Best Management Practices (BMPs) Manual for Transportation Actions in North Carolina, South Carolina, and Georgia

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How to Use the Manual

This BMP Manual is designed to assist the Federal Highway Administration, State Departments of Transportation, and the National Marine Fisheries Service in North Carolina, South Carolina, and Georgia. The BMP Manual can help standardize environmental reviews and the mitigation of impacts to federally managed species, essential fish habitat, Endangered Species Act-listed species and their critical habitats (NOAA-trust resources). The Chapters and Appendices present information on transportation actions, NOAA-trust resources, the effects of transportation actions on those resources, and relevant mitigation measures to avoid, minimize, and offset impacts. The information is presented in a way that relevant portions can be easily adapted for use in environmental review documents to comply with the Magnuson-Stevens Fishery Conservatoin and Management Act (Magnuson-Stevens Act; MSA), Endangered Species Act (ESA), and National Environmental Policy Act (NEPA).

Chapters within the manual can be used to deconstruct actions and analyze the potential impacts of transportation projects on NOAA-trust resources. To expedite project reviews, recommended BMPs should be incorporated in the planning and design phases, and implemented in the construction phase of proposed projects. Compensatory mitigation measures are included to address any unavoidable impacts. Because each project typically presents a unique set of circumstances, the analysis of effects and selection of BMPs should occur on a per-project basis in coordination among the transportation agencies and NMFS. This may lead to a balancing, or prioritizing, of recommended BMPs based on the timing and location of the project, location of habitats, and timing and distribution of species, and other factors.

Appendices included with the BMP Manual provide in-depth information on NOAA-trust resources. These appendices can be used to better understand the biology and ecology of species and the characteristics of habitats, as well as the range of effects and plausible routes of effects to species and habitats from transportation actions. Additionally, life history and distribution information contained within the appendices may be used directly in the preparation of Biological Assessments/Evaluations and NEPA documents.

Various publications address transportation-related impacts to NOAA-trust resources. These publications can be used as reference guides or in conjunction with the BMP Manual to evaluate the potential impacts of transportation projects in NC, SC, and GA:

Non-fishing impacts to essential fish habitat and recommended conservation measures. 2003. Hanson, J., Helvey, M., Strach, R., editors. 2003. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75p.

Policies for the protection and restoration of essential fish habitats from energy exploration, development, transportation, and hydropower re-licensing. 2005. South Atlantic Fishery Management Council (SAFMC). Version 1. 14p.

Impacts to marine fisheries habitat from nonfishing activities in the Northeastern United States. 2008. Johnson M.R., Boelke C., Chiarella L.A., Colosi P.D., Greene K., Lellis K., Ludemann H., Ludwig M., McDermott S., Ortiz J., et al. NOAA Tech. Memo. NMFS-NE-209.

Editorial Note

"Best Management Practices (BMPs)" is a term typically used to describe practices that are implemented to protect water quality pursuant to Clean Water Act requirements. This can include practices for treating or limiting pollutants in stormwater or preventing soil migration into adjacent waters on active construction sites. This manual uses "Best Management Practices (BMPs)" as a general term to represent the preferred practices, methods, actions, materials, and other items that avoid and minimize impacts to NOAA-trust resources. When referring specifically to water quality BMPs within the manual, the terms "stormwater" or "water quality" will be used.

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1 Background and Introduction: Resources, Stressors, and Effects

NOAA's National Marine Fisheries Service (NMFS), the Federal Highway Administration (FHWA), and the State Departments of Transportation (DOTs) in North Carolina, South Carolina, and Georgia have developed this five-part Best Management Practices (BMP) Manual to streamline consultations required by the Endangered Species Act (ESA) and the essential fish habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The purpose of the BMP Manual is to increase consistency of project design and review, reduce consultation time, and contribute to the conservation of natural resources. This chapter summarizes MSA and ESA consultation requirements, provides an overview of NOAA-trust resources affected by transportation projects, discusses how transportation projects affect NOAA-trust resources, and provides suggested BMPs for avoiding, minimizing, and compensating for impacts. Chapter 2 focuses on erosion, turbidity, and sedimentation; Chapter 3 focuses on pile installation, removal, and blasting; Chapter 4 focuses on bridges and culverts; finally, Chapter 5 focuses on shoreline stabilization.

1.1 Endangered Species Act

The purpose of the Endangered Species Act (ESA) is to provide a program for the conservation of threatened and endangered species, and the conservation of the ecosystems on which they depend. Through this legislation, Congress directs federal agencies to utilize their authorities to further the purpose of the ESA. The ESA provides protection to species listed as threatened and endangered, as well as their designated critical habitat[1]. Some species are listed as one unit throughout their range and some species are listed as distinct population segments (DPSs). ESA-listed species and critical habitat under the jurisdiction of NMFS in NC, SC, and GA that may be impacted by transportation projects are listed in *Table 1.1* and *Table 1.2*.

Section 7(a)(2) of the ESA of 1973, as amended (16 U.S.C. §1531 *et seq*.), requires that each federal agency ensure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of those species[2]. Consultations on most listed marine species and their designated critical habitat are conducted between the action agency and NMFS. Consultations are required if a federal agency determines that an action may effect a listed species or critical habitat. If an action agency determines there is no effect to listed species or critical habitat, consultation is not required. Consultations are concluded after NMFS determines the action is not likely to adversely affect listed species or critical habitat (usually by concurring with the action agency) or issues a Biological Opinion ("Opinion") that determines whether a proposed action is likely to jeopardize the continued existence of a federally listed species, or destroy or adversely modify federally designated critical habitat. The Opinion also states the amount or extent of listed species incidental take that may occur and develops non-discretionary measures that the action agency must take to reduce the effects of said anticipated/authorized take. The Opinion may also recommend discretionary conservation measures. No

[1] Critical habitat is defined as specific areas: (1) within the geographical area occupied by the species at the time of listing, if they contain physical and biological features essential to conservation, and those features may require special management considerations or protection; and, (2) outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation. Critical habitat applies only when Federal funding, permits, or projects are involved.

[2] State Departments of Transportation regularly act on behalf of the Federal Highway Administration as the non-federal designated representative to conduct informal consultation or prepare biological assessments in accordance with 50 CFR Section 402.08. The ultimate responsibility for compliance with Section 7 of the ESA remains with the Federal agency.

destruction or adverse modification of critical habitat may be authorized. The issuance of an Opinion detailing NMFS's findings concludes ESA Section 7 consultation.

Table 1.1 Listed Species that May be Affected by Transportation Projects in NC, SC, and GA.

Common Name	Scientific Name	ESA-Listed Status
Fish		
shortnose sturgeon	*Acipenser brevirostrum*	Endangered
Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*	Endangered
Sea Turtles		
hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
leatherback sea turtle	*Dermochelys coriacea*	Endangered
green sea turtle	*Chelonia mydas*[3]	Endangered/Threatened
loggerhead sea turtle	*Caretta caretta*[4]	Threatened

Table 1.2 Designated Critical Habitat that May be Affected by Transportation Projects in NC, SC, and GA

Species	Unit
Atlantic sturgeon	82 FR 39160

Atlantic sturgeon critical habitat rivers in the Southeast U.S. are for the Carolina and South Atlantic DPS units.

When a Federal action agency determines that there is *no effect* to listed species or critical habitat from a proposed action, consultation or communication with the NMFS is not required. If a *no effect* determination cannot be made, the Federal action agency must engage in interagency consultation with the NMFS. The interagency consultation process for endangered species and critical habitat is detailed at 50 CFR Part 402, and numerous tools currently exist to aid Federal action agencies in the consultation process (e.g., Endangered Species Consultation Handbook, 1998). However, information most applicable to ESA Section 7 consultation with NMFS in NC, SC, and GA is found at: http://sero.nmfs.noaa.gov/protected_resources/section_7/index.html

[3] Green turtles are listed as threatened except for the Florida and Pacific coast of Mexico breeding populations, which are listed as endangered. On March 23, 2015, a proposed rule was published to list 11 DPSs of green sea turtles as threatened or endangered. The populations within Florida would be listed as part of the North Atlantic DPS and listed as threatened; thus, any animals potentially affected by the proposed action would be members of that proposed DPS.

[4] Northwest Atlantic Ocean (NWA) distinct population segment (DPS).

As noted in the tables above, transportation projects may affect sea turtles and sturgeon, due to the nature and location of projects, as well as species distributions and life history traits. Sturgeon occur in marine and estuarine environments, as well as large freshwater rivers. Sea turtles occur in marine and estuarine environments, and rarely occur in freshwater areas (inland of the saltwater/freshwater interface). *Appendix A* provides detailed information on the biology and life history of ESA-listed species as well as information on critical habitat relevant to transportation projects in NC, SC, and GA. *Appendix B* details critical habitat for Atlantic sturgeon in the Southeast, while *Appendix C* details the current distribution and occurrence of shortnose and Atlantic sturgeon in NC, SC, and GA. *Appendix H* details times of the year when sturgeon will most likely be migrating and spawning in specific rivers. FWHA/state DOTs can use *Appendix H* in conjunction with *Appendix C* to determine times of the year that would be most beneficial to avoid in-water work in order to avoid and minimize potential impacts to sturgeon. Adhering the dates listed in *Appendix H* could limit or eliminate the plausible routes of effect to sturgeon, which could aid transportation agencies in making no effect or may affect, but not likely to adversely affect determinations for proposed projects.

1.2 Magnuson-Stevens Fishery Conservation and Management Act (MSA) - Essential Fish Habitat (EFH)

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act; MSA) was amended in 1996 to include requirements for the NMFS, regional fishery management councils (FMCs), and other Federal agencies to identify and protect essential fish habitat (EFH). NMFS and the FMCs, with assistance from NMFS, are required to designate EFH in fishery management plans (FMPs) or FMP amendments for all federally managed fisheries. Pursuant to Section 305(b)(2) of the MSA, Federal action agencies which fund, permit (authorize), or carry out activities that may adversely affect EFH are required to consult with NMFS regarding the potential impacts of their actions on EFH, and respond in writing to any NMFS recommendations. The purpose of addressing habitat in the MSA is to further one of the Nation's important marine resource management goals – maintaining sustainable fisheries. Achieving this goal requires the long-term maintenance of suitable marine fishery habitat quality and quantity. Guidance and procedures for implementing the 1996 amendments were published by the NMFS in 2002 (50 CFR Section 600.805 – 600.930).

Essential Fish Habitat (EFH) in North Carolina, South Carolina, and Georgia

EFH includes all types of aquatic habitat (waters and substrates) necessary to fish for spawning, breeding, feeding, or growth to maturity[5]. NMFS and the regional FMCs identify EFH for federally managed species and identify habitat areas of particular concern (HAPCs) using the best available scientific information. HAPCs are subsets of EFH which are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area[6]. HAPCs are not afforded any additional regulatory protection under the MSA; however, Federal actions with potential adverse impacts to HAPCs will be more carefully scrutinized during the consultation process and will be subject to more stringent EFH conservation recommendations.

EFH Designations

[5] Full definition is found at 50 CFR 600.10.
[6] 50 CFR 600.815(a)(8)

The effort to identify and designate EFH in the various FMPs was a rigorous process that involved numerous State and Federal agencies and the public at large. The South Atlantic Fishery Management Council (SAFMC), Mid-Atlantic Fishery Management Council (MAFMC), and the NMFS have designated in their fishery management plans EFH germane to transportation projects in coastal NC, SC, and GA. The NMFS directly manages highly migratory species (HMS), though few EFH designations within the fishery management plan for this group extends into waters where impacts from transportation projects may occur. The MAFMC and NMFS fishery management plans designate EFH for some species in the waters of NC, SC, and GA; however, many of these EFH designations are broad and overlap EFH designated by the SAFMC.

Fishery Management Plans Designating EFH Applicable to Transportation Projects in NC, SC, and GA

- SAFMC - FMP for the Shrimp Fishery of the South Atlantic Region
- SAFMC - FMP for the Snapper-Grouper Fishery of the South Atlantic Region
- SAFMC - FMP for the Coastal Migratory Pelagic Resources (Mackerels)
- MAFMC - FMP for the Bluefish Fishery
- MAFMC - FMP for Summer Flounder, Scup, and Black Sea Bass
- NMFS Consolidated Atlantic Highly Migratory Species (HMS) FMP

Specific plans, amendments, descriptions of EFH and EFH-HAPC, and other information can be found at: http://safmc.net/ and http://www.mafmc.org/. A list of species most commonly impacted by transportation projects in NC, SC, and GA is provided in *Appendix D*. EFH relevant to transportation projects in NC, SC, and GA is provided in *Appendix E*.

EFH and HAPCs

The official EFH and HAPC designation language for those managed species found in waters of NC, SC, and GA are contained in each relevant FMP and related amendments. The designations describe the geographical extent in which EFH is found, the type of habitats utilized by each species, and in some cases, each life-stage of a species.

Broadly, EFH can be grouped into two categories: estuarine areas and marine areas. However, estuarine areas are predominantly impacted by transportation projects, whereas transportation projects rarely affect marine areas. The primary estuarine areas that may be impacted by transportation projects include, but are not limited to, tidal freshwater (palustrine), estuarine and marine emergent wetlands (intertidal marshes), tidal creeks, oyster reefs, intertidal non-vegetated flats, unconsolidated bottom (soft sediments) habitats, submerged aquatic vegetation, and coastal inlets. EFH in marine areas can include live/hard bottom, coral, and coral reefs.

To aid in understanding EFH and EFH-HAPC, the SAFMC has produced the *Users Guide to Essential Fish Habitat Designations by the South Atlantic Fishery Management Council*, November 2016.

http://safmc.net/download/SAFMCEFHUsersGuideFinalNov16.pdf

Additionally, NMFS has various publications to aid Federal agencies in the EFH consultation process, these include:

Essential Fish Habitat – South Atlantic – Version 201703

http://sero.nmfs.noaa.gov/habitat_conservation/documents/efh_safmc_2017.pdf

Preparing Essential Fish Habitat Assessments: A Guide for Federal Action Agencies - Version 1.

http://www.habitat.noaa.gov/pdf/preparingefhassessments.pdf

Essential Fish Habitat Consultation Guidance – Version 1.1

http://www.habitat.noaa.gov/pdf/efhconsultationguidancev1_1.pdf

Essential Fish Habitat: A Marine Fish Habitat Conservation Mandate for Federal Agencies – South Atlantic Region

http://sero.nmfs.noaa.gov/habitat_conservation/efh/guidance_docs/sa_guide_2010.pdf

1.3 Stressors Generated from Transportation Projects

Transportation projects cover broad categories of activities and sub-activities, which can adversely affect species and habitats. The broader categories of activities include, but are not limited to, earthwork activities (i.e. land clearing), bridge projects, road widenings, culvert projects, and shoreline stabilization projects. Sub-activities may include dredging, filling, impounding or discharging watering, and pile driving. Stressors generated from transportation activities and sub-activities may eliminate, diminish or disrupt the functions of aquatic habitat and directly kill, harm, or harass individual organisms. These stressors are categorized and described below. Adverse effects resulting from the stressors are discussed in the following section. There is broad overlap for many of the stressors, and numerous stressors may result in the same, or similar, adverse effects to species and habitats. For these reasons, the discussion of stressors is broad and stressors that are unique to certain actions are discussed in the most relevant Chapter within this series.

A detailed list of project types, activities, and sub-activities, as well as stressors generated from each activity and their effects can be found in *Appendix F (Effect Analysis Spreadsheet)*.

1.3.1 Stressors

Natural communities are structured by a complex combination of physical and biological interactions, of which environmental stressors are a primary component (Paine 1966; Connell 1978; Menge and Sutherland 1987). Environmental stressors are physical, chemical, or biological factors that impose constraints on species and habitats. These stressors can affect organisms by altering physiological and behavioral traits as well as species interactions and community dynamics (i.e., competition) (Paine 1966; Connell 1978; Menge and Sutherland 1987; Killen et al. 2013). This section focuses specifically on anthropogenic stressors generated by transportation projects.

Stressors are broadly defined as any human-induced factor that alters the environment in a way that constrains species or habitat productivity. Stressors may lead organisms to adjust behavior or physiology, which can demand higher performance, mediate the expression of traits, lead to morphological changes, and decrease survivorship and fitness (Killen et al. 2013). Stressors may also result in adverse effects to habitats, decreasing the quantity or quality of habitats and reducing overall habitat function (Hanson et al. 2003). Anthropogenic stressors from transportation activities can be both biotic and abiotic, and are short-term (temporary) and long-term (permanent and chronic). Stressors are generated throughout all phases of construction, during the lifespan and operation of a structure (e.g., bridge), and through eventual landscape urbanization (Hanson et al. 2003; Angermeier et al. 2004; Johnson et al. 2008). Stressors are categorized below to best represent the primary mechanism leading to adverse impacts.

1.3.1.1 Habitat Loss and Degradation

Habitat loss results when natural habitats are permanently destroyed or converted to other habitats that provide no value to organisms. Additionally, anthropogenic activities can degrade natural habitats in a variety of ways that diminish the function of those habitats. This includes transforming contiguous natural areas into fragmented patches and other physical and chemical impacts to habitats. Furthermore, habitat degradation can include reducing species richness, abundance, diversity, and altering community composition, as well as altering other biotic interactions and abiotic processes. Reducing species richness, abundance, and altering community composition threatens ecosystem integrity by altering biotic interactions, abiotic processes, and resiliency to further environmental change (Wiegand et al. 2005; Worm et al. 2006).

1.3.1.1.1 Dredging and Filling

Dredging involves removing or excavating bottom sediments from the aquatic environment; anywhere below the surface of the water. This typically includes removing vegetation, benthic fauna, or other features that are present in or on the bottom sediments. Filling constitutes the placement of material so that the material replaces any portion of the water with dry land, or changes the bottom elevation beneath the surface of the water. Overburden from excavation activities and dredged spoil are commonly used as fill material (USACE 2015).

1.3.1.1.2 Vegetation Removal or Alteration

Removal or alteration of vegetation is common in transportation projects where areas need to be cleared for construction, construction access, or when construction components affect vegetation. Aquatic, intertidal, or nearshore vegetation may be directly removed for a variety of purposes using methods including dredging, excavating, clearing, direct pull, or cutting. Additionally, vegetation may be altered in a way that diminishes the quality or quantity of the vegetation in an area (Williams and Thom 2001). This can include smothering or compacting vegetation, chopping, slicing or shearing vegetation (typically with a propeller), or other alterations that do not lead to direct removal or elimination of vegetation (Hanson et al. 2003; Johnson et al. 2008).

1.3.1.1.3 Sediment Compaction

Sediment compaction can result from a number of activities ranging from human trampling to the placement of timber mats or grounding of work barges in salt marshes or other areas. Ground modifications also lead to sediment compaction, however, ground modifications typically result in fill of existing habitat, which would be considered the dominant impact. Compaction of sediment from increased external pressure reduces sediment pore space, thus restricting air and water movement in the sediment and reducing the interstitial spaces habitable for infaunal organisms and sub-surface structures of vegetation (Robertson and Campanella 1983; Hsu 2009). Compaction is affected by numerous factors, including the force and duration of the external pressure, as well as the physical properties of the sediment. Sediment compaction can eliminate habitat for benthic species and lead to an overall decrease in habitat function and value, as the distribution of macroinfauna in marine and estuarine zones is mostly mediated by sediment properties, among which sediment firmness is a key factor (Rhoads 1974). Additionally, sediment compaction can cause vegetation die-off and prevent regrowth and restoration.

1.3.1.1.4 Alteration to Hydrodynamics

Numerous in-water activities can alter the hydrodynamics of a site by introducing structures or modifying physical and biological components of the aquatic environment (Hanson et al. 2003). Alterations to the hydrodynamics of an area may be temporary, through the construction phase of projects, or permanent, through the long-term placement of structures. Wave energy and water transport (flow and currents, including velocity) are the most common hydrodynamic features impacted by transportation projects (Hanson et al. 2003; Johnson et al. 2008).

1.3.1.1.5 Shading

Shading results from the placement of elevated structures in natural habitats. In this context, shading will primarily result from elevated structures within or adjacent to aquatic habitats (Nightingale and Simenstad 2001; Hanson et al. 2003). Shading typically results from bridge components such as pilings, bents, and the bridge deck, but shading can also result from the placement of other structures, such as culverts. Shading reduces the available light to habitats by blocking light energy and casting a shadow beneath the structure. The shading footprint and shadow morphology of any elevated structure depends on the height, width, orientation and material of the structure (Nightingale and Simenstad 2001; Hanson et al. 2003; Alexander 2012).

1.3.1.1.6 Material/Debris Introduction

Material or debris introduction can result from various activities and can eliminate, modify, or degrade habitats, and displace species. Material or debris introduction into aquatic systems may be intentional or incidental, but can result in a range of impacts from behavior modification to mortality. Additionally, temporary or permanent reductions in habitat function can also result from the introduction of material or debris (Hanson et al. 2003; Johnson et al. 2008). The introduction of material and debris can also result from stochastic events such as storms that affect construction work areas.

1.3.1.2 Discharge or Resuspension of Contaminants/Pollutants

Discharge or resuspension of contaminants and pollutants can result from numerous construction and maintenance activities as well as throughout the lifetime operation of roadways and bridges (from runoff). Discharges of pollutants and contaminants into the aquatic environment can result from the accidental release of petroleum-based products such as fuels and hydraulic fluids, heavy metals from fuel additives, and brake/tire dust, application of pesticides, herbicides, and fertilizers, use of salts and deicing chemicals, and other pollutants. Pollutant and contaminant resuspension typically occurs when bottom sediments are physically redistributed throughout the water column by direct (e.g., excavator bucket) or indirect (e.g., flow generated from propeller) mechanisms (Hanson et al. 2003; Johnson et al. 2008).

1.3.1.3 Increased Erosion, Turbidity, and Sedimentation

Anthropogenic changes to the frequency, rate, and intensity of erosion, turbidity, and sedimentation in natural systems can adversely affect aquatic systems in a variety of ways. Increased erosion into aquatic environments and increases in suspended and deposited sediments is recognized as a major environmental stressor resulting from anthropogenic activity and is recognized as a primary form of aquatic habitat degradation (Junjie et al 2014). Increased erosion, turbidity, or sedimentation in aquatic environments can decrease water quality, diminish the function of habitats, and can destroy or eliminate habitats. Additionally, increased erosion, turbidity, and sedimentation can adversely affect individual organisms in ways ranging from behavior modification to physical injury and mortality (Hanson et al. 2003; Johnson et al. 2008; Chapman et al 2014). Short-term increase in erosion, turbidity, and sedimentation typically result from construction activities, while long-term (chronic) increases in erosion, turbidity, and sedimentation result from the permanent placement of roads and roadway structures (Hanson et al. 2003).

1.3.1.4 Elevated Noise/Pressure Levels

The increased presence of anthropogenic sound can negatively affect animals and decrease the function of habitats (Popper and Hastings 2009). Pile driving and underwater blasting are the primary causes of anthropogenic underwater noise related to transportation projects, but vessel operation, drilling, and other activities are also responsible for elevated noise/pressure levels in the aquatic environment. Anthropogenic sound is categorized as impulsive or non-impulsive. Impulsive sounds are transient, brief, broadband, and typically consist of a high peak pressure with rapid rise time and rapid decay. Typical impulsive sound sources include airguns, impact pile drivers (impact hammers), and underwater explosions. Non-impulsive sounds can be broadband, narrowband, or tonal, brief or prolonged, continuous or intermittent, and typically do not have a high peak pressure with rapid rise time. Non-impulsive sounds are typically generated from sources like sonar, vibratory pile drivers (vibratory hammers), and vessel/propeller noise. Anthropogenic-induced elevated noise and pressure levels can reduce the function of habitats and result in impacts to individuals ranging from temporary behavior modification to physical injury and mortality (Hastings and Popper 2005).

Species vary in their responses to anthropogenic underwater noise, which is reflected in differences in behavioral and injury thresholds. When source levels of noise are greater than thresholds, there are impacts to organisms. By using a series of equations with various project-specific inputs, the distances to which those effects may extend can be calculated. Noise impact calculations are essential in analyzing project impacts and are a typical component of any Biological Assessment or evaluation. The currently accepted impact pile-driving threshold noise levels for ESA-listed fish and sea turtles are found in *Table 1.3*. Non- ESA-listed species likely have similar injury and behavioral thresholds.

Table 1.3 Impact pile-driving threshold noise levels for fish and sea turtles..

Effect	**Animal**	**Threshold Level (dB re 1 µPa)[e]**
Physical Injury (peak pressure)	Fish & sea turtles	206 (peak pressure)
Physical Injury (cumulative exposure)	Fish & sea turtles	183 cSEL
Behavior Modification	All fish	150 (RMS)
	Sea turtles	160 (RMS)

Measurements of pressure and energy, such as peak pressure, root mean square (RMS), and cumulative Sound Exposure Level (cSEL) are defined and described in further detail in Chapter 3.

Decreased Water Quality

Decreased water quality can result from various transportation-related activities and may consist of altered temperature regimes, reduced dissolved oxygen, nutrient loading and eutrophication, altered salinity regimes, and introduction of pollutants and contaminants (Hanson et al. 2003). Alteration of temperature regimes can result from the removal of shoreline and riparian vegetation, and from radiant heating and run-off from impervious services. Temperature influences life processes of aquatic organisms and influences community and ecosystem interactions. Increased water temperatures can also reduce the dissolved oxygen concentration in aquatic systems, as warm water holds less oxygen than cooler water. Reduced dissolved oxygen concentrations can also result from other mechanisms and can affect the survival of many aquatic organisms and have negative consequences for ecosystem functioning. Nutrient loading and eutrophication is a cause of reduced dissolved oxygen in aquatic systems and can lead to increased frequency, severity, extent, and persistence of hypoxic conditions (Johnson et al. 2008). Additionally, nutrient loading and eutrophication can increase the incidence of nuisance or toxic species of phytoplankton, lead to alterations in the dominant phytoplankton species, and lead to greatly increased turbidity in the water column from increased phytoplankton (Hanson et al. 2003). The long-term placement of roads can alter salinity regimes by rerouting flow paths and concentrating stormwater flow towards estuarine areas like salt marshes and tidal creeks. Combined with the removal of vegetation adjacent to roadways, large and rapid influxes of freshwater can alter the salinity regime of areas, thereby altering the species composition of estuarine habitats. Roads and culverts can also restrict the flow in tidal creeks, lowering the head-of-tide, and reduce natural tidal flushing (Hanson et al 2003; Johnson et al. 2008).

1.3.1.5 Impingement and Entrainment

Impingement and entrainment of aquatic organisms result from various construction activities common to transportation projects. Impingement and entrainment primarily affect aquatic fauna including fish and shrimp. Impingement refers to organisms being pinned against intake structures (i.e., screens) during the suction and pumping of water where they can be injured and killed. Entrainment is defined as the direct uptake of aquatic organisms and consists of organisms being drawn into an intake system where they are killed, injured, or can become trapped. Impingement and entrainment are largely a result of the suction and pumping of water for water diversion, cofferdam pump-outs, and dredging related activities and not only injure and kill aquatic organisms, but can reduce the quality of habitats if sediments, vegetation, and prey species are removed or displaced (through direct uptake/suction) (Johnson et al. 2008).

1.3.1.6 Habitat Barriers

Roads placed within or across aquatic habitats can represent a significant barrier to the movement of aquatic life and reduce the connectivity of habitats through physical separation and fragmentation (FHWA 2012). The use of bridges and culverts can reduce these impacts, but may still present a barrier or diminish connectivity. During the construction phase of transportation projects, the physical presence of construction materials, temporary work structures, and machinery may create barriers to aquatic life and temporarily fragment habitat. Anthropogenic noise can create similar acoustic barriers, where continuous sound pressure waves and impulsive forces can create “acoustic walls” within the water column (Popper and Hastings 2009). Habitat barriers can interrupt the basic life processes of aquatic species, diminish or eliminate access to habitats, and diminish the function of habitats (Hanson et al. 2003).

1.3.1.7 Vessel Interaction

Transportation projects undertaken within or near the aquatic environment typically result in increased vessel traffic due the demands of construction. Top-down construction methods can largely avoid the increased use of vessels, but maintaining bridges and roads to local traffic in coastal areas normally prohibits the use of top-down methodologies. Increased vessel traffic can result from the use of barges, vessels to transport workers to temporary work trestles or other structures, or for other construction purposes. Furthermore, the long-term presence of in-water structures may lead to increased vessel traffic from recreational users who may use in-water structures for fishing, mooring, or other activities. Vessels can directly injure or kill individual organisms, shear or cut vegetation, and lead to elevated underwater noise. Increased vessel operation can also diminish the function of habitats (Hanson et al. 2003; Johnson et al. 2008).

1.4 Effects of Transportation Projects

The adverse effects of transportation activities on aquatic species and habitats are well documented and range from the most severe species effect (mortality) to discrete, sub-lethal effects including behavioral changes and modification of life-history strategies. Adverse effects to habitats are also broad and include complete habitat loss and diminished habitat function. Many effects of transportation projects overlap and numerous effects may result from the same, or similar, actions or stressors. For this reason, discussions of effects are broad and effects that are unique to certain actions are discussed in detail in the most relevant chapter in this Manual. The level of effect, or effects, will be a function of a species' or habitat's exposure and response to various stressors. Exposure considers the distribution, timing, duration, and magnitude of each stressor in relation to the occurrence of species and habitats.

A detailed list of project types, activities, and sub-activities, as well as stressors generated from each activity and their effects can be found in *Appendix F (Effect Analysis Spreadsheet)*.

1.4.1 Habitat Effects

This section details and describes the likely adverse effects to habitats from transportation projects. Impacts to individual organisms and species are described in the following section.

1.4.1.1 Habitat loss and Degradation

Transportation activities can lead to a variety of adverse effects, including habitat loss and degradation, which reduces the quantity and quality of habitat for species. Filling, burying/covering, or converting aquatic and riparian habitats with sediments, structures (columns, spread footers, etc.) or other materials removes productive habitat (Hanson et al. 2003; Johnson et al. 2008). The loss and degradation of habitats can reduce the production of detritus, an important food source for aquatic invertebrates; alter the uptake and release of nutrients to and from adjacent aquatic and terrestrial systems; reduce the quantity of wetland vegetation, an important source of food for vertebrates and invertebrates; hinder physiological processes in aquatic organisms (e.g., photosynthesis and respiration) caused by degraded water quality, increased turbidity and sedimentation; alter hydrological dynamics, including flow dynamics, flood control and groundwater recharge; reduce filtration and absorption of pollutants from uplands; and alter atmospheric functions, such as nitrogen and oxygen cycles (Johnson et al. 2008). Furthermore, many habitats are used for essential life functions such as foraging, sheltering, migration, and spawning and elimination of those habitats can lead to the displacement of organisms, interruption of life processes, and behavior modifications (Hanson et al. 2003). Early life history stages of many fish, shellfish, and shrimp species use the physical structures of aquatic habitats as refugia. Eliminating or degrading these habitats can adversely affect federally managed species, ESA-listed species, and their prey (Collette and Klein-MacPhee 2002).

Transportation projects can introduce overwater structures and turbidity plumes of suspended particulates into environments that alter habitats and physiological processes like photosynthesis by reducing light penetration through the water column (Nightingale and Simenstad 2001). Reduced light transmittance from shading and increased suspended sediments in the water column can adversely affect vegetation, habitat complexity, and overall net primary production (Struck et al. 2004; Whitecraft and Levin 2007; Johnson et al. 2008; Alexander 2012). Overwater structures, suspended sediments and other factors that attenuate light may adversely affect estuarine marsh food webs by reducing macrophyte growth, soil organic carbon, and altering the density and diversity of benthic invertebrates (Alexander and Robinson 2006; Whitcraft and Levin 2007). Reductions in primary productivity and invertebrate abundance reduce available prey resources for federally managed and ESA-listed species as well as other important commercial and recreational species. Prey resource limitations affect movement patterns and the survival of many juvenile fish species (Alexander and Robinson 2006; Whitcraft and Levin 2007).

Activities that result in the production of anthropogenic underwater noise or elevated pressure can also have negative impacts on habitats. The presence of underwater noise can lead to habitat degradation by making areas temporarily unsuitable for organisms (Hanson et al. 2003). Underwater noise can result in the physical exclusions of organisms from habitats, as mobile species will avoid the areas where anthropogenic noise is present. Additionally, avoidance of an area by prey species and variable return times of those species reduces the function of the habitat to federally managed and ESA-listed species (Johnson et al. 2008).

1.4.1.2 Decreased Water Quality

Many activities can result in elevated levels of sediment particles or organic matter in the water column (increased suspended solids). Turbidity plumes can reduce light penetration and impact the behavior of aquatic organisms. If human-induced suspended sediment loads remain high for an extended period, fish may suffer increased larval mortality (Wilber and Clark 2001), reduced feeding ability (Robertis et al. 2003), and be prone to fish gill injury (Nightingale and Simenstad 2001). The contents of suspended solids may also react with dissolved oxygen, leading to oxygen depletion (Nightingale and Simenstad 2001).

Numerous transportation activities can introduce or lead to the resuspension (recirculation) of toxic metals, hydrocarbons, pesticides, pathogens, nutrients, and other materials into the water column. Many recirculated toxins, pathogens, and organics may become biologically available to organisms either in the water column or through food chain processes (Hanson et al. 2003). Contaminants introduced into aquatic environments can be taken up by aquatic organisms and magnified through the food web, affecting animal reproduction and viability (Johnson et al. 2008). Other contaminants and toxins, like copper and polycyclic aromatic hydrocarbons, if taken up by aquatic organisms can cause impairments, including changes in animal behavior, reduced olfaction, increased incidence of cancer, reproductive abnormalities, immune dysfunction, and impaired growth and development (Johnson et al. 1999; Sandhal et al. 2007).

The release of sediments and introduction of runoff also affects water quality by changing temperature regimes, levels of dissolved oxygen, pH, and salinity regimes. These factors and others can lead to various lethal and sub-lethal effects to the species that use those habitats, or result in avoidance of habitats or displacement (Hanson et al. 2003). Reductions in water quality can impair and limit the ability of aquatic organisms to grow, feed and reproduce (Deegan and Buchsbaum 2005).

1.4.1.3 Altered Hydrodynamics; Altered Flow Dynamics and Wave Energy Regime

Changes to wave energy and water transport from permanent and temporary in-water and shoreline structures, construction machinery, and other structures may have substantial negative impacts to near shore detrital food webs through alterations in the distribution of organic matter as well as substrate size, distribution and abundance (Hanson et al. 2003). Altering sediment and organic matter transport and flow dynamics can adversely affect natural processes like substrate building for plant propagation, animal rearing, and spawning (Thom et al. 1997). Structures such as pilings placed in the water can negatively affect habitats through alterations of wave energy and substrate composition. Structures may disrupt water flow, increasing flow rates immediately around the base of some structures, which can cause scour and erosion downstream and sedimentation/siltation of adjacent habitats or organisms (Johnson et al. 2008). These sediment and flow alteration as well as changes in organic matter transport may change the plant and animal communities within a given site (Thom 2000).

1.4.2 Species Effects

This section details and describes the likely adverse effects to individuals and species from transportation projects.

1.4.2.1 Physical Injury and Mortality

Transportation activities generate numerous adverse effects that can lead to physical injury (trauma) or immediate or delayed mortality in aquatic organisms, including fish, sea turtles, and other aquatic organisms. Adverse effects can occur to all life stages of aquatic organisms, including eggs/embryo and larva. Transportation activities can lead to physical injury and mortality in aquatic organisms through direct physical contact, changes in ambient pressures, exposure to suction and pumping forces, exposure to suspended sediments, toxins, pathogens, and exposure to anoxic conditions (Hanson et al. 2003; Johnson et al. 2008). Physical injury to external structures like fins, flippers, scales and other structures and tissues can result from direct contact with equipment, changes in ambient pressure, and other stressors, which can lead to diminished locomotion and reduced survivorship (Popper et al. 2014). Severe external injury may include the removal of structures such as fins and flippers, which can negatively affect survival rates, reproduction rates, and other life history traits (Johnson et al. 2008). External injuries can also include scale and skin loss and abrasion, gill abrasion and other gill injury typically resulting from exposure to suspended sediments (Nightingale & Simenstad 2001; Kjelland et al. 2015). Elevated turbidity levels (suspended solids) have been documented to cause increased larval mortality (Wilber & Clark 2001) and reduced feeding ability (Robertis et al. 2003) in fish.

Internal injuries can also result from direct contact with construction machinery, changes in ambient pressures resulting from blasting, pile driving, suction and pumping forces, and other factors. Internal injuries can, but do not always, lead to mortality. Internal injuries can include visceral damage, hemorrhaging, embolisms, hematomas, and damage to auditory, equilibrium, and electrosensory systems (Carlson et al. 2011; Popper et al. 2014). In fish species, the swim bladder is the most commonly damaged organ when fish are exposed to rapid pressure changes (barotrauma[7]), but the swim bladder may also be damaged through the application of external physical force. Swim bladder injuries can result in the inability to regulate buoyancy, causing fish to become more vulnerable to predation (Govoni et al.

[7] Barotrauma is the physical damage caused by rapid changes from ambient pressure and can result from exposure to blasting, pile driving, or other activities.

2003; Popper et al. 2014). Hemorrhaging can occur in animals exposed to direct physical force and rapid ambient pressure changes. This can range from non-lethal hemorrhaging in muscle tissues to lethal hemorrhaging in the heart, brain and other vital organs. Hemorrhaging has also been documented in the eyes of aquatic animals exposed to rapid pressure changes, and can result in reduced or lost vision (Popper and Hastings 2009).

Embolisms, visceral damage, and damage to auditory, equilibrium, and electrosensory systems can result from external forces such as rapid ambient pressure changes and can lead to injury or mortality in aquatic organisms. Embolisms resulting from extreme pressure differences inside and outside of blood vessels result in the formation of gas bubbles that combine into embolisms (Carlson et al. 2011; Popper et al. 2014). Hair cell receptors, neuromasts within the lateral line of fishes, ciliary hairs and otoliths, and other auditory, equilibrium, and electrosensory systems can also be temporarily or permanently damaged by external physical forces and pressure changes. Temporary or permanent damage to these structures and others can result in temporary hearing loss or threshold shifts in aquatic animals, and can lead to the disruption in orientation and locomotion, predator detection, navigation, and other essential functions (Popper and Hastings 2009).

Aquatic organisms may also experience physical injury or mortality from other anthropogenic stressors including crushing or rapid compaction. Crushing and rapid compaction of anatomical structures or entire organisms can result from machinery, suction forces, or other factors including the placement of structures and fill material (Johnson et al. 2008). Many species exhibit demersal (bottom dwelling) characteristics during some or all life stages and many species forage on infaunal and bottom-dwelling organisms, such as crustaceans and polychaete worms. Activities like dredging and pile driving (sedimentation) can result in adverse effects by directly removing, burying, or crushing organisms or their prey or through the direct uptake of those organisms (Hanson et al. 2003).

