable North Carolina Criterion (Purple) and One-half the Applicable Criterion (Orange)

Toxicity data for rainbow trout summarized in Table 11 and illustrated in Figure 9 include data from the Ingersoll et al. (2014) study discussed above. The hardness-normalized LC50s for effective mortality for sturgeon exposed at 30 days post hatch and trout exposed at 32 days post hatch were 54.63 and 2.55 µg/L, respectively. Yet the effective mortality LC50s for sturgeon exposed at 72 days post hatch and rainbow trout exposed 74 days post hatch were comparable, at 3.02 and 2.62 µg/L, respectively. Four-day survival LOECs for rainbow trout exposed at 18, 32, 46, 60, 74, and 95 days post hatch had risk quotients ranging from 0.57 to 1.6 but response magnitudes were substantial, ranging from 20+/-14.14% to 92.5 +/-9.57%. Risk quotients for the LC10s reported for these exposures by Ingersoll et al. (2014) ranged from 0.76 to 3.7.

Data indicating adverse effects may occur due to waterborne exposures within the North Carolina freshwater acute criteria limits include altered behavior, growth, and development of juvenile fish. Sloman et al. (2003a) exposed rainbow trout to cadmium at a concentration that was equivalent to the acute criterion concentration limit for 24 hours, indicating a risk quotient of 1, Many fish species, including salmonids, develop a social structure within shared habitat (Gilmour et al. 2005, Villegas-Ríos et al. 2022). Dominance, usually established through agression, conveys advantages in food, sheltering, and reproduction. Subordinate fish have reduced activity and feeding, lower growth ratesimmunosuppression, poor and increased mortality (Gilmour et al. 2005). The ability to establish dominance through aggression was evaluated in rainbow trout when paired with another cadmium-exposed fish or an unexposed control fish of the same size. A successful attack is an aggressive action that results in actual body contact. The dominant fish was identified as the individual with lighter coloration swimming freely in the tank and the submissive fish as the individual with darker coloration hovering either at the bottom of the tank or near the surface. Cadmium-exposed fish pairs attempted fewer attacks than control fish pairs during the period over which dominance was established. Cadmium-exposed fish that were paired with control fish had a decreased ability to establish dominance.

In a companion study, juvenile rainbow trout were exposed to a lower concentration of cadmium providing a risk quotient of 1.6 and assessed for the ability to establish dominance over one, two, three, and five days (Sloman et al. 2003b). Control fish were more likely to establish dominance than cadmium-exposed fish up until the fifth day. At five days post exposure, cadmium-exposed and control fish were equally likely to establish dominance. This corresponded with clearance of cadmium from olfactory rosettes of the cadmium-exposed fish. In fish, olfaction is important for homing, avoiding predators, finding mates, and locating food (Hara 1994, Kelley and Magurran 2003, Scott and Sloman 2004, Tierney et al. 2010, Leduc et al. 2013, Bett and Hinch 2016, Gerlach et al. 2019). The authors described the ecological implications of this effect in context of fish migrating from a contaminated area and competing with non-exposed fish for foraging and breeding.

While the Sloman et al. (2003a, 2003b) studies' 24 hour exposure duration exceeds the acute criterion exposure duration limit of one hour, the time required for cadmium exposure to affect olfaction or other receptors influencing behavior (e.g., taste, lateral line) was not addressed. NMFS expects that short exposures would have likely resulted in the same or similar response because effects at sensory receptors occur rapidly. A 2.3–3.0 µg/L increase in copper over background can impair olfaction in coho salmon within minutes of exposure (Baldwin et al. 2003) and four-hour exposures of sea bass to 5 µg/L cadmium resulted in lateral line system damage and impaired C-start escape response[9] that persisted for 20 days (Faucher et al. 2006).

NMFS is taking these acute behavioral studies into consideration because, while sturgeon are a primitive species group, there is evidence that they have a complex of social behaviors usually attributed to less primitive species (Kynard and Horgan 2002, Lilly et al. 2020). Kynard and Horgan (2002) reported a dominance hierarchy based on fish size and competition for foraging space in shortnose sturgeon. Their tests of Atlantic sturgeon did not indicate a dominance

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[9] The fish lateral line sensory system detects movement and vibration in the surrounding water. The C-start escape response is a rapid startle escape reflex so named because it causes the fish to first contract in tight bend to the opposite side of a predator's approach forming a "C shape" followed by a "kick" out of the contraction to dart away from the threat (Tytell and Lauder 2002).

hierarchy, but this was attributed to an absence of competition due to abundant food and lower fish density.

While the four-day EC50 risk quotient of 0.57 reported for effects on growth in rainbow trout suggests that some impact on growth would be expected for acute exposures within criterion limits (Table 8, Wang et al. 2014), the actual criterion duration limit is one hour and NMFS does not expect growth effects resulting from a one hour exposure would be detectable.

Adverse effects on survival of rainbow trout exposed within acute criteria limits is suggested by the magnitude of responses in reported LOECs, risk quotients for LC10s, and the abundance of LC50s with risk quotients exceeding a value of 0.5 among acute toxicity tests. The LC50 risk quotients for rainbow trout reported in 108 toxicity tests ranged from less than 0.001 to 2.9, averaging 0.79+/-0.6 (n=108). Among these, 73 tests reported LC50s exceeding a risk quotient of 0.5 and 32 LC50s exceeded a risk quotient of one.

Table 11. Summary of Toxicity Data for Rainbow Trout Exposures to Cadmium

Effect	Endpoint	N	Exposure Range µg/L	Risk Quotient range	Sources
Acute					
Behavior	MATC	1	30	0.1	Birge et al. 1993; Sloman et al. 2003a,b
	LOEC	4	2-50	0.061-1.6	
Growth and Development	EC50	1	5.1	0.57	Wang et al. 2014
Survival	MATC	8	1.86-4.02	0.75-1.6	Besser et al. 2007; Birge et al. 1983; Calfee et al. 2014; Call et al. 1981; Chapman 1978; Cusimano et al. 1986; Daoust 1981; Davies 1976; Davies and Brinkman 1994; Davies et al. 1993; Goettl and Davies 1976; Goettl et al. 1976; Hansen et al. 2002; Hollis et al. 1999; Ingersoll et al. 2014; Mebane et al. 2012; Naddy et al. 2015; Niyogi et al. 2004; Pascoe et al. 1986; Phipps and Holcombe 1985; Stratus Consulting Inc. 1999
	LC10	14	0.11-3.67	0.57-5.7	
	LC20	19	0.16-4.04	0.51-3.9	
	LC50	108	0.32-5700	<0.001-2.9	
	LOEC	14	1.01-8.45	0.18-1.6	
	LT50	58	0.51-10.6	0.16-1.8	
Chronic					
Growth and Development	MATC	7	0.16-7.5	0.049-1.9	Adiele et al. 2011; Besser et al. 2007; Ingersoll et al. 2014; Mebane et al. 2008; Wang et al. 2014
	EC10	7	0.15-9.2	0.083-2	
	EC20	6	1.8-6.8	0.032-0.42	
	LOEC	9	0.16-11.2	0.031-1.9	
Survival	MATC	24	0.4-17.6	0.089-4.5	Anadu et al. 1989; Besser et al. 2007; Birge 1978; Birge et al. 1978, 1979, 1980; Call et al. 1983; Chapman 1978; Chapman and Stevens 1978; Cusimano et al. 1986; Davies and Brinkman 1994; Davies and Gorman 1987; Davies et al. 1993; Goettl et al. 1976; Hansen et al. 2002; Ingersoll et al. 2014; Mebane et al. 2008; Roch and Maly 1979; Roch and McCarter 1986; Stratus Consulting Inc. 1999; Stubblefield et al. 1999; Wang et al. 2014
	LC10	13	0.7-11	0.075-0.34	
	LC20	14	0.25-17	0.048-1.1	
	LC50	34	0.35-280	0.0048-0.86	
	LETC	5	6.1-123	0.013-0.26	
	LOEC	10	0.7-26	0.041-2.3	
		26			

Among screened data, chronic toxicity tests are those with exposure durations exceeding four days. Hansen et al. (2002) reported five-day LC50s that ranged from 0.36 to 2.07 µg/L for rainbow trout exposed to cadmium under differing temperature and water hardness conditions. Risk quotients for these data ranged from 0.84 to 0.86 for exposures under an average water hardness of 30.4 mg/L $CaCO_3$ and temperature of 9.4 degrees Celsius. At a mean temperature of 7.8 degrees Celsius, risk quotients ranged from 0.35 to 0.58 correlating with water hardness values of 30 to 90 mg/L $CaCO_3$. Risk quotients for LC50s reported by a larger study with a similar design ranged from 0.24 to 0.81 (Stratus Consulting Inc. 1999).

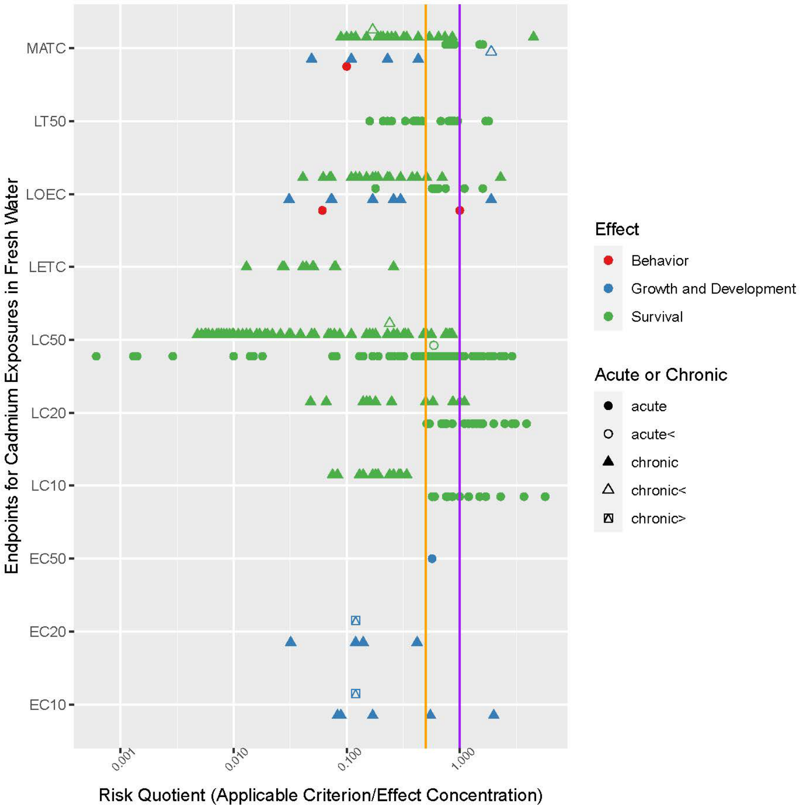

Figure 9. Distribution of Risk Quotients for Freshwater Exposures of Rainbow Trout to Cadmium in Context of Reference Lines Representing the North Carolina Criterion Applicable to Sturgeon Waters (Purple) and One-half the Applicable Criterion (Orange)

The risk quotients representing growth and development of rainbow trout ranged from 0.03 to 2 (Besser et al. 2007, Mebane et al. 2008a, Adiele et al. 2011, Ingersoll et al. 2014, Wang et al. 2014). The LOECs reported by Mebane et al. (2008) underscore the influence of temperature on cadmium toxicity. The risk quotient of 1.78 represents response magnitudes of five percent reduction in length and 17% reduction in weight at 12.5 degrees Celsius and hardness of 29.4 mg/L $CaCO_3$. At 9.8 degrees Celsius and hardness of 19.7 mg/L $CaCO_3$, risk quotients were 0.03 and 0.07 Mebane et al. (2008).

NMFS concludes that EPA's approval of North Carolina's adoption of the acute and chronic freshwater water quality criteria for cadmium may affect, and is likely to adversely affect individual shortnose sturgeon, the Carolina DPS of Atlantic sturgeon or migrating and foraging Gulf of Maine, New York, Bight, Chesapeake Bay, or South Atlantic DPSs of Atlantic sturgeon because the magnitude of responses at LOECs for exposures at or near the North Carolina's proposed freshwater acute and chronic cadmium criteria were substantial for both white sturgeon and rainbow trout and rainbow trout LC10 and LC50 data indicate adverse effects will result from exposures to cadmium within criteria limits.

The implications of EPA's approval of North Carolina's proposed freshwater cadmium criteria for ESA-listed sturgeon will be addressed in the Risk Analysis Section of this Opinion.

7.1.7 Quantity and Quality of Forage within the Freshwater Cadmium Criteria Limits

Examination of the data behind the risk quotients presented in Figure 10 indicates that adverse effects will occur in invertebrates exposed to cadmium within the chronic and acute criteria limits. 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. Although diets are likely to be location-specific based on availability, larval stages of both green and white sturgeon were reported to rely on zooplankton and small benthic macroinvertebrate 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, but when evaluating effects to forage species it is the abundance and quality of forage species that is of concern. NMFS does not expect that EPA's approval of the cadmium acute criterion and chronic criterion will affect the quality of forage species because Mebane (2006) concluded that exposures to cadmium within criterion limits is unlikely to result in accumulation in tissues to levels that would result in adverse effects to aquatic invertebrates or fish.

While adverse effects may occur in invertebrates exposed to cadmium within both the freshwater and saltwater acute criterion and chronic criterion limits, the bulk of the data indicate effects occurring above criterion limits. Early-life-stage sturgeon rely on zooplankton. Excluding the extreme risk quotient value greater than 100 in Figure 10, risk quotients for freshwater planktonic species ranged from less than 0.001 to 7.9 in 26 species. Data indicating adverse effects within criteria limits are for Hyalella, Daphnia, and Ceriodaphnia species. About half of the risk quotients in Figure 10 are from toxicity tests of Daphnia and Ceriodaphnia species, which are used in toxicity tests because they are extremely sensitive to aquatic pollutants. Among food items consumed by larger sturgeon, including mollusks, worms, and larger crustaceans like crayfish or crab, risk quotients ranged from less than 0.001 to 0.45 in 26 freshwater species.