1.4.2.2 Behavioral Modification/Altered Behavior

Behavior modification or altered behavior patterns of aquatic organisms can result from various transportation-related stressors. Behavioral changes can result from the presence of construction machinery or direct physical contact with construction machinery or materials, changes in ambient pressures resulting from blasting, pile driving, suction, and pumping forces, and the increases presence of humans and vessels (Hanson et al. 2003). Behavioral modification can range from the temporary avoidance of areas to the permanent shift in foraging habitat from placement of permanent structures. For most temporary behavioral modifications, how animals respond to a particular stressor (e.g., sound pressure wave, presence of construction machinery) will likely vary based on the motivational state of the animal at the time they are exposed to the stressor (Dahl et al. 2015). Generally, behavior modification can be characterized as avoidance, displacement, cessation of feeding, and changes in feeding and sheltering strategies (Johnson et al. 2008). Other behavioral modifications have been observed in aquatic organisms, which can be described as erratic behaviors. This can include behaviors such as jumping out of the water, in order to avoid anthropogenic sounds (Johnson et al. 2008; Kastelein et al. 2013).

Behavioral modification that results from transportation activities largely depends on the frequency, duration, and intensity of the stressor and the exposure of organisms to the stressors. Additionally, behavioral responses of individual organisms may also largely depend on the availability of similar unaffected nearby habitats. Though a broad range of impacts result from the alteration of natural behaviors, behavioral changes resulting from human-induced stressors typically effect energy costs related to food-foraging costs, survival, and fecundity (Dahl et al. 2015). Behavioral effects may also include altered migration routes and altered behavior in the presence of predators (Hanson et al. 2003). Anthropogenic stressors such as elevated noise levels may reduce the ability of organisms to hear and avoid predators and could lead to increased predation (Carlson et al. 2011; Popper et al. 2014).

Behavioral modifications can often lead to interrupted life processes and overlap between these effects is broad. For example, installing a barrier that hinders migration will disrupt the migration process, but will also result in behavioral changes in individual organisms. Life processes for aquatic organisms can include foraging, migrating, spawning, and other functions necessary for survival and reproduction (Hanson et al. 2003). Anthropogenic activities can disrupt critical life processes by generating various stressors and by physically excluding organisms from areas or entire habitats. Stressors may include, but are not limited to, changing water flows, introducing construction materials and machinery, elevating noise and sound pressure levels, elevated turbidity levels, and the permanent placement of structures. Anthropogenic stressors can lead organisms to abandon migration activity and seasonal spawning. For some species that breed infrequently such as sturgeon, abandoning reproductive efforts for one season could have long-term negative consequences on entire populations (SSRT 2010).

1.4.2.3 Stress Response

Numerous transportation activities can lead to stress effects that reduce fitness in aquatic organisms by causing changes in stress hormones (mainly plasma/serum cortisol) (Johnson et al. 2008). Elevated levels of cortisol indicate a primary response to stress, which can present as behavior changes, like rapid jumping or swimming, or more subtle effects (Hanson et al. 2003). Studies have demonstrated that exposure to non-traumatic stress such as rapid environmental changes, suboptimal water quality, suboptimal or altered physical environments, altered habitat connectivity and pollution can predispose fish to opportunistic infections (Hasting and Popper 2005; Johnson et al. 2008; Popper et al. 2014). Furthermore, it has been documented that exposure to chronically high levels of suspended sediments in the water column cause organisms to experience elevated disease prevalence, which is likely a result of decreased immune function (Pollock et al. 2014). Additionally, fish and other organisms showing significant stress effects have been observed to be more susceptible to predation than fish that do not experience stress effects (Hanson et al. 2003). Stress has also been shown to decrease growth and reproductive rates in aquatic organisms (Johnson et al. 2008). Physiological stress may also result in changes in cardiac output, ventilation rate, blood sugar level and others, all of which may lead to reduced fitness (Popper and Hastings 2009).

1.5 Regularly Authorized Transportation Projects (Activities) and Sub-Activities

Numerous transportation projects are regularly authorized in areas that could potentially affect NOAA-trust resources. Construction, maintenance, and demolition activities impact species and habitats in various ways, as described above. The six major project types undertaken by FHWA/state DOTs in NC, SC, and GA are described below as well as sub-activities common to many project types. Additional project types and sub-activities exist and those described below are not intended to represent the full spectrum of transportation projects or sub-activities. Many of the projects and sub-activities below are described in more detail throughout various chapters in the manual, whereas some of the projects and sub-activities do not require further explanation or description.

1.5.1 Transportation Project (Activity) Description

1.5.1.1 New Alignments/Roadways and Road Widening (Roadway Construction)

New alignments or roadways include constructing roadways in new locations, where there is no existing infrastructure and include placing fill/embankment. Road widening projects typically include placing fill immediately adjacent to the existing roadway to match the existing grade, paving, and preparing side slopes. Installation of guardrails, medians, and other safety components are typically included in these road projects. Shoreline stabilization on newly formed side slopes is common to these projects.

1.5.1.2 New Bridge, Bridge Replacement, and Bridge Widening; New, Replacement, or Relocated Piers and Docks

New bridges (also piers and docks) include constructing structures where there is no existing infrastructure. Activities may consist of the permanent placement of substructures and approach fill into waters of the U. S. necessary for the construction of structures. Additional activities may include the placement of bridge components including substructures, superstructures, and shoreline stabilization. Bridge widening and replacement activities typically replace functionally obsolete and/or structurally deficient bridges or expand, restore, or improve safety and functionality of existing bridges. Bridge widening projects expand the roadway width and typically consist of adding girders, interior bents and expanding the bridge deck, consistent with the components of the existing structure. Bridge replacement projects construct new bridges parallel to, or on the same alignment as, an existing bridge; no structural components from the existing bridge are used in the new bridge. For bridge replacement projects the existing bridge typically is removed following completion of the new bridge.

1.5.1.3 Bridge Repair, Maintenance and Retrofit; Dock and Pier Repair, Maintenance, and Retrofit

Bridge (also pier and dock) repair, maintenance, and retrofit activities are implemented to prolong the use and function of bridges, ensure motorist safety, and protect the environment. Bridge repair typically consists of removing and replacing deteriorated deck concrete or rehabilitating other existing components of the bridge, including piles and girders. Bridge repairs may also consist of seismic retrofitting, which includes such items as strengthening pilings and bents. Whether a bridge is repaired, rehabilitated, or replaced depends on the age of a bridge and damage that may occur to a bridge (e.g., from a storm event, earthquake, or vehicle or boat collision). Scour repair work is a common type of bridge maintenance where materials (typically riprap) is placed in the water to protect existing substructures. Maintenance activities may include washing, painting, debris removal from bridge piers, guardrail repairs, lighting and signage repairs, and structural rehabilitation. Seismic retrofitting activities involve modifying existing structures for increased resistance to seismic activities. This can include replacing bolts and rivets and adding longitudinal restrainers. Maintenance can also include adding pile jackets to protect existing pilings.

1.5.1.4 Culvert Installation, Replacement, Repair, Maintenance, and Cleaning

Culvert projects consist of replacing undersized, broken, or damaged culverts with new structures to sustain adequate flows, or placing (installing or constructing) new culverts in areas where they did not previously occur. Culvert maintenance projects include making repairs to the structural integrity of the culvert or protecting an existing culvert with shoreline stabilization. Cleaning involves removing sediments or debris from within or near the opening of a culvert

1.5.1.5 Shoreline Stabilization

Shoreline stabilization involves the direct protection of embankments at bridges, culverts, and roadway sections from erosive forces of flowing water. A variety of structures or materials can be built or placed parallel to shore on an existing, restored, or modified shoreline. Revetments, bulkheads, seawalls, and gabions protect the area immediately behind them, but afford no protection to adjacent areas or areas in front. These structures stabilize shorelines by enclosing and protecting areas, preventing the shoreline from functioning normally. Living shorelines may also be used, which is shoreline stabilization made up mostly of native material, often incorporating vegetation or other living, natural elements.

1.5.1.6 Pavement Preservation

Pavement preservation consists of patching, repairing, and replacing roadway surfaces and pavement. These include three types of pavement: (1) asphalt, (2) chip seal, and (3) concrete. If the existing pavement is in good condition, it may be covered over with a new layer of asphalt. Repair of badly deteriorated pavement could require grinding of existing pavement or replacement of the road foundation material prior to repaving. This typically involves grinding off and replacing the existing asphalt pavement.

1.5.2 Transportation Sub-Activity Descriptions

1.5.2.1 Staging Area Establishment

Transportation activities may require the need for staging areas. Staging areas facilitate the delivery and storage of construction materials and equipment, contractor office and storage trailers, and parking. Staging areas vary in size and may require vegetation clearing, grubbing, grading, or excavation to level the site, and installation of drainage improvements.

1.5.2.2 Cofferdams/Dewatering

Cofferdams are often installed to create isolated work areas that can be dewatered for construction to allow work to be done in-the-dry. Cofferdams are also used to create diversion channels to divert water around an area. Cofferdams may consist of sandbags, causeways/earthen structures, and/or large casings or structures created out of sheet piles. They may be installed with hammers, by crane and excavator, or placed by hand, depending on size.

1.5.2.3 Temporary Platforms and Access Fills; Stabilization

Fill and grading may be required prior to stabilization. Construction of temporary access fills and roads may be required to provide a working platform or access for machinery. Scour repair measures including fill and stabilization structures may be necessary. Fill may also be associated with disposal of excavated or dredged material.

1.5.2.4 Demolition/Blasting

Transportation projects may involve mechanical dismantling of structures from an adjacent structure or barge, or via land or through blasting. Structural components may be removed using a variety of methods such as cutting/sawing, blasting/chemical expansion (bentonite), hydraulic drilling, excavating, or by using a hoe ram, wrecking ball, clamshell dredge, or splitting wedges and hydraulic impact hammer. Demolition debris is typically mechanically removed and demolished structures are typically barged or trucked offsite for disposal.

1.5.2.5 Pile Installation/Removal

Piles support decking, provide temporary support during construction, serve as fenders and dolphins to protect structures, support navigation markers, and may support cofferdams, breakwaters, and bulkheads. They can be made of steel, concrete, wood, or plastic, and may be in the form of single piles or sheets. Piles can be driven into the substrate by impact or vibratory hammers, water jetting, or drilled/augured in by drilled shafts or rock sockets and may be removed by vibratory hammer, direct pull, clamshell bucket grab, cutting/breaking below the mudline, mechanical demolition, or blasting.

1.5.2.6 Dredging/Excavation

Dredging is typically done with hydraulic or mechanical equipment to remove sediment, deepen or widen a waterway, or to return an area to pre-construction conditions. Dredging or excavation may be associated with the installation of sub-structures, placement of erosion and scour control measures or utility lines or cables, or to remove debris. Excavation is often necessary to key in stabilization materials.

1.5.2.7 Vessel Activities

Construction and maintenance of transportation projects can increase vessel traffic. Equipment access may be from barges, depending on site characteristics. An increase in vessel traffic is usually temporary, ceasing when the construction is complete; however, certain actions can allow vessel access to an area that was previously inaccessible.

1.5.2.8 Habitat Restoration, Establishment, and Enhancement

Habitat restoration, establishment, or enhancement can restore areas impacted temporarily during the construction of a project, or be used as compensatory mitigation. This may include excavation, grading, fill, planting, invasive plant removal, channel reconstruction, shell placement, and living shorelines. Habitat restoration may also include demolition of abandoned or obsolete structures, debris removal, and/or sediment remediation. Habitat restoration is typically done to restore temporarily impacted areas to pre-construction conditions following completion of construction. Pre-construction surveys and post-construction monitoring are necessary for this type of restoration. Additionally, a common restoration method involves removing old approach fill from bridges that are replaced on parallel alignment. These areas should be graded down to surrounding habitat levels, as determined through on-site surveys.

1.5.2.9 Scientific Measurement Devices/Survey Activities

The use of scientific measurement devices or survey activities may be necessary to collect data at a project site in advance of project design or construction or as a part of required monitoring. Such devices or survey activities may include staff or current gages, water recording and biological observation devices, soil borings, core sampling, historic resource surveys, and side scan sonar.

1.6 General and Incidental Construction Activities

Numerous general and incidental construction activities are common to transportation projects, some of which are outlined above (section 1.5). These are undertaken for numerous reasons, including initial site exploration activities, to facilitate primary construction activities, and to comply with construction site regulations and guidelines (Hanson et al. 2003). These activities can have various adverse impacts on

NOAA-trust resources, which are typically short-term (temporary) and physical, but can also be long-term (permanent and chronic) and chemical in nature (Angermeier et al. 2004).

General and incidental construction activities for transportation projects include building, establishing, installing and maintaining: temporary construction/access roads, stabilized construction entrances/exits (SCEs), cofferdams, staging areas and other secondary construction areas, temporary fills, platforms, and work trestles, erosion/turbidity/sediment control measures, and temporary stormwater systems. Additional activities include cable and other communication equipment installation, site exploration using scientific devices, vehicles and vessels, brush clearing and grubbing, and grading. The use of vehicles and vessels are also considered general and incidental construction activities. Roadway construction activities in upland areas may also affect aquatic areas through increasing runoff and subsequent water quality effects (Hanson et al. 2003; Johnson et al. 2008).

Each general and incidental construction activity has the potential to produce similar stressors, depending on the equipment or specific construction techniques used. The stressors include habitat loss and degradation, discharge or resuspension of contaminants/pollutants, erosion, turbidity and sedimentation, elevated noise/pressure levels, decreased water quality, impingement and entrainment, habitat barriers and vessel interaction. Detailed information on the effects resulting from stressors produced by general and incidental construction activities are outlined above, and are described in detail here and in subsequent Chapters. These effects include habitat loss and degradation, decreased water quality, and altered hydrodynamics. Species effects can include physical injury and mortality, behavioral modification/altered behavior, interruption of life processes, and stress effects.

Many impacts of general and incidental construction are viewed as minor and temporary, such as clearing vegetation to perform shoreline surveys or using vehicles on temporary access roads. However, some activities, such as constructing cofferdams, can have more significant and long-term impacts on NOAA-trust resources (Hanson et al. 2003). Numerous structural and non-structural tools and methods can be implemented to avoid and minimize impacts to NOAA-trust resources from general and incidental construction related materials and activities. For general and incidental activities not directly addressed in any of the chapters, the Effects Analysis Spreadsheet (*Appendix F*) should be used in combination with agency engineering and environmental analysis expertise to determine the potential impact of an activity and optimal BMPs to avoid and minimize impacts. Additionally, many Chapters and BMPs can be broadly applied to numerous activities. For example, if it is determined that an incidental construction activity leads to increased turbidity and erosion, Chapter 2 should be used to analyze impacts and identify appropriate BMPs. Additionally, numerous BMPs in section 1.8 of this manual are applicable to general and incidental construction.

Temporary Rock Jetties & Temporary Rock Platforms

Temporary rock jetties and temporary rock platforms are structures commonly used to facilitate construction in areas where other methods, such as temporary work platforms/trestles, work barges, and top-down construction, are not feasible. Both structures are typically used in riverine environments, constructed in the water by placing riprap on a layer of geotextile fabric. Side slopes for both structures are typically between 2:1 and 3:1. Jetties are shore-perpendicular, shore-connected strucutures that are generally rectangular - jetties originate on the bank of the waterbody and extend into the water. Platforms are not connected to the shore and are generally smaller than jetties - platforms are generally square, isolated riprap islands located in the waterbody. Both structures typically have a surface that can support excavators, cranes, and other heavy construction machinery.

Temporary rock jetties and temporary rock platforms produce similar stressors. These stressors include habitat loss and degradation, specifically filling habitats, compacting sediments, and altering hydrodynamics, discharge of pollutants, increases in sedimentation and turbidity, as well as creating habitat barriers. Detailed information on the effects resulting from stressors produced are outlined above, and are described in detail here and in subsequent Chapters. These effects include habitat loss and degradation, decreased water quality, and altered hydrodynamics. Species effects can include physical injury and mortality, behavioral modification/altered behavior, interruption of life processes, loss of possible foraging, resting, and spawning areas, or loss of access to those areas, and stress effects.

Due to the nature of transportation projects, temporary rock jetties and work platforms are typically required for months to years (continuous or total time). Therefore, their use can result in the temporary short- and long-term loss of bottom habitat and shoreline vegetation (for jetties) for multiple seasons over many years. Depending on location, bottom habitats can be used for spawning, foraging, resting and migration for NOAA-trust resources and their prey. In addition to the temporary loss of habitats, installation of temporary rock jetties and platforms may have negative impacts on individual fish and their access to habitats upstream of the project area; representing habitat barriers. Extending rock jetties from shoreline areas into waterbodies and river channels can create dam-like features, preventing upstream and downstream passage of aquatic organisms. Migrating fish encountering these dams may discontinue upstream movements, abandon their spawning activity for the season, or use excess energy attempting to navigate around the jetties, potentially reducing spawning rates. Large rock platforms may produce similar effects.

Installation of rock jetties and work platforms can also result in changes to the hydrodynamics of a waterbody. When these in-water structures are installed, water is forced through smaller areas around the structures. These openings can represent significant reductions in the typical bank-full width of a waterbody, increasing water velocities and volumes as water is funneled through a reduced opening. Increased water velocity may limit the upstream migration of fish or lead to the use of excess energy, potentially reducing spawning rates. Individual organisms may also be injured or killed through physical contact with riprap or with construction machinery during the placement of riprap. Additional effects to individual organisms from the presence of temporary rock jetties and work platforms may include behavior modification and avoidance due to the presence of the structures, equipment, personnel and other construction elements. Use of the temporary rock jetties and work platforms may also lead to indirect impacts to adjacent aquatic habitats and water quality from heavy equipment operation and potential contaminant release, as these platforms and jetties place equipment directly above the water.

When temporary rock jetties or work platforms are necessary for project construction, a comprehensive analysis of potential effects to species and habitats is necessary for environmental review. This should include the need for sizes, shapes and durations of jetties or platforms, as well as analyses of all temporary impacts to habitats and the accurate characterization of those habitats (e.g., spawning, foraging, resting, or migration habitat). Additionally, included in this should be hydrodynamic analyses based on the proposed structures, their positions in the waterbody, and the length of time they will be placed in the water. Providing this complete information as early as possible during the interagency coordination process will likely reduce overall consultation time.

1.7 Mitigation

Compensatory mitigation is undertaken to offset unavoidable impacts to waters of the U.S. authorized through the issuance of Department of the Army permits pursuant to section 404 of the Clean Water Act (33 U.S.C. 1344) and/or section 9 or 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 401, 403). Compensatory mitigation replaces the loss of existing aquatic resource functions through various options, including mitigation banks, in-lieu-fee programs, in-kind mitigation, and out-of-kind mitigation. The most appropriate form of compensatory mitigation should be determined in accordance with the 2008 Mitigation Rule. If no mitigation banks are available with credits suitable for offsetting impacts to EFH, the NMFS generally recommends on-site, in-kind permittee responsible mitigation for the unavoidable impacts to EFH, rather than out-kind mitigation through a mitigation bank or in-lieu-fee program.

1.8 Recommended Best Management Practices Applicable to All Projects

Implementing recommended best management practices (BMPs) will aid FHWA/state DOTs in avoiding and minimizing impacts to NMFS-trust resources by reducing the exposure of species and habitats to stressors and eliminating the plausible routes of effects. Projects that cannot avoid or sufficiently minimize impacts to species or habitats may need to implement mitigation measures. Though a comprehensive list of BMPs is provided, innovative techniques and methodologies may lead to the development of additional BMPs, but their use should be coordinated with NMFS on a case-by-case basis.

The BMPs are discretionary measures that transportation agencies can incorporate during project planning to avoid and minimizing potential impacts to NOAA-trust resources. The BMPs provide more transparency and predictability to FHWA and State DOTs regarding species conservation, habitat needs, and NMFS' recommendations. Frontloading BMPs into early design phases of projects will likely lead to reduced consultation timeframes, reduced delays, and could reduce the potential for future redesign of projects. Many BMPs can be incorporated into the design of projects, while others may be addressed as environmental commitments for contractors.

***** *All best management practices related to structural project components and construction techniques are contingent upon engineering feasibility and other design considerations.*

Environmental Windows/Moratoria

EW1 Activities should be timed and located in ways that avoid and minimize potential adverse impacts to NOAA-trust resources. This includes reducing or avoiding impacts to sensitive life history stages of organisms, and times of the year when critical activities such as migration, spawning, or egg and young-of-the-year development are occurring.

EW2 To the maximum extent practicable[8], activities should be conducted when species are not present in the project area, or are present in low densities.

[8] Practicability is generally defined as feasibility as it relates to technology, cost, and logistics viewed in terms of the overall project purpose.

EW3 Seasonal work windows are specific to regional environmental conditions, specific locations and waterbodies, and species requirements, therefore specific work windows should be coordinated with NMFS.

General and Incidental Project Activities

GP1 To the maximum extent practicable, projects should be designed in ways that avoid and minimize impacts to aquatic habitats, aquatic life, and their movements.

GP2 Non water-dependent actions should not be located in aquatic areas if such actions may have adverse impacts on NOAA-trust resources.

GP3 Activities that may result in significant adverse effects on fishery habitat should be avoided where less environmentally harmful alternatives are available. If alternatives do not exist, impacts of these actions should be minimized to the maximum extent practicable.

GP4 To the maximum extent practicable, projects should avoid filling aquatic habitats, minimize any permanent fill in aquatic areas, and avoid temporary fills for construction purposes; only clean fill should be used when fill is necessary.

GP5 Project footprints, including secondary areas for staging and other purposes, should be minimized to the maximum extent practicable.

GP6 All activities should be confined to construction work areas, as indicated on plans and drawings. This includes active right-of-way, staging areas, and access areas.

GP7 Temporary or permanent project elements should not impede or obstruct movement of any NOAA-trust resources.

GP8 All activities in shallow water habitats and sensitive habitats such as streams and tidal creeks, salt marsh, submerged aquatic vegetation (SAV), salt marsh, shellfish beds, and intertidal areas should be avoided and minimized to the maximum extent practicable (including work footprint, structures, temporary and permanent fill, excavation, etc.)

GP9 Construction in and shading of SAV, areas which historically supported SAV, and/or areas which are potential habitat for recolonization by SAV should be avoided; consult historic SAV surveys and conduct new pre-construction SAV surveys in the growing season.

GP10 Sensitive habitats, including SAV, shellfish beds, and saltmarsh, should be identified and marked in the field by a qualified, professional biologist prior to the start of any work activities to aid on-site personnel in avoiding unintended impacts to these habitats.

GP11 Permanent elevated structures should span aquatic environments to the maximum extent practicable; causeways and causeway fill should be minimized to the maximum extent practicable by extending bridges, steepening side slopes, using mechanically stabilized earth (MSE) walls, and other techniques.

GP12 Temporary water crossings should be minimized to the maximum extent practicable; temporary water crossings should be located in areas that disturb the least amount of area.

- Elevated bridges that minimize fill should be used for temporary water crossings.
- Environmental windows apply to in-water temporary water crossings.

GP13 In-water work areas should be isolated to minimize and avoid sediments and noise in the water (e.g., use siltation curtains, bubble curtains, isolation casings, etc.).

GP14 Appropriate water quality Best Management Practices (BMPs) for erosion and turbidity control should be used during all stages of construction and in all construction areas; inspect and maintain water quality BMPs regularly.

GP15 To the maximum extent practicable, all erosion, and sedimentation control measures should be installed prior to land clearing/disturbing activities (e.g., clearing and grubbing). Minimal land clearing may be necessary to install erosion and sedimentation control devices.

GP16 To the maximum extent practicable, all refueling, maintenance, and staging of equipment and vehicles should occur in locations where spills would not drain directly into aquatic habitat. All reasonable precautions should be taken to prevent spills from entering aquatic habitats during refueling and maintenance of machinery located on barges or trestles. Refueling should not take place on temporary rock jetties when the equipment can be moved into upland areas.

- To the maximum extent practicable, refueling should be done at least 250 feet from any water body and be outside of active stream channels, outside of any tidal areas, and away from ditches or channels that enter flowing waters; designated refueling sites in upland areas at least 250 feet away from receiving waters are preferred.

GP 17 All materials that will be placed in the water, including sheet piles, concrete piles, and erosion control materials, should be free of sediments and/or contaminants.

GP18 A spill response plan should be created for each project/activity. The plan and all materials necessary for its implementation should be accessible on-site. Toxicant input into any waters of the U.S. should be avoided; petroleum products, chemicals, live or raw concrete (freshly poured or concrete that has not yet set), or water contaminated by the aforementioned should not be allowed to enter flowing waters.

- To the maximum extent practicable, concrete washout pits/pans/pools should be located at least 500 feet from any water body and be outside of active stream channels, outside of any tidal areas, and away from ditches or channels that enter flowing waters; designated sites in upland areas at least 500 feet away from receiving waters are preferred.

GP19 A Spill Prevention, Control, and Countermeasure Plan (SPCC Plan; Section 311(j)(1)(C) of the Clean Water Act as amended by the Oil Pollution Act of 1990) should be created when appropriate. The rule may be found at Title 40, Code of Federal Regulations, Part 112.

GP20 To the maximum extent practicable, upland areas should be used for all general and incidental construction, including temporary construction access roads, SCEs, staging areas, and other secondary construction areas.

GP22 To the maximum extent practicable, all waste/borrow areas should be located in upland areas; spoils and stockpiles should be placed in upland areas and properly contained (e.g., with erosion and sedimentation controls).

GP22 Any work in wetlands or intertidal areas should be done using low ground pressure vehicles or temporary work trestles, to the maximum extent practicable. If necessary, crane/timber mats should only be used for short periods. Barge grounding should be avoided.

GP23 When practicable, existing ingress or egress points should be used to access work areas or work should be performed from the top of banks.

GP24 Measures that avoid tracking sediments out of the project area, such as stabilized construction entrances/exits, should be used.

GP25 Work pads, falsework (e.g., braces and scaffolding), and other construction items within wetlands or over water should be removed prior to the end of any construction window and as soon as work is complete.

GP26 A project schedule and plan should be developed prior to construction that avoids and minimizes impacts to NOAA-trust resources. Once initiated, projects should be carried to completion in an expeditious manner to minimize disturbance.

GP27 Upon completion, or where there is an extended work stoppage, all disturbed areas should be stabilized with vegetative cover and/or riprap, as appropriate. Locally native vegetation and/or native seed mixtures for the stabilization and landscaping should be used, to the maximum extent practicable. Planting media should be free of all debris and non-native or invasive species.

GP28 Placement or removal of fill and other structures should avoid impacts to sensitive habitats such as SAV and oyster aggregations. If avoiding SAV or oyster aggregations is not practicable, a relocation plan should be developed for the oyster aggregations and SAV within the project area. Any potential SAV or oyster relocation should be discussed and coordinated with NMFS (state agencies are generally included in this coordination). Compensatory mitigation should be provided for any unavoidable impacts.

GP29 All buffer areas, including riparian buffers, should be maintained to avoid and minimize disturbance. Buffer areas should not be used for general or incidental project construction if it can be avoided.

GP30 Watercourse diversions shall be minimized to the maximum extent practicable; all water bodies should be managed to minimize flooding of construction sites/work areas.

GP31 If temporary fills are unavoidable, geotextile fabric should be placed first to ensure that any fill will be removed completely at the end of construction. Clean riprap, free of debris, is the preferred material for temporary fills.

GP32 The use of temporary work platforms/trestles should follow the recommendations/guidance outlined in Chapter 4 for piling installation and removal.

GP33 Methods that smother marsh vegetation and compact sediments should be avoided, to the extent practical (e.g., crane/timber mats and barge grounding). Floating barges, temporary work platforms/trestles, and low ground pressure vehicles (vehicles that exert low pressure on the soil/substrate) should be utilized.

GP34 In-water lines, ropes, or chains should be made of materials and installed in a manner (properly spaced) to minimize the risk of entanglement by using thick, heavy, and taut lines that do not loop or entangle. Lines can be enclosed in a rigid sleeve.

GP35 Turbidity controls should be properly designed and implemented in a way that does not block entry to/from habitats. Turbidity controls should be monitored to ensure aquatic species do not become entangled or entrapped.

GP36 Cofferdams should be constructed and removed in accordance with Chapter 4 and should be placed to avoid main channels of streams, rivers, and tidal creeks.

GP37 Structures (temporary and permanent) should not impede or obstruct movement of species; individuals should not be prevented from accessing areas and habitats up and downstream of the project potentially used for spawning, foraging, resting, and migration.

GP38 Temporary scientific monitoring devices should be removed and the substrate restored to pre-construction elevations no later than 24 months from initial installation, or upon completion of data acquisition.

GP39 Monitoring devices should be used to ensure temperature and dissolved oxygen levels remain within the appropriate ranges for NOAA-trust species during project construction.

GP40 All obsolete and temporary structures and fill should be removed and areas restored to their pre-construction state. Any disturbed areas should be restored to pre-construction conditions.

GP41 All sedimentation and erosion control devices should be removed following final grading and stabilization of the project area.

GP42 In areas where listed species are expected, an observer plan should be discussed with and submitted to NMFS SERO PRD for review.

GP43 All vessels should be operated in adequate water depths to avoid scour or grounding and should travel at low speeds to avoid wake damage to shorelines and other habitats. Additional precautions, such as operating at no-wake speeds, should be taken if ESA-listed species may be present in the area.

GP44 The size/footprint of temporary rock jetties and rock platforms and time they are placed in the water should be minimized to the maximum extent practicable.

GP45 Temporary rock jetties and rock platforms should not exceed 50% of the width of the waterbody at a given time. In tidal areas, the width of the water body should be considered/measured at mean low water (MLW).

GP46 Temporary rock jetties and rock platforms that are greater than 25% of the width of the waterbody should have culvert(s) installed to allow for aquatic organism passage.

GP47 For temporary rock jetties, work at the terminal ends of the jetties should be proioritized for completion; removal of the jetties should then begin from the terminal ends to the extent practicable, working back towards the shoreline, allowing for stepwise widening of the passable opening in the waterbody.

GP48 Geotextile fabric should be placed first to ensure that any riprap from temporary rock jetties and rock platforms will be removed completely at the end of construction.

GP49 Any habitat restoration, such as restoring temporary impact areas to pre-construction conditions or removing and grading old-approach fill areas should be done by using systematic onsite surveys of pre-construction conditions and/or adjacent habitat conditions. Additionally, monitoring should occur following completion of restoration activities.

GP50 If no mitigation banks are available with credits suitable for offsetting impacts to EFH, mitigation for unavoidable impacts to EFH should occur on-site and be in-kind.

GP51 All projects should adhere to NMFS's *Sea Turtle and Smalltooth Sawfish Construction Conditions*, dated March 23, 2006. These conditions should also apply to Atlantic and shortnose sturgeon, including the requirement that construction stops temporarily if an ESA-listed species is sighted within 50 feet of mechanical construction equipment. The document can be found at: http://sero.nmfs.noaa.gov/protected_resources/section_7/guidance_docs/documents/

1.9 Conservation Recommendations

Section 7(a)(1) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. §1531 *et seq*.) directs Federal agencies to use their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. This section of the ESA makes it clear that all Federal agencies should participate in the conservation and recovery of species listed as threatened or endangered. Under this provision, Federal agencies often enter into partnerships with the NMFS for implementing or funding conservation efforts. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

Many of the recommendations below will benefit sturgeon and sea turtles, and could offset potential project impacts. The following conservation recommendations are reasonable, necessary, and appropriate to conserve and recover sturgeon, sea turtles, and Atlantic sturgeon critical habitat. These measures were developed after considering recovery actions identified in various recovery plans (e.g., Final recovery plan for shortnose sturgeon, NMFS 1998; Recovery plan for the northwest Atlantic population of the loggerhead sea turtle, NMFS and USFWS 2008). In order to keep NMFS informed of actions taken to conserve and recover sturgeon, sea turtles, and Atlantic sturgeon critical habitat, FHWA/state DOTs should notify NMFS of the implementation of any conservation recommendations.

General Conservation Measures

CM1 Preserve, restore, or enhance habitats, ecological connectivity, and normative physical processes within the stream-floodplain corridor, which could include:

CM1.1 Removing old/existing fill (embankment) and grading areas to surrounding habitat levels (e.g., floodplain wetlands). This can apply to bridge replacement projects, abandoned roadways, or other projects. For bridge replacement projects, this process would occur following new bridge construction, during demolition of the old/existing bridge.

CM1.2 Removing fill, materials, debris or other obstructions that impede or obstruct normal surface water flow into or out of any waters of the U.S.

CM1.3 Spanning water bodies and floodplains entirely to allow for long-term dynamic channel stability, floodplain connectivity, retention of existing habitat, maintenance of food (primary producers and benthic invertebrate) production, and minimize risk of failure.

CM1.4 Removing culverts and replacing them with bridges that span the water body and flood plain entirely.

CM1.4 Increasing culvert size during culvert installation/repair/replacement projects to ensure culverts are sized sufficiently large enough and/or embedded deep enough into the channel to allow the natural movement of bedload, formation of a stable bed inside the culvert, and tohandle various flows (e.g., minimum flows, storm flows). Culverts sized approximately 1.2 times bank full width are typically acceptable. FHWA should develop culvert plans in cooperation with NMFS to accommodate site-specific conditions.

CM2 Preserve, restore, or enhance overall water quality (e.g., dissolved oxygen levels, temperature profiles) by reducing contaminants and pollutants (including thermal pollution).

CM2.1 Bridge and other roadway stormwater collection and treatment systems should be used to reduce or, if possible, remove point and nonpoint sources of contaminants, nutrient loads, sediments, or thermal effluents. Small increases (above the minimum necessary) in the capacity and number (and size for solids) of targeted pollutants of stormwater collection and treatment systems may have disproportionately large positive impacts on water quality.

CM2.2 Impacts to natural riparian buffers should be avoided. Where possible, large riparian buffers should be avoided (protected) during the design phase of projects. During construction, protected riparian buffers should be marked with signs and flagging to avoid any potential impacts.

CM3 Minimize vessel strikes to sturgeon and sea turtles during and after construction.

CM3.1 Measures such as protected areas, no motor zones/idle zones, or speed regulations should be considered for specific areas as appropriate. Temporary (during construction) and permanent (post-construction) signs may be placed on/under bridges in specific areas if deemed appropriate. FHWA/state DOTs should collaborate with NMFS to identify potential areas of high vessel interaction.

CM3.2 All docks, piers and bridges in areas where sea turtles are present should be posted with signs about the risk of sea turtle vessel strikes and contact information for the sea turtle stranding network.

CM3.3 Information about the risk of vessel strikes should be easily acquired by the public through websites and other outlets.

Noise

CM4 Determine ambient noise levels in a variety of in-water settings through NC, SC, and GA. For instance, determine the ambient noise levels of the Atlantic Intracoastal Waterway compared to open water environments and tidal creeks.

CM5 Pile Driving: To better understand the cumulative effects of noise from pile-driving and cast-in-place (augering) activities, FHWA/state DOTs should conduct independent studies to characterize all aspects of noise-producing construction activities (such as pile driving) in the states of NC, SC, and GA. The study should characterize both specific sources of noise as well as ambient noise measurements in various areas throughout the states. Major noise-producing activities should be identified and measurements of noise from these activities should be recorded and reported in appropriate units of measurement (e.g., peak levels, cSEL, RMS) to estimate the acoustic footprint of the activities, duration, frequency, and relative contribution to ambient noise levels in the states of NC, SC, and GA. Methodologies of field measurements should be coordinated with NMFS personnel. Such data would help quantify the relative contribution of pile driving and cast-in-place (augering) activities on ambient noise levels, compared to other known sources, and could be used to conduct cumulative impact analyses in NC, SC, and GA waters. Following completion of any studies, FHWA/state DOTs should hold a FHWA/DOT/NMFS workshop with industry representatives to cooperatively discuss the results of any studies and identify any technology- or method-based recommendations to reduce ambient noise in the marine environment, and any other future actions that may be necessary to reduce noise impacts from in-water construction activities in NC, SC, and GA.

Outreach, Research, and Education

CM6 Engage in public outreach and education on sea turtles, sturgeon, and Atlantic sturgeon critical habitat, in an effort to minimize interactions, injury, and mortality. Use educational/interpretive exhibits and signs on FHWA/state DOT bridges and piers, where appropriate.

CM7 Provide funding to conduct directed research that will help further our understanding of both sturgeon species.

CM8 Conduct or support surveys (e.g., side-scan sonar) within Atlantic sturgeon critical habitat to determine coverage/distribution of suitable spawning habitat.

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2 Erosion, Turbidity, and Sedimentation

2.1 Introduction

Sediments are important components of biogeochemical cycles and are natural and important to element cycling in rivers, streams, lakes, and coastal ecosystems (Nichols 1999; Kemp et al. 2011). Organic and inorganic sediment particles are both natural and fundamental components of all aquatic ecosystems and are essential to habitat heterogeneity and ecological functioning (Wood and Armitage 1997; Yarnell et al. 2006). Eroded or disturbed sediments are transported by rivers to estuaries and the oceans, which represent important pathways in the global biogeochemical cycle. The erosion-deposition cycle is a biogeochemical process that includes sediment erosion, suspension (turbidity), transport, and deposition (sedimentation). These natural processes occur on land and in, and adjacent to, aquatic environments. Erosion, turbidity and sedimentation are defined as follows:

> *Erosion*: Erosion is the wearing away of the land surface by water, wind, ice or other agents that abrade, detach and remove soil or other material from one point [and deposit it at another point]. Accelerated erosion is used to describe erosion in excess of natural rates, usually as a result of anthropogenic activities (Soil Science Society of America 2008). Biotic or abiotic factors, as well as natural or anthropogenic agents or processes, can cause erosion. Erosion can occur on any natural surface or material, but erosion of banks and shorelines of lotic systems (rivers and streams) and estuaries are most relevant to FHWA/state DOT activities and NOAA-trust resources. Erosion is a general term encompassing a wide variety of mechanisms and subtypes. Scour is a type of erosion defined as the removal of granular bottom or bed particles by hydrodynamic forces.
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> *Turbidity*: Turbidity is a decrease in the transparency of a solution due to light attenuation from scattering and reflection of incident light primarily caused by suspended particulate matter. Turbidity causing materials can include inorganic particles (sediments) such as silts and clays, and organic particulates including phytoplankton, leaf litter and other non-living detritus (Kirk 1994). Water with finer suspended particles transmits less light than water with coarse suspended particles because smaller particles can occur in greater densities and have a larger surface area to scatter light. Therefore, light attenuation in the water column is influenced by the amount of suspended sediments and the composition and particle size of the particulate matter (Cho 2007).
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> *Sedimentation*: Sedimentation is the process of sediment deposition. In aquatic environments, materials are introduced and transported through a system, eventually settling out of the water column. Heavier inorganic particles typically settle out first, while lighter, organic particles usually remain in suspension for longer periods of time (Soil Science Society of America 2008).

Numerous biotic and abiotic factors play major roles in eroding, transporting, distributing sediments, and shaping the shorelines of aquatic environments. Water and wind are the primary erosional forces of land-based sediments. Once introduced into aquatic systems, currents and waves transport suspended sediments, many of which are deposited on the bottom. Lotic systems, those with flowing waters like rivers and streams, are the primary transport mechanisms for sediments (Kjelland et al. 2015). Bed load and suspended load are the primary types of sediment transport in aquatic environments. Bed load describes sediment particles that are transported along the bed, generally by sliding or rolling, and typically move at slower velocities than the flow. Suspended load refers to the suspension of small particles that are carried in the water column that move at the same velocity as the flow (Murphy and Aguirre 1985). In coastal areas characterized by estuaries, such as the U.S. Atlantic coast, rivers and streams generally do not transport much sediment to the ocean during normal flow conditions because the relatively low current speeds of estuarine waters cause particles to settle out and collect in estuaries. Additionally, estuarine circulation generally leads to up-estuary sediment transport, with many river-borne sediments becoming trapped in estuaries by the predominantly landward flow of estuarine bottom waters (Meade 1969; Maren et al. 2015). During storm-flow conditions, large quantities of sediments can be transported through estuaries, into inlets and to the open ocean, often causing numerous problems to waterway navigability (USACE 2015).

Other processes of the erosion-deposition cycle, such as the action of waves and longshore currents (longshore drift), leads to the development of sandbars, barrier islands and other geomorphic features. When waves encounter shores, they can erode or disturb sediments, which can be transported by longshore currents. Deposition of sediments on the edges of currents (where their velocity is reduced) leads to the formation of sandbars that run parallel to the shore. On larger spatial and temporal scales, this same process, combined with the stabilization of sediments by vegetation, is responsible for forming barrier islands, which are dominant geomorphic features along the U.S. Atlantic and Gulf Coasts (Hayes 2005). Human activities routinely and purposefully interfere with the longshore drift system, especially when beachfront areas of barrier islands experience severe erosion. Groins are regularly used to disrupt the natural longshore drift system (Segar & Segar 2007). Groins are shore-connected beach stabilization structures, typically made of rock, extending perpendicular to the beach from the backshore out beyond the surf zone. The purpose of the groin is to block the longshore current so that sand accumulates on the updrift side of the groin, widening the beach. However, this further depletes the sediment supply to the beach on the downdrift side, which may lead to severe erosion. A common solution to this problem is to build a series of groins, often extending the entire length of a beach (USACE 1992).

In addition to physically structuring aquatic environments and cycling nutrients and elements, sediments provide habitat for floral and faunal species that live in or among sediment particles, and live on or attached to the bottom. Sediment characteristics are important to the species composition of the benthos, as sediment particle size, organic matter composition, and other factors largely determine benthic faunal biodiversity and community composition; sediment particle size is often the primary driver of benthic diversity (Wood and Armitage 1997; Kemp et al. 2011). Benthic organisms have functional roles crucial to many ecosystem processes and are important to sustaining NOAA-trust resources (Thrush and Dayton 2002). Non-benthic species also rely on benthic habitats to carry out essential biological and ecological functions, using bottom sediments and species as sources of food, refuge, and areas for spawning, growth, and development. The relationship between benthic and other communities (e.g., water-column species), combined with the influence of environmental conditions is primarily responsible for aquatic ecosystem function (Van Son et al. 2013).

Anthropogenic alterations to the global biogeochemical cycle can transform and destroy natural habitats, which leads to alterations in species richness, abundance, community composition, and overall ecosystem function. Anthropogenic activities and alterations to the erosion-deposition cycle generally result in increased erosion, turbidity, and sedimentation in aquatic environments. Though benthic and non-benthic species are adapted to accommodate a range of sediment loads and turbidity based on the natural variability in aquatic systems, artificially altered levels of erosion, turbidity, and sedimentation from human activities are typically outside this natural range (Kemp et al. 2011). On large spatial and temporal scales, anthropogenic-induced erosion, turbidity and sedimentation increases are typically gradual, whereas rapid increases are more common on smaller temporal and spatial scales, such as near active construction or dredging sites (Fabricius 2005). The distribution, timing, frequency, and duration of anthropogenic activities and subsequent increases in patterns of erosion, turbidity, and sedimentation largely determine the level of adverse impacts on aquatic environments and species. Sustained anthropogenic stressors can drastically change aquatic communities and effects can persist long after anthropogenic activities have ceased (Harding et al. 1998; Maloney et al. 2008). High sediment loads can have a range of physical, chemical and ecological effects on aquatic ecosystems, leading to ecological responses including shifts in community assemblage and food chain structure (Wood and Armitage 1997; Kemp et al. 2011). Ecosystems under chronic stress often shift in composition to more generalist species and undergo reductions in diversity (Vitousek et al. 1997). Increased erosion into aquatic environments and increases in suspended and deposited sediments is a major environmental stressor resulting from anthropogenic activity and is recognized as a primary form of aquatic habitat degradation (Junjie et al 2014).

2.2 Effects

2.2.1 Types of Effects

Types of effects that are expected to result from increased erosion, turbidity, and sedimentation are described below. While some effects overlap, these categories are generally accepted as the environmental effects of increased erosion, turbidity, and sedimentation. Numerous effects are outlined in Chapter 1, but are discussed in detail here. Increased erosion, turbidity, and sedimentation can be viewed as stressors and effects. However, this chapter focuses on the effects from increased erosion, turbidity, and sedimentation, regardless of the route of effect or specific cause.

Anthropogenic increases in levels of erosion, turbidity, and sedimentation resulting from transportation projects can have various adverse effects on species and habitats. Unlike other stressors such as elevated noise pressure levels that are usually brief, increased erosion, turbidity, and sedimentation can occur in both the short- and long-term and have lasting impacts on species, habitats, and overall ecosystem function. Therefore, the FHWA/state DOTs should evaluate the potential short- and long-term impacts of increased erosion, turbidity, and sedimentation from proposed transportation projects.

Short-term: Short-term increases in erosion, turbidity, and sedimentation typically results from transportation project construction, maintenance, or demolition activities. For example, pile driving typically results in elevated turbidity that dissipates quickly following completion or stoppage of work. Short-term increases are typically experienced for minutes, hours, or days.

Long-term: Long-term increases in erosion, turbidity, and sedimentation can result from the placement of roadways and other structures that permanently alter the erosion-deposition cycle of an area. These impacts can last throughout the lifetime and operation of a structure or roadway, typically though altered hydrodynamics of the area. For example, the placement of new piles in a waterway that results in scouring and continual sedimentation downstream represents an alteration to the erosion-deposition cycle that leads to long-term sedimentation impacts. Long-lasting operations, such as dredging, can also lead to long-term increases in erosion, turbidity, and sedimentation. Long-term increases are typically experienced for months or years.

2.2.1.1 Erosion

Increased erosion can lead to numerous adverse effects, however, many of these effects result from subsequent increases in turbidity and sedimentation. Natural erosion from gullies, slopes and other upland features are the major source of sediment introduced into rivers, streams, and coastal ecosystems (Castro & Reckendorf 1995). Accelerated erosion, or erosion in excess of natural (background) rates, results from various anthropogenic activities and is a recognized threat to aquatic organisms and ecosystems. In addition to accelerating the rates of erosion, anthropogenic activities may also alter the frequency and duration of erosion, as well as the location and distribution of erosion in a system (Soil Science Society of America 2008). Erosion resulting from anthropogenic activities typically changes shoreline and bottom habitat morphology and composition, as well as species abundance, distribution, and composition (Kemp et al. 2011). Accelerated erosion can also alter the sediment quality of an environment by delivering lower quality sediments at higher rates than occur in an undisturbed system (Castro & Reckendorf 1995). As a result, accelerated erosion and subsequent sedimentation and turbidity are drivers for a variety of in-water effects that can reduce the physical and biological function of aquatic habitats (Allan 2004; Nagy et al. 2011). Accelerated erosion (and subsequent turbidity and sedimentation) can also affect up and downstream environments, typically resulting in reduced overall ecosystem function (Allan 2004).

Streams, rivers, and estuaries depend in part on the physical and biological characteristics of their shorelines for dynamic stability. Water circulation, temperature and other characteristics of water bodies are mediated by shoreline size, morphology, composition, presence of vegetation, and other factors (Gellis et al. 2009). Human actions that lead to the alteration of these shorelines and surrounding landforms are a principal threat to the ecological integrity of aquatic systems, impacting habitat, water quality, and the biota via numerous and complex pathways (Allan et al. 1997; Townsend et al. 2003; Allan 2004). Within estuaries, shoreline erosional patterns can affect hydrography, cause sediment smothering, and baffle tidal currents that carry pelagic larvae into upper reaches of estuarine rivers (Hanson et al. 2003; ASMFC 2007). Erosional processes also have the potential to alter freshwater flows into habitats essential for eggs, larvae, and juveniles, which typically require certain salinities for proper development and survival (Johnson et al. 2008). For estuarine-dependent species, a critical phase of most life-history patterns is the passage through narrow inlets or into mouths of estuaries that connect the ocean and estuarine habitats. Inlet passages are few in number along much of the Atlantic coast of the United States and therefore serve as bottlenecks to recruitment for many species (Reyier and Shenker 2007). If erosional processes alter inlets important for passage, critical elements of fish species life history may be impacted, resulting in variation in fish maturity scheduling and timing, directly affecting annual and lifetime reproductive outputs for fishery species (Midway and Scharf 2012).

Short-term increases in erosion regularly occur because of transportation projects in NC, SC, and GA. This typically results from construction activities such as removing vegetation, disturbing soil, and redirecting drainage. Though wind and water are the primary forces (agents) of erosion, erosion by water is of primary concern related to transportation construction activities. The highest risk of increased erosion on active construction sites is following vegetation removal (clearing & grubbing) and any disturbance that exposes sediments to water. Erosional processes by water can be categorized in the following way (WSDOT 2014):

Raindrop or splash erosion: Sediment particles are displaced by raindrop impact.

Sheet erosion: Uniform layer of shallow flow that moves loose sediment particles.

Rill erosion: Concentrated flows create small eroded channels and erosive energy begins to increase.

Gully erosion: High-volume, high-velocity concentrated flows displace large amounts of sediment quickly, creating large eroded channels.

Channel or streambank erosion: Shear stress along conveyance walls removes sediment.

Mass wasting or slumping: Sediment structural failure is caused by factors such as saturation, vegetation, and sediment type.

Additionally, increased wave energy caused by construction-related vessel traffic and in-water work activities, such as pile installation, can have substantial impacts on aquatic shoreline and near-shore areas, resulting in the disturbance and loss of shoreline habitats (Klein 1997; Hanson et al. 2003). Vessel wakes can cause shoreline erosion, damage aquatic vegetation, and disturb bottom sediments, though a number of factors (e.g., water depth and wave energy) influence these processes (Klein 1997; Fonseca and Malhotra 2012). Vessel wakes have also been shown to alter sediment erosion rates over large extents, substantially exceeding those of natural wind-wave events (Fonseca and Malhotra 2012). Erosion, turbidity, and sedimentation impacts associated with vessel traffic may be most pronounced in shallow water habitats with fine sediments (Klein 1997; Johnson et al. 2008).

Long-term changes to natural erosion can also result from transportation projects, mainly the long-term placement of roadway structures. Alterations to shoreline habitats, vegetation, in-water hydrodynamics (e.g., currents and circulation), and stormwater flows (e.g., redirecting terrestrial flows and concentrating flows) can lead to chronic increases in erosion rates. Roads introduce an impervious surface into the landscape, which intercepts rain and increases runoff, carrying soil, sand, and other sediments more readily into aquatic habitats (Ziegler *et al*. 2001). However, the rate of soil erosion around roads is primarily a function of storm intensity, surfacing material, road-slope, and traffic levels. Erosion in or adjacent to aquatic habitats can be acute following heavy precipitation or chronic from road placement and maintenance activities (Hanson *et al*. 2003). For roads located in steep terrain, mass soil movement triggered by roads can occur for decades after roads are built (Furniss et al. 1991). Long-term erosion can be worsened by the loss and replacement of wetlands, which retain and slow the flow of water, with impervious surfaces that accelerate flows and contribute to higher peak flows. Additionally, the placement of in-water structures can lead to the long-term scouring of bottom sediments, which can lead to chronic turbidity and sedimentation problems (Johnson et al. 2008).

2.2.1.2 Turbidity

Turbidity is a measure of the cloudiness or haziness of a water body and can be influenced by concentrations of suspended sediments, organic and inorganic compounds, particle size, and hydraulic conditions (Wilber and Clarke 2001). Organic and inorganic suspended particles naturally occur in aquatic systems, primarily resulting from erosion, disturbance (resuspension), and primary productivity. Suspended sediment concentrations are best measured directly as total suspended sediments (TSS) in mg/L, but indirect measurements using nephelometric turbidity units (NTUs) are often used. Indirect measurements of suspended sediments are often generally referred to as “turbidity measurements,” however, turbidity is a general term, and can be expressed in various forms, including NTU. When evaluating and analyzing potential impacts of transportation projects, turbidity is typically measured as TSS, expressed in mg/L. Suspended sediment concentrations, expressed in mg/L, are easily compared across studies, whereas turbidity measures are not.

Elevated levels of turbidity reduce the transmission and penetration of light through water by absorbing and scattering light. This can result in various environmental effects, including decreased photosynthesis and increased absorption of heat energy. Decreased photosynthesis (decreased primary productivity) can directly impact dissolved oxygen levels (Berry et al. 2003), while elevated heat energy can raise water temperature and further reduce dissolved oxygen levels (Ryder and Pesendorfer 1989). In-water and near-water construction activities, including pile installation and removal, culvert-related activities, and dredging activities are the primary transportation activities that result in elevated turbidity in aquatic environments (Castro & Reckendorf 1995).

Although aquatic organisms are adapted to a range of naturally occurring suspended particles, artificially elevated levels outside the normal range of variation can interrupt migration, foraging, spawning, or other essential life-cycle elements (Johnson et al. 2008). Additionally, turbidity may cause direct or indirect physical injury, behavior modifications, and can lead to mortality. Increases in suspended sediment loads, frequencies, and timing of events are often related directly to anthropogenic activities (Kjelland et al. 2015). Elevated turbidity resulting from human activities is typically caused by excess inorganic particles (e.g., sand and silt) that have been introduced or re-suspended in the water column, but human activities can also lead to increased suspended organic particles (e.g., eutrophication).

Effects of elevated turbidity on species and habitats can range from the individual level (e.g., spawning success) to the ecosystem level (e.g., decreased species richness), and interact on various spatial and temporal scales (Chapman et al. 2014). Kjelland et al. (2015) presents a comprehensive review of the potential effects of suspended sediment on fishes. Here we summarize the work presented in Kjelland et al. (2015), while including discussions on the potential effects of suspended sediment on invertebrates, sea turtles, and habitats. The effects of turbidity are influenced by various factors, including the physical parameters of sediment particles and plumes (e.g., frequency and duration) as well as the life stage, life history, sediment tolerance, and occupied niche of a species and tolerance of the habitat.

Behavior and movement

If species are disturbed by conspicuous sediment plumes or generally elevated suspended sediment concentrations in the water column, they will likely move away from or out of an area of higher concentration to an area with lower concentration. Fish and sea turtles have the ability to move further away from these areas more quickly than sessile or less mobile species; mobile invertebrate animals (e.g., shrimp) can also move away, though not as quickly. Therefore, the majority of species will experience sub-lethal effects, like stress, rather than lethal effects. Physiological and behavioral adjustment and avoidance are the primary stress pathways resulting from elevated turbidity. These can include social disruption, disruptions to migratory, spawning, and feeding patterns, displacement of organisms, predator-prey interactions, and intraspecific aggression (Kjelland et al. 2015). There are few studies that document, in-situ, the ability of fish to avoid suspended sediment plumes, but Carlson et al. (2001) documented numerous behavioral modifications of salmonids in response to dredging associated plumes, including changes in habitat use and timing. Behavioral adjustments could lead to various negative impacts, such as increased predation, increased energy expenditure, cessation of feeding, and breeding, or disruptions of other basic biological functions. Mobile species may leave an area for more suitable foraging or spawning grounds, or avoid migration paths because of elevated turbidity (Hanson et al. 2003). Overall, the behavior and movement of species in relation to elevated suspended sediment will depend on numerous factors, including the "perceived" options in the water body and the motivational state of individuals during elevated suspended sediment events (Kjelland et al. 2015).

Foraging and predator-prey interactions

Elevated levels of turbidity can change foraging behaviors and alter foraging success by making prey less visible. Elevated turbidity can disrupt foraging activities and decrease foraging efficiency, though this depends on the foraging strategy of a species (Robertis et al. 2003). In some cases, turbid environments benefit some species and life stages, due to the decreased ability of visual predators. However, it is more common for species to experience adverse effects in the context of foraging and predator-prey interactions from elevated turbidity (Kjelland et al. 2015).

Foraging success in environments with elevated turbidity is largely dependent upon an organisms' sensory capabilities and adaptive strategies. However, even turbidity-tolerant species have been shown to experience decreased feeding behavior (e.g., feeding rate) as sediments in a system increase (Chapman et al. 2014). Additionally, slight increases in suspended sediments can have negative impacts on turbidity-sensitive species, with low turbidity levels reducing the overall efficacy of foraging and prey captures in turbidity-sensitive species (Bash et al. 2001; Kemp et al. 2011). The majority of literature focuses on water-column species, but species that forage on or near the benthos appear to be impacted by elevated turbidity more than species that forage within other sections of the water column (Kjelland et al. 2015). Furthermore, bottom-foraging species have been shown to experience high mortality compared with other species with greater foraging plasticity during acute elevated turbidity conditions, likely resulting from reductions in benthic food sources (Sullivan and Watzin 2010). Atlantic and shortnose sturgeon are bottom-dwelling omnivorous benthic feeders that filter quantities of mud along with their food. Adult sturgeon diets including various benthic vertebrates and invertebrates, while juvenile sturgeon typically feed on aquatic insects and other invertebrates (ASSRT 2007). Due to this feeding strategy, both sturgeon species may be adversely impacted by elevated levels of suspended sediments, more so than generalist and water-column species. Other predator-prey interaction modifications have been shown to result from increased turbidity, including decreased predator avoidance behaviors and declines in reaction distance to predators with increased turbidity (Robertis et al. 2003; Kemp et al. 2011).

Physical impacts and physiological stress

Prolonged direct exposure to high concentrations of suspended sediments can impact the anatomy and physiology of aquatic organisms. Prolonged exposure can cause gill and eye abrasion in fish, and likely results in similar impacts to sea turtles (eye) and invertebrates (gill), though research is lacking for these taxa (Wilber et al. 2005). In fish, prolonged exposure can result in increased mucus production, decreased oxygen transfer and respiratory distress. Reduced oxygen concentrations and increased water temperatures may be cumulative stressors that exacerbate the effects of respiratory distress on fish from extended exposure to high concentrations of suspended sediments (Nightingale and Simenstad 2001; Wilber et al. 2005; Johnson et al. 2008).

Though less common than sub-lethal impacts, direct mortality can result from acute concentrations of suspended sediments. During short term, episodic events, concentrations of suspended sediments can be greater than several thousand mg/L, with the highest concentrations of suspended sediments typically experienced nearest to the source of the event (Kjelland et al. 2015). Life stage of the organism is an important factor determining the type and level of impact, especially mortality, related to suspended sediments (e.g., egg, larval, juvenile and adult fish experience differential impacts of suspended sediments). Additionally, other differences in life stages across species, such as egg forms (i.e., demersal adhesive eggs, demersal semi-buoyant eggs and pelagic eggs) will also affect exposure and response; demersal adhesive eggs are generally impacted most by suspended sediments (Wilber and Clarke 2001). The eggs and larvae of nonsalmonid estuarine fishes exhibit some of the most sensitive responses to suspended sediment exposure of all taxa and life history stages for which data were available in a review conducted by Wilber and Clarke (2001). Reduced survival has been shown in larval striped bass and yellow perch during two to four day exposures of 2500 mg/L. Additionally, concentrations of 1000 mg/L affected the hatching success of striped bass and yellow perch, but lower concentrations had little or no impact (Wilber and Clarke 2001). American shad larvae were shown to be less tolerant than larval striped bass and yellow perch, showing reduced survival after two to four days of exposure to 1000 mg/L (Auld and Schubel 1978). In a study of pacific herring embryonic development and early larval life stages, concentrations of 250-500 mg/L for two to four days led to both lethal and sub-lethal effects (Griffin et al. 2009). According to Wilber and Clarke (2001), hatching is delayed for striped bass and white perch eggs exposed for one day to sediment concentrations of 800 and 100 mg/L, respectively. Additionally, Atlantic silversides and white perch are among the estuarine fish with the most sensitive lethal responses to suspended sediment exposures, exhibiting 10% mortality at sediment concentrations less than 1,000 mg/L for durations of 1 and 2 days, respectively (Wilber and Clarke 2001).

Other studies of the effects of turbid water on fish suggest that concentrations of suspended solids can reach thousands of milligrams per liter before an acute toxic reaction is expected (Burton 1993). In these studies, TSS levels have been shown to have adverse effects on fish at 580 mg/L for the most sensitive species, with 1,000 mg/L more typical; see summary of scientific literature in Burton 1993). Additionally adverse impacts to benthic communities have been shown at 390 mg/L (EPA 1986)). *Table 2.1* outlines and describes suspended sediments for some activities typically associated with transportation projects.

Table 2.1 Extent, Magnitude and Duration of Elevated Turbidity Associated with Specific Activities

2.2.2 Action	**2.2.3 Turbidity Effects**
Hopper Dredging	Near-bottom turbidity plumes caused by hopper dredges may extend approximately 2,300 to 2,400 feet downcurrent from either side of the dredge, and approximately 1,000 feet behind the dredge the two plumes merge into a single plume (USACE 1983). Suspended solid concentrations may be as high as several tens of parts per thousand (ppt; grams per liter) near the discharge port and as high as a few parts per thousand near the draghead. In a study done by Anchor Environmental (2003), nearfield concentrations ranged from 80.0-475.0 mg/L. Turbidity levels in the near-surface plume appear to decrease exponentially with increasing distance from the dredge due to settling and dispersion, quickly reaching concentrations less than one ppt. Studies also indicate that in almost all cases, the vast majority of resuspended sediments resettle close to the dredge within one hour, and only a small fraction takes longer to resettle (Anchor Environmental 2003).
Cutterhead Dredging	Based on a conservative total suspended sediment (TSS) background concentration of 5.0 mg/L, modeling results of cutterhead dredging indicated that elevated TSS concentrations (i.e., above background levels) would be present throughout the bottom six feet of the water column for a distance of approximately 1,000 feet (USACE 1983). Based on these analyses, elevated suspended sediment levels are expected to be present only within a 1,000-foot radius of the location of the cutterhead dredge. Turbidity levels associated with cutterhead dredge sediment plumes typically range from 11.5 to 282.0 mg/L with the highest levels

	detected adjacent to the cutterhead dredge and concentrations decreasing with greater distance from the dredge (Nightingale and Simenstad 2001).
Mechanical Dredging	Suspended sediment levels from conventional mechanical clamshell bucket dredging operations have been shown to range from 105 mg/L in the middle of the water column to 445 mg/L near the bottom (210 mg/L, depth-averaged) (USACE 2001). Furthermore, a study by Burton (1993) measured turbidity levels 500, 1,000, 2,000 and 3,300 feet from dredge sites in the Delaware River and were able to detect turbidity levels between 15 mg/L and 191 mg/L up to 2,000 feet from the dredge site. Based on these analyses, elevated suspended sediment levels of up to 445 mg/L may be present in the immediate vicinity of the clamshell bucket, and suspended sediment levels of up to 191 mg/L could be present within a 2,000-foot radius from the location of the clamshell dredge.
Pile Driving	The installation of piles will disturb bottom sediments and may cause a temporary increase in suspended sediment in the action area. Using available information, we expect pile driving activities to produce total suspended sediment (TSS) concentrations of approximately 5.0 to 10.0 mg/L within approximately 300 feet of the pile being driven (FHWA 2012). The small resulting sediment plume is expected to settle out of the water column within a few hours.

The information reflects general guidance from the available literature. Effects of the actions may vary based on site specific conditions. If information is available on how conditions (e.g., currents) and material (e.g., sand versus silt) may influence turbidity at a site, action agencies and applicants should consider it in addition to the general guidance provided. Testing how local conditions may influence turbidity so that site-specific information may be used in the consultation is encouraged. Adopted from the Great Atlantic Regional Fisheries Office of NOAA-NMFS.

Resisting stressors and mounting stress responses are energetically costly, and the energy required to deal with the stress must be reallocated, generally in the form of increased oxygen consumption and metabolic rate (Kjelland et al. 2015). Several studies have found that increased levels of turbidity can elicit primary stress responses by increasing blood cortisol levels. These can result in changes in other blood constituents, heart rate, metabolism, and osmoregulation (Kjelland et al. 2015). For example, Berli et al. (2014) observed changes in metabolic parameters associated with swimming performance for fish exposed to suspended sediment; in general, as turbidity increased, swimming performance decreased. Overall, stress responses lead to lowered resistance to disease, slow growth rate, and change in behavior, which can all result in increased mortality. Furthermore, reproduction is a primary life history stage impacted by stress. Increased sediment loads can cause physiological, bioenergetic and behavioral alterations, which may in turn impact egg quantity or quality and embryo development in fish (Bash et al. 2001).

Though most studies focus on fish species, invertebrates are also negatively impacted by stressors. Stressors in aquatic environments, including reduced oxygen levels, have been shown to lead to reduced osmoregulatory capacity and increased mortality in shrimp during the molt cycle (Mugnier and Soyez 2005). Additionally, sub-lethal stressors have also been shown to increase the susceptibility of shrimp to bacterial diseases and viruses (Cheng et al. 2002; Lehmann et al. 2016). The immune response of shrimp are influenced by water quality variables such as temperature and salinity, and activities that diminish water quality can lead to increase disease susceptibility (Legmann et al. 2016). Additionally, increases in suspended sediments could lead to direct abrasion and interference with respiration and feeding (ingestion) in shrimp and other invertebrates. However, numerous studies investigating the direct impacts of suspended sediments on shrimp showed that suspended sediment concentrations exceeding 10,000 mg/L were necessary to elicit mortality (mortality levels less than 25%) (Wilber and Clarke 2001).

Sea turtles appear to be resistant to the direct effects of elevated turbidity levels from transportation projects, aside from rare instances (e.g., eye abrasion). Turbidity could impact movement patterns and migrations of sea turtles, though this has not been studied directly. The primary impacts of turbidity on sea turtles results from impacts to the fish, invertebrates, and other species that make up the prey base for many sea turtles. As described above, turbidity can impact the distribution, abundance and diversity of prey species by altering movement and habitat utilization patterns. Additionally, for sea turtle species that forage on aquatic plants, increased turbidity decreases photosynthesis, which can reduce primary productivity, and could reduce the distribution and abundance of aquatic plants.

Habitat Effects

Habitat effects resulting from suspended sediments in the water column include decreased light transmittance, decreased primary productivity, and dissolved oxygen levels. Additionally, elevated levels of suspended sediments raises the water temperature, as sediment particles absorb heat energy. Habitats with high turbidity provide little value to species, because mobile species will move away from areas with high sediment levels, eliminating the opportunity to breed, feed, shelter or carry out other essential biological functions within those habitat areas (Kjelland et al. 2015). Elevated turbidity can reduce diversity and densities of benthic invertebrate, which are prey for many NOAA-trust species, and further reduce the value of the habitat. For oysters and oyster reefs, which are designated EFH-Habitat Areas of Particular Concern (HAPC); high concentrations of suspended sediments have been suggested to interfere with the feeding apparatus. However, because oysters occur in naturally turbid environments, they have adapted a filtering mechanism to separate inorganic particulates from food in suspension (Wilber and Clarke 2010).

Short- and Long-term Impacts

Short- and long-term increases in suspended sediments in the water column can result from various activities. The majority of construction, maintenance, and demolition activities will result in short-term increases in the form of ephemeral sediment plumes. However, permanent placement of roadway structures can result in long-term increases in erosion and changes to hydrodynamics and flows, which can lead to chronic elevated turbidity. Chronic exposure to elevated levels of turbidity can have a cascade of negative impacts on species and habitats, which can result in decreased species abundance and diversity and degraded habitat and ecosystem function (Wilber et al. 2005).

2.2.3.1 Sedimentation

Anthropogenic changes to natural rates of sedimentation can lead to numerous negative effects to aquatic systems. These can include reduced hydraulic retention, reduction or loss of stream-floodplain connectivity, loss of habitat heterogeneity, and reduction in organic matter retention and stable substrate (Allan 2004). Furthermore, the sedimentation (burying/covering) of individual organisms and habitats and changes in benthic environments via alteration to sediment quality, quantity, and changes in grain size can reduce species diversity and decrease overall ecosystem function (Thrush and Dayton 2002). Direct physical injury and mortality, and covering or burying, are the primary effects of sedimentation. Additionally, particle size is one of the main drivers of benthic faunal biodiversity and community composition; therefore, changes to sediment composition can affect the benthic prey resources of NOAA-trust resources (Wood and Armitage 1997).

The direct physical injury and mortality from sediment deposition on species can result from direct burying or covering. Many adult organisms are highly mobile and can move away from deposited sediment rapidly, minimizing the impacts of sediment deposition. However, if sediment deposition is rapid and deep (e.g., dredge disposal), there is little opportunity for species to move away, leading to direct burial and mortality (Kjelland et al. 2015). In general, early life history stages (eggs, larvae and juveniles), benthic organisms (e.g., shrimp), demersal fish (e.g., sturgeon) and sessile organisms (e.g., oysters/oyster reefs) are the most sensitive to sedimentation effects; even thin layers of deposited sediments (0.5-1.0 mm thick) can result in mortality (Wilber et al. 2005). Sedimentation may result in mechanically crushing or smothering organisms or lead to anoxic conditions that result in mortality or sub-lethal effects (Hanson et al. 2003; Kjelland et al. 2015). Short-term burial may have little impact, if sediments are promptly removed by tides or storm events, but even thin layers of fine sediment have been shown to decrease gas exchange in fish eggs and adversely affect the settlement of bivalve larvae (Wilber et al. 2005; Johnson et al. 2008). Human-induced sedimentation can require organisms to reallocate energy away from other important life history functions to survive the event, like escaping burial. Some sessile organisms can accommodate small levels of sedimentation, though increased sedimentation and turbidity has been shown to increase disease prevalence among sessile species (Pollock et al. 2014). Additionally, sedimentation impacts to oysters and oyster reefs, which are designated EFH-habitat areas of particular concern (HAPC), is well studied. Oyster recruitment can be affected by sedimentation because larval oysters settle on hard substrates and prefer to settle on adult oyster shell. Additionally, juvenile and adult oysters can be buried by sediments leading to partial or total mortality; substantial sediments can lead to catastrophic losses of oyster reefs (Wilber and Clarke 2010).

Although impacts to species results from sedimentation, the primary effects from sediment deposition are to habitats. Sedimentation can reduce the quantity of available habitats by eliminating (covering and smothering) spawning, feeding and rearing grounds, refuge sites, and other areas important to various life stages (Hanson et al. 2003). Many species require specific parameters and substrate for breeding and spawning activities. For example, both Atlantic and shortnose sturgeon deposit their highly adhesive eggs on the bottom substrate, usually on hard surfaces like gravel and cobble. Covering these gravel and cobble areas with deposited sediment or altering their composition could eliminate their use as spawning areas for sturgeon (ASSRT 2007). Numerous habitats can be directly eliminated, altered or degraded from sedimentation, reducing or eliminating overall function. Transportation activities can also alter bottom sediments, bottom topography and alter circulation, which can lead to sedimentation and shoaling of benthic habitats (human activities can also directly lead to sedimentation and shoaling from the introduction of sediments). Sedimentation can also adversely impact benthic resources such as spawning and foraging grounds, and sensitive areas like submerged aquatic vegetation (SAV) and shellfish beds through changes in sediment quantity, quality and composition (Wilber et al. 2005). Additionally, the direct burial of habitats can lead to the mortality of the species that make up those habitats (e.g., oysters and sea grass). Furthermore, the distribution of infaunal and epibenthic species, which are prey for many species, can be impacted directly through changes in the composition of the substrate resulting from human-induced sedimentation (Berry et al. 2003). Sediments can fill interstitial spaces, eliminate refuge used by fish to avoid predators, create a homogeneous environment leading to lower fish densities, reduce macroinvertebrate abundance, and decrease the depth and area of pools used by juveniles and adults (Johnson et al. 2008). Overall, sedimentation leads to a decrease in the quantity and quality of habitat necessary for species to carry out essential life processes (Castro & Reckendorf 1995).

Short- and long-term alterations to natural sediment deposition can result from various activities. The majority of construction, maintenance, and demolition activities could result in acute alterations to sediment deposition that may permanently or temporarily impact resources. Permanent placement of roadway structures can result in long-term increases in altered sediment deposition from increases in erosion and changes to hydrodynamics. Chronic sedimentation can have myriad negative impacts on species and habitats, which can result in decreased species abundance and diversity and degraded habitat and ecosystem function (Wilber et al. 2005). Scouring around permanent project elements is a common long-term source of downstream or down-current sedimentation that can adversely impact species and habitats through burial, covering and elimination or degradation of habitat function (Castro & Reckendorf 1995).

2.3 Actions

Numerous actions related to transportation projects can lead to increased erosion, turbidity, and sedimentation in aquatic systems. These actions can range from surveying activities to dredging and transporting bottom sediments for disposal. Due to the breadth of transportation actions with the potential to result in increased erosion, turbidity, and sedimentation, a list of actions/activities is provided along with the likelihood that the action/activity will result in increased erosion, turbidity, or sedimentation. The FHWA/state DOTs can use *Table 2.2* to aid in evaluating their potential project impacts and use the BMPs outlined in Section 4 to avoid and minimize those impacts. *Table 2.2* addresses regularly occurring activities, but does not represent a complete list of activities that could result in increased erosion, turbidity, and sedimentation. The FHWA/state DOTs should use the information provided herein, their expertise, and other sources to evaluate potential impacts from activities that appear in *Table 2,* as well as other activities that may lead to erosion, turbidity, or sedimentation.

The underlying assumption of *Table 2.2* is that the actions/activities take place in or directly adjacent to lotic systems, estuaries or marine environments.

Table 2.2 Project Actions and Activities Resulting in Increased Erosion, Sedimentation and Elevated Turbidity

Project Action/Activity	**Likelihood of Erosion, Turbidity and Sedimentation Impacts**
Minor vegetation removal	Very Low
Human & vehicle activity	Very Low
Constructing and using temporary access roads	Low
Installing stormwater BMPs	Moderate
Placement of barges & crane/barge/timber mats	Moderate
Use of drill rigs (rubber-tire & tracked) and/or propeller-driven machinery	High
Geotechnical drilling (surveys)	High
Clearing and grubbing	Moderate
Removal of structures/obstructions (land)	Low
Roadway/drainage excavation (land)	Low
Grading and shaping (land)	Low

Removal of structures/obstructions (water)	Moderate
Grading and shaping (shoreline and/or intertidal)	High
Fill placement	Moderate
Piling and footing installation	Moderate
Piling removal (cutting, direct pull, hammer)	High
Blasting (pile removal, excavation)	High
Vessel traffic/activity	Low
Dredging (underwater excavation; removal of bottom sediments)	Very High
Placement and removal of spuds; "spudding"	Moderate
Culvert removal/replacement	Very High
Removal of failing shoreline stabilization	High
Placement of new shoreline stabilization	Moderate
Water diversions/pump-outs/dewatering	High

The information in the table is primarily based on project-related experience and peer-reivewed and technical literature. Some actions (e.g. dredging) have extensive literature and are described herein.

Numerous variables influence the impacts resulting from individual projects. The distribution, timing, frequency, and duration of activities will largely determine the level of increased erosion, turbidity, sedimentation, and subsequent impacts to resources. Additionally, species-specific traits and environmental variables will also influence the erosion, turbidity, or sedimentation impacts resulting from a project or its activities. Environmental variables include the hydrodynamics of an area, shoreline morphology, and sediment composition. Therefore, each project must be evaluated on a case-by-case basis.

Table 2.2 generally focuses on short-term increases in erosion, turbidity, or sedimentation caused by transportation-related construction, maintenance, or demolition activities. However, FHWA/state DOTs should also evaluate potential long-term impacts that result from projects. Some activities have the potential to result in both short- and long-term impacts, such as the construction and installation of piles and dredging. Short-term increases typically result from construction activities while long-term increases primarily result from alterations to shorelines and the hydrodynamics of an area, which can lead to long-term scouring. Because dredging and dredge material disposal are significant causes of increased erosion, turbidity, and sedimentation, dredging operations are described in detail below.

2.3.1 Dredging

Dredging is defined as underwater excavation and involves removing bottom sediments from the aquatic environment. Dredging is typically done to create or maintain waterways to support navigation, vessel access to channels, ports, and marinas. Dredging can also consist of removing debris, sediments, or other obstructions from the aquatic environment. For transportation projects, dredging is typically used to gain access to project sites and remove sediments to place piles.

2.3.1.1 Mechanical Dredging

Mechanical dredges remove bottom sediments by direct application of mechanical force to dislodge and scoop the sediments from the bottom. Mechanical dredges are primarily used for smaller sites; clamshell dredges (buckets) and excavators are the most common mechanical dredges. Clamshell dredges employ a vertical loading grabber connected to wire rope, which is lowered in the open position into the sediment, closes around the sediment load, and is raised above the water to be deposited into a barge. Clamshell dredges operate from atop barges, which are moved or positioned using spuds. Barges are typically equipped with three spuds: two forward and one aft.

Excavator dredging involves a backhoe excavator that uses its bucket to remove sediments from beneath the water line, bring the sediments to the surface in the open bucket, and deposit the sediments, typically on the shoreline or in a barge or truck. This is a common method of dredging associated with transportation projects. Excavator dredging can occur from the shoreline or from atop barges. Barges used for excavator dredging are typically configured with spuds in the same way as clamshell dredges.

2.3.1.2 Hydraulic Dredging

Hydraulic dredges remove bottom sediments by suction force and the sediments are pumped away from the site in liquid slurry form. Hydraulic dredges are typically used for larger sites; cutterhead/pipeline and hopper (suction) are the two common hydraulic dredges. Cutterhead dredges are equipped with rotating cutter apparatuses that surround the intake end of a suction pipe. The rotation of the cutterhead breaks up bottom sediments and facilitates the pumping of the sediment water slurry through the pipe. The pipeline discharges dredged material directly to a disposal site, which enables continuous work. Cutterhead dredges are the most common dredge in the U.S. Cutterhead dredges are typically held in position and advanced with spuds.

Suction or hopper dredges suck dredged material from the bottom through long intake pipes, called drag arms, and store it in hoppers. Hopper dredges are self-propelled ships with large hopper bins (“hoppers”; containment areas) that are fitted with powerful pumps to facilitate the suction process. Dredging stops when the hoppers are full and ships must dispose (in-water) of the dredged material. Hopper dredges are typically viewed as the dredging method with the highest potential to adversely affect species, including ESA-listed species. Because of high rates of listed-species takes in the 1990s resulting from hopper dredging projects, NMFS developed a regional biological opinion concerning the use of hopper dredges in channels and borrow areas along the Southeast U.S. Atlantic coast (referred to as SARBO, 1997). The biological opinion includes a number of conservation recommendations to protect species. SARBO is currently used (applicable/precedent) for hopper dredging projects in the Southeast region.

2.3.1.3 Knockdown/Bed-leveling

Knockdowns employ an I-beam or similar equipment to redistribute shoaled sediment into deeper areas within dredging sites. This method is typically employed for smoothing the bottom after conventional dredging, and for managing localized mounds of sediment. Knockdowns are commonly used for shoaling in ports and marinas.

2.3.1.4 Disposal

Sediments that are removed from below the water surface during the dredging process must be transported and disposed of. Dredged material may be deposited in several location types, depending on purpose, need, permitting, and other factors. On-site disposal is typically used if dredged material is intended to be used as fill material; the use of off-site dredge disposal sites is also common. Beneficial use of dredged material is encouraged, provided the sediments meet certain physical, chemical and biological criteria.