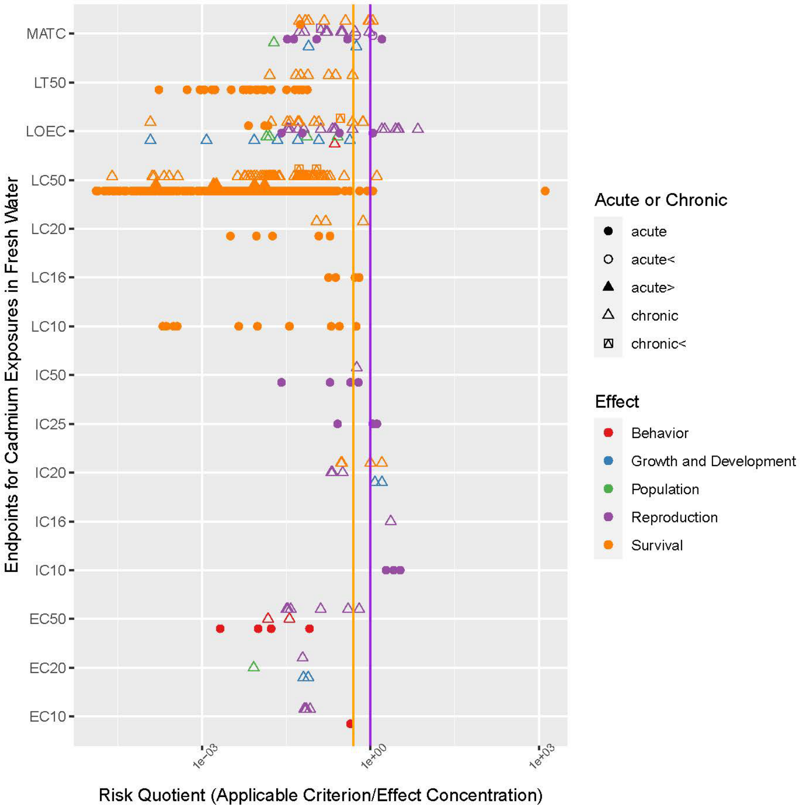

Figure 10. Distribution of Risk Quotients for Freshwater Exposures of Invertebrates to Cadmium in Context of Reference Lines Representing the Criterion Applicable to Sturgeon Waters (Purple) and One-Half the Applicable Criterion (Orange)

The implications of any effects on the abundance and quality of forage species for shortnose and Atlantic sturgeon is attenuated by the wide variety of forage species sturgeon consume. A reduction in the abundance of one benthic species is likely to be compensated for by an increase in other species (Wesolek et al. 2010). NMFS does not expect that cadmium exposures within chronic or acute criteria limits are likely to affect the abundance or quality of forage for shortnose sturgeon and the Gulf of Maine, New York Bight, and migrating Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon.

NMFS concludes that the exposure of forage species to cadmium within the freshwater criteria limits may affect, but is not likely to adversely affect the quantity and quality of prey for ESA-listed sturgeon because they consume a wide range of invertebrate taxa and the criteria were derived to protect aquatic life based on the fifth percentile of sensitive genera. The criteria are also implemented under conservative exposure durations and frequencies (i.e., the acute criterion is a one hour average derived from four day tests and the chronic criterion is a four day average).

7.1.8 Saltwater Cadmium Criteria Limits

Data for exposures of saltwater fish species in Figure 11 do not indicate that increased mortality would be expected to occur within the cadmium saltwater acute criterion limit. Given that mortality, growth and development LOECs, inhibition concentrations, and lethal thresholds

(ICxx and LETC in Figure 11, respectively) are at concentrations close to an order of magnitude higher than the chronic criterion and acute criterion, it is reasonable to expect that reproduction and other effects would not occur within the saltwater acute criterion or chronic criterion limiteither. However, a single study using sea bass indicated that a four-hour exposure to 5 µg/L cadmium resulted in a nearly 60% decline in the C-start escape response and damage to the lateral line receptors (Faucher et al. 2006). With the acute saltwater criterion of 33 µg/L, the risk quotient for this response is 6.6. Escape behaviors are critical to early life stage sturgeon that are vulnerable to predation. For example, juvenile C-start escape reflex in lake sturgeon was one quarter that of larval fish (Wishingrad et al. 2014). However, only juvenile and adult shortnose and Atlantic sturgeon occur in marine waters and these life stages have few predators (SSSRT 2010, NMFS 2022b).

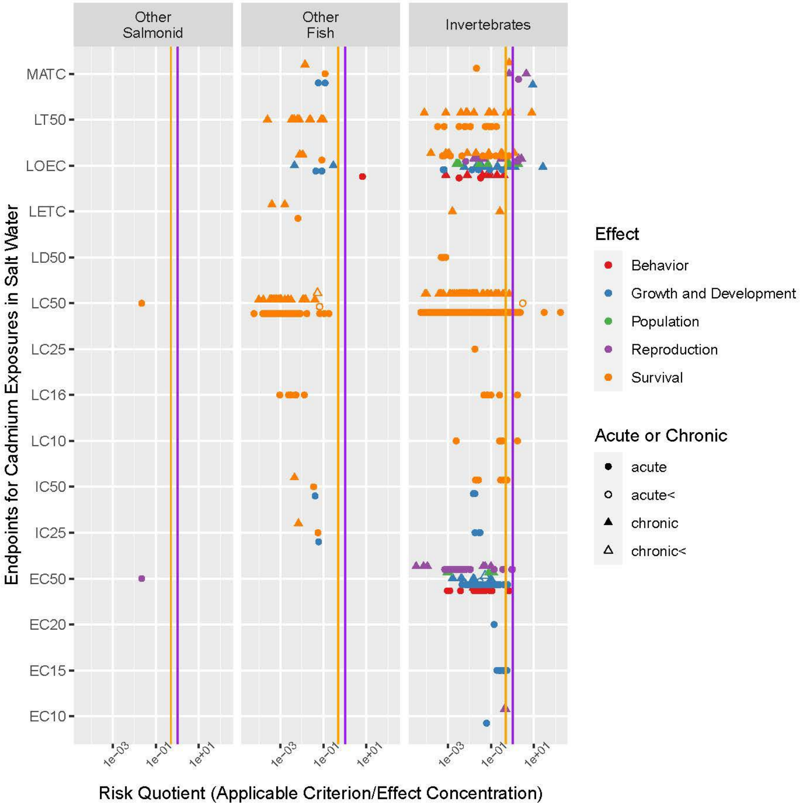

Figure 11. Distribution of Risk Quotients for Saltwater Exposures to Cadmium in Context of Reference Lines Representing the Applicable Criterion (Purple) and One-Half the Applicable Criterion (Orange)

The plotted risk quotients for the effects of cadmium on saltwater invertebrates include growth and development, reproduction, behavior, population productivity, and mortality responses. While the bulk of the invertebrate data indicate responses occurring above criterion limits, risk quotients representing LC50s for amphipod (Meador 1993), daggerblade grass shrimp and mud crab (Thorpe 1990), harpacticoid copepod (Forget et al. 1998), opossum shrimp (Nimmo et al. , Roberts et al. 1982, Ward 1989, Voyer and Modica 1990), and rock crab (Johns and Gentile 1981) indicate that mortality will occur at concentrations below the saltwater acute criterion.

Effects within the chronic criterion limits are also indicated by risk quotients representing reproduction LOECs for sea urchin (Jonczyk et al. 1991, Arizza et al. 2009), growth and development of cuttlefish (Lacoue-Labarthe et al. 2010) and daggerblade grass shrimp (Manyin and Rowe 2009) and reproduction and population stability of *Moina monogolica* (Wang et al. 2009).

Only adult and juvenile sturgeon occur in marine waters, so larger prey items that would be consumed are of interest: mollusks, gastropods, polychaetes, crabs, oysters, and mussels (excluding larval stages) in terms of potential effects to listed sturgeon due to effects to prey. The risk quotients for effects (i.e., excluding NOECs) in species likely to be consumed by adult and juvenile sturgeon ranged from less than 0.001 to 0.44, with 85% of risk quotients below 0.05.

NMFS concludes that EPA's approval of North Carolina's adoption of the saltwater National Criteria for cadmium may affect, but is not likely to adversely affect shortnose sturgeon, the Carolina DPS of Atlantic sturgeon or migrating and foraging Gulf of Maine, New York, Bight, Chesapeake Bay, or South Atlantic DPSs of Atlantic sturgeon because responses in surrogate species are extremely unlikely to occur such that effects are expected to be discountable in ESA-listed sturgeon.

NMFS also concludes that the exposure of forage species to cadmium within the saltwater criteria limits may affect, but is not likely to adversely affect the quantity and quality of prey available to ESA-listed sturgeon because they consume a wide range of invertebrate taxa and the criteria were derived to protect aquatic life based on the fifth centile of sensitive genera. The criteria are also implemented under conservative exposure durations and frequencies (i.e., the acute criterion is a one-hour average derived from four day tests and the chronic criterion is a four day average).

7.1.9 Risk of Cadmium Exposures within Criteria Limits

This risk analysis evaluates the consequences of effects in individuals to the populations those individuals represent, and the species those populations comprise. Thus far this Opinion concluded that exposures to cadmium within the acute and chronic freshwater criteria limits are likely to adversely affect individual shortnose and Atlantic sturgeon (Section 8.2.2.1), but not the quantity and quality of their forage species (Section 8.2.2.2). Meanwhile Section 8.2.2.3 concluded that exposures to cadmium within the acute and chronic saltwater criteria limits are not likely to adversely affect individual shortnose or Atlantic sturgeon or the quantity and quality of forage species. Therefore, this risk analysis section addresses the population level risk posed by freshwater exposures of shortnose and Atlantic sturgeon to cadmium within criteria limits.

SURVIVAL

Although the risk quotients for white sturgeon survival, growth, and development LOECs and MATCs indicate responses at exposures above cadmium acute criterion and chronic criterion limits, the magnitude of the responses at the MATCs and LOECs suggest that exposures of shortnose sturgeon and Atlantic sturgeon to cadmium within the acute criterion and chronic criterion limits would result in mortality and reduced growth. In addition, within genus comparability of sensitivity to toxicants is not always consistent (see discussion in Section 2.3.2). NMFS considers rainbow trout to be a suitable surrogate and data from multiple sources indicate mortality in early-life-stage fish exposed to cadmium within both the acute and chronic criterion limits proposed by North Carolina. While data are not available to perform a population viability analysis for ESA-listed sturgeon populations in North Carolina waters, these data are important because the viability of these populations are highly sensitive to juvenile mortality resulting in lower numbers of sub-adults recruiting into the adult breeding population (NMFS 1998a, ASSRT 2007).

GROWTH AND DEVELOPMENT

Growth is an important determinant of survival, and thus recruitment into the reproductive population (Anderson 1988, Poletto et al. 2018). Significant effects of cadmium on growth was reported to occur within criterion limits, but was temperature dependent (Mebane et al. 2008b). The white sturgeon studies did not evaluate the effect of temperature on cadmium toxicity. The studies comparing white sturgeon to rainbow trout ran toxicity tests at each of species’ optima, 15+/-1 degrees Celsius for sturgeon and 12+/-1 degrees Celsius for trout (Calfee et al. 2014, Ingersoll et al. 2014, Wang et al. 2014). The test in the Mebane et al. (2008b) study reporting rainbow trout growth effects within criteria limits was conducted at 12.5 degrees while the tests conducted at 9.8 degrees Celsius had LOECs resulting in risk quotients of 0.03 and 0.07. With increasing temperatures expected under climate change (IPCC 2021), NMFS expects that cadmium exposures within chronic criterion limits may impair growth of early life stage and juvenile shortnose and Carolina DPS of Atlantic sturgeon spawned and rearing in North Carolina waters and migrating and foraging juvenile members of the Gulf of Maine, New York Bight, Chesapeake Bay, and South Atlantic DPSs of Atlantic sturgeon.

REPRODUCTION

Data for the effects of cadmium on reproduction in sturgeon and salmonid species are not available. Data for other fish species do not indicate effects on reproduction within cadmium criteria limits. While reproduction is critical to population persistence, fish must first survive and grow in order to reproduce. Given that cadmium exposures within criteria limits are expected to adversely affect early-life-stage survival and growth, it is reasonable to expect that these effects will, in turn reduce recruitment of reproductive fish.

7.1.10 Likely to Adversely Affect Determination for EPA Approval of North Carolina DEQ Adoption of Freshwater Cadmium Criteria

NMFS concludes that EPA’s approval of North Carolina’s adoption and implementation of the recommended National Recommended Water Quality Criteria for cadmium in freshwater is likely to adversely affect shortnose sturgeon and the Carolina DPSs of Atlantic sturgeon and migrating Gulf of Maine, New York Bight , Chesapeake Bay, and South Atlantic Atlantic sturgeon DPSs because:

1. Permitting and monitoring of North Carolina DEQ-regulated waters indicate that exposures to cadmium will occur;
2. Current monitoring data indicate that the North Carolina DEQ practical quantitation limits are insufficient to detect cadmium within chronic criteria limits in greater than 90% of samples and within acute criteria limits for at least 15% of samples from Sturgeon Waters;
3. The toxicity of cadmium in surrogate species[10] indicate that exposures within criteria limits will likely result in adverse effects to the survival of early-life-stage shortnose and Atlantic sturgeon;
4. With increasing temperatures under climate change (IPCC 2021), temperature-dependent effects of cadmium exposure on growth in surrogate species indicates that exposures within criteria limits are likely to affect growth of shortnose sturgeon and Atlantic sturgeon; and
5. The viability of ESA-listed sturgeon populations in North Carolina's waters is highly sensitive to juvenile mortality resulting in lower numbers of sub-adults recruiting into the adult breeding population (NMFS 1998a, ASSRT 2007).

7.2 Selenium

Selenium is a naturally occurring element in the earth's crust. It is an essential nutrient, present in selenoproteins with roles in thyroid function, cellular energy production, DNA synthesis, oxidative stress defense, and protein repair (Janz et al. 2010). Selenium is used commercially in personal care products, nutritional supplements, and other consumer products (ATSDR 2003). In excess, selenium is toxic, with egg laying vertebrates generally the most vulnerable to selenium toxicity (Janz et al. 2010).

Anthropogenic activities resulting in excess selenium in water include: agricultural irrigation drainage, treated oil refinery effluent, mountaintop coal mining/valley fill leachate, copper mining discharge, fly ash disposal effluent, phosphate mining overburden, and treated agricultural drainage (USEPA 2021a). Fly ash disposal effluent is the most relevant source of selenium in North Carolina. Selenium can enter surface waters as drainage from fly-ash basins and fly-ash deposits on land (Gillespie and Baumann 1986). Fly ash deposits have a high surface area to volume ratio, resulting in rates of selenium in leachate several times higher than from the parent feed coal (Fernández-Turiel et al. 1994). Fly ash is sometimes used as structural fill, but data indicate that metal leachate from this use is generally below EPA protective limits for drinking water (Aydilek and Cetin 2013).

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[10] Explained in Section 8.1.2.1, particularly the fifth paragraph.

Diet and maternal transfer are the primary exposure pathways leading to selenium toxicity. Ambient selenium in water becomes incorporated into the food web through uptake by periphyton thereafter biomagnifying along the consumer-to-predator continuum. Incorporation into the food web is highly dependent on site specific factors such as food web structure and hydrology. At harmful levels, selenium disrupts physiological processes resulting in impacts to growth and development. As such, selenium toxicity manifests markedly in early life stages resulting in toxicity and lethality to embryos and deformity in developing young (Janz et al. 2010, USEPA 2021a). The mechanism for selenium toxicity is attributed to the generation of free radicals and the damage they cause. Free radicals indiscriminately oxidize proteins, nucleic acids, and cell membranes. This damage stimulates defensive measures and repair or replacement of cells. Accumulating damage at the cellular level depletes energy reserves and damages tissues, impairing organ function (Birnie-Gauvin et al. 2017).

The EPA proposes to approve North Carolina DEQ adoption of the freshwater selenium National Recommended Criteria for the Protection of Aquatic Life (USEPA 2021a). The proposed criteria consist of two components, one based on the concentration of selenium in fish tissue on a dry weight basis and one based on the concentration of selenium in the water column. There are two elements in the first component, a fish egg/ovary selenium concentration and fish whole-body and/or muscle element concentration. Fish tissue elements are steady-state concentrations and provide instantaneous point measurements that reflect integrative accumulation of selenium over time and space in fish populations at a given site. Fish tissue components supersede the water column component when both fish tissue and water concentrations are measured. Egg/ovary tissue results, where available, supersede all other tissue and water column components.

The EPA guidelines do provide exceptions to this hierarchy: NPDES permitting applies the water column criteria and the water column criteria take priority in cases where there is a new selenium source and the organisms in the receiving water have not yet come to equilibrium with the new source. The EPA Selenium Guideline states that it takes about two to three years for an aquatic ecosystem to reach equilibrium.

Table 12. National Recommended Selenium Water Quality Guidelines for the Protection of Aquatic Life that EPA Proposes to Approve for Implementation by North Carolina

	FISH TISSUE		**WATER COLUMN**
Criteria Limits	**Egg/Ovary**	**Fish Whole Body or Muscle**	**Monthly Average (dissolved fraction)**
Magnitude	15.1 mg/kg dry weight	8.5 mg/kg dry weight whole body OR 11.3 mg/kg dryweight muscle (skinless, boneless fillet)	3.1 µg/L in lotic aquatic systems
Duration	Instantaneous	Instantaneous measurement	30 days
Frequency	Not to be exceeded	Not to be exceeded	Not more than once in three years on average

Data are expressed on a dry weight basis to normalize for differential hydration among samples due to native hydration of the organism or changes due to method of storage. Fish tissue is generally about 70 to 80% moisture (USEPA 2021b). Unless otherwise stated in this Opinion, all biological tissue data are in dry weight.

7.2.1 Exposure to Selenium in the Action Area

Before addressing the potential for adverse effects from implementing the cadmium criteria, it is first necessary to identify natural and anthropogenic sources of cadmium that may contribute to aquatic impairments or be regulated under the criteria. Regarding natural sources, North Carolina is not in a region of the United States with naturally selenium-enriched soils (Figure 12). Where stream sediments were assessed for selenium, concentrations were below three parts per million (Figure 13). Because selenium is not naturally enriched in North Carolina soils, we would not expect selenium to be redistributed to aquatic habitats through agricultural irrigation or sediment and soil disturbing activities in areas without anthropogenic sources. As of August 2022, there are no active oil refinery facilities in North Carolina and North Carolina DEQ has not received any applications for proposed oil refinery facilities (NCDEQ 2022b). In the absence of natural sources, selenium would reach Sturgeon Waters through permitted discharges and coal ash sources.

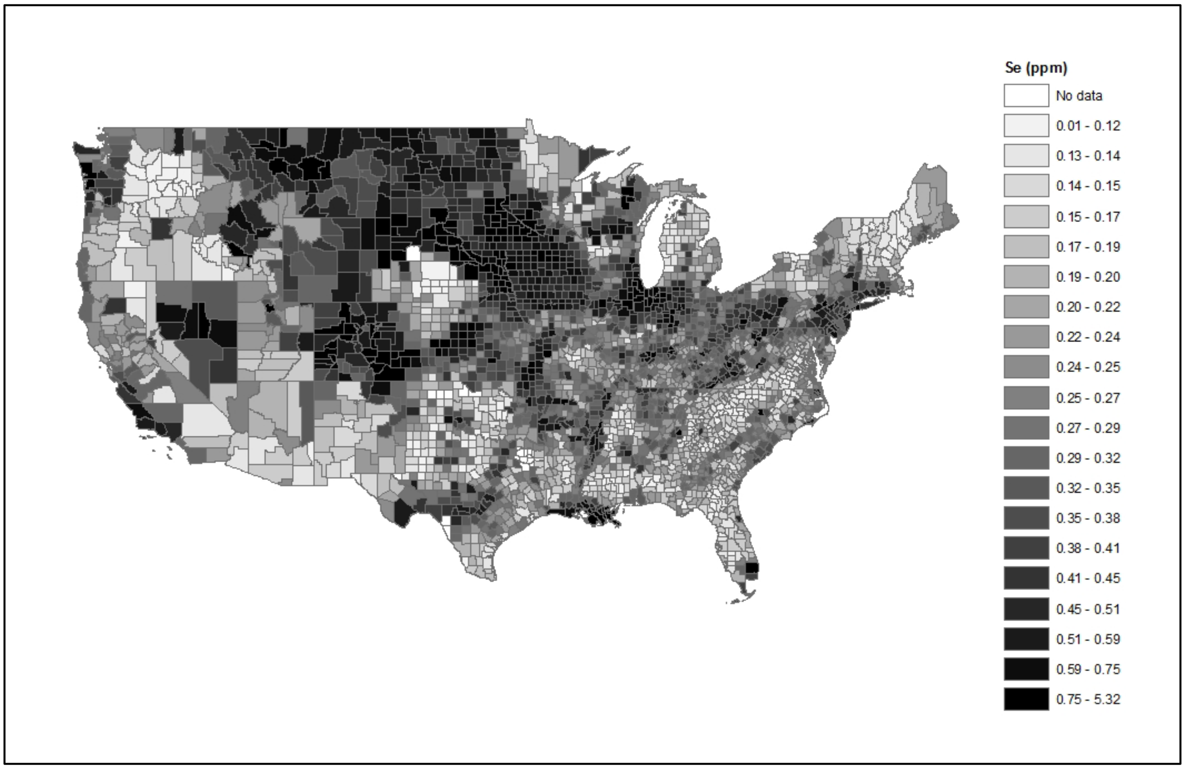

Figure 12. Selenium in Surficial Soils and Aquatic Sediments in counties of the Conterminous United States, U.S. Geological Survey Open-File Report 2004-1001. URL: http://mrdata.usgs.gov/geochem/doc/averages/countydata.htm (after USEPA 2021a)

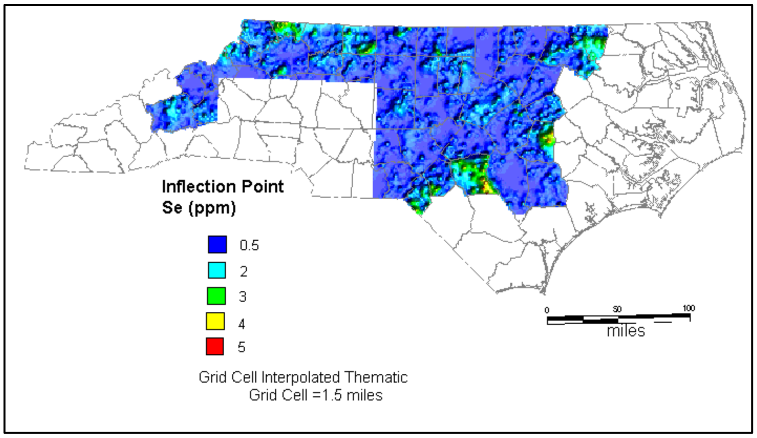

Figure 13. Distribution of Selenium in North Carolina Stream Sediments

7.2.2 Permitted Discharges

It is reasonable to expect that any selenium discharger with the “reasonable potential” to cause a water quality impairment under existing criteria due to selenium in effluent currently has selenium limits in their permit. A review of EPA ECHO database identified three permitted discharges within catchments adjacent to Sturgeon Waters that are required to monitor for selenium. These are the same facilities that are also required to monitor for cadmium. The SIC codes for these dischargers are SIC 4911, electric services, and 2874, phosphatic fertilizers (expired). There are seven other permits for SIC 4911 facilities that are not required to monitor for selenium, but may contribute selenium resulting in in-stream concentrations that are below levels considered to have “reasonable potential” to cause an impairment. In addition to these sectors, there are several coal ash basins and coal ash structural fills located within catchments adjacent to or associated with Sturgeon Waters.

The EPA’s 2013 Permit Quality Review of North Carolina’s NPDES permits observed that data provided in application forms lacked detailed information regarding method detection limits; applications that contained “Non-Detect” in the field (versus an indication of method detection limit) were deemed complete. An indication of Non-Detect is insufficient to determine if sufficiently-sensitive analytical methods were employed and, thus, quantifying the pollutant with respect to applicable water quality critia. As a result, EPA recommended that North Carolina require use of “sufficiently sensitive analytical methods” and ensure method detection limits are documented in application forms. The EPA’s 2019 Permit Quality Review of North Carolina’s NPDES permits reported that North Carolina has implemented this recommendation. Nevertheless, information on permit compliance status for North Carolina’s NPDES discharges is uncertain because, at the time of this writing, North Carolina is experiencing issues affecting the upload of data that may cause NPDES-permitted facilities to erroneously be displayed in ECHO as being noncompliant. Monitoring data reported for these three facilities, accessed on November 9, 2022, identified few discharges above analytical detection limits, although there do appear to be data missing for selenium. As described in Section 2, NPDES monitoring requires the use of sufficiently sensitive analytical methods, but "sufficiently sensitive analytical methods" can include the method with the lowest minimum level of all methods approved by the EPA for the pollutant but cannot "achieve the minimum levels necessary to assess reasonable potential or to monitor compliance with a permit limit." The EPA standard methods for selenium identify instrument and method detection limits ranging from 1.3 to 20 µg/L using Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES), Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), and Atomic Absorption Biohydride Reduction. Method detection limits are sample dependent and may vary as the sample matrix varies.

7.2.3 Coal Ash

There are 23 active and 11 inactive coal ash basins at 14 coal-fired power plants in North Carolina. Coal ash has been used as structural fill to construct stable base layers for roads, bridges, airfields and large buildings across the state. Coal ash has been widely used, especially during the 1980s and 1990s, because it is considered stronger and easier to work with than other materials. While North Carolina DEQ has mapped the known locations of coal ash structural fills, there were few rules or records regarding the use of coal ash as fill prior to 1987, and coal ash used as structural fill was not required to be reported to the state environmental agency until 1994 (NCDEQ 2022a).

In February 2014, the hazard posed by coal ash basins at coal-fired power plants came to the fore when an estimated 39,000 tons of coal ash spilled into the Dan River in Eden after a stormwater pipe beneath an ash basin at Duke Energy's Dan River Steam Station ruptured. In 2014, the North Carolina General Assembly passed the Coal Ash Management Act (CAMA). The CAMA puts Duke Energy on a timetable to close all its coal ash basins. This triggered reuse plans as structural fill for coal ash currently stored at several Duke Energy plants. The CAMA requires new coal ash structural fills to be permitted by the Division of Waste Management and added additional requirements for existing structural fills. The CAMA statute adds to and in some cases supersedes existing rules.

Structural fills constructed prior to 2014 that are greater than 10,000 cubic yards are inspected annually. Historical or existing structural fills less than 10,000 cubic yards are not addressed in CAMA. However, these latter facilities are required to be maintained with adequate cover and are inspected as necessary. A new structural fill must not be within the 100-year floodplain, within four-feet of the seasonal high ground water table, within 25-feet of a property boundary bedrock outcrop, within 50-feet of a property boundary, wetland, bank of a perennial stream or other surface water body, or within 300-feet of a private dwelling or well. Structural fills shall not restrict the flow of the 100-year flood, reduce the temporary water storage capacity or result in washout of the waste to pose a hazard to human life, wildlife or land or water resources.

There have only been two structural fills larger than 8,000 tons per acre permitted since the enactment of CAMA in 2014. There have been no structural fills less than 8,000 tons per acre permitted since CAMA. Should a structural fill less than 8,000 tons per acre/80,000 tons per project be proposed, the Division of Waste Management also requires submission of Toxicity Characteristic Leaching Procedure results for arsenic, barium, cadmium, lead, chromium, mercury, selenium, and silver below hazardous levels. Any structural fills that are more than 8,000 tons per acre or 80,000 tons per project requires submission of construction plans which include a liner, a leachate collection system, a cap, sufficient dust control, and a groundwater monitoring system. A licensed geologist or professional engineer must certify that the groundwater monitoring system is effective in providing early detection of any release of hazardous constituents from any point in a structural fill or leachate impoundment to the uppermost aquifer. Finally, an application must include financial assurance that will ensure that sufficient funds are available for facility closure, post-closure maintenance and monitoring any corrective action required, and to satisfy any potential liability for accidental occurrences, and subsequent costs in response to an incident. Among the coal ash basins and structural fills in North Carolina, 11 basins and 17 coal ash structural fills are located within catchments that are adjacent to Sturgeon Waters or catchments neighboring these catchments (Figure 14).