2.4 Recommended Best Management Practices

Implementing recommended best management practices (BMPs) will aid FHWA/state DOTs in avoiding and minimizing impacts to NOAA-trust resources by reducing the exposure of species and habitats to stressors and eliminating the plausible routes of effects. Projects that cannot avoid or sufficiently minimize impacts to species or habitats may need to implement compensatory mitigation/measures. Though a comprehensive list of BMPs is provided, innovative techniques and methodologies may lead to the development of additional BMPs, but their use should be coordinated with NMFS on a case-by-case basis.

The BMPs are discretionary measures that transportation agencies can incorporate during project planning to avoid and minimizing potential impacts to NOAA-trust resources. The BMPs provide more transparency and predictability to FHWA and State DOTs regarding species conservation, habitat needs, and NMFS' recommendations. Frontloading BMPs into early design phases of projects will likely lead to reduced consultation timeframes, reduced delays, and could reduce the potential for future redesign of projects. Many BMPs can be incorporated into the design of projects, while others may be addressed as environmental commitments for contractors.

State DOTs have sediment and erosion control specifications and standards that typically address a number of stressors and effects.

***** *All best management practices related to structural project components and construction techniques are contingent upon engineering feasibility and other design considerations.*

2.4.1 General Erosion, Turbidity, and Sedimentation

ETS1 Project elements should be located in ways that avoid and minimize long-term alterations to erosion, turbidity, and sedimentation; in-water project elements (e.g., pilings) should be placed in areas that avoid or minimize long-term scour (e.g., piles should not be placed in the center of channels).

ETS2 The amount and extent of erosion, turbidity, and sedimentation should be avoided and minimized by using appropriate controls such as sediment control fence, silt curtains, settling basins, cofferdams, isolation casings, and operational (equipment and timing) modifications; all measures to be used should be specified in construction plans.

ETS3 Stormwater BMPs should be used in accordance with National Pollution Discharge Elimination System (NPDES) Stormwater Pollution Prevention Plans (SWPPP) and other local/regional/state guidelines.

ETS4 When working in, or adjacent to, sensitive habitats such a submerged aquatic vegetation (SAV) or shellfish/oyster areas, multiple erosion, turbidity, and sedimentation controls should be used to minimize or avoid habitat impacts.

ETS5 To the maximum extent practicable, erosion control measures should be installed prior to ground-disturbance; erosion control measures should be used on any disturbed land not actively under construction (e.g., temporary seeding).

ETS6 Erosion and sediment control measures should be surveyed regularly for deficiencies. All deficiencies should be repaired or replaced immediately.

ETS7 Pumping turbid (sediment-laden) water directly into receiving waters without treatment should be avoided (e.g., settling basins, filter bags should be used).

ETS8 In intertidal areas, activities that disturb sediments should be conducted during low tide periods when sediments are exposed to reduce impacts of turbidity and sedimentation, to the maximum extent practicable.

ETS9 Aquatic turbidity and sedimentation control measures should be properly secured and monitored to ensure aquatic species are not entangled or trapped in the project area.

ETS10 Fills (temporary and permanent) should be placed in ways that will not be eroded by high water flows, storm flows, or chance (stochastic) events.

ETS11 Any fill material stockpiled for later use should be located in upland areas and surrounded by appropriate controls to avoid migration of material into nearby waterbodies.

ETS12 All erosion, turbidity, and sedimentation control measures should be promptly removed upon project completion.

ETS13 Measures to avoid tracking sediments out of the project area should be used, such as stabilized construction entrances/exits.

ETS14 Stormwater treatment facilities including ponds, swales, and retention/detention areas should be placed in low quality uplands if possible and avoid wetlands, salt marsh, tidal creek, and estuarine waters.

2.4.2 Dredging

DR1 New dredging should be avoided to the maximum extent practicable. Activities commonly requiring dredging such as the placement of piles/columns should be designed to eliminate the need for any maintenance dredging.

DR2 Dredging area and volume should be reduced to the maximum extent practicable that will still accomplish the project goal(s); areas that are within the project area, but are deeper than the target dredge depth should be avoided.

DR3 Dredge disposal sites should be appropriately considered (using the volumes of proposed dredged material) prior to dredging so disposal sites will adequately contain dredge material.

DR4 For maintenance dredging, sources of erosion in the watershed should be identified that may be contributing to excessive siltation and sedimentation and the need for maintenance dredging. To the maximum extent practicable, techniques or programs should be implemented that reduce erosion and sedimentation.

DR5 Silt or turbidity curtains should be used during dredging to reduce the impact of suspended sediments and potential for siltation of adjacent habitats.

DR6 For any dredging operations conducted during sea turtle nesting and emergence season, all lighting aboard dredging vessels/equipment near sea turtle nesting beaches should be limited to the minimum lighting necessary to comply with U.S. Coast Guard and/or Occupational Safety and Health Administration requirements. All non-essential lighting on dredging vessels/equipment should be minimized through reduction, shielding, lowering, and appropriate placement of lights to minimize illumination of the water to reduce potential disorientation effects on female sea turtles approaching the nesting beaches and sea turtle hatchlings making their way seaward from their natal beaches.

DR7 To the maximum extent practicable, dredging should be avoided in areas with fine sediments to reduce turbidity plumes and the release of nutrients and contaminants.

DR8 To the maximum extent practicable, dredging should be avoided in shellfish areas, intertidal and wetland habitats, in areas with SAV, areas that historically supported SAV, and areas, which are potential habitat for SAV. Surveys of historic and current SAV should be conducted to determine distribution and potential for recolonization of SAV.

DR9 To the maximum extent practicable, the use of suction/hopper dredges should be avoided.

DR10 If suction/hopper dredging is necessary, operations should be conducted in accordance with the regional biological opinion concerning the use of hopper dredges in channels and borrow areas along the Southeast U.S. Atlantic coast (referred to as SARBO).

DR11 Specialized equipment to avoid and minimize impacts to species should be used during dredging activities. These include, but are not limited to, sea turtle deflector dragheads and floating pipelines. Inflow screening baskets should be installed to monitor the intake and overflow of the dredge.

DR12 Operational modifications should be used to minimize turbidity and sedimentation during dredging. This could include using an environmental bucket, reducing lift speeds, and using small diameter cutterhead dredges.

DR13 Relocation trawling or scare/deterrence methods should be used to minimize impacts to species that may be present in the dredging project area.

DR14 Beneficial uses of uncontaminated sediments should be considered whenever practicable; materials that contribute to habitat restoration and enhancement should be prioritized.

DR15 Contaminant testing should be conducted on sediments prior to dredging and disposal and should meet U.S. Environmental Protection Agency requirements and standards.

DR16 Any accessory equipment such as pipelines associated with dredging activities should be placed to avoid sensitive habitats including shellfish areas, intertidal and wetland habitats, and in areas with SAV.

DR17 All work crews and personnel should be informed about any ESA-listed species that could occur in the dredge area. An action plan (typically in the species watch plan) should be available to all personnel, which outlines their responsibilities.

DR18 Dredge disposal areas should be properly sited, managed, and monitored to avoid impacts associated with dredge material placement.

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3 Pile Installation, Removal, and Blasting

3.1 Actions

This chapter addresses the activities commonly employed during construction, maintenance, and demolition of substructures, such as piles and footings.

Substructures: Piles and Footings

Substructures include all parts of a bridge or pier supporting the superstructures (i.e., beams and deck) and include abutments, interior bents, end-bents, footings, and piles/columns. Bents support a vertical load and are placed transverse to the length of the structure. The vertical elements of a bent are columns or piles. Horizontal bent elements on top of piles are bent caps, while elements below the piles are foundations, which are categorized as shallow or deep. Shallow foundations, known as footings, are used when surface soils are sufficiently strong enough to support loads and are typically rectangular reinforced concrete structures near the surface. The bearing capacity of the soil largely determines the size of the footing.

Piles are typically made of steel, concrete, or wood (timber). Various types (e.g., pre-cast and pre-stressed, cast-in-place), shapes (e.g., cylindrical, H-piles, sheet piles), sizes and configurations of piles are used for transportation projects depending on need, site-specific conditions, and other factors. Piles are typically penetrated into the ground and are categorized as deep foundations. Piles provide support by transferring loads to deeper soil strata with higher bearing capacities. Some piles, such as metal sheet piles used for cofferdams and retaining walls, do not support a vertical load.

3.1.1 Pile Installation

Pile installation methods can be categorized as displacement or replacement. Displacement piles are driven or vibrated into the ground, displacing the surrounding soil. Replacement piles are placed or constructed within previously drilled boreholes, replacing the excavated soil. Various methods exist for displacement and replacement pile installation and a combination of methods are typically used.

3.1.1.1 Pile Driving

Pile driving is a type of displacement method using mechanical force to drive piles into substrates. Impact hammers and vibratory hammers are the most common type of pile drivers. Impact hammers use a heavy ram weight raised hydraulically or mechanically above a pile, which is then dropped or propelled onto the head of a pile to move the pile into the substrate. Cushions are typically used between the ram and the pile in order to avoid physical breakdown. Numerous types of impact hammers exist, including simple drop/gravity hammers, single and double acting compressed air, steam, or hydraulic hammers, and diesel hammers (single or double acting). Impact pile hammers produce high-intensity impulsive sounds.

Vibratory hammers vibrate piles at frequencies, which move soil particles, significantly reducing friction around the pile shaft. Electrically or hydraulically produced vibrations are transmitted from the pile to the soil, allowing for penetration. Vibratory hammers are most effective in granular soils, but can also be effective in cohesive soils. Vibratory hammers produce non-impulsive sounds. For all pile drivers, pile diameter and hammer energy are correlated; with increased pile diameters, requiring increased hammer energy.

Jetting, or water jetting, is another type of displacement pile driving method. Jetting uses high-pressure water pumps to force a hole in the bottom substrate for the placement of piles. Jetting is typically used in association with impact and vibratory hammers; jetting is typically used to begin pile installation, then a hammer is used to complete the installation.

3.1.1.2 Cast-in-Place Piles

Cast-in-place (CIP) piles are the primary type of replacement pile installation method. CIP piles are reinforced concrete piles cast on-site in holes drilled to predetermined depths. CIP piles are commonly referred to as "drilled shafts." For CIP piles in aquatic environments, steel casings are typically installed using a vibratory hammer, after which drilling takes place inside of the casing with an auger or other type of drilling equipment (e.g., drilling buckets) to the desired depth. After drilling is complete, a rebar cage is placed inside of the casing and concrete is poured into the casing; the casing is later removed. CIP piles generally produce less vibration and lower sound levels than driven piles.

3.1.1.3 Footings

Footings are constructed to support piles or columns, both of which are composed of reinforced concrete. In aquatic environments, cofferdams facilitate construction of footings (and below-water sections of piles or columns). Cofferdams are typically rectangular structures composed of steel sheet piles installed with a vibratory hammer. Once a cofferdam is in place, it is dewatered to create dry conditions and work proceeds as if on land: the soil is excavated and foundation is constructed with reinforced concrete. Piles/columns may also be constructed within the cofferdam, which is later removed

3.1.2 Pile and Footing Removal

Pile and footing removal takes place for various reasons, such as piles or footings are structurally deficient or functionally obsolete or piles are part of temporary structures. There are five general types of pile and footing removal:

Direct pull or clamshell method: Piles are typically grasped or held with an excavator bucket or clamshell bucket and are repeatedly moved or shaken until they are pulled directly out of the substrate. Piles may also break below the mudline using this method.

Pile hammer: Vibratory hammers are used to vibrate the pile in order to break the bonds between the pile and sediment and reduce friction of soil particles against the pile shaft. Piles are slowly pulled out of the substrate while being vibrated; soil will typically slough off during removal.

Cutting: Piles are cut off at, or just below, the mudline while the pile is supported from above the cut line. The portion of the pile below the mudline typically remains in the substrate.

Mechanical demolition: Piles are mechanically broken down with a bucket or other machinery (e.g., hammer) and pieces are removed from the water.

Blasting: Described below.

3.1.3 Blasting

Blasting involves using explosive charges to break-up or remove rock, reinforced concrete, or other structures for excavation, construction, or demolition purposes. Blasting charges use various explosive weights and time delays that generate high-energy impulsive sounds and pressure waves. For transportation projects, underwater blasting is typically employed to remove sub-structure components of old/existing bridges or excavate bottom sediments for the placement of new sub-structures. The most common type of blasting (above- or underwater) used in transportation projects is confined blasting, which consists of placing explosive charges into pre-drilled holes (blast holes) within a structure prior to detonation. Stemming is typically used with confined blasts and involves placing inert material into blast holes (to cover the charge) prior to detonation. Stemming material typically includes angular crushed stone or gravel. Confined blasts typically produce lower peak sound pressure levels than unconfined blasts, but surface and bottom boundaries can reflect pressure waves and create a complex series of positive and negative pressure peaks in shallow water conditions.

3.2 Stressors

3.2.1 Types of Stressors

Types of stressors generated from pile installation, removal, and blasting are outlined below. While some of the stressors overlap, these are generally accepted as the environmental stressors potentially resulting from pile installation, removal, and blasting activities and the long-term placement of structures. Detailed descriptions and explanations of stressors can be found in Chapter 1.

3.2.2 Pile and Footing Installation

Pile and footing installation generates numerous stressors through placing piles and footings and operating specialized equipment and vessels to place or construct piles and footings in aquatic environments. The primary stressors generated from these activities are elevated noise/pressure levels, increased turbidity and sedimentation, and habitat loss and degradation, specifically filling habitats and altering flow dynamics. Additional stressors generated from pile and footing installation activities include vessel interaction, decreased water quality, and resuspension of contaminants and pollutants.

3.2.3 Pile and Footing Removal

Pile and footing removal activities generate numerous stressors through removing piles and footings, operating equipment, using specialized methods to demolish piles or footings, and removing materials from the aquatic environment. Increased turbidity and sedimentation is the primary stressor generated from these activities, but elevated noise/pressure levels, habitat loss, and degradation also occur. Stressors can also include vessel interaction, decreased water quality, and the resuspension of contaminants, and pollutants.

3.2.4 Blasting

Blasting generates numerous stressors through the detonation of explosive charges and can introduce debris into the aquatic environment. Stressors include elevated noise/pressure levels, habitat degradation, resuspension of contaminants and pollutants, and elevated turbidity, and sedimentation.

3.3 Effects

3.3.1 Types of Effects

Types of effects expected to result from pile installation, removal, and blasting are described below. While some effects overlap, these categories are generally accepted as the environmental effects of pile installation, removal, and blasting activities, as well as the long-term placement of structures on NOAA-trust resources. Numerous effects are also described in Chapter 1.

3.3.2 Pile and Footing Installation; Blasting

Pile and footing installation, and blasting (for the purpose of pile installation) may adversely affect species and habitats in numerous ways, but elevated sound/pressure levels are the primary source of adverse impacts to species and habitats. These impacts are broadly categorized as hydroacoustic effects and are described in detail below. Additional effects resulting from the installation of piles and footings, and blasting are described in later sections.

Hydroacoustic Effects to Species

***Anthropogenic sounds can affect marine mammals in numerous ways, but due to the nature and location of roadway and highway projects in North Carolina, South Carolina, and Georgia, hydroacoustic effects on ESA-listed marine mammals are not discussed in this manual.**

Table 3.1 Typical Sound Levels in Underwater Estuarine and Marine Environments

Sound Source	Sound Pressure Level (dB SEL)
High explosive at 100 meters	220
Airgun array at 100 meters	200
Large ship at 100 meters	160
Fish trawler passby (low speed) at 20 meters	140

Adopted from California Department of Transportation (CalTrans), Division of Environmental Analysis. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish, November 2015.

Sounds waves, or fluctuations (disturbances) of pressure, are produced by the vibration of particles and transfer of energy between particles away from the source of the vibration. In the context of this chapter, piles installed with impact hammers are the primary source of underwater sound waves (vibrations), though CIP piles and vibratory hammers also create sound waves, as does blasting. Sound waves travel through all types of media, including solids (bottom substrate), liquids (seawater), and gases (air), and the characteristics of the sound waves will vary based on the properties of each medium, sound source, and other environmental variables. Sound in water follows the same physical principles as sound in air except that the higher speed of sound in water (approximately 1,500 m/sec vs. approximately 500 m/sec in air) results in longer wavelengths (Kalmijn 1988; Popper 2005). Decibels (dB) are the units used to express sound levels and best describe the magnitude of sound pressure levels. Peak pressure, sound exposure level (SEL), and Root Mean Square (RMS) are three metrics commonly used in evaluating hydroacoustic impacts:

**Noise in water is reference to 1 µPa while noise in air is referenced to 20 µPa due to the density differences between the two media.*

<u>Measurements of Pressure</u>

Peak Pressure: Peak pressure is the maximum positive pressure between zero and the greatest pressure of signals in units of dB re 1 μPa_{peak} or $_{0\text{-}peak}$. Peak levels are generally higher than RMS levels and often used to determine injury ranges from pressure (the peak can be an overpressure or an under pressure peak in the signal).

Root Mean Square (RMS): The square root of the average of the square of the pressure of the sound signal over a given duration in units of dB re 1 μPa_{rms}. This is often used to determine behavioral responses to audible sounds.

Measurements of Energy

Sound Exposure Level (SEL): SEL is the time cumulative sum of squares pressure divided by the duration of the sound (usually 1 second for a pile drive strike). SEL levels have units of dB re 1 $\mu Pa^2 \cdot s$ and can be used to calculate the cumulative risk to multiple exposures over time from things like repeated pile driving strikes or blasts.

Single Strike SEL (sSEL): sSEL is the amount of energy in one strike of a pile.

Cumulative SEL (cSEL): cSEL is the energy accumulated over multiple strikes or continuous vibration over a period of time; the cSEL value is not a measure of the instantaneous or maximum noise level, but is a measure of the accumulated energy over a period of time to which an animal is exposed.

The currently accepted impact pile-driving thresholds noise levels for ESA-listed species are found in *Table 3.2*. Non- ESA-listed species, including federally managed species, likely have similar injury and behavioral thresholds. The currently accepted continuous noise thresholds levels for ESA-listed species from exposure to vibratory pile-driving noise are found in *Table 3.3*. Non- ESA-listed species, including federally managed species, likely have similar injury and behavioral thresholds.

Table 3.2 Impact pile-driving threshold noise levels for fish and sea turtles.

Effect	**Animal**	**Threshold Level (dB re 1 µPa)[e]**
Physical Injury (peak pressure)	Fish & sea turtles	206 (peak pressure)
Physical Injury (cumulative exposure)	Fish & sea turtles	183 cSEL
Behavior Modification	All fish	150 (RMS)
	Sea turtles	160 (RMS)

Table 3.3 Continuous noise threshold levels for fish and turtles from exposure to vibratory pile-driving noise.

Effect	**Animal**	**Threshold Level (dB re 1 µPa)**
Physical Injury (peak pressure)	Sturgeon & Sea Turtles	206 (peak pressure)

Effect	Animal	Threshold Level (dB re 1 µPa)
Physical Injury (Cumulative exposure)	Fish larger than 0.06 grams	234 cSEL
Behavior	Fish	150 (RMS)
	Sea Turtles	160 (RMS)

There are no SEL criteria for sea turtles for continuous noises. Fish are considered more sensitive to physical injury than sea t turtles; therefore, fish thresholds are used for sea turtles as conservative interim criteria

Impact pile hammers and explosive charges are high-intensity sound sources that produce impulsive sounds, which are transient, brief, broadband, and typically consist of a high peak pressure with rapid rise time and rapid decay. Based on these physical characteristics, impulsive sounds generated from impact hammers and blasting have a greater potential to adversely affect species and degrade habitats (temporarily) than vibratory hammers and CIP piles. Non-impulsive sounds generated from vibratory hammers and CIP piles may affect species and habitats, but generally to a lesser degree. In fact, there are no established injury criteria for CIP pile installation (Caltrans 2015). Impacts from vibratory hammers (continuous sound) have only recently been considered in project impact analyses (Popper et al. 2014).

Impact hammers are typically viewed as the standard or "starting point" for pile installation effects analyses. In most cases, if the hammer type is unknown for a project, most evaluations assume an impact hammer will be used in order to analyze "worst-case" scenarios. Though impact hammers typically generate the highest sound pressure levels and energy, sound pressure levels and energy generated from all pile installation activities are dependent on numerous factors including the size and material composition of the pile, the hammer used to install the pile, and the water depth in which the pile is installed. Additionally, sound attenuates over time and distance (transmission loss), so the distance at which sound is received will also affect the potential impacts from pile installation activities. *Table 3.4* outlines various pressures and energies generated from unattenuated pile installation activities, adopted from the *Compendium of Pile Driving Sound Data* (Caltrans 2015). Additional data and scenarios can be found in the *Compendium*.

Table 3.4 Summary of Typical Near-Source Unattenuated Sound Pressure Levels for In-Water Pile Installation.

Approximately Pile Size and Type	Hammer Type	Relative Water Depth	Distance	Average Sound Pressure Level Measured in dB		
				Peak	RMS	SEL
0.30-meter (12-14 in) timber Pile	Cushioned Impact	2-4 meters	10 meters	180	170	160
0.30-meter (12-14 in) timber Pile	Cushioned Impact	2-4 meters	20 meters	170	160	NA
0.41-meter (16 in) steel pipe pile	Cushioned Impact	3 meters	10 meters	171	NA	147
0.41-meter (16-in) concrete pile	Cushioned Impact	10 meters	10 meters	184	173	NA
0.61-meter (24-in) concrete pile	Cushioned Impact	3-4 meters	10 meters	185	173	NA
0.30-meter (12-14 in) timber Pile	Impact	2-4 meters	10 meters	206	196	186
0.30-meter (12-in) steel H-type - Thick	Impact	5 meters	10 meters	200	183	170
0.61-meter (24-in) AZ steel sheet	Impact	15 meters	10 meters	205	190	180

0.61-meter (24-in) concrete pile	Impact	15 meters	10 meters	188	176	166
0.36-meter (14-in) steel pipe pile	Impact	15 meters	10 meters	200	184	174
1-meter (36-in) steel pipe pile	Impact	<5 meters	10 meters	208	190	180
1-meter (36-in) steel pipe pile	Impact	10 meters	10 meters	210	193	183
1.5-meter (60-in) Cast-in-steel shell	Impact	<5 meters	10 meters	210	195	185
0.30-meter (12-in) steel pipe pile	Vibratory	<5 meters	10 meters	171	155	155
1-meter (36-in) steel pipe pile – typical	Vibratory	5 meters	10 meters	180	170	170
0.6-meter (24-in) AZ steel sheet – typical	Vibratory	15 meters	10 meters	175	160	160
1-meter (36-in) steel pipe pile – loudest	Vibratory	5 meters	10 meters	185	175	175
1.8-meter (72-in) steel pipe pile – typical	Vibratory	5 meters	10 meters	183	170	170

Adopted from California Department of Transportation (CalTrans), Division of Environmental Analysis. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish, November 2015. Compendium of Pile Driving Sound Data.

Invertebrates, fish, sea turtles, and marine mammals use sound for various purposes such as navigation, prey and predator detection, and communication (e.g., finding mates). These taxonomic groups, as well as species within each group, vary in their abilities to produce and detect sound, which is largely based on anatomical, physiological, and behavioral differences (Hastings and Popper 2005). The aquatic environment also affects acoustic capabilities of species. Studies on marine mammals and fish represent the majority of research on the impacts of anthropogenic noise. Aquatic invertebrates and sea turtles have not been as widely studied, but limited information does exist on exposure and response to some anthropogenic sounds. Generally, the effects of exposure to anthropogenic sound include behavior modification, physical injury, or mortality, and the masking of sounds used in communication and other life processes.

Invertebrates

Information on invertebrate "hearing" is limited, but it appears some invertebrates are able to detect vibrations and movements associated with sound (Popper et al. 2001; Breithaupt 2002; Lovell et al. 2006). Invertebrates appear to be capable of detecting vibrations through two types of receptors: statocysts (or otocsysts), and water flow detectors/sensory hairs. Statocysts are fluid-filled structures containing cilia that help animals maintain equilibria. Statocysts appear to be similar to fish otoliths, therefore it has been suggested invertebrates may be able to detect vibrations associated with sound (Budelmann 1992). Flow detectors are sensory cilia on the surface of invertebrates, such as marine crustaceans, or fan-like projections, potentially capable of detecting vibrations in the water column (Popper et al. 2001). Invertebrates may detect and respond to acoustic cues, as observed by directional movement towards settlement areas, or orienting themselves within their environments. Eastern oyster larvae (*Crassostrea virginica*) have been shown to choose settlement sites based on the sound characteristics of different substrates (Lillis et al. 2013). Additional research suggests other marine invertebrates, such as coral (*Montastraea faveolata*), were able to detect reef sounds and respond to those sounds in a directional manner through movement towards the sound source (Vermeij et al. 2010). This ability is likely used to settle on optimal substrate.

Anthropogenic noise in marine environments may result in adverse effects to invertebrates through physical damage to sensory structures, such as external sensory hairs/water flow detectors and internal statocysts. Damaging these structures could prevent animals from carrying out essential life-cycle functions such as hunting, evading predators, or reproducing. Additionally, exposure to very high sound levels and rapid changes in pressure could lead to hematomas (bleeding), hemorrhages, embolisms, and rupture of internal structures leading to physical injury or death (Popper et al. 2001; Andre et al. 2011). Injuries resulting from rapid pressure changes are collectively known as barotraumas. Furthermore, masking could also result from increased underwater anthropogenic noise if the sound prevents invertebrates from detecting biologically relevant sounds, including sounds used for spawning and feeding or sounds free-swimming invertebrate larva use to select optimal settlement sites (Popper et al. 2001). The presence of anthropogenic sound may also lead to behavioral modifications such as the cessation of feeding and avoidance of an area (for motile invertebrates).

Sea Turtles

Limited information exists on hearing by sea turtles and its biological significance, but sea turtles may use sound to find prey, avoid predators, navigate, and for general environmental sensory awareness. The ear of sea turtles does appear to be adapted to detect sound in water, due to the retention of air in the middle ear, suggesting they are able to detect sound pressure (Lenhardt et al. 1985). Furthermore, hearing studies have shown some sea turtles are able to detect low frequency acoustic and vibratory stimuli underwater and in air (Bartol and Ketten 2006; Bartol and Bartol 2011; Lavender et al. 2012; Martin et al. 2012). Sea turtles do not appear to use sound for communication.

The limited research on the effects of anthropogenic noise on sea turtles is generally restricted to loggerhead or green sea turtles and the ways in which their behaviors change in response to noise. Many sea turtle studies have investigated the impacts of noise produced by seismic airguns (impulsive sound source), and the conclusions range from observing no behavioral changes (or changes in sea turtle abundances) to increased swimming and erratic behavior in response to approaching airguns (O'Hara and Wilcox 1990; Moein et al. 1995; McCauley et al. 2000; Weir 2007; DeRuiter and Doukara 2012). Research has not been conducted on the impacts of anthropogenic noise on individual or population-level survivorship, fecundity, growth, or the potential additive effects of noise with other stressors. It is likely exposure to very high sound levels and drastic changes in pressure could lead to barotraumas, potentially resulting in physical injury or death, though this is based on the properties of anthropogenic noise and sea turtle biology and physiology (mainly the retention of air in the middle air) (Popper et al. 2014). Sea turtles are highly mobile species, which have the ability to avoid construction equipment and anthropogenic noise, if disturbed by the presence of equipment or noise. Furthermore, sea turtles do not rely on sound for communication, so masking is likely not a significant threat to sea turtles.

Fish

Numerous studies have examined how and why fish use sound, as well as the impacts of pile driving and blasting, including physical injury, mortality, and behavior modification, on fish (see reviews Hastings and Popper 2005; Popper and Hastings 2009; Kolden and Aimone-Martin 2013; Popper et al. 2014). Over 800 species of fish are known to produce sound, but because fish represent a morphologically and taxonomically diverse group of species, many more are likely capable of producing sound than are currently known (Radford et al. 2014). Hearing sensitivities vary among fish species due to anatomical and physiological differences as well as differences in behavior, which influences how species are impacted by anthropogenic sound (Popper and Hastings 2009). Sound production, detection, and response are also tied to environmental factors within the habitats individual species occupy.

Biological factors common to certain taxa allow general inferences to be made regarding sound use and hearing abilities in fish (Popper et al. 2014). Fish are able to detect and process sounds via two independent, but related sensory systems: the ear, or auditory system, and the lateral line system (Popper et al. 1992; Popper and Fay 1993). These systems both include mechanosensory hair cells and together are often referred to as the "octavolateralis system" (Popper et al. 1992; Popper 2005). The lateral line system is used by fishes to detect particle motion in the water, assisting fish in maintaining their position in a school, avoiding predators, and finding prey (Coombs and Montgomery 1999) while the ear is involved in detection of sound as well as the detection of angular acceleration and changes in the fish's positive relative to gravity (Popper and Hastings 2009). The lateral line system has the same type of sensory hairs as those found in the inner ear of fish, known as neuromasts (Cahn 1967). The displacement-sensitive neuromasts respond to the relative motion between the body's surface and surrounding water, which only takes place very close to sound sources (where there is a steep gradient of pressure and particle motion). Therefore, the lateral line system best detects pressure changes and particle motion in near field conditions (Kalmijn 1988). The auditory system likely plays a larger role in sound detection, via direct stimulation of the otoliths found in the inner ears of fish, and is more susceptible to anthropogenic sound sources than the lateral line system (Popper and Fay 1993). Otoliths consist of dense calcareous masses containing a sensory epithelium. The sensory epithelium has numerous hair cells that release a neurochemical signal when the hair cells are bent. When sound pressure waves pass through the bodies of fish (which have approximately the same density as water), the otoliths move. Since the otoliths are denser than fish, they move more slowly than the body of fish in response to traveling sound. The differential motion of the otoliths and the fish body results in displacement of the otoliths and movement of sensory cilia on hair cells on the epithelium of the inner ear. The movement between the otoliths and hairs cells is interpreted as sound (Popper and Fay 1993; Popper and Hastings 2009; Popper and Fay 2010). Excessive otolith movement may damage or shear off the sensory hairs (Popper and Hastings 2009).

Swim bladders also impact acoustic pressure sensitivity differences in fish, as many fish are able to detect sound pressure via the swim bladder or other gas-filled structures which re-radiate energy (via particle motion) to the otoliths (Chapman and Sand 1974; Rogers and Zeddies 2008). The presence and type of swim bladder as well as the proximity and linkage of the swim bladder to the inner ear influences the ability of fish to detect and respond to sound; generally, fish with swim bladders are more sensitive to sound (from anthropogenic or natural sources) (Popper et al. 2003; Braun and Grande 2008). Air within a swim bladder is at a much lower density than the body of a fish, which enables the air (and swim bladder) to be compressed by sound pressure waves traveling through body tissues. Compression of the air in the swim bladder causes the swim bladder to change in size. Movements of the swim bladder wall are transmitted to, and stimulate, the inner ear (Popper and Fay 1993; Popper and Hastings 2009). Two types of swim bladders exist: physostomous (primitive bony fishes such as sturgeon and salmon possess these) and physoclistous (derived bony fishes such as bass possess these) (Kalmijn 1988). Physostomous swim bladders have a connection to the intestinal tract, via the pneumatic duct, which allows the fish to fill the swim bladder or expel air out of the swim bladder at the surface (Kalmijn 1988). This method of gulping and expelling air allows fish to expel air more rapidly in response to sound exposure, which may limit injury; deflated swim bladders represent lower risk of injury from sound exposure (Popper and Hastings

2009; Popper et al. 2014). Physoclistous swim bladders are not connected to the intestinal tract, and must regulate pressures through specialized glands enabling slow diffusion of gases into and out of the swim bladder (Halvorsen et al. 2012). These fish are likely more sensitive to exposure to impulsive sounds since regulating the volume of air in the swim bladder is a much slower process compared to physostomous fishes. Fish without swim bladders (e.g., sharks) or those with small or reduced swim bladders (e.g., gobies) have relatively poor auditory sensitivity, but are capable of detecting particle motion in the water column (Popper and Hastings 2009). These fish are less susceptible to anthropogenic sound than fishes with larger, more developed swim bladders (Halvorsen et al. 2012).

In addition to the auditory and lateral line system, some fish possesses special hearing adaptations, which generally allow fish to have lower thresholds and wider hearing bandwidths. These anatomical specializations typically link the swim bladder and the inner ear of the fish with other gas-filled spaces (increasing vibration and particle motion), which increases a fish's ability to detect and respond to sound. Clupeiform species (e.g., herring, shad, and alewives) have a pair of elongated gas ducts ending in "bullae" extending from the swim bladder, travel through the skull, and come into direct contact with the inner ear (Fay et al. 2008). The bubble of compressible gas in the bullae and its proximity to the inner ear enhances stimulation of the ear, increasing hearing sensitivity (Popper et al. 2014). The fish known to have the widest hearing frequency bandwidth are limited to the members of the clupeiform genus *Alosa* (Mann et al. 2001); the American shad can detect ultrasonic frequencies up to 180 kHz (Mann et al. 1997). Other species possess a series of specialized small boney structures called Weberian ossicles. These structures are modified bones of the vertebral column connecting the swim bladder to the inner ear, enhancing sound transmission and overall hearing sensitivities (Wright 1884; Ladich 1999).

Physical effects to the auditory tissues of fish can occur from exposure to low levels of sound for a relatively long period, or exposure to higher levels of sound for short periods, which may result in auditory tissue damage (damage to the sensory hair cells of the ear) or temporary hearing loss, known as "temporary threshold shift" (TTS). Both peak sound pressure and sound exposure level (SEL) can affect hearing through auditory tissue damage or TTS. A TTS is a reduction in hearing sensitivity resulting from temporary changes in sensory hair cells (including loss of cells) of the inner ear and/or damage to auditory nerves innervating the ear (Popper et al. 2014). A TTS may last minutes to weeks and the amount of hearing loss may be related to the intensity and duration of the sound source compared to the hearing sensitivities of the fish (Popper and Hastings 2009). Sensory hair cells are constantly added in fishes and are replaced when damaged, so the effects of sound-induced hair cell death can be mitigated over time by the addition of new hair cells. A decrease in hearing sensitivity is generally considered recoverable (Smith et al. 2006; Popper and Hasting 2009). A "permanent threshold shift" (PTS) is discussed in the literature as a permanent loss of hearing and is generally accompanied by death of the sensory hair cells of the ear (Oestman et al. 2009; Popper and Hastings 2009). However, the literature on PTS is very limited (Popper et al. 2014; Caltrans 2015). Indirect impacts of hearing loss in fish relate to reduced fitness through disrupted communication, reduced success of predators or prey detection, and/or inability to assess the environment (Pooper et al. 2014). Anthropogenic sound may also lead to the masking of other biologically relevant sounds for fish species, which could combine with hearing loss to have additive affects, however this has not yet been studied extensively in fishes (Popper and Hastings 2009).

Other physical injuries, such as barotraumas, can also occur from exposure to high sound levels or continuous sound (Kolden and Aimone-Martin 2013). Rapid changes in pressure can cause gas volumes to expand and contract rapidly (mainly in the swim bladder) damaging surround tissues and organs, and can cause the rupture of the swim bladder (Popper et al. 2014). Numerous studies have indicated the swim bladder is the causal factor producing internal damage due to the repeated motion of the walls of the swim bladder in response to impulsive forces, including pile driving (Hasting and Popper 2005; Popper et al. 2014; Caltrans 2015). Damage seen in the major internal organs most closely positioned to the swim bladder, such as the kidneys, gonads and spleen, further supports the swim bladder is responsible for further internal damage (Popper and Hastings 2009; Halvorsen et al. 2012; Kolden and Aimone-Martin 2013). Injuries from barotrauma are variable, but it appears sudden changes in pressure are more likely to result in damage than gradual changes (Kolden and Aimone-Martin 2013; Popper et al. 2014). Additionally, the pattern of pressure changes as well as the physiological state of the fish at the time of exposure, combined with other factors, will influence the impact from barotrauma (Popper and Hastings 2009). Barotrauma can lead to mortality (immediate or delayed) as well as numerous injuries, most of which are considered recoverable. Injuries such as fin hematomas, capillary dilation, and the loss of sensory hair cells may lead to mortality through increased likelihood of predation, though this is usually categorized as indirect mortality (Kolden and Aimone-Martin 2013; Popper et al. 2014).

Rapid changes in pressure can cause blood gases to come out of solution (Popper et al. 2014). Sound at sufficiently high-pressure levels can generate bubbles from micronuclei in the blood and other tissues (ter Haar et al. 1982; Hastings and Popper 2005). Because blood vessels in fish are particularly small in diameter, if bubbles are forced to come out of solution at low frequencies, they could cause an embolus or clot and burst small capillaries. This also can occur in the eyes of fish, where tissue might have high levels of gas saturation (Turnpenny et al. 1994; Gisiner 1998). Traumatic brain injury can be caused by high-level transient sound, it is believed fish with swim bladders or other air bubbles near the ear could be susceptible to neurotrauma when exposed to high sound pressure levels (Popper and Hastings 2009). Whereas it is possible that some (although not all) species of fish would swim away from a sound source, thereby decreasing exposure to sound, larvae and eggs are often found at the mercy of currents or move very slowly, leaving them more vulnerable to high sound pressure scenarios (Popper et al. 2014).

Behavioral impacts also result from the introduction of anthropogenic sound in aquatic environments, and may be of greater concern than physical or physiological impacts, though little research has been conducted on this topic (Popper et al. 2014). Most species of fish are likely to move away from a sound source if it is too loud or disruptive, which will minimize physiological damage, injury and mortality (Johnson et al. 2008; Popper and Hastings 2009; Dahl et al. 2015). The more significant concern may be the behavioral responses of fish to anthropogenic sound, much like marine mammals, which could result in fish moving away from feeding or breeding sites, ceasing feeding or breeding, or avoiding habitats (Popper and Hastings 2009; Dahl et al. 2015). These behavioral modifications can lead to reduced survivorship due to increased predation, decreased foraging efficiency, and increased energy expenditure (Popper et al. 2014). Additionally, anthropogenic sounds can mask biologically important sounds ranging from the soundscape to sound produced by the same species, prey, or predator species (Dahl et al. 2015).

Erosion, Turbidity and Sedimentation Effects to Species

Increased erosion, turbidity and sedimentation is another potential impact resulting from pile installation and blasting activities. These activities can lead to the suspension of sediments, which may result in harmful levels of turbidity. Invertebrates, fish and potentially sea turtles in the vicinity of pile installation/removal and blasting activities where turbidity is elevated may suffer adverse effects including behavioral impacts such as avoidance and abandonment of an area, reduced feeding ability and growth, impaired respiration, and a potential reduction in egg hatching success (Hanson et al. 2003; Kjelland et al. 2015). These taxonomic groups can also experience gill and eye abrasion from suspended sediment in the water column. Additionally, larval fish may experience reduced survival with elevated turbidity. Reduced water transport rates and filter efficiency of fishes and invertebrates as well as decreased foraging efficiency of sight feeders may also result from artificially elevated turbidity (Messieh et al. 1991; Wilber and Clark 2001; Kjelland et al. 2015). Predation rates on federally managed species may also increase, as turbidity plumes may be used to conceal predators. Furthermore, pile installation and blasting activities can also lead to the sedimentation or covering/smothering of species – including aquatic plants, benthic invertebrates and others - leading to physical injury, and direct or indirect mortality (Hanson et al. 2003; Kjelland et al. 2015). Detailed descriptions of effects resulting from erosion, turbidity, and sedimentation can be found in Chapter 2.