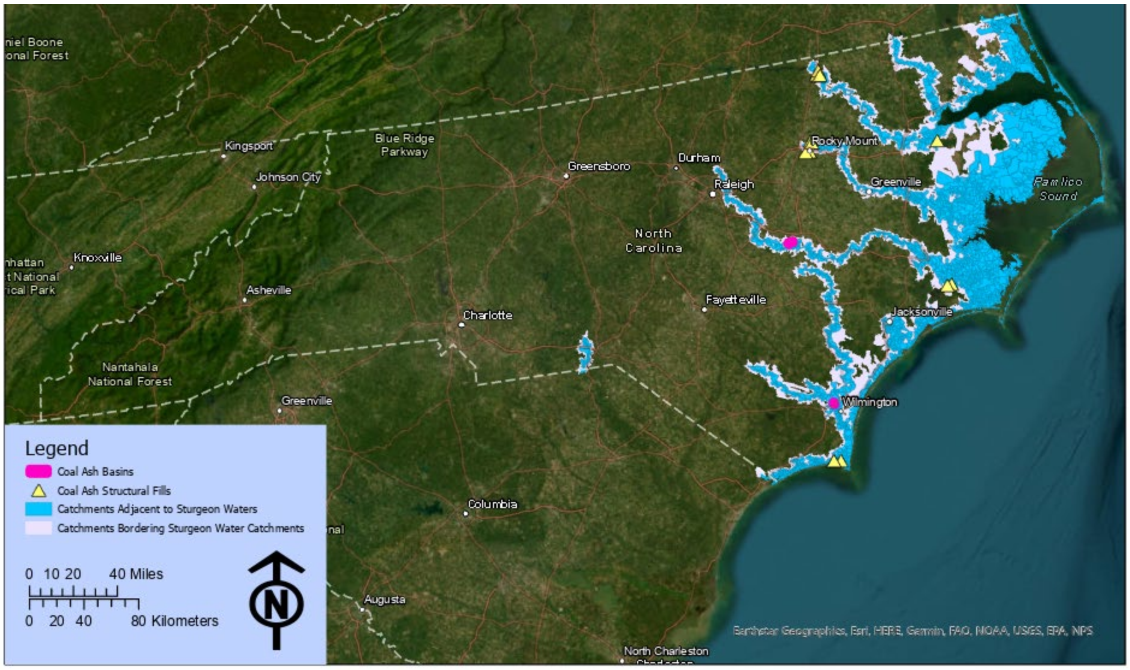

Figure 14. Coal Ash Basins and Structural Fills Potentially Affecting Sturgeon Waters

All coal ash structural fills in these areas are listed as closed. The basins are associated with the Lee Energy Complex abutting the Neuse River in Goldsboro (Figure 15) and the Sutton Energy Complex abutting the Cape Fear River in Wilmington (Figure 16). The emergency action plan for the Lee Energy Complex identified its single active ash basin as having significant hazard potential (H.F. Lee Energy Complex 2022).

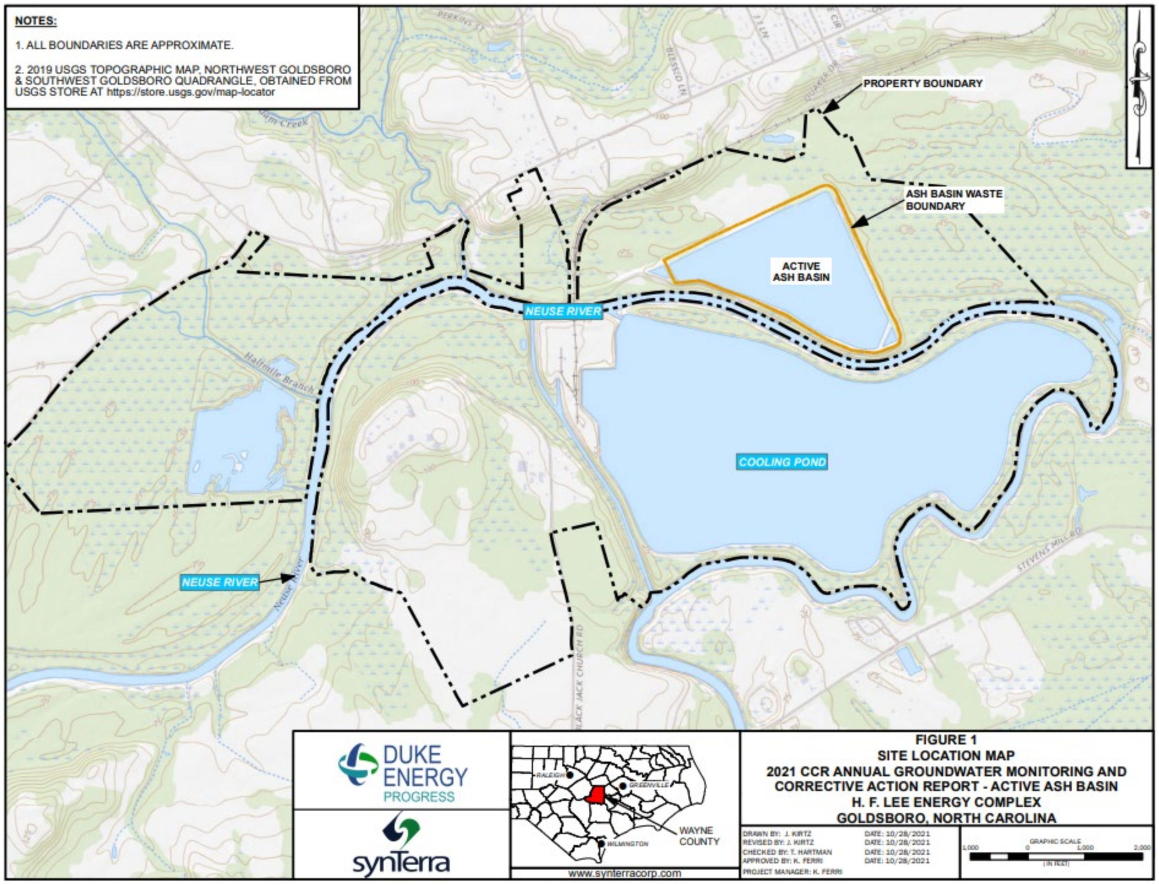

Figure 15. Lee Energy Complex Active Coal Ash Basin abuts the Neuse River

The emergency action plan for the Sutton Energy Complex identifies two active ash basins constructed adjacent to each other in 1971 and 1984 as high hazard potential (L.V. Sutton Energy Complex 2018). These basins are depicted as a single area with an internal berm in Figure 16.

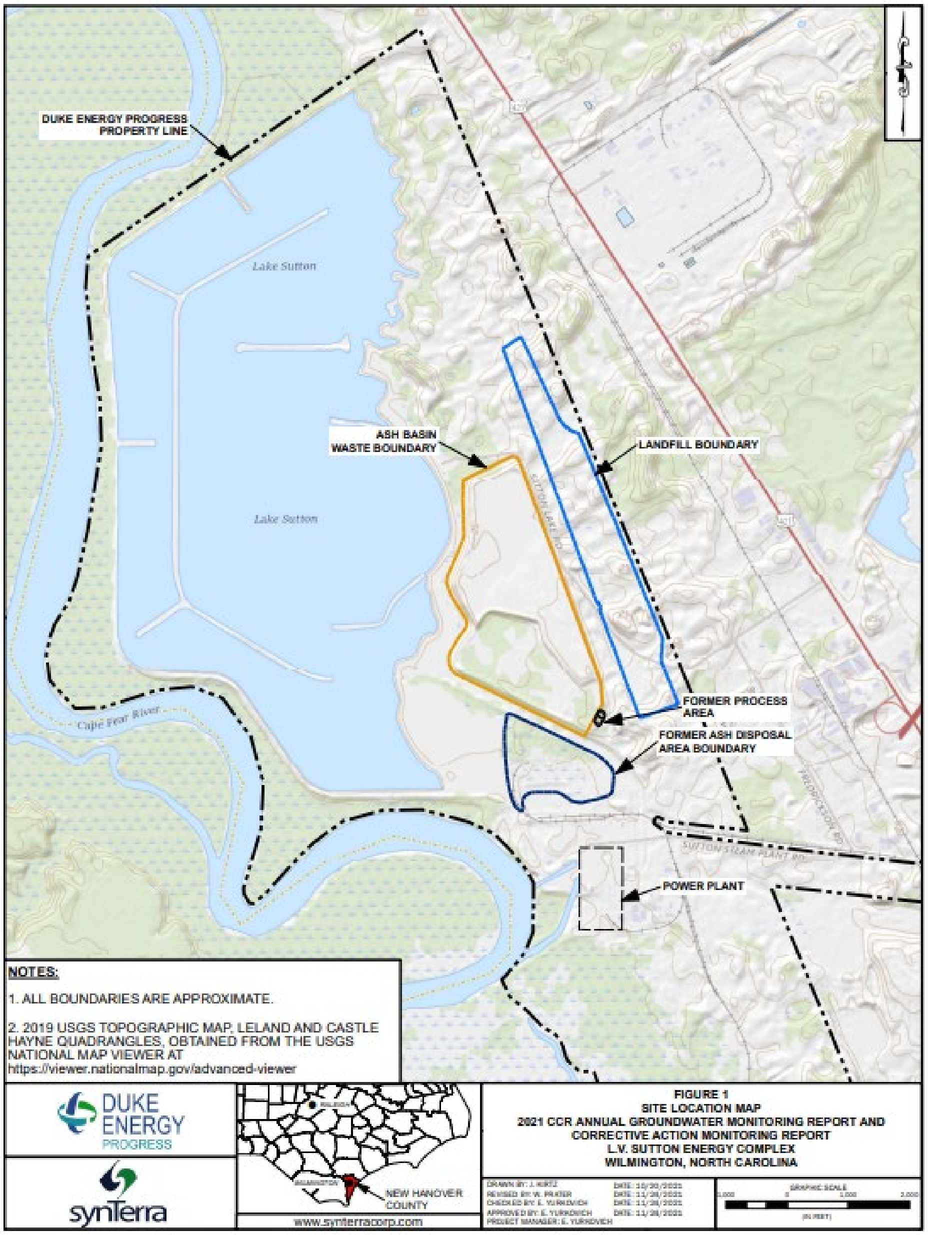

Figure 16. Sutton Energy Complex abuts the Cape Fear River

7.2.4 Monitoring Data

Annual Groundwater Monitoring and Corrective Action Reports for the respective Energy Complexes detail ground water monitoring data for fall of 2020 and spring of 2021 (H.F. Lee Energy Complex 2022a, L.V. Sutton Energy Complex 2022). Selenium was below the detection limit of 1 µg/L for all but one observation of 1.14 µg/L at the Lee Energy Complex and ranged from below the detection limit of 1 µg/L to 42.6 µg/L at the Sutton Energy Complex. To place these data in context, the EPA drinking water limit for the protection of human health is 50 µg/L, and the criteria for the protection of aquatic life in lotic (flowing) systems, which include

Sturgeon Waters, is 3.1 µg/L. There are no surface water or tissue selenium monitoring data for waters near these potential sources.

Water monitoring data integrate the multiple point and nonpoint sources affecting water quality conditions, but unless monitored continuously or systematically, the data are merely snapshots in time of the water chemistry and conditions at the time each sample was taken. The amount of monitoring data for Sturgeon Waters in the Water Quality Portal is sparse. Selenium concentrations from a creek receiving bridge-deck stormwater runoff in 2009 and 2010 ranged from 0.1 to 0.89 µg/L with an average of 0.3 µg/L. In-stream monitoring of the Neuse River between 2012 and 2014 about 54 km downstream of the Lee Energy Complex indicate selenium concentrations ranging from 0.06 to 0.17 µg/L. Data from both locations were reported by the United States Geological Survey's North Carolina Water Science Center. Monitoring between 2015 and 2020 did not detect selenium at a station 5 km downstream of the Sutton Energy Complex. Among all data reported for Sturgeon Waters, detection limits for selenium in freshwater monitoring were sufficiently sensitive to detect selenium within the chronic criterion limit of 3.1 µg/L after 2012. Instream monitoring data collected by North Carolina DEQ in 2017 and 2018 in preparation for adoption of selenium criteria were all below the quantitation limit of 1 µg/L. Among 64 monitoring stations, only two were within five kilometers of one of the state's 33 ash basins and both stations were upstream of the ash basins.

Data for selenium in aquatic organisms from North Carolina DEQ and the Water Quality Portal are placed in context of coal ash selenium sources on Figure 17. The vast majority of the North Carolina DEQ data were collected were for lentic stations and fish from lentic waters (i.e., non-flowing) generally had higher selenium concentrations. Selenium concentrations in fish sampled from streams and rivers are summarized in Table 13. Data reported as wet weight were converted to dry weight assuming 75% moisture. Fish tissue data were collected from 13 stations in 2017 by North Carolina DEQ in preparation for adoption of selenium criteria. These include tissue data for three river stations: Neuse River at Goldsboro, Lumber River, within the Pee Dee watershed, at the NC 72 Ramp, and Tar River, within the Pamlico Watershed, near Greenville. Fish muscle (n=19) and ovary (n=3) tissue concentrations ranged from 1 to 8 mg/kg and 4 to 4.7 mg/kg selenium, respectively.

Water Quality Portal data collected between 2000 and 2009 include whole-body values for silver perch ranging from 2.56 to 2.92 mg/kg and white perch ranging from 2 to 5.04 mg/kg. Muscle (with skin) values reported for largemouth bass range from 0.94 to 1.58 mg/kg, blue catfish from 1.07 to 1.25 mg/kg, and channel catfish from 0.65 to 1.4 mg/kg. These values are all below the criteria concentrations if 8.5 mg selenium/kg dry weight in whole body, 11.3 mg/kg for muscle, and 15.1 mg/kg in eggs or ovaries. Other Water Quality Portal data not readily comparable to the criteria include whole body values for the mollusc *Corbicula* ranging from 1.7 to 7 mg/kg and fish liver values ranging from 3.8 to 7 mg/kg (white sucker, redbreast sunfish, and carp). These data were collected between 1992 and 1997.

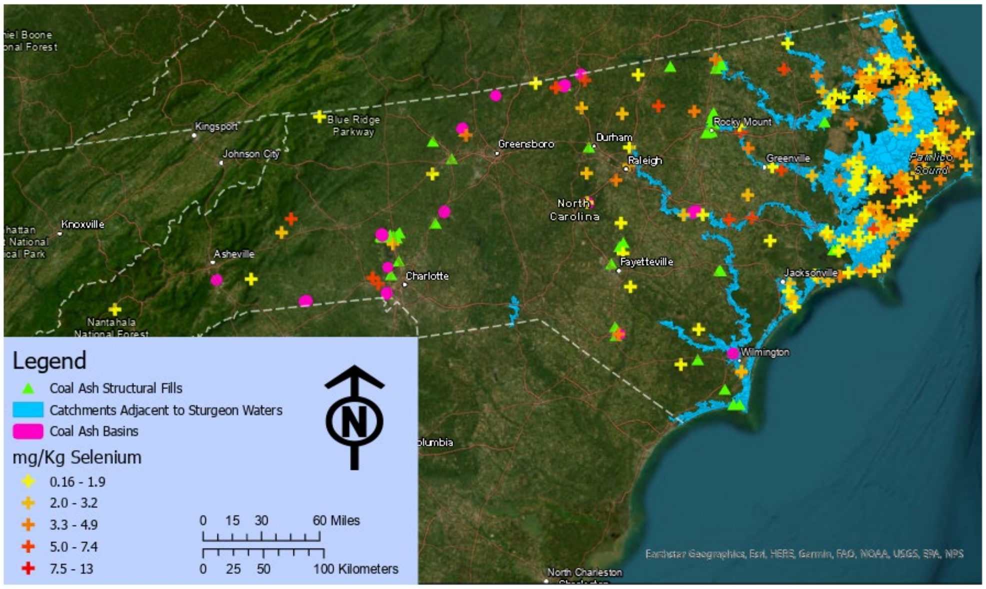

Figure 17. Fish and Invertebrate Tissue Selenium Concentrations in Context of Selenium Sources and Sturgeon Waters

Table 13. Summary of Selenium Concentrations Reported in Tissues of Freshwater Organisms Inhabiting North Carolina Streams and Rivers

Basin	Year	Species	Tissue	N	Selenium mg/kg dry weight
Albemarle-Chowan	1992	*Corbicula*	Whole Organism	1	5.7
Lower Pee Dee	2017	Bluegill	Muscle	1	1.5
		Largemouth Bass	Ovaries	3	3.2-5
			Muscle	11	1-8.1
		Redbreast Sunfish	Muscle	2	1
		Redear Sunfish	Muscle	2	1.5-1.9
		Spotted Sunfish	Ovaries	1	3.5
			Muscle	2	1.4-1.6
		Warmouth	Ovaries	1	3.2
			Muscle	2	1.3-1.6
Neuse	1992	*Corbicula*	Whole Organism	6	1.7-3.8
	1993	Redbreast Sunfish	Liver	3	5.4-6.5
	1997	*Corbicula*	Whole Organism	2	2.2-3.5
		Redbreast Sunfish	Liver	2	5.9-7.2
	2017	Blue Catfish	Muscle	1	1.2
		Bluegill	Muscle	3	2-2.6
		Channel Catfish	Muscle	3	1.4-1.5
		Largemouth Bass	Ovaries	3	4-4.7
			Muscle	3	1.7-2.8
		Redear Sunfish	Muscle	4	1.5-2.3
		Striped Bass	Muscle	5	1-1.6

Basin	Year	Species	Tissue	N	Selenium mg/kg dry weight
Pamlico	1992	*Corbicula*	Whole Organism	4	2.8-3.6
	1993	Redbreast Sunfish	Liver	4	3.8-7
	2017	Black Crappie	Muscle	1	1.6
		Bluegill	Ovaries	1	4.4
			Muscle	3	1.6-1.8
		Chain Pickerel	Muscle	2	0.92-1
		Largemouth Bass	Ovaries	2	2.2-3
			Muscle	9	0.81-1.8
		Redbreast Sunfish	Muscle	1	1.7
		Redear Sunfish	Ovaries	1	2.7
			Muscle	3	2.2-2.6
Roanoke	1992	*Corbicula*	Whole Organism	1	3.2
Santee	1995	*Corbicula*	Whole Organism	2	3.1-7
		White Sucker	Liver	1	7
	1997	Common Carp	Liver	1	5.4

With ash basins within catchment adjacent to Sturgeon Waters classified as having significant or high hazard potential, there is potential for exposure of ESA-listed sturgeon. Monitoring data indicate selenium is present in surface waters and in fish tissue at concentrations below criterion limits in some locations in North Carolina, but the available data are not from samples associated with coal ash basin sources. The question that must now be addressed is whether exposure to selenium within criteria limits may result in adverse effects.

7.2.5 Responses to Selenium Exposure within Water Column Criteria Limits

As explained previously, the toxicity data figures in this Opinion present test-specific risk quotients plotted in the context of reference lines representing a risk quotient of one (purple) for exposures at the criterion concentration and a risk quotient of 0.5 (orange) representing exposures at one-half the criterion concentration. Risk quotients plotted to the right of the purple reference line indicate responses occurring at an exposure concentration below the applicable criterion (i.e., higher risk). Risk quotients are plotted on a log scale to enhance resolution.

Figure 7 illustrates the screened ECOTOX selenium data for exposures to selenium freshwater included 120 toxicity tests from 90 studies exposing 10 species of fish from 4 taxonomic families. About one third of the freshwater fish data are for exposures of rainbow trout. Data for invertebrates, representing forage species, were provided by 21 studies that conducted 81 toxicity tests evaluating the effects of cadmium on 22 invertebrate species from 9 taxonomic families. Nearly half of the invertebrate data are for exposures of *Daphnia*. These data are also summarized in Table 14.

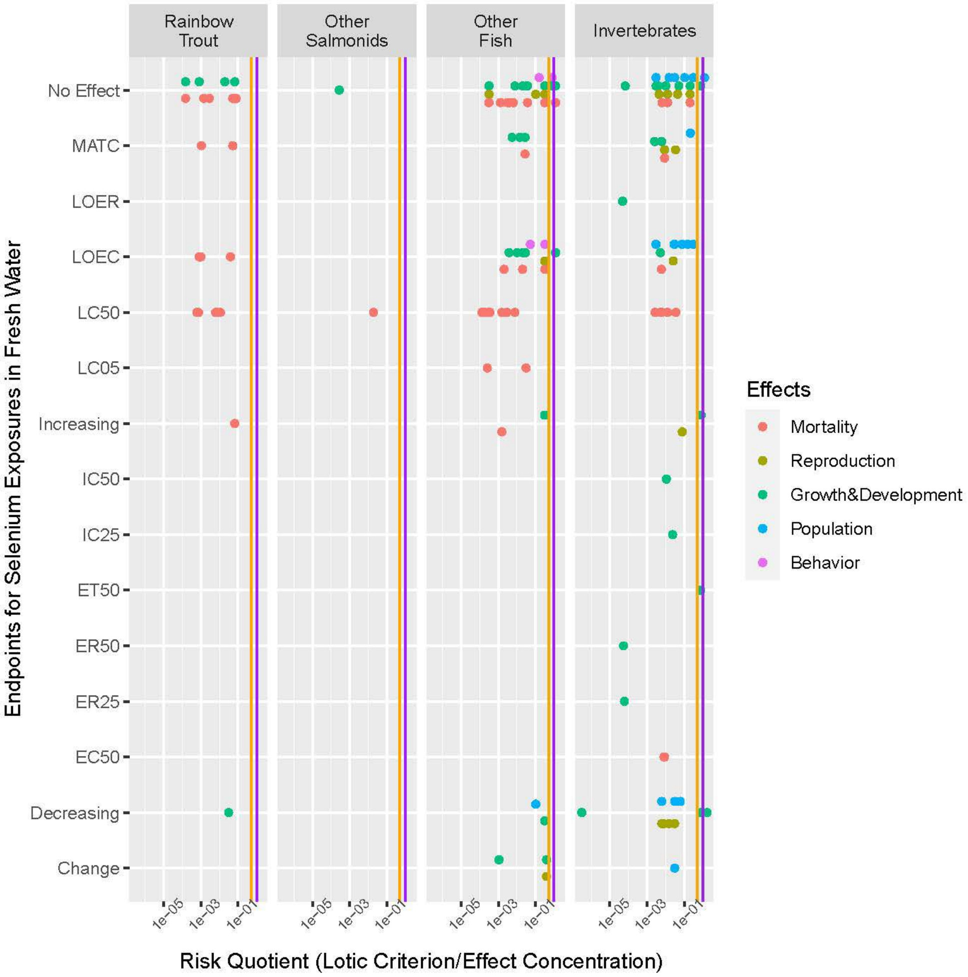

Figure 18. Distribution of Risk Quotients for Freshwater Exposures to Selenium in Context of Reference Lines Representing the Applicable North Carolina Criterion (Purple) and One-half the Applicable Criterion (Orange)

The majority of risk quotients indicate responses occurring in fish at exposure concentrations well above the lotic water column criterion of 3.1 µg/L. Exceptions are LOECs of 2.6 µg/L for growth and development effects in lake chub and bluegill (Hermanutz et al. 1996, Phibbs et al. 2011). The condition factor, weight divided by length, of lake chub actually increased in fish placed in a lake with elevated selenium relative to fish placed in a reference lake (Phibbs et al. 2011). Meanwhile Hermanutz et al. (1996) reported a 15 percent increased frequency of spine and back deformities in bluegill exposed at the same selenium concentration (after Mebane 2022). The Phibbs et al. (2011) study did not report the presence or absence of spinal deformities. The condition factor in exposed fish reflects a greater body weight relative to length. Increased mass does not necessarily indicate a beneficial effect. It may indicate edema, a condition in which capillaries leak resulting in fluid accumulation and swelling in surrounding tissues. Edema, particularly of the pericardium, is a commonly reported histological effect of selenium exposure (see Hermanutz et al. 1992, Holm 2002, Teh et al. 2002, Palace et al. 2004, Muscatello et al. 2006, Hinck et al. 2007, Liao et al. 2007, Muscatello and Janz 2009, Janz et al.

2010, Kalishwaralal et al. 2015, Zee et al. 2016, Kumar et al. 2018, Shi et al. 2018, Brix et al. 2021). Among data for invertebrates, those risk quotients indicating adverse effects due to exposure concentrations near or below the lotic criterion concentration of 3.1 µg/L are from a single study: Franz et al. (2011), for effects on weight and emergence of a single species, the midge *Chironomus dilutus*.

Table 14. Summary of Screened Toxicity Data for the Effects of Freshwater Exposures to Selenium on Aquatic Life

Effect	Endpoint	N	Exposure Range µg/L	Risk Quotient Range	Sources
Rainbow Trout					
Growth & Development	**Decreasing**	1	0.1	0.031	Hunn et al. 1987
Mortality	**MATC**	2	0.06-2.9	0.0011-0.052	Goettl et al. 1976; Spehar 1986
	Increasing	1	0.047	0.066	Hunn et al. 1987
	LC50	7	0.28-5.2	<0.001-0.011	Adams 1976; Birge 1978; Birge et al. 1980; Goettl and Davies 1975; Goettl et al. 1976
	LOEC	3	0.08-3.8	<0.001-0.039	Goettl et al. 1976; Spehar 1986
Other Salmon**ids**					
Mortality	**LC50**	1	0.16	0.019	Adams 1976
Other Fish					
Behavior	**LOEC**	3	0.0095-0.059	0.053-0.33	Masse et al. 2013; Weber et al. 2008
Growth & Development	**MATC**	3	0.11-0.57	0.0055-0.027	Kimball 1978; Spehar 1986
	Change	2	0.0079-2.8	0.0011-0.39	Cleveland et al. 1993; Coyle et al. 1993
	LOEC	6	0.0026-0.82	0.0038-1.2	Dobbs et al. 1996; Hermanutz et al. 1996; Kimball 1978; Phibbs et al. 2011; Spehar 1986
Mortality	**MATC**	1	0.11	0.027	Kimball 1978
	Increasing	1	2	0.0016	Ellis et al. 1937
	LC05	2	0.1-12	<0.001-0.031	Niimi and Laham 1976
	LC50	8	0.4-24	<0.001-0.0078	Adams 1976; Cardwell et al. 1976
	LOEC	3	0.0097-1.5	0.002-0.32	Hermanutz et al. 1993; Kimball 1978; Spehar 1986
Population	**Decreasing**	1	0.03	0.1	Hermanutz 1992
Reproduction	**Change**	1	0.0079	0.39	Coyle et al. 1993
	LOEC	2	0.01	0.31	Ouellette et al. 2013
Invertebrates					
Growth & Development	**MATC**	2	0.5-1.2	0.0026-0.0062	Dunbar et al. 1983; Ingersoll et al. 1990
	Decreasing	3	0.0018-10000	<0.001-1.7	Franz et al. 2011; Siekierska et al. 1993
	ER25	1	51	<0.001	Gallego-Gallegos et al. 2013
	ER50	1	57	<0.001	Gallego-Gallegos et al. 2013
	ET50	3	0.004	0.78	Franz et al. 2011
	IC25	1	0.13	0.024	Gallego-Gallegos et al. 2013

Effect	Endpoint	N	Exposure Range µg/L	Risk Quotient Range	Sources
	IC50	1	0.28	0.011	Gallego-Gallegos et al. 2013
	Increasing	3	0.0038-0.0043	0.72-0.82	Franz et al. 2011
	LOEC	1	0.59	0.0052	Gallego-Gallegos et al. 2013
	LOER[a]	1	64	<0.001	Gallego-Gallegos et al. 2013
Mortality	**MATC**	2	0.35	0.0089	Adams and Heidolph 1985
	LC50	7	0.086-1.1	0.0027-0.036	Brasher and Ogle 1993; Kimball 1978; Pieterek and Pietrock 2012
	LOEC	2	0.52	0.006	Adams and Heidolph 1985
Population	**MATC**	1	0.014	0.22	Pratt and Bowers 1990
	Change	1	0.1	0.031	Lawrence and Holoka 1981
	Decreasing	3	0.05-0.5	0.0062-0.062	Boyum 1984
	LOEC	19	0.01-1	0.0031-0.31	Dobbs et al. 1996; Lawrence and Holoka 1981; Pratt and Bowers 1990; Swift 2002
Reproduction	**MATC**	4	0.09-0.35	0.0089-0.034	Adams and Heidolph 1985; Kimball 1978; Stephan 1978
	Decreasing	6	0.1-0.5	0.0062-0.031	Boyum 1984; Brasher and Ogle 1993; Reading and Buikema 1983
	Increasing	1	0.039	0.079	Stover et al. 2000
	LOEC	2	0.12	0.026	Kimball 1978; Stephan 1978

[a] LOER = Lowest Observed Effect Residue

NMFS concludes that EPA's approval of North Carolina's adoption of the lotic National Water Quality Criterion for selenium in lotic waters may affect, but is not likely to adversely affect shortnose sturgeon, the Carolina DPS of Atlantic sturgeon or migrating and foraging Gulf of Maine, New York, Bight, Chesapeake Bay, or South Atlantic DPSs of Atlantic sturgeon. As reflected in Figure 18, responses in surrogate species are extremely unlikely to occur. Therefore, effects are expected to be discountable in ESA-listed sturgeon.

NMFS also concludes that the exposure of forage species to selenium within the freshwater lotic selenium criterion limits may affect, but is not likely to adversely affect, the quantity and quality of prey available to ESA-listed sturgeon because they consume a wide range of invertebrate taxa and the criteria were derived to protect aquatic life based on the fifth centile of sensitive genera. The criteria are also implemented under conservative exposure durations and frequencies (i.e., the acute criterion is a one-hour average derived from four-day tests and the chronic criterion is a four-day average).

7.2.6 Responses within Selenium Fish Tissue Criteria Limits

The most deleterious effect on aquatic organisms is due to the bioaccumulative properties of selenium, primarily through transfer to the eggs and subsequent reproductive effects. Bioaccumulation and transfer through aquatic food webs is the major exposure pathway for selenium in aquatic ecosystems. Periphyton, phytoplankton, and other microorganisms accumulate inorganic selenium dissolved in water to concentrations that are two or more orders of magnitude greater than ambient levels. Selenium in these primary producers is biotransformed into organoselenium (e.g. selenomethionine, selenocysteine). Along with selenium adsorbed to particulate matter, organoselenium is transferred to aquatic primary consumers such as zooplankton, insect larvae, larval fish, and filter feeding bivalves then to predators such as fish and birds (Hamilton 2002, USEPA 2021a).