Other Effects to Species

Pile installation activities may result in the direct injury or mortality to species through the placement of piles (crushing) or from interaction with construction machinery. However, these adverse effects are not considered likely for fish and sea turtles because they have the ability to leave areas rapidly. Invertebrates may be injured or killed if piles or construction machinery is placed on or near individual animals (Hanson et al. 2003). Many invertebrates also have the ability to move away from piles and machinery, though not as rapidly as fish and sea turtles, due to their small size and swimming abilities. Contaminants contained within sediments near pile and footing sites may also be released into the water column and become available to aquatic plants and animals as pile installation and blasting activities are undertaken (Johnson et al 2008). These can result in numerous negative impacts, including stress effects, resulting in decreases in survivorship (Kjelland et al. 2015).

Habitat effects

Placing piles or footing foundations into aquatic habitats constitutes filling, which removes productive habitat and eliminates important functions for species. Aside from the direct quantitative loss of habitats from placing piles and footings, filling benthic, wetland, or other aquatic habitats reduces the production of detritus, alters the uptake and release of nutrients, reduces wetland vegetation, hinders physiological processes in aquatic organisms, alters hydrodynamic regimes, including increasing scouring, reduces filtration and absorption of pollutants, and can lead to reductions in flood control capacity (wetlands) (Hanson et al. 2003; Johnson et al. 2008).

Additionally, the noise generated from pile installation and blasting activities can lead to hydroacoustic habitat effects, including decreased function and value of habitat (Hanson et al 2003). These impacts can vary temporally, spatially, and in severity, based on specific pile installation and blasting activities. Underwater anthropogenic sound adversely affects the ecological function of habitats by causing species to avoid or abandon habitats, including federally managed species and their prey (Johnson et al. 2008). In many cases, blasting activities are rapid/instantaneous, therefore do not have the same level of habitat effect as prolonged pile driving; the main impacts of blasting are to species and include physical injury and mortality. Increased turbidity generated from pile installation and blasting activities can also degrade habitats by reducing light penetration in the water column and lowering the rate of photosynthesis and benthic prey species (Nightingale and Simenstad 2001; Hanson et al. 2003; Kjelland et al. 2015). High levels of suspended sediments can also smother or cover habitats near the vicinity of pile installation and blasting activities as sediments are deposited (Kjelland et al. 2015). Detailed descriptions of effects resulting from erosion, turbidity, and sedimentation can be found in Chapter 2.

3.3.3 Pile and Footing Removal; Blasting

Pile and footing removal and blasting (for pile and footing removal) activities may adversely affect species and habitats in numerous ways, but elevated sound/pressure levels and elevated turbidity and sedimentation are the primary source of adverse impacts to species and habitats. The impacts resulting from increased underwater sounds generated from these activities can broadly be categorized as hydroacoustic effects, and are the same species and habitat effects as those described in the section above (3.1.1). The main difference related to these hydroacoustic effects is the source of the anthropogenic sound; blasting and vibratory hammers are used more regularly for pile and footing removal.

Turbidity and sedimentation effects generated from pile and footing removal also adversely affect species and habitats. Removing piles can result in elevated turbidity and sedimentation from disturbing and sloughing off of sediments from pile extraction, leading to similar turbidity and sedimentation effects described in the section above (3.1.1). Sedimentation effects, such as covering, smother, or burying, are likely to occur when piles are extracted and sediments slough off in the water column and are deposited on bottom substrates. Detailed descriptions of effects resulting from erosion, turbidity, and sedimentation can be found in Chapter 2.

Contaminants contained within sediments near piles may also be released into the water column and become available to aquatic plants and animals as piles are removed. The extraction of piles may lead to the physical alteration of habitat and lead to depressions in the benthic habitat, which can cause erosion and loss of sediment as well as become hazards for aquatic organisms (mainly invertebrates)(Johnson et al. 2008; Kjelland et al. 2015). These depressions may also change the characteristics of the benthic habitat by causing the settlement of fine sediments and silt, decreasing the value and function of the habitat. Breaking or cutting a pile at the mudline may suspend a small amount of sediment, provided the remaining section of pile is left in the substrate and little digging is required to access the pile (Hanson et al. 2003; Kjelland et al. 2015).

3.3.4 Consideration of Climate Change and Sea Level Rise

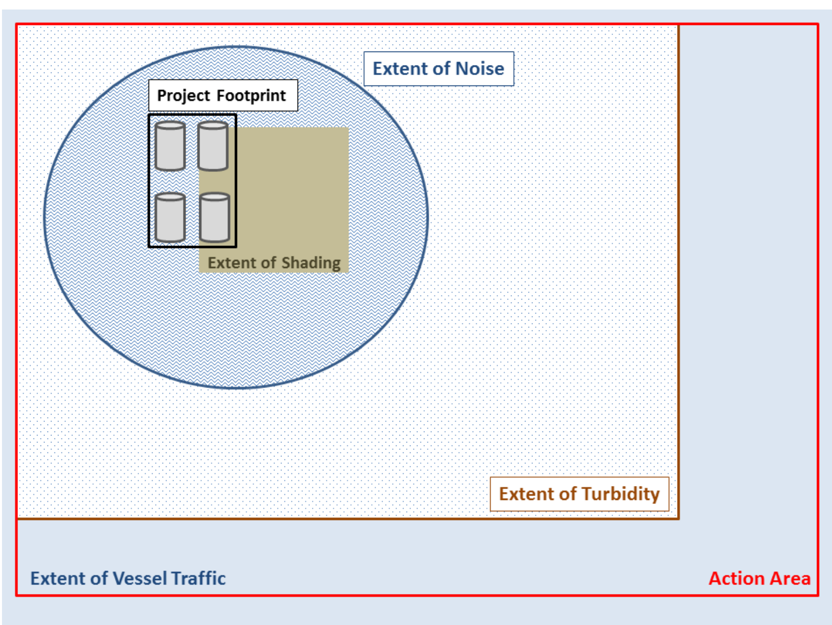
Planners and engineers face unprecedented changes in several variables relevant to the planning, design and construction processes of long-life assets, including piles and footings. These variables include climate change and sea level rise (SLR), which have wide-ranging impacts on all natural and human (built) systems, including transportation infrastructure (Doll et al. 2012). Climate change is the result of increased global mean surface temperatures due to anthropogenic activities, primarily from increases in well-mixed greenhouse gases (WMGHG) in the atmosphere (IPCC 2014). Warming of the climate system is unequivocal and changes to the climate system are extensive; multi-decadal changes in regional temperatures, the water cycle, global energy budget, the cryosphere, and oceans have been consistently modelled and observed (IPCC 2013; USGCRP 2014). Although the impacts of climate change and SLR are widespread and vary by region, many impacts are concentrated in riverine and coastal areas, where NOAA-trust resources occur (FHWA 2014 and 2016). These areas also represent the intersection of NOAA-trust resources with transportation assets. Therefore, impacts from climate change and SLR on transportation infrastructure, including piles and footings, may influence impacts to NOAA-trust resources.

The primary changes to the climate system related to transportation infrastructure where NOAA-trust resources occur include (1) changes in precipitation patterns; increased mean precipitation and increases in intense precipitation events; (2) increasing frequency and/or intensity of extreme weather events; and, (3) rising sea levels and associated storm surge (USGCRP 2014). The resiliency and adaptive capacity of transportation infrastructure to the predictable impacts of climate change and SLR is largely dependent on the location and design of structures. Numerous adaptation strategies exist for coping with future climate change and SLR and generally include increased maintenance and redundancy, constructing protective measures, accommodation (through design) and relocation, all of which have differential impacts on NOAA-trust resources (FHWA 2014). Because climate change and SLR affects transportation infrastructure in areas where NOAA-trust resources occur, climate change and SLR should be considered through all phases of highway project development.

3.4 Assessing Hydroacoustic Impacts

Conducting analyses on potential impacts of a proposed project is essential for MSA and ESA consultations with NMFS. All aspects of a project with potential impacts (have a plausible route of effect) should be assessed as part of a comprehensive project evaluation (*Figure 3.1*). If pile installation, removal, or blasting is a component of a proposed project in or near estuarine waters or freshwater rivers where sturgeon occur, the environmental analysis should include an evaluation of potential hydroacoustic effects to species and habitats. Hydroacoustic impacts will differ if the activity takes place in open water (*Figure 3.2*) or in a confined river, stream, or tidal creek (*Figure 3.3*). Placement of footings must also be evaluated for their potential impacts on species and habitats. However, due to the routes of effect from footing placement (e.g., filling habitat and turbidity), hydroacoustic analysis is typically not required.

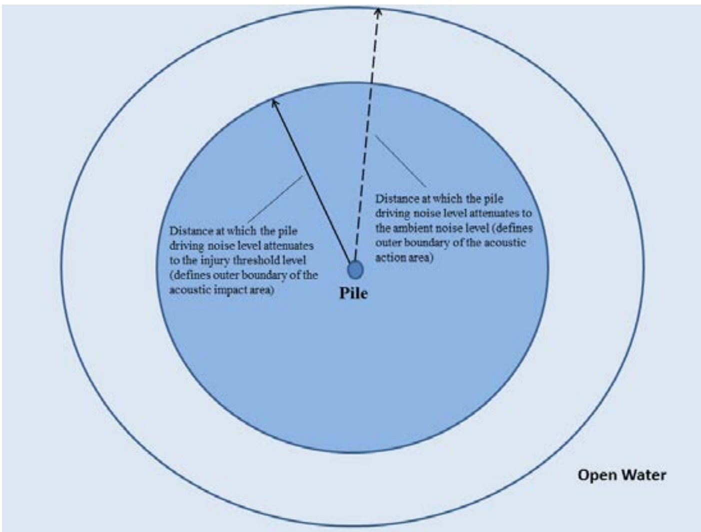
Figure 3.1 Conceptual project model with project related impacts/action area.



Adopted from the Great Atlantic Regional Fisheries Office of NOAA-NMFS.

Three general factors will aid in completing a comprehensive evaluation of potential project impacts, including hydroacoustic impacts. These include: (1) habitats; occupied and utilized by species, (2) behavior and life history characteristics of species; including seasonal movements and migration, and (3) sound sensitivity and hearing ability/specializations of species.

Figure 3.2 Pile driving acoustic impact and action area in open water.



Adopted from California Department of Transportation (CalTrans), Division of Environmental Analysis.

Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish, November 2015.

3.4.1 Pile Driving Impact Analysis and Evaluation

There are numerous information needs for evaluating hydroacoustic impacts on NOAA-trust resources from pile driving activities. This information should be provided to the NMFS as part of the project evaluation, but numerous pieces of information are also necessary as inputs into equations used to estimate impacts. For EFH consultations, a "worst case scenario" approach is typically sufficient to conduct consultations. However, for ESA Section 7 consultations specific information is required for NMFS consultation biologists to conduct comprehensive hydroacoustic effects analyses for listed species. A "worst case scenario" approach may be used in Section 7 consultation, though this could result in larger and more severe estimation of impacts as well as more restrictive construction conditions. The following items should be considered when analyzing hydroacoustic impacts, as they will influence calculations:

- **Type and size of pile**
- **Type of pile driver (e.g., impact hammer or vibratory hammer)**
- **Type of noise attenuation (if used)**
- **Any seasonal in-water work moratoriums**
- **Number of hours in a day pile driving will occur**
- **Site-specific conditions such as channel dimensions, substrate, geometry, and depth.**

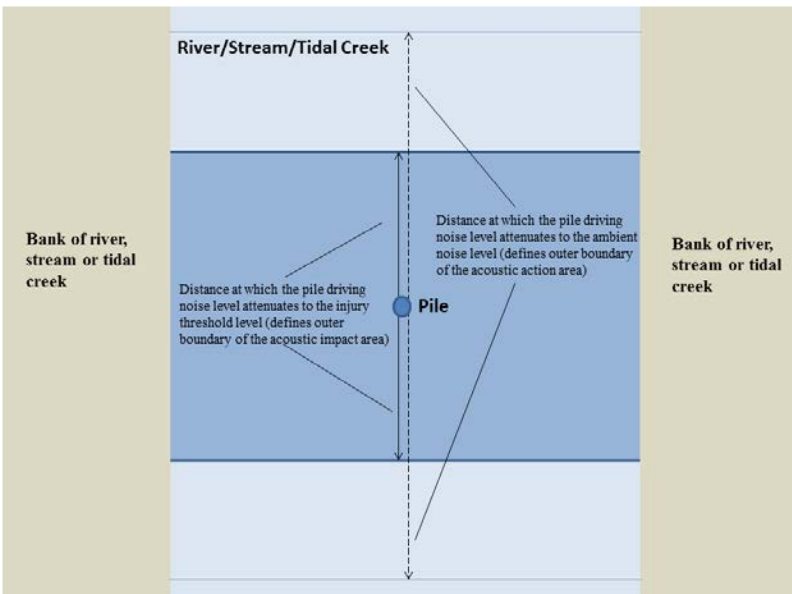
Specific information required for hydroacoustic calculations can include:

- **Estimated single strike peak pressure (dB re: 1 μPa)**
- **Distance from the pile where peak pressure was measured**
- **Estimated single strike SEL (dB re: 1 μPa^2•s)**

- **Distance from the pile where SEL was measured**
- **Estimated single strike RMS pressure (dB re 1 µPa)**
- **Distance from the pile where RMS was measured**
- **Expected total number of pile strikes in a single day (Impact driving)**
- **Expected total amount of time vibratory hammers will be used in a single day (Vibratory driving)**
- **Transmission Loss constant**

The California Department of Transportation (Caltrans) has developed tools for completing hydroacoustic analyses for projects involving pile driving. These were developed as in-house tools for assessing potential hydroacoustic effects from pile driving. The NMFS or Caltrans assumes no responsibility for interpretation and application of the results of these models by non-NMFS users, as conditions at each project site may vary. The Southeast Regional Office of NMFS uses the Caltrans Pile Driving Calculator when conducting hydroacoustic analyses for proposed projects.

Figure 3.3 Pile driving acoustic impact and action area in confined areas (stream or tidal creek).



Adopted from California Department of Transportation (CalTrans), Division of Environmental Analysis. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish, November 2015.

Acoustic Analysis Tools

The Caltrans Pile Driving Calculator developed for impacts to NMFS trust resources, and other information, can be found at: http://www.dot.ca.gov/hq/env/bio/fisheries_bioacoustics.htm

Further information and the basis for many of the equations related to the development of hydroacoustic impact estimates are best summarized in *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish* (Caltrans 2015).

3.4.2 Blasting Analysis and Evaluation

There are numerous information needs for evaluating hydroacoustic impacts on NOAA-trust resources, mainly ESA-listed species, from blasting activities. This information should be provided to the NMFS as part of the project evaluation, but numerous pieces of information are also necessary as inputs into equations used to estimate the "blasting action area." The following items should be considered when analyzing blasting operations, some of which are considered avoidance, minimization, and mitigation measures:

- Site-specific conditions such as channel dimensions, substrate, geometry, water depth, sediment type, and potential species present.
- Type of material to be blasted – detailed description of structures.
- Size/weight of explosive charge(s) (pounds per delay).
- Time-delay to be used between charges.
- Blasting duration (number of events, hours, days, or weeks).
- Bore hole dimensions and stemming material (if applicable).
- Details of "Marine Wildlife Watch Plan" (if applicable)
- Number of observers (if applicable) and primary locations (air, land or water).
- Type(s) of "scare" charges to be used (if applicable); number and weights.
- Pre-blast survey plans and techniques (if applicable); post-blast monitoring plans and techniques.
- Dimensions of Danger Zone; dimensions of Buffer Zone (if applicable); Safety Zone.
- Type of noise attenuation (if used).
- Type of turbidity/sedimentation barrier (if used).
- Time of year restrictions (if applicable).

Figure 3.4 Blasting impact/action area.

The blasting impact/action area is the same for open water and confined areas.

A Danger Zone (also referred to as the Exclusion Zone) for blasting is established based on the maximum weight of explosives detonated (in pounds) per delay. This is calculated using the following equation:

$R = 520\,(W)^{1/3} + 500$, where W = the maximum weight of explosives in pounds per delay, and R = the Danger Zone radius in feet. Beyond the Danger Zone, a Buffer Zone is typically utilized as a "heads-up" zone to identify any animals nearing the Danger Zone (*Figure 3.4*).

The “blasting action area” of a project is defined as the Danger Zone (and Buffer Zone, if applicable) calculated for explosive use to avoid harm or harassment to NMFS-trust species, mainly ESA-listed species. The “blasting action area” is considered to be a diameter circular zone established around the center of the blast event.

Blasting plans and analyses focus primarily on ESA-listed species, including sturgeon and sea turtles, and numerous avoidance, minimization, and mitigation measures are associated with protecting those species. However, federally managed species may be adversely affected during blasting, and implementing reasonable avoidance, minimization, and mitigation measures is encouraged to reduce impacts to those species. Additionally, impacts to habitats should also be considered. Blasting is instantaneous and typically begins and ends within seconds, so habitat impacts are generally limited. However, the debris created during blasting can impact habitats and should be included in any project evaluations. Turbidity, sedimentation, and other stressors resulting from blasting events should also be evaluated.

3.5 Recommended Best Management Practices

Implementing recommended best management practices (BMPs) will aid FHWA/state DOTs in avoiding and minimizing impacts to NOAA-trust resources by reducing the exposure of species and habitats to stressors and eliminating the plausible routes of effects. Projects that cannot avoid or sufficiently minimize impacts to species or habitats may need to implement compensatory mitigation/measures. Though a comprehensive list of BMPs is provided, innovative techniques and methodologies may lead to the development of additional BMPs, but their use should be coordinated with NMFS on a case-by-case basis.

The BMPs are discretionary measures that transportation agencies can incorporate during project planning to avoid and minimizing potential impacts to NOAA-trust resources. The BMPs provide more transparency and predictability to FHWA and State DOTs regarding species conservation, habitat needs, and NMFS’ recommendations. Frontloading BMPs into early design phases of projects will likely lead to reduced consultation timeframes, reduced delays, and could reduce the potential for future redesign of projects. Many BMPs can be incorporated into the design of projects, while others may be addressed as environmental commitments for contractors.

***** *All best management practices related to structural project components and construction techniques are contingent upon engineering feasibility and other design considerations.*

3.5.1 Pile and Footing Installation

Pile selection

PI1 *Pile Type* **-** Driving steel piles results in more sound from individual pile strikes than concrete or wood piles of the same size. To the maximum extent practicable, concrete or wood piles should be used to reduce underwater sound levels from individual pile strikes.

PI2 *Pile Size* – Reducing pile size may reduce peak sound pressure levels, however, the use of smaller piles may require more piles be driven – potentially resulting in accumulated SEL values greater than with larger piles. For piles in or near sensitive habitats (such as areas where species are known to spawn, rest, or forage), the use of smaller piles should be analyzed as an avoidance and minimization measure.

Site Selection/Pile Placement

PI3 The number of piles installed and removed should be the minimum number necessary to accomplish the project purpose.

PI4 To the maximum extent practicable, piles should not be placed in streams, tidal creeks, and entrances to tidal creeks.

PI5 To the maximum extent practicable, pile installation, and removal should be avoided in shellfish areas and in areas with submerged aquatic vegetation (SAV), areas that historically supported SAV, and areas, which are potential habitat for SAV. Surveys of historic and current SAV should be conducted to determine distribution and potential for recolonization of SAV.

Pile installation Equipment

PI6 To the maximum extent practicable, vibratory hammers should be used to install driven piles, including metal sheet piles.

PI7 CIP piles (drilled-shaft methods) generate less underwater noise than impact hammers and, when possible, should also be used in lieu of pile driving with impact hammers (if vibratory hammers are not feasible).

PI8 If/when an impact hammer is necessary, a vibratory hammer should be used to first drive the pile as deep as possible.

PI9 When an impact hammer is necessary, cushions blocks (pile caps) should be placed between the top of the pile and the hammer (typical of many projects).

PI10 Water jetting should be avoided in areas with fine sediments to reduce turbidity plumes and the release of nutrients and contaminants. Jetting should also be avoided when in or adjacent to sensitive habitats, including shellfish areas and SAV.

Sound Attenuation Devices/Methods

PI11 Sound attenuation devices/methods should be used to reduce in-water noise levels generated by pile installation activities.

- *Air bubble curtains* - Air bubble curtains create a bubble screen, which can reduce or inhibit the propagation of sound from a pile. Effectiveness is largely based on the proper design and implementation of the bubble curtain. Bubble curtains are not effective in areas with strong currents.
- *Cofferdams* – Cofferdams can be used to isolate an area of the water column. Cofferdams are typically constructed of metal sheet pile and are dewatered to isolate the pile from the water, which attenuates sound by providing an air space between the pile and aquatic environment, although sound can still propagate through the ground and into the water column.
- *Isolation casings* – Isolation casings are typically hollow piles slightly larger in diameter than the pile to be installed. The casing is installed, then dewatered and permanent pile installed. The small air space between the pile and aquatic environment attenuates sound. Alternatively, the casing can be filled with sound-absorbing materials or bubbles.

- *Proprietary devices/methods* – Uncommon or proprietary attenuation devices/methods may be used following coordination/consultation with the NMFS.
- Attenuation devices/methods used in combination may have additive effects, further reducing sound generated during pile driving activities.

PI12 To the maximum extent practicable, pile installation activities should be limited to no more than 12 hours per day to allow species to move through an area during quiet periods.

PI13 Silt or turbidity curtains should be used to reduce the impact of suspended sediments and the potential for siltation/sedimentation of adjacent habitats. Curtains can also exclude species from an area.

PI14 In intertidal areas, piles should be installed during low tide periods when sediments are exposed.

PI15 Construction practices or equipment used for installing piles that smother vegetation should be avoided (e.g., barge mats placed on marsh vegetation for extended periods). Barge grounding should be avoided.

PI16 One of the following methods should be used to give animals the opportunity to leave an area prior to full-force pile driving when injurious noise levels may occur. When possible, these procedures should be used for a minimum of 10 minutes prior to full-force pile driving:

- "Ramp up" method (i.e., pile driving starts at a very low force and gradually builds up to full force),
- "Dry firing" method (i.e., operating the pile hammer by dropping the hammer with no compression), or
- "Soft start" method (i.e., noise from hammers is initiated for a short period (1 strike or 15 seconds), followed by a 1 to 3-minute waiting period – this sequence is repeated multiple times).

PI17 All pile installation activities should aim to keep acoustic levels below the behavioral and injurious thresholds for NOAA-trust resources.

3.5.2 Pile and Footing Removal

PR1 To the maximum extent practicable, the entirety of deficient or obsolete piles should be removed. If entire piles cannot be removed, piles should be cut at or below the mudline/stream bottom/substrate when possible.

PR2 To the maximum extent practicable, a vibratory hammer should be used (rather than direct pull or other methods) to remove piles, allowing sediments to slough off near the mudline. Piles should be removed slowly to give sediments a chance to slough off. Direct pull can be used if a vibratory hammer is not an option; however, the repeated movement or shaking of piles typically used during direct pull method can lead to increased turbidity and sedimentation, can alter the bottom topography near the pile, and could physically injure or kill NOAA-trust resources or their prey.

PR3 The the maximum extent practicable, holes left by removed piles should be filled with clean native sediments if they willt not fill on their own within two weeks. Consideration of this potential is important early in the coordination and permit processes, as this is typically a permitted action.

PR4 In intertidal areas, piles should be removed during low tide periods when sediments are exposed.

PR5 Construction practices or equipment used for removing piles that smother vegetation should be avoided (e.g., barge mats placed on marsh vegetation for extended periods). Barge grounding should be avoided.

PR6 To the maximum extent practicable, blasting should be avoided to remove piles and footings. Mechanical methods should be used instead of blasting.

PR7 To the maximum extent practicable, pile removal activities should be limited to no more than 16 hours per day to allow species to move through an area during quiet periods.

PR87 All pile removal activities should aim to keep acoustic levels below the behavioral and injurious thresholds for NOAA-trust resources.

3.5.3 Blasting

BL1 To the maximum extent practicable, confined blasts with stemmed charges should be used to focus/contain blast energy into the structure rather than being released into the water column.

BL2 Blast mats should be used and placed on top of structures to reduce debris ("fly rock") and lessen the acoustic signature during blasting operations.

BL3 If practical (hammers are on-site), dry-firing, ramping-up, and soft-start measured employed by pile driving hammers (if pile hammers are available on-site) should be used immediately prior to any blasting to reduce potential impacts to wildlife.

BL4 In some situations, pre-blast monitoring of the Danger Zone using nets (gill nets, trammel nets), tag receptors, and/or sonar to detect the presence/absence of listed species (e.g., shortnose and Atlantic sturgeon) may be necessary, particularly in known spawning habitats.

BL5 Noise attenuating devices, such as bubble curtains, should be employed to reduce the potential impacts of blasting activities and to reduce shockwave duration and intensity.

BL6 Blasting should be conducted during periods of low-water or low-tide to reduce impacts to habitats and species.

BL7 When ESA-listed species are known to be present, or could potentially be present, delays that turn the overall blast into a series of lesser-charged explosions should be used. The minimum delay between individual charges should be at least 9 milliseconds.

BL8 In areas where ESA-listed species are present, or are suspected to be present, detailed blasting plans should be submitted to NMFS for review and final approval prior to the commencement of blasting activities. In areas where ESA-listed species are not present, but EFH or federally managed fisheries are present, detailed blasting plans should be submitted to NMFS for review and comment prior to the commencement of blasting activities. Appropriate acoustic monitoring devices should be installed to adaptively manage the blasting plan.

BL9 In areas where ESA-listed species are present, or are suspected to be present, a weighted turbidity curtain should be placed around blast areas to act as a barrier. The area should be cleared of all ESA-listed species prior to closing the curtain by qualified fisheries biologists. If ESA-listed species are present (most likely Atlantic or shortnose sturgeon), or suspected to be present, the head fishery biologist must hold a current Section 10 permit for capturing and handling the species. If injury/mortality thresholds are expected, the turbidity curtain should be placed at a distance from the source beyond where injury thresholds would occur.

BL10 Pre-blast meetings should be held to discuss all requirements, concerns, and procedures prior to the commencement of blasting activities.

BL11 A Danger Zone around the blast area should be determined based on the maximum explosive weight per delay. A buffer zone beyond the zone of influence should also be considered (as a “heads-up” zone).

BL12 A “Species Watch Plan” should be implemented and include pre-, during, and post-blast monitoring by qualified fisheries personnel within and adjacent to the established zone of influence. Monitoring may be conducted from the air, atop elevated structures, and/or from boats or land.

BL13 All work crews and personnel should be informed about any ESA-listed species in the blast area. An action plan (typically in the species watch plan) should be available to all personnel.

BL14 Demolished materials should be removed from the aquatic environment as soon as is practicable following blasting and adhere to the Recommended Best Management Practices related to dredging in Chapter 2.

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4 Bridges, Piers, and Culverts

4.1 Actions

This chapter addresses the activities commonly employed during construction, maintenance, and demolition of bridges, piers attached to or near bridges, and culverts.

Bridges and Piers

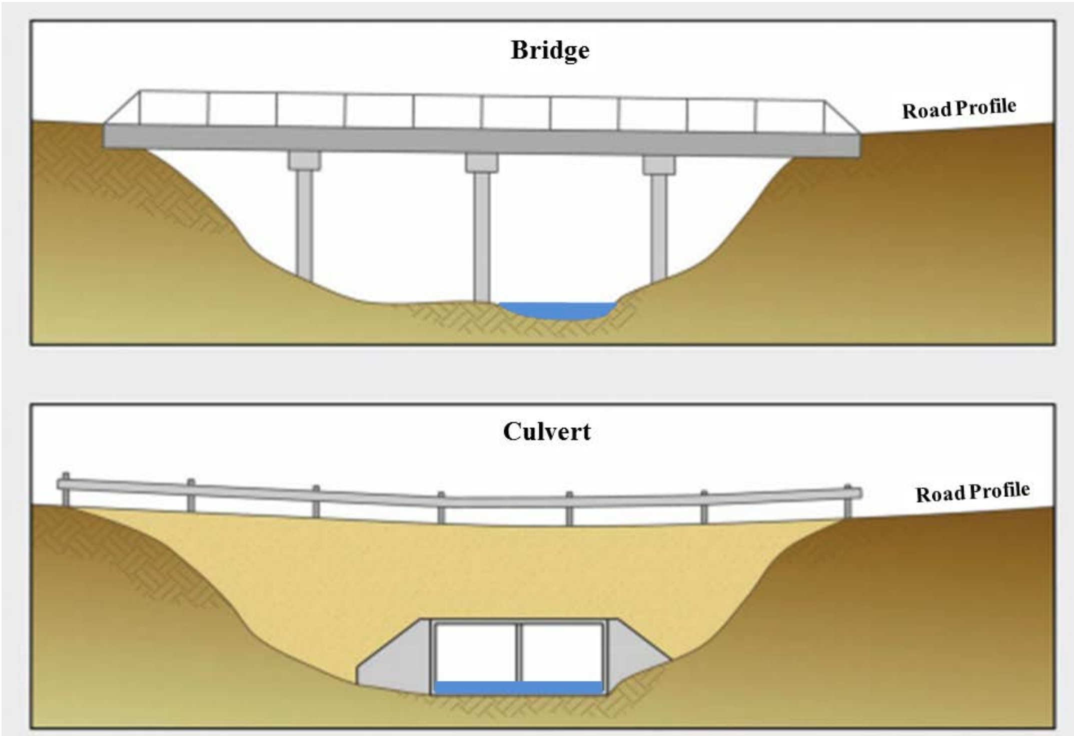
While roadway bridges are the most common type of bridge in a transportation project, pedestrian bridges, bicycle (multi-use) bridges, and fishing piers are also common. Bridges typically span from one upland location to another, whereas fishing piers extend from the shore into the water. A variety of other over-water structures exist, such as floating docks or floating breakwaters, but the FHWA/state DOT projects in NC, SC or GA rarely include these other structures.

Both bridges and piers have substructures and superstructures. The main substructure components are abutments, piers (interior bents), end-bents, footings, and piles/columns. Chapter 3 discusses these components further. The substructure supports the superstructure, which consists of the horizontal components spanning the obstacle or feature the bridge crosses and includes primary and secondary load-carrying members and connections. The main superstructure components are girders (beams), the bridge deck, rails (e.g., guardrails), drainage features, sidewalks, and lighting.

Culverts

Culverts are drains, pipes, or other conduits that convey water through or around a structure or obstruction. For transportation projects, culverts typically pass water under roads and embankments. Culverts may differ in type (shape) and include closed and open-bottom culverts. Closed culverts are mainly rectangular structures (box culverts) or circular, elliptical, or arched pipes. Commonly used open-bottom culvert shapes include arched, high and low profile arched, and rectangular (open-bottom box culverts). Culverts may be composed of plastic, corrugated metal, concrete, or reinforced concrete, and may include features, such as baffles, steps, or ledges, to aid fish passage and/or control flows. Culverts may be precast (prefabricated) or cast-in-place at the project location and may have various inlet configurations, such as sloped inlets or wing walls. Factors affecting selection of inlet configuration include performance (e.g., flow dynamics and erosion control) and aesthetics. The general differences between bridges and culverts are illustrated in *Figure 4.1*.

Figure 4.1 Bridges and Culverts for Roadway/Highway Projects



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4.1.1 Bridges and Piers

Bridge construction commonly requires barges or temporary work platforms. The deck of most roadway bridges is concrete, and the deck of most multi-use bridges is concrete, wood, composite planking, or metal grates.

4.1.1.1 New Bridge, Bridge Replacement, and Widening

New bridges or new alignments for old bridges include constructing bridges and bridge approaches in new locations where there is no existing infrastructure. Small bridges may be precast (prefabricated) and transported to a site for installation. New bridges are typically outside the right-of-way and impact area of existing bridges.

Bridge widening and replacement projects typically replace functionally obsolete and/or structurally deficient bridges, expand bridges for increased capacity, and/or improve safety of existing bridges. Bridge widening projects typically add girders (beams), add interior bents, and expand the bridge deck. Bridge replacement projects construct new bridges parallel to, or on the same alignment as, an existing bridge; structural components from the existing bridge are rarely used in the new bridge.

Bridge replacements on parallel alignment are the most common bridge project type in NC, SC, and GA for higher volume roads, because this approach maintains traffic and access to locations during construction. Bridges replaced on parallel alignment may make use of existing bridge fill and approaches. Old bridges are removed following construction of the new bridges. Bridge replacement on existing alignment is less common, and is generally used on lower volume roads. In coastal areas dominated by salt marshes and tidal creeks, access to barrier islands is typically via a single bridge making replacement on existing alignment relatively difficult and costly.

4.1.1.2 Bridge Maintenance, Removal, and Demolition

Bridge repairs aim to restore and/or improve the safety and functionality of existing bridges. Bridge repairs typically include removing and replacing deteriorated deck concrete or rehabilitating other bridge components, such as piles and girders. Bridge repairs may also include seismic retrofitting elements, such as strengthening piles. Maintenance activities, such as painting and scraping, are also common and generally grouped with repair activities.

The superstructures of small bridges can be removed as single units or sections and demolished off-site, whereas the superstructures of larger bridges can be removed in many small sections or demolished on-site. This typically requires use of excavators, jackhammers, and other specialized equipment. The substructures of bridges are removed in various ways, including direct pull of piles or blasting of columns and footings. Chapter 3 discusses demolition of bridge substructures. Demolition of bridge components leading to accumulation of material in waterbodies may require dredging to remove the material.

4.1.1.3 Fishing Pier Construction, Demolition, and Removal

The FHWA/state DOTs regularly include fishing piers to enhance the value of roadway projects. Fishing piers extend from the shoreline, terminate in the water, and are typically composed of wood planking, composite planking, or grated decking. Barges or temporary work trestles are commonly used for pier construction.

The superstructures of small fishing piers can be easily removed by hand or small machinery; removing larger piers may require excavators, jackhammers, or other specialized equipment. Pier substructures can be removed in various ways, including direct pull of piles. Chapter 3 discusses demolition of pier substructures. Demolition of pier components leading to accumulation of material in waterbodies may require dredging to remove the material.

4.1.2 Culverts

Culverts are regularly constructed or installed in (embedded) or over (bottomless culverts) freshwater and estuarine environments.

4.1.2.1 New Culvert, Culvert Upgrade, and Replacement

Roadway projects often require installation of new culverts during widening or original construction. Existing roadways may require new culverts to address hydrological impairments or erosion. Culvert replacement projects typically consist of replacing undersized, broken, or damaged culverts with new structures to sustain or increase flows. Installation or modification of culverts may require cofferdams to dewater work areas or shoreline stabilization to protect the culvert.

4.1.2.2 Culvert Maintenance, Demolition, and Removal

Culvert maintenance typically involves removing sediments or debris from within or near the opening of a culvert or protecting an existing culvert with shoreline stabilization. Culvert maintenance projects can also include repairs to culverts that have been damaged, but are still functioning as originally intended.

Culverts are removed for various reasons, including roadway removal or realignment or the culvert itself is being replaced. Culvert removal and demolition typically involves constructing coffer dams that are dewatered to obtain dry working conditions. Additionally, the use of excavators, jack-hammers or other specialized equipment or methods to break apart and remove the culvert are also employed. Culvert demolition that leads to material or debris introduction into waterbodies will likely also require dredging.

4.2 Stressors

4.2.1 Types of Stressors

Types of stressors generated from bridge, pier, and culvert projects are outlined below. While some of the stressors overlap, these are generally accepted as the environmental stressors potentially resulting from bridge, pier, and culvert activities and the long-term placement of structures. Detailed descriptions and explanations of stressors can be found in the Chapter 1.

4.2.1.1 Bridges and Piers

The construction, maintenance, and demolition of bridges and piers generate numerous stressors through a variety of mechanisms, which include: (1) the operation of specialized equipment; (2) the construction, placement, and demolition of components; (3) the construction and removal of temporary work structures; and, (4) the long-term placement of structures and components. The primary **short-term stressors** generated from bridge and pier construction and demolition activities are related to the placement, construction, and removal of substructure components, including piles and footers, resulting in elevated noise/pressure levels, increased turbidity and sedimentation, and eliminating and degrading habitats, specifically filling habitats and altering flow dynamics. These stressors and their effects are described in detail in Chapters 2 and 3. The primary **long-term stressor** generated from bridges and piers is directly related to the long-term placement of substructure and superstructure components. These components can result in habitat alteration and loss, through direct removal or modification, and because of shading. Shading result in various adverse impacts, which are described in the following section. Lastly, alteration to hydrodynamics, described in detail in Chapter 3, is a long-term stressor generated from substructure placement for bridges and piers.

4.2.1.2 Culverts

The construction, maintenance, replacement, and demolition of culverts generate numerous stressors through a variety of mechanisms, which include: (1) the operation of specialized equipment; (2) the construction, placement, maintenance, and demolition of components; (3) the construction and removal of temporary work structures such as cofferdams; and, (4) the long-term placement of structures and components. The primary **short-term stressors** generated from culvert activities include elevated noise/pressure levels, increased turbidity, and sedimentation. These stressors and their effects are described in detail in Chapters 2 and 3. Additional short-term stressors include habitat loss and degradation, and alteration to hydrodynamics. The primary **long-term stressor**s generated from culverts is directly related to culvert placement that can result in habitat loss and degradation, including elimination of bottom/bed habitat, alteration to hydrodynamics, and long-term changes to erosion, turbidity, and sedimentation that negatively impacts species and habitats. Shading is also a long-term stressor of culvert placement.

4.3 Effects

4.3.1 Types of Effects

Types of effects expected to result from the construction, operation, maintenance, and removal/demolition of bridges, piers, and culverts are described below. While some effects overlap, these categories are generally accepted as the environmental effects of bridge, pier, and culvert activities, and the long-term placement of structures on NOAA-trust resources. Numerous effects are also described in the Chapter 1.

4.3.2 Bridges and Piers

4.3.2.1 Effects of Shading

Shading results from the attenuation, interference or blocking of sunlight, which typically generate a shadow footprint. For transportation projects, the primary causes of shading in freshwater and marine environments are superstructures (e.g., bridge deck), though substructures (e.g., piles and girders) can also cause shading. The effect of the shadow cast by transportation structures is influenced by the yearly changes in the position of the Earth's axis relative to the sun, and on-site environmental conditions (e.g., topography). Generally, shading results in the degradation or alteration of habitats in the shadow cast by the structure, and a reduction in habitat quantity and quality (NCDOT 2005). Shading can also affect species by altering behavior and predator-prey interactions (Hanson et al. 2003). Shading impacts are considered permanent due to the long-term placement of structures (Johnson et al. 2008).

Light penetration largely depends on the biological, physical, and chemical properties of the water. Since light energy drives photosynthesis, light is one of the principal limiting factors controlling plant growth and survival, and overall primary productivity (Kirk 1994). In the already-reduced light environment of aquatic ecosystems, the addition of over-water structures further reduces underwater light penetration through shading (Underwood and Kromkamp 1999). Freshwater, estuarine, and marine primary producers, such as sea grasses and salt marsh plants, are particularly susceptible to light limitations (Shafer 1999; Whitcraft and Levin 2007; Shafer et al. 2008). Under-structure light levels can fall below the threshold for photosynthesis for many of these primary producers, thus adversely affecting vegetation, habitat complexity, and overall net primary production (Kenworth and Haunert 1991; Haas et al. 2002; Struck et al. 2004).