The criteria are for selenium in the tissues of freshwater fish, thus they apply to shortnose sturgeon and the Carolina DPS of Atlantic sturgeon with critical habitat designated in North Carolina Rivers. The fish tissue-based selenium criteria include 8.5 mg/kg in whole body, 11.3 mg/kg in muscle, and 15.1 mg/kg in eggs or ovaries. The selenium criteria are essentially determined by data for exposures of white sturgeon (Linville et al. 2002, Tashjian et al. 2006) because they are the most sensitive species EPA used in criteria derivation. Because white sturgeon are within the same genus as Atlantic and shortnose sturgeon, and were found to be the most sensitive species for which data are available, our assessment focuses on these data.

Data from studies examining the effects of selenium on sturgeon are summarized in Table 15. The EPA Guideline document used a dissertation evaluating the effect of 34 mg/kg dietary selenium over six months on the health and reproduction of five-year-old white sturgeon (Linville 2006). The length and weight of larvae from exposed fish did not differ from controls, but larvae hatched from the batches of eggs with selenium concentrations of 1.61, 2.68, 7.61, 11 and 20.5 mg/kg had 0.3, 0.3, 13.6, 0.3 and 33.8% combined survival, edema, and deformities, respectively. The EPA used the threshold sigmoid model equation (TRAP version 1.30a) on egg selenium concentration versus combined survival, edema, and deformities to estimate a reproduction EC10 of 15.6 mg/kg selenium. Unfortunatley, confidence intervals are not provided with such estimates.

The EPA Guideline document also used a study by Tashjian et al. (2006) exposing juvenile white sturgeon to diets containing 0.4, 9.6, 20.5, 41.7, 89.8, 191.1 mg/kg selenium over eight weeks. Survival was not affected in any treatment group but growth rates among fish fed selenium at 41.7 mg/kg or greater were significantly reduced. At eight weeks, fish body weights in these exposures ranged from 32% (191+/-12.6) to 90% (28.6+/-3.6) lower than controls (282.9+/-4.6). Muscle selenium ranged from 36.8+/-1.8 to 54.8+/-2.8 mg/kg and whole body selenium concentrations ranged from 22.5 +/-1.4 to 34.4 +/-2.3. The EPA used the TRAP program to calculate EC10 and EC20 values for reduction in body weight at 15.08 and 17.82 mg/kg for whole body selenium and 27.76 and 32.53 mg/kg for muscle tissue selenium. As noted previously, confidence intervals are not provided with such estimates.

EPA treats the white sturgeon as a suitable surrogate for other ESA-listed sturgeon, but a study by DeRiu et al. (2014) suggests this may be inappropriate. DeRiu et al. (2014) exposed juvenile green sturgeon and white sturgeon to diets containing 2.2 ± 0.2 (control), 19.7 ± 0.6, 40.1 ± 1.5, and 77.7 ± 3.6 mg/kg selenium over eight weeks. At a dietary selenium exposure of 19.7+/-0.6 mg/kg, green sturgeon growth rate was roughly half that of control fish but there was no effect on white sturgeon growth rate, survival, or hepatosomatic index,[11] or HSI. The EPA did not include this study in calculating the criteria due to the relatively high concentration of selenium in the whole body and muscle tissues of control fish of both species. This could not be attributed to accumulation from the diet because the selenium concentration remained relatively constant over the eight-week exposure. The confidence intervals were also quite large in this study. The growth rate among control green sturgeon was 6.6+/- 14.9% body weight increase per day while the growth rate of selenium-exposed green sturgeon was 2.6+/-16% body weight increase per day. The large standard deviation for growth rate is not surprising because each 90-liter exposure chamber housed 25 fish and an individual's growth rate is influenced by social dominance within a group (Fernandes and Volpato 1993, Volpato and Fernandes 1994, Lee et al. 2011a, Reed et al. 2019).

The EPA used exposure response data from this study to calculate the whole body EC10 value for green sturgeon at 16.36 mg/kg and for white sturgeon, the EC10 was nearly 50% higher at 23.94 mg/kg. The whole body EC10 value for green sturgeon hepatosomatic index was 10.86 mg/kg, but for white sturgeon there were no discernible effects. Effects may have become evident in white sturgeon and EC10 estimates may have been lower if the exposure duration matched the six month study by Linville (2006). The white sturgeon and green sturgeon exposures were identical, yet a species within the same genus as white sturgeon was substantially more sensitive to selenium. White sturgeon have also been reported to be less sensitive than green sturgeon to mercury exposure (Lee et al. 2011b). Section 2.3.2 of this Opinion also discusses surrogacy, pointing out differences in sensitivity between Atlantic and shortnose sturgeon for certain substances in the same studies.

White sturgeon data are central to the selenium tissue standards. Reproductive data for the white sturgeon from Linville (2006) provide the lowest EC10 used in calculation of the egg/ovary criterion of 15.6 mg/kg. The EPA calculated whole body reproductive chronic values directly from whole body tissue concentrations measured in the studies or by applying an egg/ovary-to-whole-body conversion factor. Whole body EC10s for the four most sensitive species ranged from 9.2 (*Acipenser*) to 13.2 (*Salmo*) mg/kg selenium. Projection of these data to the fifth percentile to represent protection of 95% of species, provides the whole body criterion of 8.5 mg/kg selenium. The EPA calculated muscle reproductive chronic values directly from muscle tissue concentrations measured in the studies or by applying an egg/ovary-to-muscle conversion factor. Muscle EC10s for the four most sensitive species ranged from 11.9 (*Acipenser*) to 13.2 (*Salmo*) 18.5 mg/kg selenium. Projection of these data to the fifth percentile provides the muscle criterion of 11.3 mg/kg selenium. While the tissue criteria are largely determined by the white sturgeon data, the suitability of white sturgeon as a surrogate species for other sturgeon is called into question by the DeRiu et al. (2014) study and the within-*Acipenser* differences in sensitivity

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[11] The hepatosomatic index is the ratio of the liver mass to whole body mass which can suggest depletion of liver glycogen reserves or liver enlargement in response to tissue damage or mounting a defensive response to toxicants.

for other substances reported in other studies (see section 2.3.2 and Dwyer et al. 2005, Lee et al. 2011c, Chambers et al. 2012). The implications of EPA's approval of North Carolina's proposed freshwater selenium criteria for ESA-listed sturgeon will be addressed in the Risk Analysis Section of this Opinion.

Table 15. Dietary and Tissue Selenium Exposure-response Data

Species/Exposure Duration	**Diet**	**Whole Body**	**Muscle**	**Egg/ Ovary**	**Response[b]**			**Source**
Green Sturgeon					Mortality	Growth/Dev.	HSI	De Riu et al. 2014
8 weeks	2.2(0.2)	7.1(0.9)	8.4(0.4)		0	6.6(15)	2(0.1)	
	19.7(0.6)	22.8(0.9)	31.1(0.3)	--	0	2.6(16)	1.3(0)	
	40.1(1.5)	27.8(1.4)	37(0.3)		7.7(4.4)	0.8(4.1)	0.8(0.2)	
	77.7(3.6)	34.3(0.3)	36.8(1.2)		23(4.4)	-1.0(4.3)	0.9(0.1)	
White Sturgeon		5.6(0.3)	9.2(0.7)		0	4.2(14)	2.6(0.2)	De Riu et al. 2014
8 weeks	2.2(0.2)	20.1(0.5)	27(1.1)		0	4.2(22)	3.6(0.2)	
	19.7(0.6)	37.8(0.3)	41.3(0.6)	--	0	2.8(21)	3.0(0.1)	
	40.1(1.5)	47.1(4.3)	57.9(1.2)		0	1.0(11)	2.2(0.4)	
	77.7(3.6)							
White Sturgeon			1.22	1.61	0.3	0.0(0.0-4.2)		Linville, 2006
6 months	1.4		1.48	2.68	0.3	0.0(0.0-4.2)		(percent abnormal)
			11.1	7.61	>0.4	13.3(3.7-24.6)		
	34		9.93	11	>0.4	0.0(0.0-4.2)		
			15.3	20.5	8.4	27.8(18.8-38.3)		
White Sturgeon		5.2(0.4)	8.2(0.6)			282.9(4.6)		Tashjian et al. 2006
8 weeks	0.4	11.8(0.9)	17.2(0.7)			285.5(9.9)		
	9.6	14.7(0.8)	22.9(1.5)			277.7(6.1)		
	20.5	22.5(1.4)	36.8(1.8)	--		191.0(12.6)		
	41.7	34.4(2.3)	52.9(3.2)			106.5(5.8)		
	89.8	27.5(4.4)	54.8(2.8)			28.6(3.6)		
	191.1							

[a] Criteria: Whole body =8.5 mg/kg; Muscle: 11.3 mg/Kg; Egg/Ovary =15.1 mg/kg

[b] Reported to two significant digits.

[c] Study was evaluating response to handling stress. Only selenium concentration in livers was reported.

7.2.7 Quality (Direct Toxicity) of Forage within the Whole Fish Tissue Selenium Criterion

It is appropriate to consider the implications of the whole body fish tissue criterion as a dietary exposure for juvenile and adult shortnose and Atlantic sturgeon because small fish and filter feeding molluscs are among their prey items. While the whole body selenium criterion is not applied to mussels and clams, exposures from consuming these species can be similar to exposures from the consumption of fish from the same system. Among monitoring data for North Carolina, *Corbicula* selenium concentrations ranged from 1.7 to 3.8 mg/kg while fish muscle concentrations from the same basins ranged from 0.8 to 2.8 mg/kg. The EPA selenium guideline document provides average muscle-to-whole body conversion factors for eight fish species ranging from 1.05 to 1.61, which suggests dietary selenium exposures to forage fish from these basins ranged from 0.84 to 4.5 mg/kg. Mussels and clams accumulate selenium to a greater degree than other aquatic invertebrates because, as filter feeders, they have higher ingestion rates. They also have lower elimination rates (Stewart et al. 2004, Luoma and Rainbow 2005, Luoma and Presser 2009). Figure 19 places effects resulting from dietary exposures to selenium in the context of the whole body selenium criterion. The risk quotients can be interpreted as effects on quality of forage in terms of potential prey toxicity. Data for larval life stages and fish species that consume algae, plankton, and aquatic invertebrates are excluded from the plot because these forage items would only reach selenium concentrations at the fish whole body criterion concentration in habitats with significant selenium contamination.

The rainbow trout data indicating effects from dietary consumption at or near the whole body selenium criterion are from two studies from the same research group. A dietary study by Wiseman et al. (2011a) reports greater plasma concentrations of sex steroid hormones in 1.5 year old female rainbow trout fed a diet of 8.47 mg/kg selenium over 126 days. At the end of the study, body mass of the selenium-exposed fish was about 20% lower and total length was about ten percent shorter than control fish. A companion study by the same researchers demonstrated changes in hormonal responses to handling stress and energy reserves to mount a stress response, but reported a slight increase in body mass and liver mass of rainbow trout fed the same diet (Wiseman et al. 2011b). The authors did not address the differences in growth effects between studies. While the implications of the hormonal responses reported in these studies on organism-level survival and reproduction is uncertain, effects on growth of rainbow trout consuming diets within the whole body fish tissue selenium criterion of 8.5 mg/kg are ambiguous.

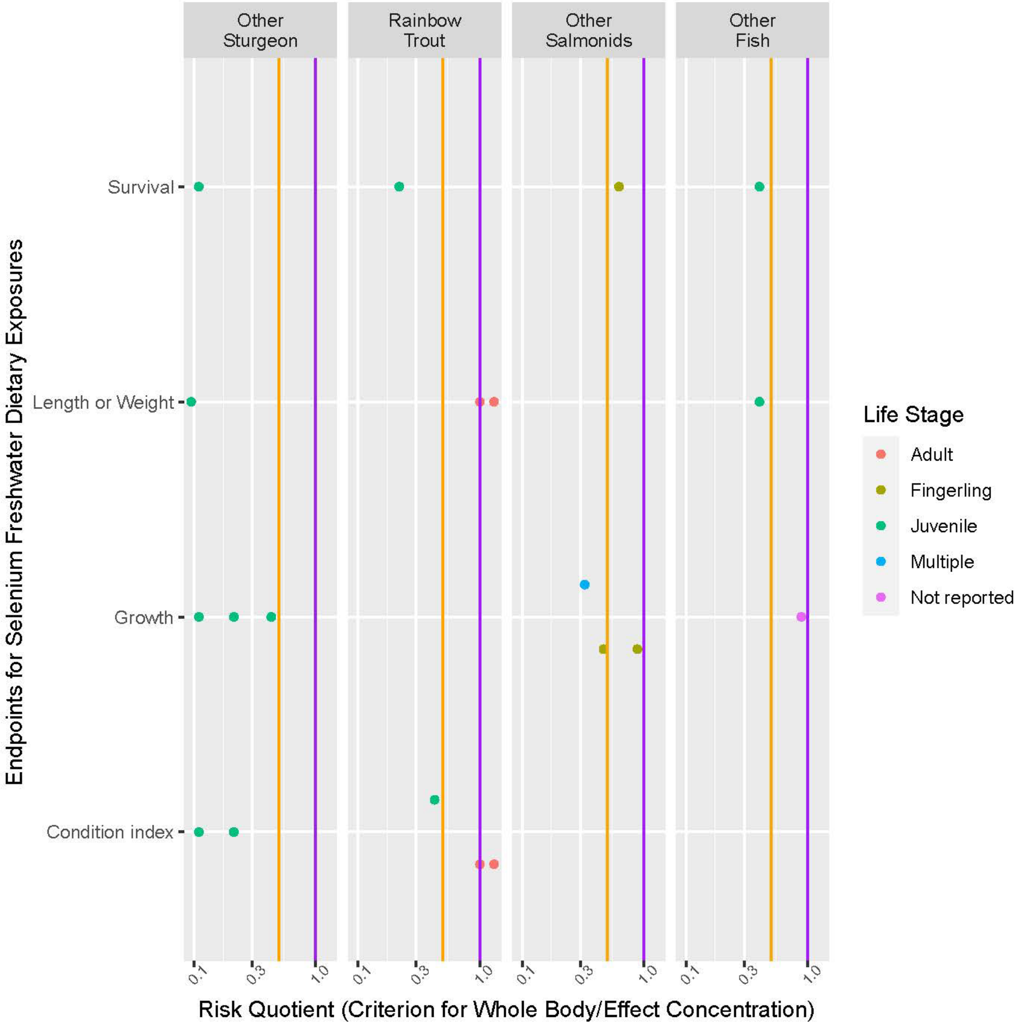

Figure 19. Distribution of LOEC Risk Quotients for Dietary Exposures to Selenium in Context of Reference Lines Representing the Whole Body Selenium Criterion (Purple) and One-half the Whole Body Selenium Criterion (Orange)

The implications of any effects on the abundance and quality of forage species for shortnose and Atlantic sturgeon is attenuated by the wide variety of forage species sturgeon consume. Because the fish tissue-based criteria were derived to protect 95% of fish species, a reduction in the abundance of one forage fish species is likely to be compensated for by an increase in other forage species (Wesolek et al. 2010). NMFS does not expect that the presence of selenium in fish tissues within criteria limits will affect the abundance or quality of forage for shortnose sturgeon or the Carolina DPS of Atlantic sturgeon.

7.2.8 Risk of Selenium Tissue Concentrations within Criteria Limits

This risk analysis evaluates the consequences of effects in individuals to the populations those individuals represent, and the species those populations comprise. Thus far this Opinion concluded that selenium tissue concentrations within tissue-based criteria limits are likely to adversely affect individual shortnose and Atlantic sturgeon (Section 8.3.3), but not the quality, in this case, the direct toxicity, of their forage species (Section 8.3.3.1). Meanwhile Section 8.3.2 concluded that exposures to selenium within the freshwater lotic criterion limit are not likely to adversely affect individual shortnose or Atlantic sturgeon or the quantity and quality of forage species. Therefore, this risk analysis section addresses the population-level risk posed by selenium tissue concentrations within tissue-based criteria limits.

SURVIVAL

As explained in section 7.2.6, bioaccumulation and transfer through aquatic food webs is the major exposure pathway for selenium in aquatic ecosystems. The most deleterious effect on aquatic organisms is due to the bioaccumulative properties of selenium, primarily through transfer to the eggs and subsequent effects on offspring: hatch survival, growth, and deformities. Accumulation of selenium tissue concentrations within criterion limits is not expected to be directly lethal. Larval mortality will reduce the number maturing to juvenile stages. While data are not available to perform a population viability analysis for ESA-listed sturgeon populations in North Carolina waters, the viability of these populations are highly sensitive to juvenile mortality resulting in lower numbers of sub-adults recruiting into the adult breeding population (NMFS 1998a, ASSRT 2007).

GROWTH AND DEVELOPMENT

Growth is an important determinant of survival and, thus, recruitment (Anderson 1988, Poletto et al. 2018). Data from DeRiu et al. (2014) indicating that green sturgeon were about 50% more sensitive to the effects of tissue selenium on growth than white sturgeon, taken with white sturgeon toxicity data determining the selenium criteria, suggest that growth would be adversely affected in green sturgeon with tissue concentrations within selenium criteria limits. We give the species addressed in this Opinion the benefit of the doubt, thus, we expect growth in shortnose sturgeon and the Carolina DPS of Atlantic sturgeon to be also be more sensitive to selenium than white sturgeon and that these species would be adversely affected by tissue concentrations within criterion limits. Growth is important to survival, and survival is important because the viability of these populations are highly sensitive to juvenile mortality resulting in lower numbers of sub-adults recruiting into the adult breeding population (NMFS 1998a, ASSRT 2007).

REPRODUCTION

The Linville (2006) study provided important data for the development of tissue-based selenium criteria. The egg/ovary EC10 for the effects of accumulated selenium on hatch success, survival, and deformity provided a muscle tissue EC10 and a whole body EC10 using an egg/ovary-to-whole body conversion factor. However, the use of EC10s to project to the fifth percentile for the protection of 95% of species is expected to be sufficiently protective of imperiled species that are plausibly more sensitive than white sturgeon, the most sensitive species used in the criteria development.

7.2.9 Likely to Adversely Affect Determination for EPA Approval of North Carolina DEQ Adoption of Selenium Fish Tissue Criteria

NMFS concludes that EPA's approval of North Carolina DEQ's adoption and implementation of the recommended National Recommended Water Quality Criteria for selenium in fish tissue is likely to adversely affect shortnose sturgeon and the Carolina DPSs of Atlantic sturgeon at the population scale because:

1. Permitting and monitoring data for of North Carolina DEQ-regulated waters indicate that exposures to selenium will occur.
2. Ash basins adjacent to Sturgeon Waters are classified as having high and significant hazard potential but monitoring data are not available for surface water or benthic organisms that may accumulate selenium and may be consumed by sturgeon.
3. The criteria are strongly influenced by EC10s for white sturgeon that were the most sensitive species included in criteria calculation, but there is evidence that white sturgeon are less sensitive to selenium exposure than the ESA-listed green sturgeon, and NMFS must give the species considered in this Opinion, shortnose and Atlantic sturgeon, the benefit of the doubt.
4. Criteria derived to protect 95% of species are not expected to be sufficiently protective of imperiled species that are likely more sensitive than white sturgeon, the most sensitive species used in the criteria development.
5. The viability of ESA-listed sturgeon populations in North Carolina's waters is highly sensitive to juvenile mortality resulting in lower numbers of sub-adults recruiting into the adult breeding population (NMFS 1998a, ASSRT 2007).

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 proposed action are not considered in this section because they require separate consultation 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 6.5), 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 et al. 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, nationwide, precipitation rates will change (Figure 20), and the frequency of heavy rainfall events will increase (Figure 21), leading to increased flooding and erosive flows resulting in unmanaged pollutant discharges and redistribution of legacy pollutants in sediments. While a climate-change related trend in precipitation had not been recorded in North Carolina, total annual precipitation is projected to increase in the winter and spring. Naturally occurring droughts are projected to be more intense because higher temperatures will increase the rate of soil moisture loss during dry periods. Additionally, hurricane-associated storm intensity and rainfall rates are projected to increase as the climate warms.

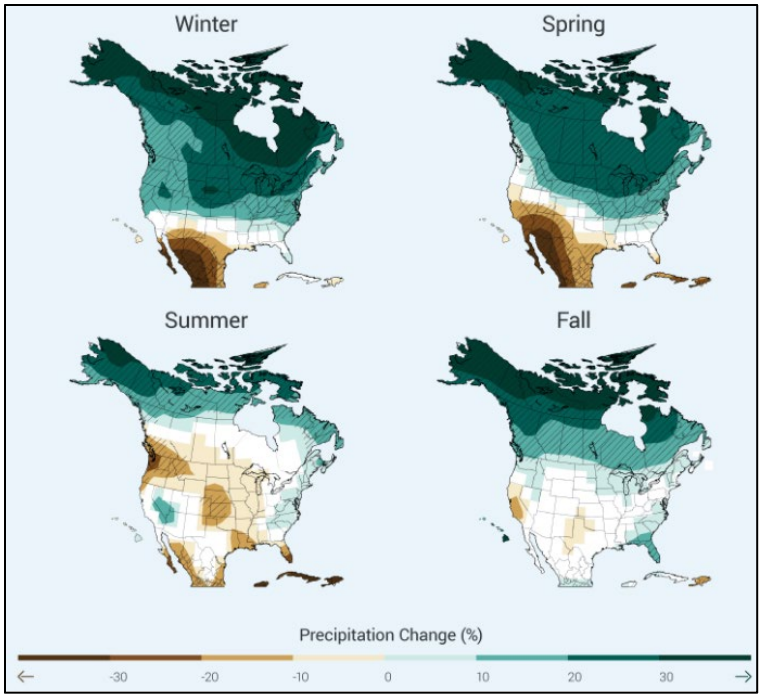

Figure 20. Seasonal Precipitation Change for 2071-2099 (Compared to 1970-1999)[12]

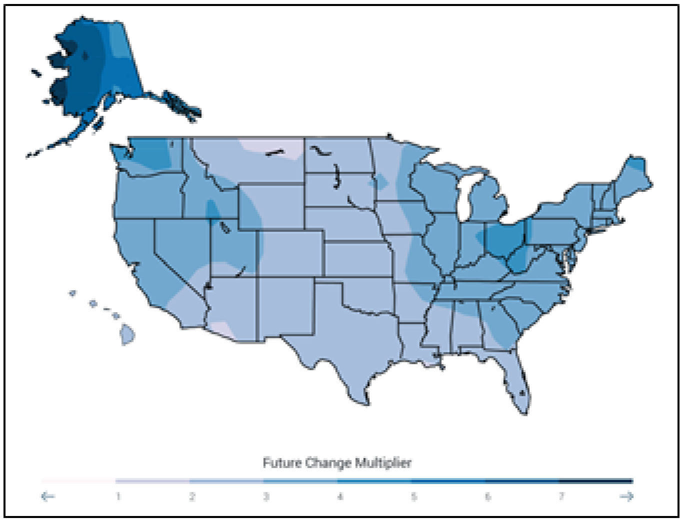

Figure 21. Increase in Frequency of Extreme Daily Precipitation Events for 2081-2100 (Compared to 1981-2000)[13]

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[12] Assumes existing emissions rate increases. Hatched areas are projected changes that are significant and consistent among models, unhatched areas indicate projected changes do not differ from natural variability. (Figure source: NOAA NCDC / CICS-NC). http://nca2014.globalchange.gov/report/our-changing-climate/precipitation-change

[13] http://nca2014.globalchange.gov/report/our-changing-climate/precipitation-change

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 8) to the *Environmental Baseline* (Section 6) and the *Cumulative Effects* (Section 9) to formulate the agency's biological opinion as to whether the proposed 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 North Carolina (Figure 2) 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 sei whale to affected waters, responses of invertebrates within the saltwater cadmium criterion limit) 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 (Sections 5.1 and 7).

The following discussions provide an overview of the findings of this Opinion and a jeopardy analysis that summarizes the probable risks the proposed action poses to shortnose surgeon and the Atlantic sturgeon Carolina DPS with critical habitat in the action areas, and migrating and foraging Atlantic sturgeon Gulf of Maine, New York Bight, Chesapeake, and South Atlantic DPSs. These summaries integrate the exposure profiles presented previously with the results of our response and risk analyses (Section 8) for each of the water quality criteria considered further in this Opinion.

9.1 Overview

This Opinion concludes that EPA approval of North Carolina DEQ adoption and implementation of Nationally Recommended Freshwater Criteria for cadmium and selenium is likely to adversely affect early life stage and young of year shortnose sturgeon and the Carolina DPS of Atlantic sturgeon that may spawn within North Carolina's rivers. The viability of ESA-listed sturgeon populations in North Carolina 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 monitoring data on cadmium in Sturgeon Waters were available, they 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 solid 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. In the absence of that information, NMFS gives the species the benefit of the doubt.

Current water quality impairments in Sturgeon Waters are attributed to DO, metals, and biological criteria (Section 6). In the Cape Fear River Basin a TMDL for cadmium in Little Troublesome Creek and one for selenium in South Buffalo Creek were approved in in 1997, but these waters are distant from Sturgeon Waters. Approved TMDLs and alternative restoration plans within Sturgeon Waters are for fecal coliform, nutrient impairments, the persistent organic legacy contaminants PCBs and dioxin, and imbalanced benthic communities. Exposures of shortnose and Atlantic sturgeon to cadmium are likely to occur through stormwater runoff and discharges from facilities that use either this metal or treat waste containing this metal. Under section 402 of the Clean Water Act, an NPDES permit will require monitoring 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)). Selenium exposures potentially occur through consuming forage species in waters adjacent to coal ash basins.

Criteria that EPA proposes to approve with this action will be implemented by North Carolina's NPDES program. North Carolina was delegated the authority to implement the Clean Water Act NPDES program in 1975. A 2007 memorandum of agreement between EPA Region 4 and the state of North Carolina (2007 NC MOA) specifies that EPA and the State agree to the following process to address issues involving federally-listed species and critical habitats, relative to issuance of NPDES permits:

1. *The State will provide notice and copies of draft permits to the U.S. Fish and Wildlife Service and National Marine Fisheries Service (the Services), unless otherwise waived in accordance with Section D.4 [of the MOA]. The State understands that it may receive information from the Services on federally-listed species and critical habitats in State, with special emphasis on aquatic or aquatically-dependent species. Also, EPA will share with State information on permits that may raise issues regarding impacts to federally-listed species or critical habitats.*
2. *The State will consider issues raised by the EPA or the Services regarding federally-listed species or critical habitats. If EPA has concerns that an NPDES permit is likely to have more than a minor detrimental effect on federally-listed species or critical habitats, EPA will contact the State to discuss identified concerns.*
3. *If the State is unable to resolve issues raised by the Services involving detrimental effects of a NPDES permit on federally-listed species or critical habitats, and if the Services have contacted EPA, EPA intends to work with the State to remove or reduce the detrimental effect. The EPA will coordinate with the State and the Services to ensure that the permit will comply with all applicable water quality standards, which include narrative criteria prohibiting toxic discharges, and will discuss appropriate measures protective of federally-listed species and critical habitats.*

4. *EPA will provide the Services with copies of any comments it provides to the State on issues related to federally-listed species or critical habitats.*
5. *The State will comply with applicable federal laws in accordance with 40 CFR § 124.59.*

According to the NMFS' Southeast Regional Office, North Carolina DEQ has not sent NPDES permits for review. Even so, this MOA only allows for review of individual permits potentially affecting ESA-listed species under NMFS' jurisdiction. Criteria are in place indefinitely and are applied to multiple sources within a watershed. Thus, there is an aggregate impact to EPA's approval of the criteria, and North Carolina DEQ's implementation, that is not addressed by existing mechanisms.

In the absence of solid monitoring information, water quality data collected *after* implementation of revised criteria may or may not indicate actual instream concentrations below effects thresholds. Often 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, one might monitor for nutrients and sugarcane pesticides, but not industrial chemicals. Sources for cadmium and selenium exist along Sturgeon Waters. The paucity of recent monitoring data is exacerbated by the incomplete upload of discharge monitoring report (DMR) data from the state's data management system to EPA's ECHO and North Carolina DEQ's list of current eDMR participants, dated November 8, 2022, indicating that about half of the users are uploading DMR reports.[14] Failure to submit DMRs can mask significant problems such as the inability to meet permit limits.

The analyses in Section 7.1.5 establish that early-life-stage shortnose sturgeon and Atlantic sturgeon are likely to be exposed to cadmium and selenium in North Carolina Sturgeon Waters and that adverse effects are expected to occur in early-life-stage exposed to these metals within their respective criteria limits. The majority of the monitoring data are historical or may not reflect current conditions because the practical quantitation limits are too high to detect cadmium in freshwater within the chronic criterion 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.