Sea grasses are important primary producers in southeast US Atlantic coastal ecosystems, though their distribution is limited to North Carolina and Florida. Seagrasses have unusually high light requirements ranging from 10 to 37 percent of in-water surface irradiance (Kenworthy and Fonseca 1996). These high light requirements are a function of reduced light harvesting efficiency of the chlorophyll within the leaves of sea grasses (Larkum 2006). The optical properties of seagrass leaves and poor light harvesting efficiency make seagrasses particularly susceptible to impacts from shading (Zimmerman 2006). Minimum light requirement for seagrass growth vary among and within species, due to biological differences, and adaptations to local light conditions (Duarte 1991; Lee et al. 2007). Shading by structures has been shown to decrease shoot density and biomass in temperate, tropical, and subtropical seagrass species, including *Zostera marina*, *Thalassia testudinum*, and *Haladule wrightii* (Czerny and Dunton 1995; Loflin 1995; Burdick and Short 1999; Shafer 1999). Studies of eelgrass have shown 75 percent of floating docks in and around eelgrass beds resulted caused complete seagrass loss underneath the dock, while the remaining docks led to significantly reduced cover (Burdick and Short 1995; 1999). Given the variety of ecological functions associated with seagrasses, reductions in their abundance and distribution can have widespread impacts on estuarine and marine ecosystems.

Other, less conspicuous primary producers, such as benthic microalgae, are also negatively impacted by shading. Benthic microalgae are ubiquitous in aquatic environments, playing important roles in freshwater, estuarine, and marine ecosystems. Benthic microalgae are an important trophic resource for bacteria and grazers, and aid in the stabilization of sediments, controlling scour and resuspension of bottom sediments (Wolfstein and Stal 2002). Furthermore, benthic microalgae are important components of nutrient cycling and exchange in the water column, and contribute significantly to the overall primary production of ecosystems (Stutes et al. 2006). Whitney and Darley (1983) found that microalgal communities in shaded areas are generally less productive than unshaded areas, with productivity positively correlated with ambient irradiance. Additionally, Meyercordt and Meyer-Reil (1999) showed that light limitation in a coastal lagoon was detrimental to benthic microalgae primary production, while Stutes et al. (2006) found a significant effect of shading on both sediment primary production and metabolism (e.g. sediment respiration).

Reductions in sub- and intertidal benthic and primary productivity, may in turn adversely affect patterns of invertebrate abundance, diversity, and species composition. Struck et al. (2004) observed invertebrate densities under bridges at 25-52 percent of those observed at adjacent reference marsh sites (also in NCDOT 2005). These results correlate with diminished macrophyte biomass, a direct result of increased shading. Density of numerically dominant taxa (oligochaetes and nematodes) as well as surface- and subsurface deposit feeders also were reduced by shading of low bridges (Struck et al. 2004; NCDOT 2005). Structures that attenuate light may also adversely affect food webs by reducing macrophyte growth, soil organic carbon and altering the density, diversity, and composition of benthic invertebrates that are prey for numerous fishery species (Whitcraft and Levin 2007; Alexander and Robinson 2006). Prey resource limitations affect movement patterns and the survival of many juvenile fish species (Johnson et al. 2008). Therefore, the adverse impacts to primary and invertebrate productivity may have effects that cascade through the food web.

Coastal areas of the southeastern U.S are dominated by intertidal salt marshes (estuarine emergent marshes/wetlands) that naturally receive full sun. These salt marsh habitats are characterized by complex systems of tidal creeks dominated by the intertidal marsh plant *Spartina alterniflora,* which is the most important primary producer for saltmarsh ecosystems on the east coast (Pomeroy et al. 1981; Bertness 2007). Coastal tidal marsh systems support complex food webs, are important to material and nutrient cycling, and provide habitats for various life stages myriad species; many of these areas are designated EFH and are utilized by ESA-listed species. Coastal marshes also buffer impacts from storms, serve as repositories for pollutants, and are important for sediment accretion (Weinstein 1979; Wiegert and Freeman 1990). *S. alterniflora* and other intertidal marsh plants also stabilize sediments in highly dynamic intertidal areas, maintaining the physical structure of tidal creek-salt marsh complexes, which are essential to maintaining the ecological integrity of estuarine ecosystems (Pomeroy et al. 1981; Sanger et al. 2004).

Shading impacts from docks, piers, and bridges has been shown to have a significant negative impact on the productivity of the salt marsh ecosystem of southeast U.S. and other areas along the East Coast (Kearney et al. 1983; Burdick and Short 1999; Sanger et al. 2004; Kelty and Blivens 2003; Alexander and Robinson 2006; 2012). Marsh plants are directly affected by shading through reductions in overall primary productivity, resulting in negative biological and physical impacts such as altered food-web dynamics, reduced habitat and refugia, altered nutrient and elemental cycling, and increased erosion and turbidity (Hanson et al. 2003; Sanger et al 2004). Alexander and Robinson (2004) observed that shading of salt marsh in Georgia created, on average, 56 percent decrease in vegetation stem density (*S. alterniflora*) beneath structures when compared to adjacent areas, reducing food and habitat for many important species. In a similar study by Alexander and Robinson (2006), *S. alterniflora* stem density was reduced under docks by 50 percent, on average. This 50 percent reduction in stem density resulted in a consequent reduction between 21-37 percent of biomass and carbon produced per meter square under dock structures (Alexander and Robinson 2006). Furthermore, Alexander and Robinson (2006) used trophic modeling to show that a 21-37 percent decrease in biomass equated to significant reductions in total annual primary nekton production (penaeid shrimp and finfish make up about 33 percent of the total nekton). In South Carolina, the density of *S. alterniflora* under docks has also been shown to be significantly lower than that which occurred adjacent (i.e., 5 meters away) to docks in estuarine marshes, with stem densities decreased by 71 percent (Sanger et al. 2004). Additional research has shown *S. alterniflora* eliminated under docks that were less than 40 centimeters high, which ultimately led to increased sediment erosion (Kearny et al. 1983). Furthermore, a bridge-shading study of marshes in North Carolina showed decreased invertebrate density and diversity beneath low bridges, which was attributed to reduced above- and below-ground macrophyte biomass that presumably resulted in fewer food resources and available refuges from predators (Struck et al. 2004; NCDOT 2005). Impacts of shading and subsequent reductions in plant and animal abundance and diversity can also lead to changes in the hydrodynamics, erosion, turbidity, and sedimentation processes of aquatic systems (Johnson et al. 2008). These changes can result in negative feedback loops that produce additive adverse impacts. For example, decreases in *S. alterniflora* (which bind and stabilize sediments, baffle currents and mediate water flows) can lead to increased erosion (scour), turbidity, and sedimentation, which lead to reductions in suitable habitat for *S. alterniflora* (Sanger et al. 2004).

Many aquatic species, primarily fish, rely on visual cues for spatial orientation, predator-prey interactions (e.g., prey capture and predator avoidance), migration, and other essential behaviors. Early life history stages of fish are primarily visual feeders that are highly susceptible to starvation - a primary cause of larval mortality in marine fish populations. Juvenile and larval fish survival is likely a critical determining factor for recruitment, with survival linked to the ability to locate and capture prey, and to avoid predation. The reduced-light conditions found under overwater structures limit the ability of fishes, especially juveniles and larvae, to perform these essential prey capture and predator avoidance activities (Johnson et al. 2008). Able et al. (1999) found that caged fish under piers had growth rates similar to those held in laboratory settings without food, while growth rates of fish caged in pile fields (vertical piles only, no horizontal structures) and open water were significantly higher. Able et al. (1998) also demonstrated that juvenile fish abundance and species richness was significantly lower under fishing piers in an urban estuary.

The shadow cast by a structure may also increase predation on species by creating a light-dark interface that allows ambush predators to remain in darkened areas and wait for prey to swim by against a bright background, resulting in high contrast and high visibility (Helfman 1981). Prey species moving around the structure may be unable to see predators in the dark area under the structure or have decreased predator reaction distances and times, thus making them more susceptible to predation, similar to the effects of sediment plumes in the water column (Helfman 1981; Bash et al. 2001). Furthermore, the reduced vegetation densities associated with over-water structures decrease the available refugia from predators, while decreasing prey availability (Alexander and Robinson 2006). Future coastal development will result in further degradation of the underwater light environment, resulting in adverse effects to near shore ecosystems and species (Nightingale and Simenstad 2001).

The overall morphology of the shadow cast by a structure is dependent on the height, width, construction material, and polar orientation of the structure. Work by Battelle Marine Science Laboratory in Washington determined that shading influence from docks could range from four to ten times the total surface area of the dock depending upon dock orientation and season (Washington DNR 2005). Alignment and design modifications to bridges and piers can significantly increase the quantity of light transmitted through or around structures to the underlying habitat, decreasing the impacts of shading (Beal *et al.* 1999; Burdick and Short 1999; Blanton *et al.* 2002; Steinmetz *et al.*2004; Fresh *et al.* 2006; Landry *et al.* 2008; Alexander 2012). Burdick and Short (1999) demonstrated that orientating docks along a north-south plane minimized the shading effect on eelgrass. Seasonality also has a large influence on shading due to the availability of photosynthetically active radiation (PAR) (Alexander 2012). Alexander (2012) showed that, because spring and summer are the major growing seasons for *S. alterniforna*, docks oriented N-S had a much smaller shading impact on the marsh than those with an E-W orientation.

Several studies have demonstrated that alterations to the height and width (height-width ratio; HW ratio) of over-water structures can lead to significant reductions in shading impacts. Dock and pier structures (typically about 4 feet in width) that are built at least 5 feet above mean higher high water (MHHW) have been shown to significantly reduce impacts on primary producers (Beal *et al.* 1999; Burdick and Short 1999; Shafer *et al.* 2008). Alexander (2012) demonstrated that shadow duration and PAR loss under docks decreases as height increases and indicated that docks should be built as high as possible above the marsh surface to minimize shading effects, though the study did not produce specific numbers or ratios. Additionally, docks built no wider than 4 feet in width have been found to reduce shading impacts, though this also depends on the height of the dock (5 feet; Shafer *et al.* 2008). The use of light transmitting material (grated decking) and increased spacing between deck boards has also been found to increase the light transmitted through overwater structures and availability of PAR, helping to decrease shading impacts resulting from these structures (Blanton *et al.* 2002, Fresh *et al.* 2006, Landry *et al.* 2008, Shafer *et al.* 2008; Alexander 2012). Alexander (2012) showed that grated decking provided more PAR under docks when compared to traditional planked decking in spring and summer, though the increase was less than 10 percent. By building traditional structures high enough above the marsh, or other freshwater and nearshore areas, it is possible to negate many of the impacts of shading. During a comprehensive study of bridge shading over estuarine marshes in North Carolina, data indicated that shading by bridges having HW ratios greater than 0.7 significantly reduced adverse impacts to the productivity and function of the underlying marsh (Struck et al. 2004; NCDOT 2005). Dock construction guidelines have been developed based on many principles discussed above, and implemented with success in Florida (NMFS and USACE 2001).

4.3.2.2 Other Effects

4.3.2.2.1 Shore-Zone Effects

Bridges and piers alter the shore-zone (shoreline and nearshore) habitat, promoting changes in flora and fauna assemblages, altering predator-prey relationships, species behavior, and habitat function (Carrasquero 2001). These impacts result from the elimination or alteration of habitat and species via fill or removal or areas for the placement of components such as bridge approach sections. Shoreline vegetation is typically altered as well, where naturally occurring species are removed and replaced with species based on ease of maintenance and aesthetics (Jennings et al. 1999). Fish and other species typically respond negatively to riparian zone changes (e.g., vegetation and woody structure removal) caused by shoreline structure placement, subsequent intensive riparian zone management, and future development that is often facilitated by the structure (Jennings et al. 1999). Elimination or alteration of shoreline habitats can also lead to reductions in sediment storage capacity and loss of organic debris (Williams and Thom 2001). Additionally, overall habitat function can be reduced due to decreases in benthic fauna abundance and diversity that results from shoreline alteration and modification (Seitz et al. 2006). Furthermore, bridge projects typically include some level of shoreline stabilization to ensure long-term structural performance, which can result in a suite of adverse effects to species and habitats. The effects of shoreline stabilization are discussed in detail in Chapter 5.

4.3.2.2.2 Stormwater and Contaminants

Bridges introduce impervious surfaces directly above water bodies, placing transportation stormwater runoff in very close proximity to receiving waters (NCDOT 2012). Roadway runoff is one of several pollutant source categories contributing to surface water impairment (USEPA 2009). Roadway runoff is considered a unique pollutant because of the pollutant –producing processes and sources. Contaminants typically originate from automotive part wear and fluids, roadway materials, and roadway maintenance activities (Jongedyk 1999; NCDOT 2012). Contaminants typically found in roadway runoff include metals, inorganic salts, aromatic hydrocarbons, suspended solids (sediments), and automotive materials such as oil, grease, rust, and rubber particles. The presence and concentrations of pollutants are a function of many factors such as traffic patterns and bridge characteristics, season, precipitation, individual storm intensity and land use (Jongedyk 1999; Dupuis 2002; Kayhanian et al. 2003).

The contaminants concentrated on bridge deck surfaces and discharged into receiving waters can have various negative impacts on species and habitats. The impacts associated with suspended and deposited sediments that can originate in stormwater runoff are discussed in detail in Chapter 2. Stormwater roadway runoff containing fertilizers and other nutrients can lead to nutrient loading and eutrophication (USEPA 2005). Contaminants contained in stormwater runoff, such as hydrocarbons and metals, can deteriorate aquatic habitats, and decrease habitat function. Additionally, contaminants can have sub-lethal effects on aquatic organisms, which can lead to increased mortality from lowered resistance to disease, slow growth rates, and changes in behavior that reduce individual fitness (i.e., stress effects). Contaminant-related stress can cause physiological, bioenergetic, and behavioral alterations, which may in turn affect egg quantity or quality and embryo development in fish (Bash et al. 2001). Exposure to contaminants can directly lead to mortality, but interference with natural physiological processes is more common, impacting reproduction, development, growth, and behavior of aquatic organisms, especially early life-history stages (Hanson et al. 2003). Contaminants and debris can also be directly introduced (not through stormwater) into aquatic systems as a result of maintenance activities like scraping and painting, bridge deck rehabilitation, and other activities that take place over receiving waters. These impacts can be minimized using containment methods such as netting and work platforms.

The impacts associated with bridge runoff are a function both the contaminants present and the drainage treatment methods that are implemented. Two primary stormwater management systems are used for bridge structures, including “direct discharge drainage systems” and “no-direct discharge drainage systems.” Direct systems allow for the collection of runoff to discharge freely to the surface waters below the bridge through deck drains or scuppers. In contrast, no-direct systems redirect runoff through constructed infrastructure that includes both closed (typically pipes) and open systems. Closed systems pipe bridge deck runoff to a central discharge location (usually to a stormwater control BMP for water quality purposes). Open systems typically include bridge gutters that redirect runoff, typically used for bridges with low runoff volume (NCDOT 2012). A combination of structural (post-construction in-situ and end-of-pipe controls) and non-structural (source control, design-related, and maintenance) control measures can be effective at minimizing or mitigation the effects of roadway runoff on aquatic environments (NCDOT 2012). However, due to the unique characteristics of each project, stormwater impacts and control measures should be evaluated on a project-by-project basis.

4.3.3 Culverts

This section is predicated on the fact that culverts are less environmentally damaging when compared to permanently filling, blocking or rerouting water bodies. However, at present, filling, blocking, or rerouting waterbodies is rarely proposed by action agencies or approved by natural resource agencies.

4.3.3.1 Short-term Effects

Construction, installation, maintenance and removal or demolition of culverts can lead to short-term adverse impacts to aquatic species and habitats, though these are ephemeral and typically dissipate in minutes, hours, or days. Many of the short-term impacts associated with culvert activities are the same as other impacts from general in-water work activities, including hydroacoustic effects and erosion, turbidity, and sedimentation effects, which can negatively impact habitats (e.g., reduce habitat function) and species (e.g., injury and behavior modification) (Hanson et al. 2003). Hydroacoustic, erosion, sedimentation, and turbidity impacts are discussed in detail in Chapters 2 and 3. Disturbance to shorelines, including vegetation removal, is also common in culvert projects, where naturally occurring plant species are replaced with other species, typically based on ease of maintenance and aesthetics (Jennings et al. 1999). Clearing of shoreline vegetation and shoreline alteration can also lead to further erosion and introduction of sediments into adjacent waters. However, during construction, stormwater BMPs are typically installed following any land clearing activities and can minimize the erosion and sedimentation effects of shoreline disturbance.

Cofferdams are commonly used to facilitate culvert-related work activities and can have negative impacts on species and habitats. The installation of metal sheet pile with pile drivers (typically vibratory hammers) for the construction of cofferdam walls can lead to elevated underwater noise that can result in temporary behavior modifications to species in close proximity to the pile driving, as well as a temporary reduction in habitat function during pile driving activities (Popper et al. 2014; Caltrans 2015). Noise and disturbance caused by cofferdam installation activities are not anticipated to cause physical injury to species due to the relatively low noise levels produced by vibratory hammers, combined with the short duration of activities. However, species may become injured or killed by becoming trapped within the cofferdam and entrained during cofferdam pump-out. Entrainment is the direct uptake of aquatic plants and animals into a mechanism (e.g. pump, hose) and typically results in injury or mortality (USACE 2015). These impacts can be avoided by using scare tactics or surveying for organisms prior to and during cofferdam construction. The placement of cofferdams can also act as habitat barriers for species, though these impacts can be mitigated by the strategic placement of cofferdams. Additionally, there will be a temporary loss of usable habitat (footprint of the cofferdam) while the cofferdam is in place, but the quality of the habitat will vary based on the location of the project, and impacts should not become permanent following removal of the cofferdam (Hanson et al. 2003). Cofferdams can also be placed in ways that avoid sensitive habitats during the planning process. Numerous impacts of cofferdams as well as other general culvert-related activities can be minimized by limiting the duration of in-water work activities and time temporary work structures are placed in the water (Johnson et al. 2008). Though many short-term impacts can result from culvert-related activities, the primary effects of culvert placement are long-term.

4.3.3.2 Long-term Effects

Numerous long-term impacts to habitats and species can result from the placement of culverts in aquatic environments. These impacts are diverse and can have additive and cumulative impacts to habitats and species. Additionally, because culverts separate up- and downstream habitats, the ecological impacts of culverts can extend to surrounding environments upstream and downstream of the structure and affect the floodplain (Wheeler et al. 2005). The primary long-term adverse ecological impacts of culverts are summarized as follows (WDFW 2003; FHWA 2012):

- Culverts result in the permanent, direct loss of in-water and riparian habitat.
- Installation and maintenance of culverts that confine or constrict the channel or floodplain disrupt ecological connectivity, fragment habitats, alter channel processes and change adjacent channel character and shape by affecting the movement of debris, sediment, channel migration, flood waters and aquatic and terrestrial organisms.
- Fish and other aquatic organism passage can be hindered or blocked at water crossings/culverts.
- Culverts increase the risk of damage to the downstream habitat due to potential culvert failure.

River, stream, and tidal creek (lotic systems) corridors provide vital habitat for a wide range of species, many of which depend on the ability to move freely throughout their ecosystem in order to complete their life cycles and perform necessary ecological functions (Jackson 2003). Aquatic fauna are particularly susceptible to the impacts from culverts and are generally at higher risk than terrestrial fauna because their movements are confined by the narrow linear geometry of stream, river, and creek channels (Wheeler et al. 2005). Roads extend through virtually every habitat, inevitably crossing over lotic systems, resulting in long-term ecological effects including loss and change of habitat, changes in biological makeup of communities, and fragmentation of habitats and populations (Spellerberg 1998; FHWA 2010). On the most fundamental level, culverts are static, rigid structures that are placed in dynamic, constantly changing aquatic environments. Because stream, river, and tidal creek channels are continually evolving, and an understanding of channel processes is essential for culvert placement, design, and long-term performance. Without proper consideration of channel processes, combined with the physical and biological characteristics of the organisms that utilize these aquatic environments, culverts can lead to severe adverse impacts to aquatic habitats and species, potentially leading to a cascade of negative impacts that are experienced great distances from the culvert itself (FHWA 2012). However, even properly designed culvert projects that consider a comprehensive suite of physical and biological factors can result in adverse effects (Spellerberg 1998).

Culverts can eliminate habitat by replacing native bed and bank material with artificially hard, uniform structures (WDFW 2003). These habitats can be necessary for organisms to feed, develop, breed, rear, and carry out other essential biological and ecological functions. Closed conduit culverts have the most direct habitat loss impacts because they replace natural bed and bank material with metal, plastic or concrete, whereas bottomless culverts, as their name suggests, replace mainly bank material with artificial structures (FHWA 2012). Additionally, culvert construction and installation can require significant channel realignment, which can eliminate natural meanders, bends, and other channel morphology that is important to habitat diversity (WDFW 2003; FHWA 2010). Culverts also typically shorten channel width, leading to increased velocities and bed instability that reduce habitat value and can affect various life stages of aquatic organisms (e.g., eggs, juveniles, and adults). Habitat loss and degradation directly up and downstream of culverts is also common. For example, important spawning habitat immediately downstream of a culvert can be scoured if flow velocity is increased through the culvert (WDFW 2003). Long-term increases in velocity and other alterations to the channel resulting from culvert placement can also lead to channel incision, or removal of bed material that lowers the overall bed elevation. Channel incision can disconnect channels from their floodplain, remove habitat and lead to an unstable channel ecosystem that will continuously erode until it reaches new equilibrium (Darby 1999; Johnson et al. 2001). The channel of a river or stream, including its geometry, bed material size, bank stability, and other characteristics, are all controlled by flow regime. Any alteration or control on a natural flowing system can modify channel size and shape and induce a range of adverse environmental effects (Gilvear et al. 2002).

Increased velocity, and subsequent increased turbulence, from a culvert can result in negative impacts to habitats and species, though these impacts are most severe with undersized culverts. Therefore, to reduce the likelihood of negative impacts from increased velocity, the flow velocity at the culvert exit should not exceed the pre-project channel velocity. However, it has been suggested that exceeding pre-project velocities by 25 percent or less would be acceptable (WDFW 2003). Increased velocity through a culvert can erode downstream banks, leading to the need for shoreline stabilization. At high flows, undersized culverts create backwaters and high head pressures, where sediments are deposited in the channel upstream and erosion of the bed and bank takes place with receding flows, often requiring further shoreline stabilization (WDFW 2003). Additionally, a culvert placed in a stream with an actively migrating channel can result in an acceleration of bank erosion and channel migration, typically requiring substantial effort to keep the channel at the culvert location (FHWA 2012). Additional adverse impacts also result from increased erosion in and around channels.

Introduced sediment into water bodies resulting from culvert placement, and the subsequent turbidity and sedimentation, can also eliminate or significantly alter habitats and impact species. Long-term increases in sediment introduction can result from shoreline alteration as well as alterations to the hydrodynamics (e.g. increased scour) of an area due to culvert placement (Johnson et al. 2008). Additionally, increased sedimentation rates can bury aquatic life and lead to mid channel bar formation, which can deflect flows towards the banks and lead to further bank erosion. Increased erosion will increase the cross sectional area of a channel, resulting in reduced velocities that ultimately reduce the channel's sediment transport capacity, and allow more sediment to settle out (Frizeell et al. 2004). Increased turbidity that results from elevated levels of introduced sediments can also have a wide range of negative impacts on species and decrease habitat function (Hanson et al. 2003).

Culvert placement can negatively affect ecological connectivity: the capacity of a landscape to support the movement of organisms, materials, or energy. Ecological connectivity is significant to the health of aquatic ecosystems and biological and physical connectivity should be managed by allowing species and material to pass unhindered through culverts (WDFW 2003). Biotic linkages in stream environments can include upstream and downstream movement of organisms like fish and aquatic invertebrates. In fact, culvert installation can significantly decrease the probability of aquatic organism movement between habitat patches (Schaefer et al. 2003). Many aquatic organisms migrate up and downstream for breeding, feeding, and other life processes, which can be hindered by the placement of culverts. This is especially true for anadromous fish such as Atlantic and shortnose sturgeon. Sturgeon, and other anadromous fish in the southeast, travel hundreds of kilometers from marine environments upstream to freshwater river reaches to spawn. Sturgeon migration and spawning events are largely tied to season, flow rate and water temperature (Post et al. 2014). Because sturgeon primarily use large, mainstem rivers, culverts would negatively impact individuals and habitats by converting shoreline into artificially hardened structures, likely reduce the bank-full width of the river, increase velocity in the channel, and lead to various other negative impacts associated with culverts. In fact, placing culverts in large, mainstem rivers would likely be viewed by numerous natural resource agencies as environmentally damaging and inconsistent with numerous regulations. Culverts and other structures that impede access to spawning and foraging habitat and modify river and stream flows or temperatures can have profound negative impacts on sturgeon and other anadromous fish (ASSRT 2007).

The detrimental impacts of culverts and other passage barriers have been studied extensively, with a majority of the research focused on fish (FHWA 2010). However, passage barriers are relevant to both fish and other aquatic organisms and include excessive water velocities, drops at culvert inlets or outlets (perched culverts), physical barriers such as weirs, baffles, or debris caught in the culvert barrel, excessive turbulence caused by flow contraction and expansion, and low flows that provide too little depth for movement (FHWA 2012). Aquatic organism movement capacities will also vary with species and life stage and are often related to seasonality (FHWA 2010). Though numerous physical characteristics of the stream environment will influence aquatic organism passage, biological and physiological traits of the species also affect their ability to move up and downstream and should be considered in culvert design (Schaefer et al. 2003; FHWA 2012).

The movement of material, such as sediment and debris, natural channel shifts, and other biogeochemical processes such as elemental cycling are also impacted by culvert placement (Segar and Segar 2007). Physical and chemical alterations restructure biotic communities and cause declines in the diversity and productivity of invertebrates and fishes (Wang et al. 2001). For example, when debris cannot pass through culverts, it can create a variety of negative impacts. These impacts can include the creation of barriers to aquatic organism passage, creation of backwaters upstream that extend the negative impacts of the culvert, and loss of debris transport downstream. Because of their small individual size, multiple, parallel culverts generally exacerbate these issues, as they can trap debris, create barriers and increase the risk of culvert failure (WDFW 2003).

Many of the long-term negative impacts associated with culvert installation and construction are exacerbated by two factors: undersized culverts, and streams, rivers and tidal creeks with multiple crossings/culverts located in succession (Trombulak and Frissell 2000; Wheeler et al. 2005). Undersized culverts can magnify the adverse impacts associated with culvert placement: primarily increased flow velocities, increase erosion, sedimentation, and turbidity, and drastically reduced passage of aquatic organisms (FHWA 2010). Additionally, undersized culverts regularly build up backwaters, altering channel morphology and negatively impacting habitats and species. Undersized culverts also have a higher risk of failure because of elevated head pressures created by constricted flows and the high risk of debris buildup (WDFW 2003). Much like undersized culverts, numerous culverts in the same water body can magnify the negative impacts associated with culvert placement. The number of road/water crossings in a stream is a sign of habitat degradation, where the more stream crossings that are present, the more degraded the habitat (Kosnicki et al. 2014). For aquatic organisms, increases in the number of culverts/crossings an individual must pass through, especially for spawning purposes, can drastically reduce reproductive output and survivorship, which can have long-term negative impacts on the health of populations (ASSRT 2007; FHWA 2010).

Numerous studies have demonstrated the adverse impacts of culverts on physical properties of lotic systems and have documented reduced upstream and downstream movement of organisms between areas separated by culverts versus other structures, or no structures (e.g., Benton et al. 2008). Regionally, the North Carolina Department of Transportation (NCDOT) commissioned an extensive study comparing the impacts of culverts versus bridges on stream habitat and aquatic fauna (Levine et al. 2007). Levine et al. (2007) found that geomorphology of streams was significantly altered by culverts as a result of channel restriction, and increased flow velocity and turbulence scour that it created; channels tended to be wider and deeper downstream of culverts (compared to upstream) and scour holes were prevalent downstream of culverts. The detrimental geomorphic conditions created by culverts could be mitigated by providing floodplain access, through oversizing culverts, though the use of bridges may be even more beneficial than oversizing culverts (Levine et al. 2007).

Levine et al. (2007) also investigated the impacts of culverts compared to bridges on aquatic organisms. Freshwater mussels are among the most threatened of aquatic organisms and various ESA-listed freshwater mussels occur in NC, SC, and GA. Levine et al. (2007) found that mussel populations were reduced for surveyed reaches (150 meters) downstream compared to upstream, and increased scour at culverts was linked with decreasing mussel abundance downstream. Furthermore, Levine et al. (2007) investigated fish passage at numerous streams in North Carolina by quantifying the impact of road crossings on stream fish abundance, diversity, and movement. Fish abundance and diversity measures showed little or no road-crossing effect. However, this was likely due to the insensitivity of stream fish variables to anthropogenic effects used in the analysis, the overall resilience of fish communities, or the shifting baseline hypothesis – that fish communities have shifted to an impacted community prior to sampling (Levin et al. 2007). The shifting baseline hypothesis is supported by Kosnicki et al. (2014), who conducted a wide-ranging study of streams in NC, SC, and GA. The study characterized the current reference condition of streams in the southeast, and determined that all streams have been influenced by anthropogenic activity, including legacy effects from historical agriculture and modern-day development pressure. In another aspect of this study, Levin et al. (2007) used passive integrated transponder (PIT) tags and remote antenna array systems to assess stream fish movement through box culverts and bridges. Mean percent movement of fish through box culverts was found to be almost half that of movement through (under) bridges (Levin et al 2007).

4.3.4 Consideration of Climate Change and Sea Level Rise

Planners and engineers face unprecedented changes in several variables relevant to the planning, design and construction processes of long-life assets, including bridges, piers, and culverts. These variables include climate change and sea level rise (SLR), which have wide-ranging impacts on all natural and human (built) systems, including transportation infrastructure (Doll et al. 2012). Climate change is the result of increased global mean surface temperatures due to anthropogenic activities, primarily from increases in well-mixed greenhouse gases (WMGHG) in the atmosphere (IPCC 2014). Warming of the climate system is unequivocal and changes to the climate system are extensive; multi-decadal changes in regional temperatures, the water cycle, global energy budget, the cryosphere, and oceans have been consistently modelled and observed (IPCC 2013; USGCRP 2014). Although the impacts of climate change and SLR are widespread and vary by region, many impacts are concentrated in riverine and coastal areas, where NOAA-trust resources occur (FHWA 2014 and 2016). These areas also represent the intersection of NOAA-trust resources with transportation assets. Therefore, impacts from climate change and SLR on transportation infrastructure, including bridges, piers, and culverts, may influence impacts to NOAA-trust resources.

Numerous changes to the climate system can affect transportation infrastructure, including in areas where NOAA-trust resources occur. The transportation sector consistently identifies the following set of climate change impacts as most relevant to transportation infrastructure: (1) increases in intense precipitation events, (2) rising sea levels and associated storm surge, (3) increases in very hot days and heat waves, and (4) increases in hurricane intensity (USGCRP 2014; USDOT 2014). The impacts to transportation infrastructure from climate change include system failures, component damage, accelerated deterioration, travel delays, and public safety risks and are experienced throughout highways, rail, air, maritime and port facilities, and general pavement systems (USDOT 2014; USDOT 2015; Douglas et al. 2017). The resiliency and adaptive capacity of transportation infrastructure to the predictable impacts of climate change and SLR is largely dependent on the location and design of structures. Numerous adaptation strategies exist for coping with future climate change and SLR and generally include increased maintenance and redundancy, constructing protective measures, accommodation (through design), and relocation, all of which have differential impacts on NOAA-trust resources (FHWA 2014). Because climate change and SLR affects transportation infrastructure design, planning, construction and maintenance in areas where NOAA-trust resources occur, climate change and SLR should be considered through all phases of highway project development.

A myriad of federal, state, and local agencies as well as universities, non- and intergovernmental organizations, and research networks have expansive research and guidance on considering climate change and SLR in many areas of planning and design. Because the amount of literature on this subject is vast and comprehensive discussion and analysis is outside the scope of this document, transportation planners and practitioners should use all of the resources at their disposal for considering climate change and SLR. These include, but are not limited to, the Intergovernmental Panel on Climate Change, U.S. Department of Transportation, U.S. Environmental Protection Agency, FHWA, NOAA, state Departments of Natural Resources and Transportation, The Nature Conservancy, and the Infrastructure and Climate Network (ICNet). These resources will aid transportation agencies in planning, designing, constructing, and maintaining long-lived assets, particularly in areas where NOAA-trust resources occur.

4.4 Recommended Best Management Practices

Implementing recommended best management practices (BMPs) will aid FHWA/state DOTs in avoiding and minimizing impacts to NOAA-trust resources by reducing the exposure of species and habitats to stressors and eliminating the plausible routes of effects. Projects that cannot avoid or sufficiently minimize impacts to species or habitats may need to implement compensatory mitigation/measures. Though a comprehensive list of BMPs is provided, innovative techniques and methodologies may lead to the development of additional BMPs, but their use should be coordinated with NMFS on a case-by-case basis.

The BMPs are discretionary measures that transportation agencies can incorporate during project planning to avoid and minimizing potential impacts to NOAA-trust resources. The BMPs provide more transparency and predictability to FHWA and State DOTs regarding species conservation, habitat needs, and NMFS' recommendations. Frontloading BMPs into early design phases of projects will likely lead to reduced consultation timeframes, reduced delays, and could reduce the potential for future redesign of projects. Many BMPs can be incorporated into the design of projects, while others may be addressed as environmental commitments for contractors.

***** *All best management practices related to structural project components and construction techniques are contingent upon engineering feasibility and other design considerations.*

4.4.1 Bridges and Piers

BP1 Fill should be limited to the minimum amount necessary to complete the project.

BP2 Activities should be limited to the minimum amounts necessary to build new structures, replace functionally obsolete and/or structurally deficient structures, or to expand, restore or improve safety and functionality of existing structures.

BP3 To the maximum extent practicable, reduce the width, increase the height, and minimize the number of in-water substructures of bridges, piers, or docks to reduce the impacts of shading.

BP4 The height-width (HW) ratio of newly constructed (new or replacement) bridges, piers, or docks should be 0.7 or great.

BP5 To the maximum extent practicable, structures should be oriented in an N-S direction to reduce the impacts of shading.

BP6 For pedestrian and cyclist bridges and for piers and docks, the use of solid decking (concrete) should be avoided or minimized, to the extent practicable. Wood or composite planking with a consistent spacing of 0.5 inches between deck boards or grated decking with maximal open spacing should be used to minimize shading impacts. Other measures to reduce shading may exist, and their use should be coordinated with NMFS.

BP7 To the maximum extent practicable, bridges should be designed (mainly the height of the bridge) to accommodate a 100-year flow event, and allow for unimpeded tidal and storm flows without encroachment into stream or tidal creek channels (e.g., superstructure components should not impede or obstruct flows).

BP8 New and replacement bridges should be evaluated in reference to projected sea level rise relating to the design life of the structure. The range of sea level rise scenarios considered should be between three and six feet by 2100, as described in The Third National Climate Assessment, 2014 (U.S. Global Change Research Program).

BP9 For twin-span bridge expansion, space between the spans should be used first before expanding outward, to the maximum extent practicable.

BP10 For bridge replacements on existing or parallel alignments, approach-fills no longer used due to modifications of the bridge design (e.g., lengthening) or fills not intended to be used for stormwater treatment, should be removed to the maximum extent practical and graded to adjacent habitat levels, as determined through on-site surveys.

- Monitoring should be done to verify establishment of target species occurs within one or two growing seasons.

- Monitoring and performance standards should be proposed if the areas will be used for mitigation; a mitigation plan should be developed.
- A functional assessment should be used to deduct all or a portion of the fill removal when determining total project impacts.
- Restoration of existing approach-fill removal areas should be coordinated with the NMFS and state resource agencies. Living shorelines should be prioritized in these areas (refer to Guidance for Considering the Use of Living Shorelines, NOAA 2015, discussed in Chapter 5).

BP11 To the maximum extent practicable, top-down construction methodologies should be used to avoid and minimize impacts.

BP12 The use of temporary work trestles, floating barges, and low ground bearing pressure track equipment should be maximized for access to construction areas. The use of temporary fills and timber/crane mats should be avoided, to the maximum extent practicable.

BP13 Work areas should be isolated from adjacent streams, tidal creeks, wetlands or other waters of the U.S. by placing silt fences, silt curtains, or other approved sediment and erosion control devices on the perimeter of the work area to prevent sediment input into any waters of the United States.

BP14 Any shoreline stabilization and placement of new material for shoreline stabilization should be minimized to amounts necessary to construct or protect a structure. See Chapter 5 for additional recommendations.

BP15 To reduce impacts to sea turtles, fishing from roadway, pedestrian, and cycling bridges should be prevented where sea turtles may occur.

BP16 In areas where sea turtles occur, artificial lighting associated with bridges should be oriented to avoid and minimize illumination of the surrounding waters at night.

BP17 Structures should be designed to minimize the need and frequency for future maintenance dredging.

BP18 For bridge maintenance activities such as scraping and painting that may result in debris or contaminants falling directly into the water, full containment measures, such as diaper curtains, should be used.

BP19 A combination of structural (post-construction in-situ and end-of-pipe controls) and non-structural (source control, design-related, and maintenance) stormwater control measures should be used to minimize or mitigate the effects of bridge runoff.

BP20 To the maximum extent practicable, stormwater systems should be designed to accommodate increased precipitation events, including heavy/intense precipitation events, which have increased as a result of climate change.

BP21 To the maximum extent practicable, systems that redirect runoff through constructed infrastructure that includes both closed (typically pipes) and open systems should be used.

BP22 To the maximum extent practicable, the use of direct systems that allow runoff to discharge freely to the surface waters below bridges through deck drains or scuppers should be avoided.

4.4.2 Culverts

CU1 Culvert installation, construction, maintenance, and demolition activities should be timed and located in ways that avoid and minimize potential adverse impacts to NOAA-trust resources. This should include implementing seasonal work windows.

CU2 The number of crossings where culverts would be necessary should be minimized by realigning roadways and consolidating water crossings.

CU3 Culvert size should accommodate a 100-year flow event and allow unimpeded tidal and storm flows without encroachment into stream or tidal creek channels.

CU4 Culverts should allow for normative physical processes within the stream-floodplain corridor by promoting natural sediment transport patterns, providing unaltered fluvial debris movement, and restoring or maintaining functional longitudinal continuity and connectivity of the stream-floodplain system. Culverts should be designed to maintain or replicate natural stream channel and flow conditions; the structure should allow unimpeded base flows, peaks flows, stormflows, and the full-range of tidal flows.

CU5 Culvert design and alternative selection should be based on the biological significance and ecological risk of a particular site – culverts should be designed with the focus on facilitating aquatic organism passage through a culvert and maintaining overall ecological connectivity.

CU6 To the maximum extent practicable, the preferred alternatives for water body crossings outlined below for both new culverts and culvert replacement projects should be followed. The alternatives and structure types should be considered in order of preference:

- Nothing – Road abandonment and reclamation; realignment to avoid crossing water bodies altogether.
- Bridge – spanning the entire water body and flood plain to allow for long-term dynamic channel stability, floodplain connectivity, retention of existing habitat, maintenance of food (primary producers and benthic invertebrate) production, and minimized risk of failure.
- Active channel design – culverts are sized sufficiently large enough and/or embedded deep enough into the channel to allow the natural movement of bedload and formation of a stable bed inside the culvert.
- Stream simulation strategies – Embedded culverts, bottomless culverts or non-floodplain spanning stream simulation.
- Hydraulic design methods/non-embedded culvert – associated with more traditional culvert design approaches limited to low slopes for fish passage.
- Culvert designed with fishway (including roughened channels) – for areas with steeper slopes.
- Baffled culvert/internal weir– for use only when other alternatives are infeasible.

CU7 Culverts should maintain low flow conditions at all times; multiple small, parallel culverts should be avoided.

CU8 Culvert replacements should be "in-kind" or follow the order of preference listed above.

CU9 To the maximum extent practicable, undersized and perched culverts should be replaced as soon as possible, following the order of preference listed above.

CU10 Damaged or poorly functioning culverts should be replaced as soon as possible, following the order of preference listed above.

CU11 For projects that may affect fish passage, project documents should describe how the proposed structure would meet the active channel design, stream simulation, or hydraulic design criteria. These criteria are described in the publications listed below. The included analysis should evaluate the existing and proposed channel conditions within the action area and vicinity. Types of analysis used to assess fish passage conditions include hydraulic, geomorphic, and sediment and debris transport.

CU12 For work on crossings with known or potential tidal restrictions, tide gauge data should be collected to quantify the restriction and develop alternatives that can be evaluated prior to and during the design phase of the project.

CU13 Unimpeded water flows to adjoining habitats should be allowed throughout all construction phases (including maintenance and demolition) of culvert projects; cofferdams may restrict or reduce flows during construction, but should not block or inhibit all flow, to the maximum extent practicable. If flow must be blocked or inhibited, the duration should be minimized to the maximum extent practicable.

CU14 Cofferdams required for culvert projects should be placed in ways that avoid sensitive habitats (e.g., submerged aquatic vegetation and oyster reefs) and do not block passage of aquatic organisms; individual stressors and effects generated from coffer dam construction should be avoided and minimized as described in other chapters (e.g., Chapter 3 for hydroacoustic effects). If flow must be blocked or inhibited, the duration should be minimized to the maximum extent practicable.

CU15 All fish, and any managed or listed species, should be removed prior to dewatering cofferdams. Removal should only be undertaken by qualified fisheries biologists. If ESA-listed species are present (most likely Atlantic or shortnose sturgeon), or suspected to be present, the head fishery biologist must hold a current Section 10 permit for capturing and handling the species.

CU16 Upstream and downstream channel and bank conditions should be maintained and stabilized if the crossing structure causes erosion or accretion problems.

CU17 Shoreline stabilization and placement of new material for shoreline stabilization associated with culverts should be limited to the minimum amounts necessary to protect culverts. See Chapter 5 for additional recommendations.

CU18 Structures should be designed and located to avoid or minimize the need and frequency for future maintenance activities, including dredging.

CU19 For culvert maintenance, removal of sediment and debris should be limited to the minimum amount necessary to restore normal flows of the waterway. Normally, this removal would be within 100 feet of the culvert. Removed sediments and debris should be placed in an upland location isolated from streams, tidal creeks, road drainages, or other waters of the United States.

CU20 All fish passage projects in NMFS' jurisdiction should be coordinated with NMFS SERO PRD and HCD biologists as early in the process as possible.

The majority of peer-reviewed and technical literature recommends that bridges should be used in lieu of culverts whenever possible. If bridges are not feasible, numerous publications provide planning and design recommendations, as well as construction specifications for the construction and placement of culverts in aquatic environments. Though numerous publications focus on salmonid passage, the principles described for salmonids are broadly applicable for the passage of most aquatic organisms. The most relevant publications include[1]:

Anadromous salmonid passage facility design. NMFS, 2011; Guidelines for salmonid passage at stream crossings. NMFS, 2001. http://www.westcoast.fisheries.noaa.gov/publications/

Design of road culverts for fish passage. Washington Department of Fish and Wildlife (WDFW). 2003. http://wdfw.wa.gov/publications/00049/

Culvert design for aquatic organism passage. Federal Highway Administration (FHWA). 2010. https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=204&id=145

Hydraulic design of highway culverts, Third Edition. Federal Highway Administration (FHWA). 2012. https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=7&id=13

Relevant publications related to the impacts of climate change and SLR should be used when developing bridges, piers, and culvert projects. These publications include, but are not limited to:

HEC-25. Highways in the coastal environment – assessing extreme events. 2014. Hydraulic Engineering Circular No. 25. https://www.fhwa.dot.gov/engineering/hydraulics/

HEC-17. Highways in the river environment – floodplains, extreme events, risk, and resilience. 2016. Hydraulic Engineering Circular No. 17, 2nd edition. https://www.fhwa.dot.gov/engineering/hydraulics

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5 Shoreline Stabilization

5.1 Actions

This chapter addresses the activities commonly employed for long-term, permanent efforts to control erosion and stabilize shorelines related to transportation projects.

5.1.1 Shoreline Stabilization Installation

Structural and material elements are typically used to permanently control erosion and stabilize shorelines associated with roadways and bridges in NC, SC, and GA. Generally, roadway and bridge shoreline stabilization elements include filter structures that allow water, but not soil/sediment, to pass through while reducing wave energy, and vertical wall structures that separate the natural shoreline from the water (and wave energy).

5.1.1.1 Shore-parallel, On-shore Structures

A variety of structures or materials can be built or placed parallel to shore on an existing, restored, or modified shoreline. Revetments, bulkheads, seawalls, and gabions protect the area immediately behind them, but afford no protection to adjacent areas or areas in front. These structures stabilize shorelines by enclosing and protecting areas, preventing the shoreline from functioning normally. By separating the shoreline from the water, these shoreline stabilization structures typically modify stream, river, and coastal processes (USACE 1992).

Rock riprap is the most common shoreline stabilization material used in transportation projects. Rock riprap is used as a general term to describe a variety of stone, rubble, concrete or other rock armoring used for shoreline protection and stabilization. Riprap is typically defined within the construction specifications of a project. Installing rock riprap consists of placing rock, typically in the form of hard quarry stone or fieldstone, on a shaped and graded slope. A transitional layer of gravel, small stone, or fabric can be placed between the underlying soil and the riprap to prevent material migration. Riprap is typically placed from the toe of the fill to the top of the fill. Various other structures, such as metal sheet piling, can be installed in conjunction with riprap for shoreline stabilization projects. Riprap is used in a variety of scenarios due to its versatility and cost.

Stone revetments are filter-type structures that reduce wave energy while preventing migration of the soil beneath. Stone revetments are constructed by placing progressively larger stones atop a graded shoreline covered in geotextile fabric. Stone revetments typically include a layer of armoring (typically large stone riprap) that reduces the energy of waves and flowing water. Beneath the armoring are various sizes of smaller stones, fine gravel, and other materials that are placed on geotextile fabric (filter cloth). The geotextile fabric is placed on backfill, which is typically graded to a 2:1 slope. Other structures, such as toe protection and a splash apron may also be installed with stone revetments. Stone revetments are typically used when groundwater influx is part of the erosional process (e.g., ground water penetrates from the underlying soil while incoming waves strike the shoreline).

Retaining walls, bulkheads, and seawalls are all vertical wall structures that separate the natural shoreline from the water. These vertical walls are typically constructed of vinyl, metal sheet pile, or prefabricated concrete slabs, but timber may also be used. These structures are typically installed from land or from a shallow-draft barge with land-based equipment by trenching, grading, or shaping the shoreline and installing vertical pieces. Vertical wall structures may be supported by piles installed by vibratory or impact hammer and/or deadmen anchors that hook underground behind the wall stabilizing them to the uplands. Footers can also be used, which are typically short/low level walls placed directly in front of a vertical wall to protect the bottom from erosion and scouring. Riprap footers are also used and are typically placed by trenching the location (i.e., dredging), placing filter fabric, and then placing riprap on top of the fabric.

Gabions are enclosures or cages filled with material. These cages can be various shapes (e.g. cylindrical or rectangular) and sizes, can be filled with a variety of materials, and can be used in a number of scenarios. For shoreline stabilization in transportation projects, gabions are typically rectangular structures made of wire mesh or galvanized steel chain link fabric filled with rock riprap. Gabions are modular, so they can be moved and placed easily, and typically contain rock riprap, which can be an advantage to loose riprap that may become dislodged and removed by hydrodynamic forces. The main benefit of gabions is that they can be filled with rocks that would individually be too small to withstand the erosive forces of water (Freeman & Fischenich 2000).

5.1.1.2 Shore-connected Structures

Shore-connected structures are those structures used for shoreline stabilization, erosion control, and sediment accretion that are connected to the shore and extend out into the water. Groins are the most common shore-connected structure used for shoreline stabilization. Groins are typically made of large rock riprap (armor stone) and are built perpendicular to the shore, extending from the backshore out into the water. Although groins are typically straight perpendicular structures, groins can be hooked or curved or have a shore-parallel T-head at their seaward end. Groins are regularly used to disrupt the natural processes and currents along shorelines, including the longshore drift system on beaches of barrier islands. The purpose of a groin is to block the downstream flow (in rivers or streams) or longshore current so that sediment accumulates on the updrift/upstream side of the groin, accreting sediment and widening the shoreline. However, this further depletes the sediment supply to the shoreline on the downdrift/downstream side, which may lead to severe erosion. A common solution to this problem is to build a series of groins, often extending the entire length of a shoreline (USACE 1992). Jetties are similar structures that are built to protect and stabilize inlets, and prevent erosion of banks and subsequent siltation of navigational channels. Jetties are rarely constructed by transportation agencies.

5.1.1.3 Living Shorelines

Living shoreline is a broad term that encompasses a range of shoreline stabilization techniques along estuarine coasts, bays, sheltered coastlines, and tributaries. A living shoreline has a footprint that is made up mostly of native material, often incorporating vegetation or other living, natural elements. Many living shoreline projects combine “soft” elements with some type of harder shoreline structure, such as oyster reefs or rock sills, for added stability. Living shoreline projects typically use natural (e.g. oyster shell) and nature-based (e.g. rocks where they do not naturally occur) materials for added stability rather than metal, concrete or synthetic materials. Living shorelines maintain continuity of the natural land-water interface and reduce erosion while providing habitat value and enhancing coastal resilience (NOAA 2015).

5.1.1.4 Indirect Shoreline Stabilization Techniques

Direct shoreline stabilization involves addressing an area or section of shoreline that is currently experiencing erosion or has a high probability of experiencing erosion in the future (including 5.1.1.1 –

5.1.1.3). Indirect shoreline stabilization techniques attempt to reduce erosion and stabilize shorelines by addressing the source of the erosion, which is primarily flowing water and its associated erosive forces. Flow deflection structures, measures to reduce or control flow volumes and energy reduction measures are the most common type of indirect shoreline stabilization techniques. These indirect techniques are mostly associated with river and stream shoreline stabilization.

5.1.2 Shoreline Stabilization Removal

Removal of shoreline stabilization projects or structures can include pile and footing removal, excavation and dredging of riprap and other material and jackhammering or other methods to break apart large concrete structures. Removal of structures, riprap, and other material is regularly coupled with re-contouring or changing slopes in shoreline areas. These activities are typically performed from the shoreline or a shallow-draft barge.

5.2 Stressors

5.2.1 Types of Stressors

Types of stressors generated from shoreline stabilization projects are outlined below. While some of the stressors overlap, these are generally accepted as the environmental stressors potentially resulting from shoreline stabilization activities and the long-term placement of structures. Detailed descriptions and explanations of stressors can be found in Chapter 1.

5.2.1.1 Shoreline Stabilization Installation

Shoreline stabilization installation generates numerous stressors through the operation of specialized equipment to place riprap and other material in aquatic environments, construction of temporary work structures, and the long-term placement of shoreline stabilization structures and materials. The primary stressors generated from shoreline stabilization installation activities are habitat loss and degradation, specifically filling habitats, removing vegetation, converting natural shorelines to artificial structures, and altering hydrodynamics. Alterations to wave energy and water transport (flow and currents) are the primary hydrodynamic features typically impacted by shoreline stabilization projects. Additional stressors include increased turbidity and sedimentation, decreased water quality, elevated noise/pressure levels and resuspension of contaminants, and vessel interaction. Dewatering of areas, including cofferdams, to obtain dry working conditions for shoreline stabilization projects can result in numerous stressors including the impingement or entrainment of aquatic organisms. The placement of cofferdams can also temporarily eliminate habitat and alter hydrodynamics.

5.2.1.2 Shoreline Stabilization Removal

Shoreline stabilization removal generates numerous stressors through the operation of specialized equipment to remove riprap and shoreline structures in aquatic environments. The primary stressors generated from shoreline stabilization removal activities are increased erosion, turbidity, sedimentation, and decreased water quality. The placement and dewatering of cofferdams can result in numerous stressors including the impingement or entrainment of aquatic organisms, resuspension of contaminants/pollutants, and increased turbidity and sedimentation. Additional stressors include elevated noise/pressure levels and vessel interaction.

5.3 Effects

5.3.1 Types of Effects

Types of effects that are expected to result from shoreline stabilization activities are described below. While some effects overlap, these categories are generally accepted as the environmental effects of shoreline stabilization activities, and the long-term placement of structures on NOAA-trust resources. Numerous effects are also described in Chapter 1.

5.3.2 Shoreline Stabilization Activities (Installation and Removal)

Species may be impacted from the placement of shoreline stabilization materials or structures, and the operation of equipment and vessels. This can lead to physical injury or mortality, as well as temporary behavior modifications, such as avoidance or abandonment of an area, or cessation of feeding due to disturbance. Furthermore, short-term elevated turbidity from shoreline stabilization construction, maintenance, and demolition activities as well as long-term elevated turbidity caused by erosion adjacent to or downstream from, the shoreline stabilization can have adverse impacts on species and habitats (Johnson et al. 2008). Additionally, hardened structures themselves provide less physically complex habitat as compared with natural shorelines, so that hardened shorelines generally support fewer species (Seitz el a. 2006).

Invertebrates, fish, and potentially sea turtles in the vicinity where turbidity is elevated may suffer adverse effects including avoidance and abandonment of an area, reduced feeding ability and growth, impaired respiration, and a potential reduction in egg hatching success (Hanson et al. 2003). These taxonomic groups can also experience gill and eye abrasion from suspended sediment in the water column. Additionally, larval fish may experience reduced survival with elevated turbidity. Reduced water transport rates and filter efficiency of fishes and invertebrates as well as decreased foraging efficiency of sight feeders may also result from artificially elevated turbidity (Messieh et al. 1991; Wilber and Clark 2001). Predation rates on federally managed species may also increase, as turbidity plumes may be used to conceal predators. Furthermore, the suspension of sediment particles can also lead to the sedimentation or covering/smothering of species, leading to physical injury, which can lead to direct or indirect mortality (Kjelland et al. 2015). Furthermore, the sedimentation (burying/covering) of habitats and changes in benthic environments via alteration to sediment quality, quantity, and changes in grain size can reduce species diversity and decrease overall ecosystem function (Thrush and Dayton 2002).

Shoreline stabilization activities may also lead to contaminant exposure in the water column by introducing, disturbing, or resuspending contaminants, which can result in direct toxicological impacts on the health or performance of exposed organisms (Hanson et al. 2003). Treated wood used in shoreline stabilization structures may contain chemicals that leach into coastal environments and pesticides, herbicides, heavy metals, toxic compounds and other contaminants are typically retained in shoreline and bottom sediments (Weis et al. 1998). The majority of effects from contaminants are sublethal, impairing the physiological or behavioral performance of individual animals in ways that decrease their growth or survival, alter migratory behavior, or reduce reproductive success (Hanson et al. 2003). Impairment of immune response and elevated stress hormone production are typical sublethal effects experienced by organisms exposed to contaminants (Arkoosh et al. 2001; Balcom and Howell 2006).

Hydroacoustic effects are also possible from shoreline grading and pile installation activities related to vertical walls, but these activities are typically limited in size and duration. Direct species impacts (physical injury or mortality) during shoreline construction, maintenance and demolition are generally seen as less severe for shoreline stabilization projects because species are mobile and will move away from shoreline stabilization activities, if they are disturbed by them, which will reduce the likelihood of injury or mortality. Hydroacoustic effects are described in detail in Chapter 3.

Although shoreline stabilization activities can have adverse impacts on individuals, the primary adverse impacts resulting from shoreline stabilization activities are habitat effects. Shoreline stabilization activities lead to reductions in the quality and quantity of aquatic habitats by converting natural shoreline habitats to uniform, artificial hard substrates. Numerous adverse impacts are associated with shoreline hardening and range from loss of individual organisms and habitats to large-scale reductions in ecosystem services (Currin et al. 2010). More specifically, these adverse impacts include the loss of marsh, sub- and intertidal habitats, and submerged aquatic vegetation, which in turn will result in the loss of critical coastal ecosystem services such as provision of nursery habitat for commercially and recreationally important fisheries, filtration of nutrients and pollutants from terrestrial runoff, carbon burial/sequestration, wave attenuation, and erosion protection (Gittman et al. 2015; Peterson et al. 2008). Furthermore, shoreline hardening severs terrestrial-aquatic linkages, which has been shown to reduce species diversity and composition (Bilkovic and Roggero 2008; Currin et al. 2010). Additionally, shoreline stabilization projects usually require vegetation removal, which is habitat for species, but also leads to changes in temperature regimes in shorelines and nearshore environments (USFWS 2001). Shoreline vegetation is also an important source of energy and nutrients in aquatic environments (Hanson et al. 2003).

Shoreline stabilization affects habitats adjacent to or downstream from the project area, which can result in a cascade of adverse effects. Shoreline armoring for stabilization causes increased energy seaward of the armoring, beach steepening, as well as changes in sediment storage capacity and loss of organic debris (Williams and Thom 2001). Furthermore, in wave-exposed areas, hardened shoreline structures reflect wave energy, which can cause erosion along the toe of the structure and erode adjacent shoreline areas (NOAA 2015). The most severe erosion resulting from reflected wave energy is typically caused by vertical wall structures such as seawalls. Scouring also results from installing shoreline stabilization, including hardened shoreline structures. Scouring removes bottom sediments, thus eliminating benthic habitat and can threaten the integrity of the shoreline stabilization (USACE 1981; Bozek and Burdick 2005). Increased erosion and scour leads to increased turbidity and sedimentation and typically results in the need for further armoring. Further armoring will result in additional direct habitat loss and degradation, sedimentation of habitats, and elevated turbidity in the water column that can reduce the function of habitats (Bozek and Burdick 2005). Unnatural rates of sedimentation adversely impacts habitats by introducing lower quality sediments at higher-than-normal rates, which can degrade the habitat and reduce species diversity. Additionally, habitat function is reduced through decreases in benthic fauna abundance and diversity that results from shoreline hardening from human structures (Seitz et al. 2006).

In riverine and stream habitats, measures to stabilize banks, such as armoring, flow deflection structures, and energy reduction measures, can adversely impact the natural morphology and function of the river or stream, thus adversely affecting fish, invertebrates, and their associated habitats (USFWS 2001). Such measures physically stabilize banks, but may increase river flow velocities, lead to or exacerbate downstream bank erosion (cross-bank distribution of energy) and lead to channel narrowing and bed degradation. These can result in losses of stream and riverine habitat, diminished floodplain connectivity, and reduced sediment and debris input, which can adversely affect nutrient cycling and creation and maintenance of aquatic habitat features. These physical aspects provide diversity of water depth, velocity, temperature and sediment size necessary to maintain habitat for fish, invertebrates, and other species (USFWS 2001).

5.3.3 Consideration of Climate Change and Sea Level Rise

Planners and engineers face unprecedented changes in several variables relevant to the planning, design and construction processes of long-life assets, including shoreline stabilization. These variables include climate change and sea level rise (SLR), which have wide-ranging impacts on all natural and human (built) systems, including transportation infrastructure (Doll et al. 2012). Climate change is the result of increased global mean surface temperatures due to anthropogenic activities, primarily from increases in well-mixed greenhouse gases (WMGHG) in the atmosphere (IPCC 2014). Warming of the climate system is unequivocal and changes to the climate system are extensive; multi-decadal changes in regional temperatures, the water cycle, global energy budget, the cryosphere, and oceans have been consistently modelled and observed (IPCC 2013; USGCRP 2014). Although the impacts of climate change and SLR are widespread and vary by region, many impacts are concentrated in riverine and coastal areas, where NOAA-trust resources occur (FHWA 2014 and 2016). These areas also represent the intersection of NOAA-trust resources with transportation assets. Therefore, impacts from climate change and SLR on transportation infrastructure, including shoreline stabilization, may influence impacts to NOAA-trust resources.

Numerous changes to the climate system can affect transportation infrastructure, including in areas where NOAA-trust resources occur. The transportation sector consistently identifies the following set of climate change impacts as most relevant to transportation infrastructure: (1) increases in intense precipitation events, (2) rising sea levels and associated storm surge, (3) increases in very hot days and heat waves, and (4) increases in hurricane intensity (USGCRP 2014; USDOT 2014). The impacts to transportation infrastructure from climate change include system failures, component damage, accelerated deterioration, travel delays, and public safety risks and are experienced throughout highways, rail, air, maritime and port facilities, and general pavement systems (USDOT 2014; USDOT 2015; Douglas et al. 2017). The resiliency and adaptive capacity of transportation infrastructure to the predictable impacts of climate change and SLR is largely dependent on the location and design of structures. Numerous adaptation strategies exist for coping with future climate change and SLR and generally include increased maintenance and redundancy, constructing protective measures, accommodation (through design), and relocation, all of which have differential impacts on NOAA-trust resources (FHWA 2014). Because climate change and SLR affects transportation infrastructure design, planning, construction and maintenance in areas where NOAA-trust resources occur, climate change and SLR should be considered through all phases of highway project development.

A myriad of federal, state, and local agencies as well as universities, non- and intergovernmental organizations, and research networks have expansive research and guidance on considering climate change and SLR in many areas of planning and design. Because the amount of literature on this subject is vast and comprehensive discussion and analysis is outside the scope of this document, transportation planners and practitioners should use all of the resources at their disposal for considering climate change and SLR. These include, but are not limited to, the Intergovernmental Panel on Climate Change, U.S. Department of Transportation, U.S. Environmental Protection Agency, FHWA, NOAA, state Departments of Natural Resources and Transportation, The Nature Conservancy, and the Infrastructure and Climate Network (ICNet). These resources will aid transportation agencies in planning, designing, constructing, and maintaining long-lived assets, particularly in areas where NOAA-trust resources occur.

5.4 Living Shorelines

NC, SC, and GA have tens of thousands of miles of sheltered (i.e., coasts not exposed to open ocean wave energy) estuarine shoreline, most of which has relatively low-relief with adjacent uplands less than a few meters in elevation. Historically, bulkheads and other vertical wall structures and revetments have been some of the most common methods for shoreline stabilization in these areas (Currin et al. 2010). However, NOAA encourages the use of living shorelines as a shoreline stabilization technique along sheltered coasts (NOAA also has a broad interest in maintaining existing natural habitats that provide shoreline protections along all coasts). Low-relief shorelines generally represent the best sites for living shorelines, because they maintain, enhance or create habitat spanning from subtidal areas, through intertidal areas and into the uplands (Currin et al. 2010). Though generally larger in footprint than vertical wall structures and revetments, living shorelines provide enhanced shoreline stabilization and erosion reduction functions while maintaining habitats and ecosystem function (Currin et al. 2010; Gittman et al. 2014).

Living shorelines can enhance resilience by reducing damage and erosion while simultaneously conserving and improving habitats and their ecosystem functions at the land-water interface (NOAA 2015). Living shorelines can also reduce many of the adverse impacts associated with shoreline hardening (discussed in detail above in section 5.3). These include the loss of habitats, critical coastal ecosystem services, and loss of individuals and overall species diversity (Gittman et al. 2015; Peterson et al. 2008). Numerous studies in the southeast have demonstrated that living shorelines enhance the quantity and function habitats, while providing increased shoreline stabilization as compared to hardened structures (Currin et al. 2010; Gittman et al. 2014; Gittman et al. 2016; see Bilkovic et al. 2017).

To facilitate the goals of living shoreline establishment and creation, NOAA encourages early coordination across multiple agencies and stakeholders to development the best shoreline stabilization options for a particular site. NOAA (2015) provided guidance for considering the use of living shorelines for shoreline stabilization. This document should be used by transportation agencies to avoid and minimize impacts to NOAA-trust resources during shoreline stabilization along sheltered coasts. The document can be found:

Guidance for Considering the Use of Living Shorelines. National Oceanic and Atmospheric Administration (NOAA), 2015. http://www.habitat.noaa.gov/restoration/techniques/livingshorelines.html

5.5 Recommended Best Management Practices

Implementing recommended best management practices (BMPs) will aid FHWA/state DOTs in avoiding and minimizing impacts to NMFS-trust resources by reducing the exposure of species and habitats to stressors and eliminating the plausible routes of effects. Projects that cannot avoid or sufficiently minimize impacts to species or habitats may need to implement compensatory mitigation/measures. Though a comprehensive list of BMPs is provided, innovative techniques and methodologies may lead to the development of additional BMPs, but their use should be coordinated with NMFS on a case-by-case basis.

The BMPs are discretionary measures that transportation agencies can incorporate during project planning to avoid and minimizing potential impacts to NOAA-trust resources. The BMPs provide more transparency and predictability to FHWA and State DOTs regarding species conservation, habitat needs, and NMFS' recommendations. Frontloading BMPs into early design phases of projects will likely lead to reduced consultation timeframes, reduced delays, and could reduce the potential for future redesign of projects. Many BMPs can be incorporated into the design of projects, while others may be addressed as environmental commitments for contractors.

***** *All best management practices related to structural project components and construction techniques are contingent upon engineering feasibility and other design considerations.*

5.5.1 Shoreline Stabilization Installation

SSI1 Activities should be limited to the minimum amount necessary for the erosion prevention/stabilization needed to accomplish the project purpose. For maintenance of existing shoreline stabilization – activities should be limited to those within the same footprint of the original permitted shoreline stabilization.

SSI2 Shoreline stabilization projects should be coordinated with the NMFS and local resource agencies to determine if living shorelines are feasible.

SSI3 To the maximum extent practicable, living shorelines should be prioritized for shoreline stabilization projects. This includes new shoreline stabilization and repairing, replacing, or maintaining existing shoreline stabilization.

SSI4 Shoreline stabilization projects emphasizing living shorelines should utilize structural and local building materials, including wetlands plants, oyster reefs, and sand fills.

SSI5 Shoreline stabilization installation projects occurring in flowing or standing water should be isolated from the rest of the waterbody by using silt fences (with sand bags on the toe), turbidity curtains, or other methods in order to prevent sediment input into the water. Work operations should cease if water rises above the silt fence. Cofferdams may also be used, but are recommended for smaller work areas.

SSI6 When riprap is required, clean rock or masonry riprap (free of pollutants, debris, soil or other materials) should be used.

SSI7 To the maximum extent practicable, materials, such as treated wood, that could leach chemicals into waters adjacent to shoreline stabilization projects should be avoided.

SSI8 To the maximum extent practicable, shoreline stabilization material related to traditional (hardened) structures, including rock riprap and armorstone, should not be placed below the water line.

SSI9 If the project involves the installation of any piles or foundations, including metal sheet piling, Chapter 3 should be used for guidance.

SSI10 If the use of metal sheet piling or piles is unavoidable, a vibratory hammer should be used for installation to reduce hydroacoustic impacts.

SSI11 Concrete mats, debris, metal sheet piling, or other similar material should not be used for shoreline stabilization, as these materials adversely impacts quality and quantity of habitats.

SSI12 To the maximum extent practicable, shoreline stabilization in streams, tidal creeks, and entrances to tidal creeks should be avoided.

SSI13 To the maximum extent practicable, shoreline stabilization should be avoided in, or adjacent to, shellfish areas and in areas with submerged aquatic vegetation (SAV), areas which historically supported SAV, and areas which are potential habitat for SAV. Surveys of historic and current SAV should be conducted to determine distribution and potential for recolonization of SAV.

SSI14 All work crews and personnel should be informed about any ESA-listed species in the area and should have a designated individual (typically environmental manager) to contact when listed species are observed.

SSI15 Work should not begin if ESA-listed species are observed in the area prior to commencement of work; Work should not begin until ESA-listed species have not been observed for a 30-minute period.

5.5.2 Shoreline Stabilization Removal

SSR1 If the project involves the removal of any piles or foundations, including metal sheet piling, Chapter 3 should be used for guidance.

SSR2 Shoreline stabilization removal projects occurring in flowing or standing water should be isolated from the rest of the waterbody by using silt fences (with sand bags on the toe), turbidity curtains, or other methods in order to prevent sediment input into the water. Work operations should cease if water rises above the silt fence. Cofferdams may also be used, but are recommended for smaller work areas.

SSR3 Failing shoreline stabilization structures/materials should be removed and disposed of off-site and/or in upland areas, where there is no chance for migration into aquatic areas.

SSR4 Following shoreline stabilization removal, areas should be restored to natural conditions. Areas that previously had shoreline stabilization should be graded to match adjacent elevations and revegetated with native vegetation, including native species that are found adjacent to the site.

SSR5 All work crews and personnel should be informed about any ESA-listed species in the area and should have a designated individual (typically environmental manager) to contact when listed species are observed.

SSR6 Work should not begin if ESA-listed species are observed in the area prior to commencement of work; Work should not begin until ESA-listed species have not been observed for a 30-minute period.

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6 Appendix A: ESA-Listed Species and Critical Habitat Relevant to Transportation Projects in North Carolina, South Carolina, and Georgia

Section 7(a)(2) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. §1531 *et seq*.), requires that each federal agency ensure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of those species. When the action of a federal agency may affect a protected species or its critical habitat, that agency is required to consult with either the National Marine Fisheries Service (NMFS) or the U.S. Fish and Wildlife Service (USFWS), depending upon the protected species that may be affected.

The purpose of this appendix is to provide the Federal Highway Administration (FHWA) and state Departments of Transportation (DOTs) with information regarding the ESA-listed species and critical habitat that may be affected by transportation projects in NC, SC, and GA. Listed species and critical habitat that occur in NC, SC, and GA, but are not likely to be affected by transportation projects are not included.

Table A1. Species that May be Affected by Transportation Projects in NC, SC, and GA.

Common Name	Scientific Name	ESA-Listed Status
Sea Turtles		
hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
leatherback sea turtle	*Dermochelys coriacea*	Endangered
green sea turtle	*Chelonia mydas*[9]	Endangered/Threatened
loggerhead sea turtle	*Caretta caretta*[10]	Threatened
Fish		
shortnose sturgeon	*Acipenser brevirostrum*	Endangered
Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*	Endangered

[9] Green turtles are listed as threatened except for the Florida and Pacific coast of Mexico breeding populations, which are listed as endangered. On March 23, 2015, a proposed rule was published to list 11 DPSs of green sea turtles as threatened or endangered. The populations within Florida would be listed as part of the North Atlantic DPS and listed as threatened; thus, any animals potentially affected by the proposed action would be members of that proposed DPS.

[10] Northwest Atlantic Ocean (NWA) distinct population segment (DPS).

Table A2. Critical Habitat that May be Affected by Transportation Projects in NC, SC, and GA.

Species	Unit
Atlantic sturgeon (proposed)	81 FR 36077 and 81 FR 41926

Proposed Atlantic sturgeon critical habitat rivers in the Southeast U.S. are for the Carolina and South Atlantic DPS units.

6.1 Status of Species Likely to be Adversely Affect by Transportation Projects

6.2 Sea Turtles

There are five species of sea turtles (green, hawksbill, Kemp's ridley, leatherback, and loggerhead) that travel widely throughout the South Atlantic, Gulf of Mexico, and the Caribbean. These species are highly migratory and therefore could occur within the action areas of transportation projects in NC, SC, and GA. Section 6.2.1 will address the general threats that confront all sea turtle species. The remainder of Section 6.2.2 through Section 6.2.5 will address information on the distribution, life history, population structure, abundance, population trends, and unique threats to each species of sea turtle.

6.2.1 General Threats Faced by All Sea Turtle Species

Sea turtles face numerous natural and man-made threats that shape their status and affect their ability to recover. Many of the threats are either the same or similar in nature for all listed sea turtle species, those identified in this section are discussed in a general sense for all sea turtles. Threat information specific to a particular species are then discussed in the corresponding status sections where appropriate.

Fisheries

Incidental bycatch in commercial fisheries is identified as a major contributor to past declines, and threat to future recovery, for all of the sea turtle species (NMFS and USFWS 1991; NMFS and USFWS 1992; NMFS and USFWS 1993; NMFS and USFWS 2008; NMFS et al. 2011). Domestic fisheries often capture, injure, and kill sea turtles at various life stages. Sea turtles in the pelagic environment are exposed to U.S. Atlantic pelagic longline fisheries. Sea turtles in the benthic environment in waters off the coastal United States are exposed to a suite of other fisheries in federal and state waters. These fishing methods include trawls, gillnets, purse seines, hook-and-line gear (including bottom longlines and vertical lines [e.g., bandit gear, handlines, and rod-reel], pound nets, and trap fisheries. Refer to the Environmental Baseline section of this Opinion for more specific information regarding federally and state-managed fisheries affecting sea turtles within the action area). The southeast U.S. shrimp fisheries have historically been the largest fishery threat to benthic sea turtles in the southeastern United States, and continue to interact with and kill large numbers of sea turtles each year.

In addition to domestic fisheries, sea turtles are subject to direct as well as incidental capture in numerous foreign fisheries, further impeding the ability of sea turtles to survive and recover on a global scale. For example, pelagic stage sea turtles, especially loggerheads and leatherbacks, circumnavigating the Atlantic are susceptible to international longline fisheries including the Azorean, Spanish, and various other fleets (Aguilar et al. 1994; Bolten et al. 1994; Crouse 1999). Bottom longlines and gillnet fishing is known to occur in many foreign waters, including (but not limited to) the northwest Atlantic, western Mediterranean, South America, West Africa, Central America, and the Caribbean. Shrimp trawl fisheries are also occurring off the shores of numerous foreign countries and pose a significant threat to sea turtles similar to the impacts seen in U.S. waters. Many unreported takes or incomplete records by foreign fleets make it difficult to characterize the total impact that international fishing pressure is having on listed sea turtles. Nevertheless, international fisheries represent a continuing threat to sea turtle survival and recovery throughout their respective ranges.

Non-Fishery In-water Activities

There are also many non-fishery impacts affecting the status of sea turtle species, both in the ocean and on land. In nearshore waters of the United States, the construction and maintenance of federal navigation channels has been identified as a source of sea turtle mortality. Hopper dredges, which are frequently used in ocean bar channels and sometimes in harbor channels and offshore borrow areas, move relatively rapidly and can entrain and kill sea turtles (NMFS 1997b). Sea turtles entering coastal or inshore areas have also been affected by entrainment in the cooling-water systems of electrical generating plants. Other nearshore threats include harassment and/or injury resulting from private and commercial vessel operations, military detonations and training exercises, in-water construction activities, and scientific research activities.

Coastal Development and Erosion Control

Coastal development can deter or interfere with nesting, affect nesting success, and degrade nesting habitats for sea turtles. Structural impacts to nesting habitat include the construction of buildings and piles, beach armoring and renourishment, and sand extraction (Bouchard et al.1998; Lutcavage et al. 1997). These factors may decrease the amount of nesting area available to females and change the natural behaviors of both adults and hatchlings, directly or indirectly, through loss of beach habitat or changing thermal profiles and increasing erosion, respectively. (Ackerman 1997; Witherington et al. 2003; Witherington et al. 2007). In addition, coastal development is usually accompanied by artificial lighting which can alter the behavior of nesting adults (Witherington 1992) and is often fatal to emerging hatchlings that are drawn away from the water (Witherington and Bjorndal 1991). In-water erosion control structures such as breakwaters, groins, and jetties can impact nesting females and hatchling as they approach and leave the surf zone or head out to sea by creating physical blockage, concentrating predators, creating longshore currents, and disrupting of wave patterns.

Environmental Contamination

Multiple municipal, industrial, and household sources, as well as atmospheric transport, introduce various pollutants such as pesticides, hydrocarbons, organochlorides (e.g., DDT, polychlorinated biphenyls [PCBs], and perfluorinated chemicals), and others that may cause adverse health effects to sea turtles (Garrett 2004; Grant and Ross 2002; Hartwell 2004; Iwata et al. 1993). Acute exposure to hydrocarbons from petroleum products released into the environment via oil spills and other discharges may directly injure individuals through skin contact with oils (Geraci 1990), inhalation at the water's surface, and ingesting compounds while feeding (Matkin and Saulitis 1997). Hydrocarbons also have the potential to impact prey populations, and therefore may affect listed species indirectly by reducing food availability in the action area.

The April 20, 2010, explosion of the Deepwater Horizon oil rig affected sea turtles in the Gulf of Mexico. There is an on-going assessment of the long-term effects of the spill on Gulf of Mexico marine life, including sea turtle populations. Following the spill, juvenile Kemp's ridley, green, and loggerhead sea turtles were found in *Sargassum* algae mats in the convergence zones, where currents meet and oil collected. Sea turtles found in these areas were often coated in oil and/or had ingested oil. Approximately 536 live adult and juvenile sea turtles were recovered from the Gulf and brought into rehabilitation centers; of these, 456 were visibly oiled (these and the following numbers were obtained from http://www.nmfs.noaa.gov/pr/health/oilspill/). To date, 469 of the live recovered sea turtles have been successfully returned to the wild, 25 died during rehabilitation, and 42 are still in care and may be returned to the wild eventually.

During the clean-up period, 613 dead sea turtles were recovered in coastal waters or on beaches in Mississippi, Alabama, Louisiana, and the Florida Panhandle. As of February 2011, 478 of these dead turtles had been examined. Many of the examined sea turtles showed indications that they had died as a result of interactions with trawl gear, most likely used in the shrimp fishery, and not as a result of exposure to or the ingestion of oil.

During the spring and summer of 2010, nearly 300 sea turtle nests were relocated from the northern Gulf to the east coast of Florida with the goal of preventing hatchlings from entering the oiled waters of the northern Gulf. From these relocated nests, 14,676 sea turtles were ultimately released from Florida beaches and included 14,235 loggerheads, 125 Kemp's ridleys, and 316 greens.

A thorough assessment of the long-term effects of the spill on sea turtles has not yet been completed. Nevertheless, the spill resulted in the direct mortality of many sea turtles and may have had sublethal effects or caused environmental damage that will impact other sea turtles into the future. The population level effects of the spill and associated response activity are likely to remain unknown for some period into the future.

Marine debris is a continuing problem for sea turtles. Sea turtles living in the pelagic environment commonly eat or become entangled in marine debris (e.g., tar balls, plastic bags/pellets, balloons, and ghost fishing gear) as they feed along oceanographic fronts where debris and their natural food items converge. This is especially problematic for sea turtles that spend all or significant portions of their life cycle in the pelagic environment (i.e., leatherbacks, juvenile loggerheads, and juvenile green turtles).

Climate Change

There is a large and growing body of literature on past, present, and future impacts of global climate change exacerbated and accelerated by human activities. Some of the likely effects commonly mentioned are sea level rise, increased frequency of severe weather events, and change in air and water temperatures. NOAA's climate information portal provides basic background information on these and other measured or anticipated effects (see http://www.climate.gov).