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[14] See North Carolina eDMR webpage (https://deq.nc.gov/about/divisions/water-resources/edmr)

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. Less is known about shortnose sturgeon populations in the southeast. In 1985 a gravid female was caught in the Pee Dee River (Yadkin basin) downstream from the US 74 bridge. None have since been detected in the North Carolina portion of the Pee Dee River, but the South Carolina Department of Natural Resources tracked several in 2002-03 to within 5.6 kilometers of the state line. The first verifiable record from the Cape Fear basin was captured in a gill net in the lower Cape Fear River in 1978. Other more recent records include an adult captured in Albemarle Sound in 1998 and another near the mouth of the Chowan River, downstream from Salmon Creek in 2016 (Tracy et al. 2020).

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 1998a). Even though shortnose sturgeon were listed under the ESA over 20 years ago, population dynamics and distribution data are lacking for many population segments. A rangewide 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 Cape Fear and Winyah Bay shortnose sturgeon population segments that are relevant to the impacts of the proposed 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."

Given the limited number of regulable sources in North Carolina (see Sections 8.2.1.1, 8.3.1.1, and 8.3.1.2), the anticipated take of shortnose sturgeon from the effects of implementing the water quality criteria for cadmium and selenium is not likely to reduce population numbers of the species over time given current population sizes and expected recruitment or impede survival. Thus, the proposed action is not likely to impede the applicable recovery objective for shortnose sturgeon and will not result in an appreciable reduction in the likelihood of the recovery of this species in the wild. We conclude the proposed action is not likely to jeopardize the continued existence of shortnose sturgeon in the wild.

9.2.2 Atlantic Sturgeon

Whether the potential effects to reproductive output would appreciably reduce the likelihood of survival of the Carolina DPS of Atlantic sturgeon, and migrating Gulf of Maine, New York Bight, Chesapeake Bay, and South Atlantic DPSs 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. Khan 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); or
3. Presence of eggs to 180-day post-hatch fish.

Near certain spawning:

1. Juveniles under 400 mm fork length in fresh- water or low-salinity areas; or
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); or
2. Telemetry detection of adult female in unknown reproductive stage in freshwater.

Uninformative Data:

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

Yet, qualitative metrics may be the result of increased research and attention, not a true increase in abundance (ASMFC 2017a). All DPSs of Atlantic sturgeon are considered depleted. All DPSs of Atlantic sturgeon are highly vulnerable to climate change due to their low likelihood to change distribution in response to climate change-drive impacts to habitat such as temperature changes. Current global climate change will also expose them 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 (NMFS 2022b, a).

In North Carolina, the Atlantic sturgeon is found in all the major rivers from the Chowan to the Yadkin Basin, except in the Lumber, Waccamaw, and Shallotte Basins. It is also found in the sounds and Atlantic Ocean (Map 3, Tracy et al. 2020). It also migrates out into the Atlantic Ocean and along the coast (SSSRT 2010). It is possible that Atlantic sturgeon historically may have migrated and spawned up into the Fall Zone in the Cape Fear, Catawba, and Broad Basins. In the Roanoke Basin, there are recent records from the Roanoke River as far upstream as Weldon, in the Chowan Basin beyond Route NC 11 in Potecasi Creek, in the Tar Basin from the Tar River near Tarboro, and in the Neuse Basin from the Neuse River at Goldsboro and Smithfield. In mid-September 2018 a large adult, perhaps a fall spawning migrant, was detected at Blewett Falls Dam near Rockingham (Tracy et al. 2020) and in 2019 migrating to and from the upper Pee Dee River to spawn (https://www.fisheries.noaa.gov/feature-story/return-atlantic-sturgeon-pee-dee-river-signals-improved-health-population).

Given the limited number of regulable sources in North Carolina (see Sections 8.2.1.1, 8.3.1.1, and 8.3.1.2), we conclude the effects of the proposed action are not likely to impede the survival and recovery of Atlantic sturgeon DPSs in the wild. A recovery plan has not been completed for the listed Atlantic sturgeon DPSs. However, a recovery outline has been prepared to guide recovery efforts until a full recovery plan is developed and approved. The stated goal of the recovery outline is that subpopulations of all five Atlantic sturgeon DPSs must be present across the historical range at sufficient size and genetic diversity to support successful reproduction and recovery from mortality events, with increases in the recruitment of juveniles to the sub-adult and adult life stages to be maintained over many years. 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.

10 CONCLUSION

After reviewing the current status of the ESA-listed species, the environmental baseline within the action area, the effects of the proposed action, and cumulative effects, it is NMFS' biological opinion that the proposed action is likely to adversely affect, but is not likely to jeopardize the continued existence of shortnose sturgeon or the Carolina DPS and migrating and foraging Gulf of Maine, New York Bight, Chesapeake Bay, and South Atlantic DPSs of Atlantic sturgeon along the coast and within the estuaries of North Carolina.

The proposed action is not likely to adversely affect fin whale, North Atlantic right whale, sei whale, green sea turtle (North Atlantic DPS), Kemp's ridley sea turtle, leatherback sea turtle, or loggerhead sea turtle (Northwest Atlantic Ocean DPS). Accordingly, this action will not jeopardize the continued existence of these species.

11 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct (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) and section 7(o)(2) of the ESA provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this incidental take statement.

Exposures of shortnose sturgeon and Carolina and migrating Gulf of Maine, New York Bight, Chesapeake Bay, and South Atlantic DPSs of Atlantic sturgeon to cadmium and selenium within criteria limits in the action area are likely to result in incidental take due to the reductions in survival of early life stage 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 actions while the extent of take specifies the impact, i.e., the amount or extent of such incidental taking on the species, which may be used if we cannot assign numerical limits for animals that could be incidentally taken during the course of an action (see 80 FR 26832).

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 proposed cadmium or selenium criteria cannot be accurately quantified or monitored as a number of individuals because the action area includes all waters of North Carolina and data do not exist that would allow us to quantify how many individuals of each species and life stage exist in affected waters. This is particularly true 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. Because we cannot quantify the amount of take, we will use the regulatory application of the criteria as a measure reflecting the potential for harmful exposures to cadmium and selenium for the extent of authorized take as a surrogate for the amount of authorized take.

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 cadmium and selenium 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.

For the reasons discussed above, the specified amount or extent of incidental take of ESA-listed shortnose and Atlantic sturgeon species requires that North Carolina DEQ’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 122.44(i)(1)(iv) of the Clean Water Act. Effects of the proposed action could manifest later in time and those discharges for which reasonable potential monitoring requirements and 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 North Carolina DEQ’s intended level of protection is met. NMFS expects that, upon identification, North Carolina DEQ and EPA will address any noncompliance with 40 CFR 136. This reflects North Carolina DEQ’s 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 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.

NMFS believes the RPMs described below are necessary and appropriate to minimize the impacts of incidental take on threatened and endangered species resulting from exposure to cadmium or selenium within criteria limits:

1. The EPA Region 4 will work within its authorities and consistent with its MOAs with the Services and North Carolina to ensure implementation of the adopted criteria in NPDES, monitoring, and listing programs.

2. The EPA will inform North Carolina DEQ in the Action Letter and Decision Document of the prohibition of unauthorized take of ESA-listed species, of NMFS' findings on the exposure of cadmium and selenium on ESA-listed shortnose and Atlantic sturgeon species, and of the conditions listed under 50 CFR §402.16(a). The EPA will encourage North Carolina DEQ to enlist NMFS technical assistance as early as practicable.

11.3 Terms and Conditions

In addition to RPMs, section 7(b)(4) of the ESA requires the Services to identify terms and conditions (including, but not limited to, reporting requirements) that must be complied with by the Federal agency or applicant, or both, to implement the RPMs. Only incidental take resulting from the agency actions that is in compliance with the 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. Therefore, to be exempt from the ESA prohibitions of take, the EPA must comply with the following terms and conditions, which implement the RPMs described above. These include the take minimization, monitoring and reporting measures required by the section 7 regulations (50 CFR § 402.14(i)). As stated above, these terms and conditions are non-discretionary in order for the EPA to be exempt from the ESA prohibition against take. If EPA fails to ensure compliance with these terms and conditions and their implementing reasonable and prudent measures, the protective coverage of section 7(o)(2) may lapse.

1. The following terms and conditions implement RPM 1:
    a) EPA will meet with NMFS at approximately six months from EPA's action date on North Carolina's 2020-2022 Triennial Review and again once EPA receives North Carolina's submission of the 2024 303(d) list to discuss actions taken by both agencies to date as a result of the RPMs and terms and conditions. The EPA will coordinate with R4 staff working in monitoring, listing, and permitting to ensure a complete listing of actions for both updates with NMFS.
    b) The EPA will share with NMFS the Action Letter and Decision Document with monitoring and Section 303(d) listing contacts in the R4 office and North Carolina DEQ.
        i. As North Carolina develops its assessment methodology for cadmium or selenium, as appropriate, following the approval of the criteria by EPA, EPA will encourage the state to coordinate closely with NMFS and EPA R4 staff prior to bringing the assessment methodology to the Environmental Management Commission.
    c) The EPA will implement the 2001 MOA between EPA and the Services to the extent possible. While not binding, Section IX of the 2001 MOA establishes a framework for coordinating actions for permitting program activities under the Clean Water Act section 402. Specifically, EPA and NMFS will follow the nine 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 NMFS' review of draft state-issued permits for discharges that may affect ESA-listed sturgeon species for the purposes of technical assistance to ensure that permitted cadmium or selenium discharges minimize take.

d) The EPA will, when reviewing permits under its regular permit review practices under Section IV. B. of the 2007 NC MOA, evaluate draft NPDES permits prepared by North Carolina's DEQ for compliance with the approved cadmium and selenium criteria, including the use of sufficiently sensitive methodology in determining monitoring requirements and discharge limits.

e) Pursuant to the 2007 NC MOA, EPA's Action Letter and Decision Document outlining EPA's analysis of North Carolina DEQ's Triennial Review revisions, EPA will describe its expectations as follows with respect to sources that potentially discharge cadmium or selenium into streams with ESA-listed sturgeon or adjacent catchments, based on industrial or hazard class or, for cadmium from urban areas, population size and land use:

   i. North Carolina DEQ will anticipate notification from EPA about any permits that may raise issues regarding impacts to federally listed species or critical habitats pursuant to NPDES MOA Section IV.E.1.

   ii. North Carolina DEQ will provide notice and copies of draft NPDES permits, public notices, fact sheets or rationale, and permit applications to the Services for review, in accordance with the NPDES MOA Section IV.D.4 and Section IV.E.1.

   iii. North Carolina DEQ will provide the draft permit record; including supporting records/analytical results to NMFS for review and anticipate notification by NMFS, either directly or through EPA, if there are concerns about the effluent test and/or sampling methods as supported by the NPDES MOA Section IV.E.2.

   iv. If the EPA determines that the effluent data submitted with the permit application have not met the requirements under 40 CFR Part 136, the EPA will inform North Carolina DEQ and copy NMFS in accordance with NPDES MOA Section IV.E.4.

2. The following term and condition implements RPM 2:

   a) The terms and conditions provided in this incidental take statement will be included in the Action Letter and Decision Document outlining EPA's analysis of North Carolina's Triennial Review revisions. The EPA will copy NMFS on the Action

Letter and Decision Document. In order for EPA to be exempt from take, this letter will inform North Carolina DEQ of the following:

i. Unauthorized 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 Gulf of Maine DPS of Atlantic Sturgeon under section 4(d) of the ESA (50 CFR §223.211). "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. Harm is further defined by regulation to include significant habitat modification or degradation that results in death or injury to ESA-listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering.

ii. Exposures to cadmium or selenium at or below the proposed criterion may adversely affect ESA-listed shortnose and Atlantic sturgeon species under NMFS' jurisdiction.

iii. EPA is approving the adopted cadmium and selenium criteria. However, if scientifically defensible data[15] become available suggesting that exposures to cadmium or selenium under the criteria, as implemented by North Carolina DEQ, results in surface water quality conditions that are found to be more harmful to shortnose or Atlantic sturgeon than anticipated, for example, through monitoring in receiving waters where discharges are considered to be compliant with the cadmium or selenium criteria, EPA will work with North Carolina and ensure compliance with Section 7 of the ESA and 50 CFR § 402.16(a).

iv. EPA's approval does not foreclose either the formulation by NMFS, or the implementation by the EPA, of any alternatives that might be determined to be needed to comply with section 7(a)(2).

v. The Action Letter and Decision Document will also strongly encourage North Carolina DEQ to enlist technical assistance from NMFS as early as practicable in order to avoid prohibited take by any activities, authorizations, or decisions regarding potential cadmium or selenium sources or concentrations in waters where ESA-listed species under NMFS' jurisdiction occur. The EPA will include the following example:

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[15] Information and analyses that are consistent with the Service's Policy on Information Standards Under the Endangered Species Act (59 FR 34271)

> *"For example, NMFS could advise North Carolina DEQ on any ESA implications of 303(d)/305(b) monitoring and listing decisions affecting such waters."*

11.4 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 designated critical habitat, to help implement recovery plans or develop information (50 CFR § 402.02).

Actions or measures that could also minimize or avoid adverse effects of North Carolina DEQ's adopted cadmium and selenium criterion on ESA-listed sturgeon species under NMFS' jurisdiction include:

1. Encourage North Carolina to implement EPA's recommended freshwater acute cadmium guideline to all of North Carolina's freshwaters where ESA-listed sturgeon may occur.
2. Coordinate with nationally recognized sturgeon experts from government and academic institutions to close gaps in our understanding of the effects of cadmium and selenium on the biology, ecology, and recovery of shortnose and Atlantic sturgeon.
3. Coordinate with state and Federal agencies that carry out water quality monitoring in North Carolina waters where sturgeon occur or could reestablish to sample and analyze for cadmium and selenium where sources occur or are suspected. For example, the presence of skeletally deformed fish may suggest selenium accumulation to toxic levels.
4. Use information gained in items 1) and 2) above, along with up-to-date toxicity data, to determine whether sturgeon are at risk from exposure to cadmium or selenium.
5. If the analysis in item 3) above indicates 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.
6. Collaborate with NMFS on the development of a baseline water quality condition tool for stressors in waters where Atlantic and shortnose sturgeon occur. This collaboration will periodically review water quality conditions potentially affecting Atlantic and shortnose sturgeon and changes in water quality, gaps in information regarding water quality, and approaches to resolving those gaps.

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 designated critical habitat, EPA should notify the ESA Interagency Cooperation Division of any conservation recommendations they implement in their final action.

12 REINITIATION NOTICE

This concludes consultation on EPA approval of cadmium and selenium water quality criteria for the state of North Carolina. 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.

In particular, discovery of information, either found or newly generated, indicating that an ESA-listed species' exposure or response to exposures within a criterion's limit is no longer discountable or insignificant could be considered "new information" and could trigger reinitiation of consultation for EPA's approval of that criterion.

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