Climate change impacts on sea turtles currently cannot be predicted with any degree of certainty; however, significant impacts to the hatchling sex ratios of sea turtles may result (NMFS and USFWS 2007a). In sea turtles, sex is determined by the ambient sand temperature (during the middle third of incubation) with female offspring produced at higher temperatures and males at lower temperatures within a thermal tolerance range of 25°-35°C (Ackerman 1997). Increases in global temperature could potentially skew future sex ratios toward higher numbers of females (NMFS and USFWS 2007a).

The effects from increased temperatures may be intensified on developed nesting beaches where shoreline armoring and construction have denuded vegetation. Erosion control structures could potentially result in the permanent loss of nesting beach habitat or deter nesting females (NRC 1990). These impacts will be exacerbated by sea level rise. If females nest on the seaward side of the erosion control structures, nests may be exposed to repeated tidal overwash (NMFS and USFWS 2007a). Sea level rise from global climate change is also a potential problem for areas with low-lying beaches where sand depth is a limiting factor, as the sea may inundate nesting sites and decrease available nesting habitat (Baker et al. 2006; Daniels et al. 1993; Fish et al. 2005). The loss of habitat as a result of climate change could be accelerated due to a combination of other environmental and oceanographic changes such as an increase in the frequency of storms and/or changes in prevailing currents, both of which could lead to increased beach loss via erosion (Antonelis et al. 2006; Baker et al. 2006).

Other changes in the marine ecosystem caused by global climate change (e.g., ocean acidification, salinity, oceanic currents, dissolved oxygen levels, nutrient distribution) could influence the distribution and abundance of lower trophic levels (e.g., phytoplankton, zooplankton, submerged aquatic vegetation, crustaceans, mollusks, forage fish) which could ultimately affect the primary foraging areas of sea turtles.

Other Threats
Predation by various land predators is a threat to developing nests and emerging hatchlings. The major natural predators of sea turtle nests are mammals, including raccoons, dogs, pigs, skunks, and badgers. Emergent hatchlings are preyed upon by these mammals as well as ghost crabs, laughing gulls, and the exotic South American fire ant (*Solenopsis invicta*). In addition to natural predation, direct harvest of eggs and adults from beaches in foreign countries continues to be a problem for various sea turtle species throughout their ranges (NMFS and USFWS 2008).

Diseases, toxic blooms from algae and other microorganisms, and cold stunning events are additional sources of mortality that can range from local and limited to wide-scale and impacting hundreds or thousands of animals.

6.2.2 Loggerhead Sea Turtle – Northwest Atlantic DPS

The loggerhead sea turtle was listed as a threatened species throughout its global range on July 28, 1978. NMFS and USFWS published a Final Rule, which designated 9 DPSs for loggerhead sea turtles (76 FR 58868, September 22, 2011, and effective October 24, 2011). This rule listed the following DPSs: (1) Northwest Atlantic Ocean (threatened), (2) Northeast Atlantic Ocean (endangered), (3) South Atlantic Ocean (threatened), (4) Mediterranean Sea (endangered), (5) North Pacific Ocean (endangered), (6) South Pacific Ocean (endangered), (7) North Indian Ocean (endangered), (8) Southeast Indo-Pacific Ocean (endangered), and (9) Southwest Indian Ocean (threatened). The Northwest Atlantic (NWA) DPS is the only one that occurs within the action area, and therefore it is the only one considered in this Opinion.

Species Description and Distribution
Loggerheads are large sea turtles. Adults in the southeast United States average about 3 ft (92 cm) long, measured as a straight carapace length (SCL), and weigh approximately 255 lb (116 kg) (Ehrhart and Yoder 1978). Adult and subadult loggerhead sea turtles typically have a light yellow plastron and a reddish brown carapace covered by non-overlapping scutes that meet along seam lines. They typically have 11 or 12 pairs of marginal scutes, 5 pairs of costals, 5 vertebrals, and a nuchal (precentral) scute that is in contact with the first pair of costal scutes (Dodd Jr. 1988).

The loggerhead sea turtle inhabits continental shelf and estuarine environments throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans (Dodd Jr. 1988). Habitat uses within these areas vary by life stage. Juveniles are omnivorous and forage on crabs, mollusks, jellyfish, and vegetation at or near the surface (Dodd Jr. 1988). Subadult and adult loggerheads are primarily found in coastal waters and eat benthic invertebrates such as mollusks and decapod crustaceans in hard bottom habitats.

The majority of loggerhead nesting occurs at the western rims of the Atlantic and Indian Oceans concentrated in the north and south temperate zones and subtropics (NRC 1990). For the NWA DPS, most nesting occurs along the coast of the United States, from southern Virginia to Alabama. Additional nesting beaches for this DPS are found along the northern and western Gulf of Mexico, eastern Yucatán Peninsula, at Cay Sal Bank in the eastern Bahamas (Addison 1997; Addison and Morford 1996), off the southwestern coast of Cuba (Moncada Gavilan 2001), and along the coasts of Central America, Colombia, Venezuela, and the eastern Caribbean Islands.

Non-nesting, adult female loggerheads are reported throughout the U.S. Atlantic, Gulf of Mexico, and Caribbean Sea. Little is known about the distribution of adult males who are seasonally abundant near nesting beaches. Aerial surveys suggest that loggerheads as a whole are distributed in U.S. waters as follows: 54% off the southeast U.S. coast, 29% off the northeast U.S. coast, 12% in the eastern Gulf of Mexico, and 5% in the western Gulf of Mexico (TEWG 1998).

Within the NWA DPS, most loggerhead sea turtles nest from North Carolina to Florida and along the Gulf Coast of Florida. Previous Section 7 analyses have recognized at least 5 western Atlantic subpopulations, divided geographically as follows: (1) a Northern nesting subpopulation, occurring from North Carolina to northeast Florida at about 29ºN; (2) a South Florida nesting subpopulation, occurring from 29°N on the east coast of the state to Sarasota on the west coast; (3) a Florida Panhandle nesting subpopulation, occurring at Eglin Air Force Base and the beaches near Panama City, Florida; (4) a Yucatán nesting subpopulation, occurring on the eastern Yucatán Peninsula, Mexico (Márquez M. 1990; TEWG 2000); and (5) a Dry Tortugas nesting subpopulation, occurring in the islands of the Dry Tortugas, near Key West, Florida (NMFS 2001).

The recovery plan for the Northwest Atlantic population of loggerhead sea turtles concluded that there is no genetic distinction between loggerheads nesting on adjacent beaches along the Florida Peninsula. It also concluded that specific boundaries for subpopulations could not be designated based on genetic differences alone. Thus, the recovery plan uses a combination of geographic distribution of nesting densities, geographic separation, and geopolitical boundaries, in addition to genetic differences, to identify recovery units. The recovery units are as follows: (1) the Northern Recovery Unit (Florida/Georgia border north through southern Virginia), (2) the Peninsular Florida Recovery Unit (Florida/Georgia border through Pinellas County, Florida), (3) the Dry Tortugas Recovery Unit (islands located west of Key West, Florida), (4) the Northern Gulf of Mexico Recovery Unit (Franklin County, Florida, through Texas), and (5) the Greater Caribbean Recovery Unit (Mexico through French Guiana, the Bahamas, Lesser Antilles, and Greater Antilles) (NMFS and USFWS 2008). The recovery plan concluded that all recovery units are essential to the recovery of the species. Although the recovery plan was written prior to the listing of the NWA DPS, the recovery units for what was then termed the Northwest Atlantic population apply to the NWA DPS.

Life History Information

The Northwest Atlantic Loggerhead Recovery Team defined the following 8 life stages for the loggerhead life cycle, which include the ecosystems those stages generally use: (1) egg (terrestrial zone), (2) hatchling stage (terrestrial zone), (3) hatchling swim frenzy and transitional stage (neritic zone[11]), (4) juvenile stage (oceanic zone), (5) juvenile stage (neritic zone), (6) adult stage (oceanic zone), (7) adult stage (neritic zone), and (8) nesting female (terrestrial zone) (NMFS and USFWS 2008). Loggerheads are long-lived animals. They reach sexual maturity between 20-38 years of age, although age of maturity varies widely among populations (Frazer and Ehrhart 1985; NMFS 2001). The annual mating season occurs from late March to early June, and female turtles lay eggs throughout the summer months. Females deposit an average of 4.1 nests within a nesting season (Murphy and Hopkins 1984), but an individual female only nests every 3.7 years on average (Tucker 2010). Each nest contains an average of 100-126 eggs (Dodd Jr. 1988) which incubate for 42-75 days before hatching (NMFS and USFWS 2008). Loggerhead hatchlings are 1.5-2 inches long and weigh about 0.7 oz (20 g).

As post-hatchlings, loggerheads hatched on U.S. beaches enter the "oceanic juvenile" life stage, migrating offshore and becoming associated with *Sargassum* habitats, driftlines, and other convergence zones (Carr 1986; Conant et al. 2009; Witherington 2002). Oceanic juveniles grow at rates of 1-2 inches (2.9-5.4 cm) per year (Bjorndal et al. 2003; Snover 2002) over a period as long as 7-12 years (Bolten et al. 1998) before moving to more coastal habitats. Studies have suggested that not all loggerhead sea turtles follow the model of circumnavigating the North Atlantic Gyre as pelagic juveniles, followed by permanent settlement into benthic environments (Bolten and Witherington 2003; Laurent et al. 1998). These studies suggest some turtles may either remain in the oceanic habitat in the North Atlantic longer than hypothesized, or they move back and forth between oceanic and coastal habitats interchangeably (Witzell 2002). Stranding records indicate that when immature loggerheads reach 15-24 in (40-60 cm) SCL, they begin to reside in coastal inshore waters of the continental shelf throughout the U.S. Atlantic and Gulf of Mexico (Witzell 2002).

After departing the oceanic zone, neritic juvenile loggerheads in the Northwest Atlantic inhabit continental shelf waters from Cape Cod Bay, Massachusetts, south through Florida, The Bahamas, Cuba, and the Gulf of Mexico. Estuarine waters of the United States, including areas such as Long Island Sound, Chesapeake Bay, Pamlico and Core Sounds, Mosquito and Indian River Lagoons, Biscayne Bay, Florida Bay, as well as numerous embayments fringing the Gulf of Mexico, comprise important inshore habitat. Along the Atlantic and Gulf of Mexico shoreline, essentially all shelf waters are inhabited by loggerheads (Conant et al. 2009).

Like juveniles, non-nesting adult loggerheads also use the neritic zone. However, these adult loggerheads do not use the relatively enclosed shallow-water estuarine habitats with limited ocean access as frequently as juveniles. Areas such as Pamlico Sound, North Carolina, and the Indian River Lagoon, Florida, are regularly used by juveniles but not by adult loggerheads. Adult loggerheads do tend to use estuarine areas with more open ocean access, such as the Chesapeake Bay in the U.S. mid-Atlantic. Shallow-water habitats with large expanses of open ocean access, such as Florida Bay, provide year-round resident foraging areas for significant numbers of male and female adult loggerheads (Conant et al. 2009).

Offshore, adults primarily inhabit continental shelf waters, from New York south through Florida, The Bahamas, Cuba, and the Gulf of Mexico. Seasonal use of mid-Atlantic shelf waters, especially offshore

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[11] Neritic refers to the nearshore marine environment from the surface to the sea floor where water depths do not exceed 200 meters.

New Jersey, Delaware, and Virginia during summer months, and offshore shelf waters, such as Onslow Bay (off the North Carolina coast), during winter months has also been documented (Hawkes et al. 2007)Georgia Department of Natural Resources, unpublished data; South Carolina Department of Natural Resources, unpublished data). Satellite telemetry has identified the shelf waters along the west Florida coast, The Bahamas, Cuba, and the Yucatán Peninsula as important resident areas for adult female loggerheads that nest in Florida (Foley et al. 2008; Girard et al. 2009; Hart et al. 2012). The southern edge of the Grand Bahama Bank is important habitat for loggerheads nesting on the Cay Sal Bank in The Bahamas, but nesting females are also resident in the bights of Eleuthera, Long Island, and Ragged Islands. They also reside in Florida Bay in the United States, and along the north coast of Cuba (A. Bolten and K. Bjorndal, University of Florida, unpublished data). Moncada et al. (2010) report the recapture of 5 adult female loggerheads in Cuban waters originally flipper-tagged in Quintana Roo, Mexico, which indicates that Cuban shelf waters likely also provide foraging habitat for adult females that nest in Mexico.

Status and Population Dynamics

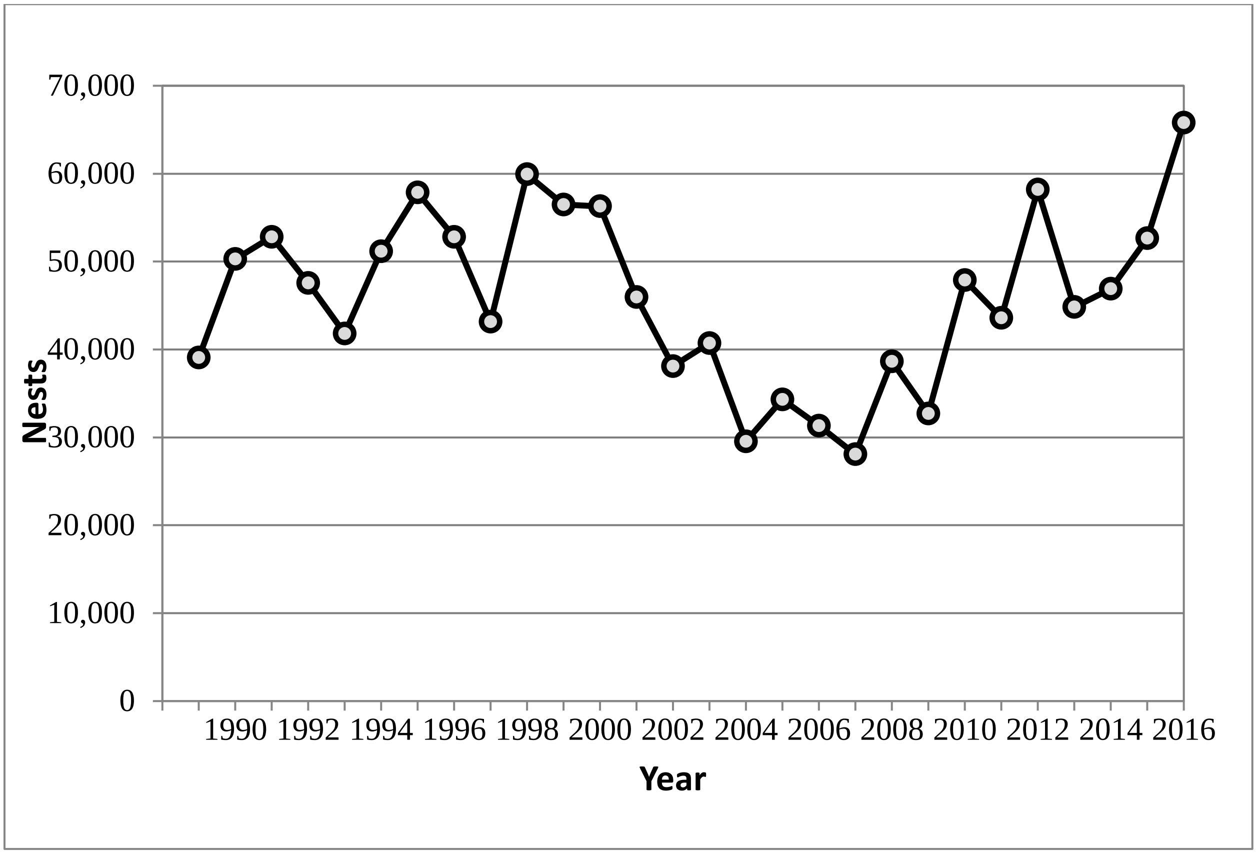
A number of stock assessments and similar reviews (Conant et al. 2009; Heppell et al. 2003; NMFS-SEFSC 2009; NMFS 2001; NMFS and USFWS 2008; TEWG 1998; TEWG 2000; TEWG 2009) have examined the stock status of loggerheads in the Atlantic Ocean, but none have been able to develop a reliable estimate of absolute population size.

Numbers of nests and nesting females can vary widely from year to year. Nesting beach surveys, though, can provide a reliable assessment of trends in the adult female population, due to the strong nest site fidelity of female loggerhead sea turtles, as long as such studies are sufficiently long and survey effort and methods are standardized (e.g., NMFS and USFWS 2008). NMFS and USFWS (2008) concluded that the lack of change in 2 important demographic parameters of loggerheads, remigration interval and clutch frequency, indicate that time series on numbers of nests can provide reliable information on trends in the female population.

<u>Peninsular Florida Recovery Unit</u>

The Peninsular Florida Recovery Unit (PFRU) is the largest loggerhead nesting assemblage in the Northwest Atlantic. A near-complete nest census (all beaches including index nesting beaches) undertaken from 1989 to 2007 showed an average of 64,513 loggerhead nests per year, representing approximately 15,735 nesting females per year (NMFS and USFWS 2008). The statewide estimated total for 2015 was 89,295 nests (FWRI nesting database).

In addition to the total nest count estimates, the Florida Fish and Wildlife Research Institute (FWRI) uses an index nesting beach survey method. The index survey uses standardized data-collection criteria to measure seasonal nesting and allow accurate comparisons between beaches and between years. This provides a better tool for understanding the nesting trends (Figure A1). FWRI performed a detailed analysis of the long-term loggerhead index nesting data (1989-2016; http://myfwc.com/research/wildlife/sea-turtles/nesting/loggerhead-trend/). Over that time period, 3 distinct trends were identified. From 1989-1998, there was a 24% increase that was followed by a sharp decline over the subsequent 9 years. A large increase in loggerhead nesting has occurred since, as indicated by the 71% increase in nesting over the 10-year period from 2007 and 2016. Nesting in 2016 also represents a new record for loggerheads on the core index beaches. FWRI examined the trend from the 1998 nesting high through 2016 and found that the decade-long post-1998 decline was replaced with a slight but nonsignificant increasing trend. Looking at the data from 1989 through 2016, FWRI concluded that there was an overall positive change in the nest counts although it was not statistically significant due to the wide variability between 2012-2016 resulting in widening confidence intervals (http://myfwc.com/research/wildlife/sea-turtles/nesting/loggerhead-trend/).



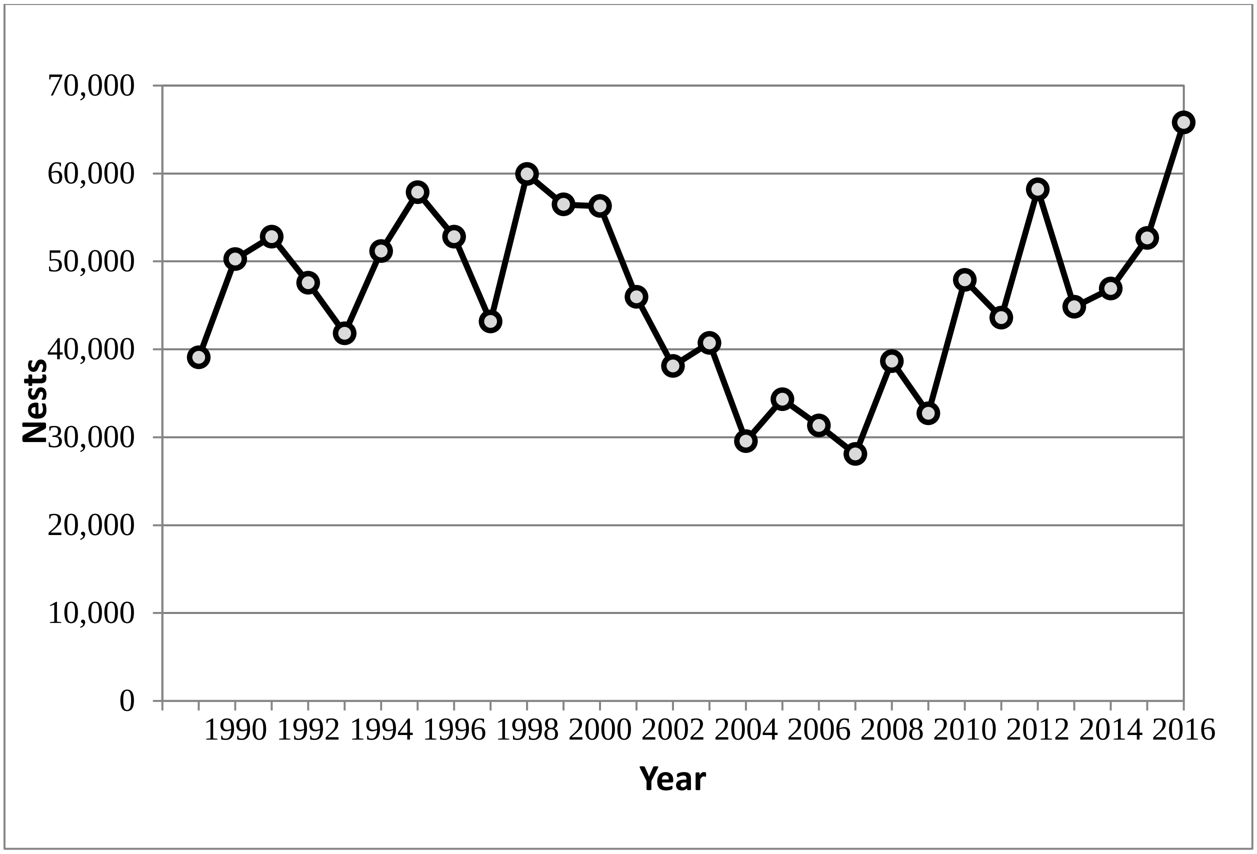


Figure A1. Loggerhead sea turtle nesting at Florida index beaches since 1989.

Northern Recovery Unit

Annual nest totals from beaches within the Northern Recovery Unit (NRU) averaged 5,215 nests from 1989-2008, a period of near-complete surveys of NRU nesting beaches (Georgia Department of Natural Resources [GADNR] unpublished data, North Carolina Wildlife Resources Commission [NCWRC] unpublished data, South Carolina Department of Natural Resources [SCDNR] unpublished data), and represent approximately 1,272 nesting females per year, assuming 4.1 nests per female (Murphy and Hopkins 1984). The loggerhead nesting trend from daily beach surveys showed a significant decline of 1.3% annually from 1989-2008. Nest totals from aerial surveys conducted by SCDNR showed a 1.9% annual decline in nesting in South Carolina from 1980-2008. Overall, there are strong statistical data to suggest the NRU had experienced a long-term decline over that period of time.

Data since that analysis (Table A3) are showing improved nesting numbers and a departure from the declining trend. Georgia nesting has rebounded to show the first statistically significant increasing trend since comprehensive nesting surveys began in 1989 (Mark Dodd, GADNR press release, http://www.georgiawildlife.com/node/3139). South Carolina and North Carolina nesting have also begun to shift away from the past declining trend. Loggerhead nesting in Georgia, South Carolina, and North Carolina all broke records in 2015 and then topped those records again in 2016.

Table A3. Total Number of NRU Loggerhead Nests (GADNR, SCDNR, and NCWRC nesting datasets compiled at Seaturtle.org).

Nests Recorded	2008	2009	2010	2011	2012	2013	2014	2015	2016
Georgia	1,649	998	1,760	1,992	2,241	2,289	1,196	2,319	3,265
South Carolina	4,500	2,182	3,141	4,015	4,615	5,193	2,083	5,104	6,443
North Carolina	841	302	856	950	1,074	1,260	542	1,254	1,612
Total	**6,990**	**3,472**	**5,757**	**6,957**	**7,930**	**8,742**	**3,821**	**8,677**	**11,320**

South Carolina also conducts an index beach nesting survey similar to the one described for Florida. Although the survey only includes a subset of nesting, the standardized effort and locations allow for a better representation of the nesting trend over time. Increases in nesting were seen for the period from 2009-2012, and 2012 shows the highest index nesting total since the start of the program (Figure A2).

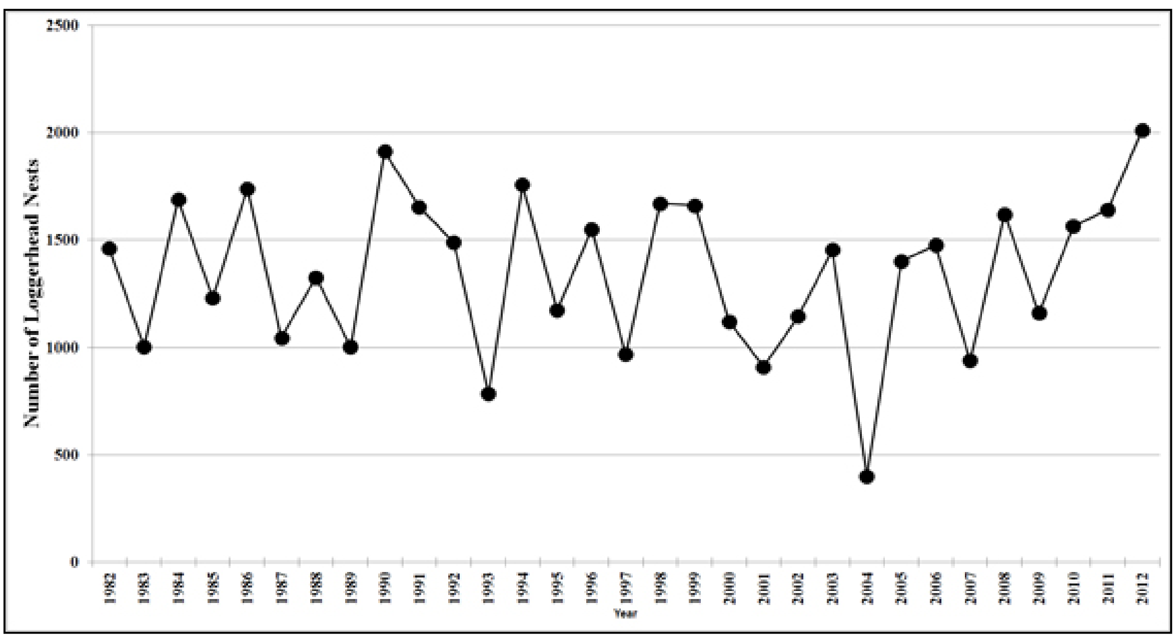


Figure A2. South Carolina index nesting beach counts for loggerhead sea turtles (from the SCDNR website: http://www.dnr.sc.gov/seaturtle/nest.htm)

Other Northwest Atlantic DPS Recovery Units

The remaining 3 recovery units—Dry Tortugas (DTRU), Northern Gulf of Mexico (NGMRU), and Greater Caribbean (GCRU)—are much smaller nesting assemblages, but they are still considered essential to the continued existence of the species. Nesting surveys for the DTRU are conducted as part of Florida's statewide survey program. Survey effort was relatively stable during the 9-year period from 1995-2004, although the 2002 year was missed. Nest counts ranged from 168-270, with a mean of 246, but there was no detectable trend during this period (NMFS and USFWS 2008). Nest counts for the

NGMRU are focused on index beaches rather than all beaches where nesting occurs. Analysis of the 12-year dataset (1997-2008) of index nesting beaches in the area shows a statistically significant declining trend of 4.7% annually. Nesting on the Florida Panhandle index beaches, which represents the majority of NGMRU nesting, had shown a large increase in 2008, but then declined again in 2009 and 2010 before rising back to a level similar to the 2003-2007 average in 2011. Nesting survey effort has been inconsistent among the GCRU nesting beaches, and no trend can be determined for this subpopulation (NMFS and USFWS 2008). Zurita et al. (2003) found a statistically significant increase in the number of nests on 7 of the beaches on Quintana Roo, Mexico, from 1987-2001, where survey effort was consistent during the period. Nonetheless, nesting has declined since 2001, and the previously reported increasing trend appears to not have been sustained (NMFS and USFWS 2008).

<u>In-water Trends</u>

Nesting data are the best current indicator of sea turtle population trends, but in-water data also provide some insight. In-water research suggests the abundance of neritic juvenile loggerheads is steady or increasing. Although Ehrhart et al. (2007) found no significant regression-line trend in a long-term dataset, researchers have observed notable increases in catch per unit effort (CPUE) (Arendt et al. 2009; Ehrhart et al. 2007; Epperly et al. 2007). Researchers believe that this increase in CPUE is likely linked to an increase in juvenile abundance, although it is unclear whether this increase in abundance represents a true population increase among juveniles or merely a shift in spatial occurrence. Bjorndal et al. (2005), cited in NMFS and USFWS (2008), caution about extrapolating localized in-water trends to the broader population and relating localized trends in neritic sites to population trends at nesting beaches. The apparent overall increase in the abundance of neritic loggerheads in the southeastern United States may be due to increased abundance of the largest oceanic/neritic juveniles (historically referred to as small benthic juveniles), which could indicate a relatively large number of individuals around the same age may mature in the near future (TEWG 2009). In-water studies throughout the eastern United States, however, indicate a substantial decrease in the abundance of the smallest oceanic/neritic juvenile loggerheads, a pattern corroborated by stranding data (TEWG 2009).

<u>Population Estimate</u>

The NMFS Southeast Fisheries Science Center developed a preliminary stage/age demographic model to help determine the estimated impacts of mortality reductions on loggerhead sea turtle population dynamics (NMFS-SEFSC 2009). The model uses the range of published information for the various parameters including mortality by stage, stage duration (years in a stage), and fecundity parameters such as eggs per nest, nests per nesting female, hatchling emergence success, sex ratio, and remigration interval. Resulting trajectories of model runs for each individual recovery unit, and the western North Atlantic population as a whole, were found to be very similar. The model run estimates from the adult female population size for the western North Atlantic (from the 2004-2008 time frame), suggest the adult female population size is approximately 20,000-40,000 individuals, with a low likelihood of females' numbering up to 70,000 (NMFS-SEFSC 2009). A less robust estimate for total benthic females in the western North Atlantic was also obtained, yielding approximately 30,000-300,000 individuals, up to less than 1 million (NMFS-SEFSC 2009). A preliminary regional abundance survey of loggerheads within the northwestern Atlantic continental shelf for positively identified loggerhead in all strata estimated about 588,000 loggerheads (interquartile range of 382,000-817,000). When correcting for unidentified turtles in proportion to the ratio of identified turtles, the estimate increased to about 801,000 loggerheads (interquartile range of 521,000-1,111,000) (NMFS-NEFSC 2011).

Threats (Specific to Loggerhead Sea Turtles)

The threats faced by loggerhead sea turtles are well summarized in the general discussion of threats in Section 6.2.1. Yet the impact of fishery interactions is a point of further emphasis for this species. The joint NMFS and USFWS Loggerhead Biological Review Team determined that the greatest threats to the NWA DPS of loggerheads result from cumulative fishery bycatch in neritic and oceanic habitats (Conant et al. 2009).

Regarding the impacts of pollution, loggerheads may be particularly affected by organochlorine contaminants; they have the highest organochlorine concentrations (Storelli et al. 2008) and metal loads (D'Ilio et al. 2011) in sampled tissues among the sea turtle species. It is thought that dietary preferences were likely to be the main differentiating factor among sea turtle species. Storelli et al. (2008) analyzed tissues from stranded loggerhead sea turtles and found that mercury accumulates in sea turtle livers while cadmium accumulates in their kidneys, as has been reported for other marine organisms like dolphins, seals, and porpoises (Law et al. 1991).

While oil spill impacts are discussed generally for all species in Section 6.2.1, specific impacts of the Deepwater Horizon oil spill event on loggerhead sea turtles are considered here. Impacts to loggerhead sea turtles occurred to offshore small juveniles as well as large juveniles and adults. A total of 30,800 small juvenile loggerheads (7.3% of the total small juvenile sea turtle exposures to oil from the spill) were estimated to have been exposed to oil. Of those exposed, 10,700 small juveniles are estimated to have died as a result of the exposure. In contrast to small juveniles, loggerheads represented a large proportion of the adults and large juveniles exposed to and killed by the oil. There were 30,000 exposures (almost 52% of all exposures for those age/size classes) and 3,600 estimated mortalities. A total of 265 nests (27,618 eggs) were also translocated during response efforts, with 14,216 hatchlings released, the fate of which is unknown (DWH Trustees 2015). Additional unquantified effects may have included inhalation of volatile compounds, disruption of foraging or migratory movements due to surface or subsurface oil, ingestion of prey species contaminated with oil and/or dispersants, and loss of foraging resources which could lead to compromised growth and/or reproductive potential. There is no information currently available to determine the extent of those impacts, if they occurred.

Unlike Kemp's ridleys, the majority of nesting for the Northwest Atlantic Ocean loggerhead DPS occurs on the Atlantic coast, and thus loggerheads were impacted to a relatively lesser degree. However, it is likely that impacts to the NGMRU of the NWA loggerhead DPS would be proportionally much greater than the impacts occurring to other recovery units. Impacts to nesting and oiling effects on a large proportion of the NGMRU recovery unit, especially mating and nesting adults likely had an impact on the NGMRU. Based on the response injury evaluations for Florida Panhandle and Alabama nesting beaches (which fall under the NFMRU), the Trustees estimated that approximately 20,000 loggerhead hatchlings were lost due to DWH oil spill response activities on nesting beaches. Although the long-term effects remain unknown, the DWH oil spill event impacts to the Northern Gulf of Mexico Recovery Unit may result in some nesting declines in the future due to a large reduction of oceanic age classes during the DWH oil spill event. Although adverse impacts occurred to loggerheads, the proportion of the population that is expected to have been exposed to and directly impacted by the DWH oil spill event is relatively low. Thus, we do not believe a population-level impact occurred due to the widespread distribution and nesting location outside of the Gulf of Mexico for this species.

Specific information regarding potential climate change impacts on loggerheads is also available. Modeling suggests an increase of 2°C in air temperature would result in a sex ratio of over 80% female offspring for loggerheads nesting near Southport, North Carolina. The same increase in air temperatures at nesting beaches in Cape Canaveral, Florida, would result in close to 100% female offspring. Such highly skewed sex ratios could undermine the reproductive capacity of the species. More ominously, an air temperature increase of 3°C is likely to exceed the thermal threshold of most nests, leading to egg mortality (Hawkes et al. 2007). Warmer sea surface temperatures have also been correlated with an earlier onset of loggerhead nesting in the spring (Hawkes et al. 2007; Weishampel et al. 2004), short inter-nesting intervals (Hays et al. 2002), and shorter nesting seasons (Pike et al. 2006).

6.2.3 Green Sea Turtle

The green sea turtle was originally listed as threatened under the ESA on July 28, 1978, except for the Florida and Pacific coast of Mexico breeding populations, which were listed as endangered. On April 6, 2016, the original listing was replaced with the listing of 11 distinct population segments (DPSs) (81 FR 20057 2016). The Mediterranean, Central West Pacific, and Central South Pacific DPSs were listed as endangered. The North Atlantic, South Atlantic, Southwest Indian, North Indian, East Indian-West Pacific, Southwest Pacific, Central North Pacific, and East Pacific were listed as threatened. For the purposes of this consultation, only the South Atlantic DPS (SA DPS) and North Atlantic DPS (NA DPS) will be considered, as they are the only two DPSs with individuals occurring in the Atlantic and Gulf of Mexico waters of the United States.

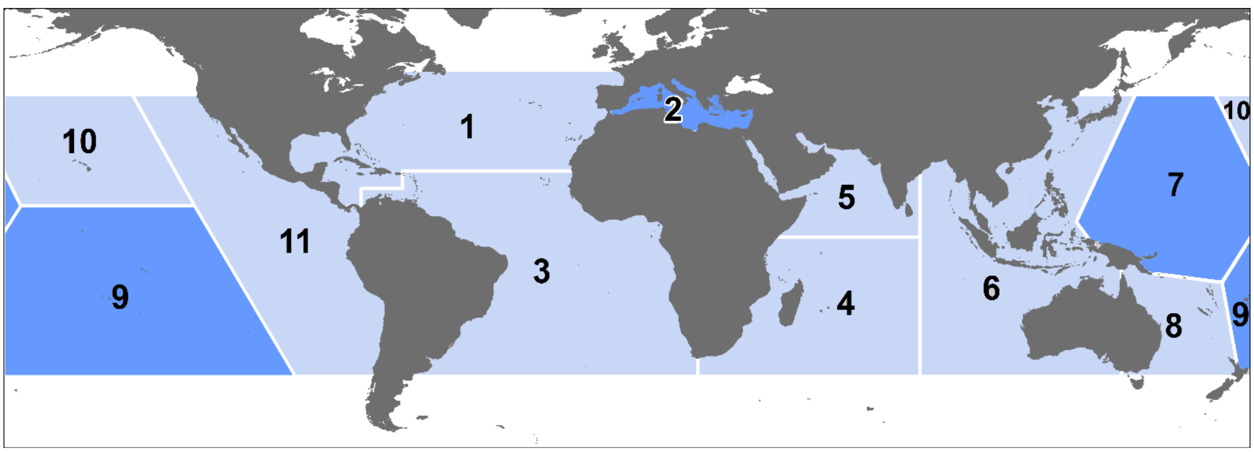


Figure A 1. Threatened (light) and endangered (dark) green turtle DPSs: 1. North Atlantic, 2. Mediterranean, 3. South Atlantic, 4. Southwest Indian, 5. North Indian, 6. East Indian-West Pacific, 7. Central West Pacific, 8. Southwest Pacific, 9. Central South Pacific

Species Description and Distribution

The green sea turtle is the largest of the hardshell marine turtles, growing to a weight of 350 lb (159 kg) with a straight carapace length of greater than 3.3 ft (1 m). Green sea turtles have a smooth carapace with 4 pairs of lateral (or costal) scutes and a single pair of elongated prefrontal scales between the eyes. They typically have a black dorsal surface and a white ventral surface, although the carapace of green sea turtles in the Atlantic Ocean has been known to change in color from solid black to a variety of shades of grey, green, or brown and black in starburst or irregular patterns (Lagueux 2001).

With the exception of post-hatchlings, green sea turtles live in nearshore tropical and subtropical waters where they generally feed on marine algae and seagrasses. They have specific foraging grounds and may make large migrations between these forage sites and natal beaches for nesting (Hays et al. 2001). Green sea turtles nest on sandy beaches of mainland shores, barrier islands, coral islands, and volcanic islands in more than 80 countries worldwide (Hirth 1997). The two largest nesting populations are found at Tortuguero, on the Caribbean coast of Costa Rica (part of the NA DPS), and Raine Island, on the Pacific coast of Australia along the Great Barrier Reef.

Differences in mitochondrial DNA properties of green sea turtles from different nesting regions indicate there are genetic subpopulations (Bowen et al. 1992; FitzSimmons et al. 2006). Despite the genetic differences, sea turtles from separate nesting origins are commonly found mixed together on foraging grounds throughout the species' range. Within U.S. waters, individuals from both the NA and SA DPSs can be found on foraging grounds. While there are currently no in-depth studies available to determine the percent of NA and SA DPS individuals in any given location, two small-scale studies provide an insight into the degree of mixing on the foraging grounds. An analysis of cold-stunned green turtles in St. Joseph Bay, Florida (northern Gulf of Mexico) found approximately 4% of individuals came from nesting stocks in the SA DPS (specifically Suriname, Aves Island, Brazil, Ascension Island, and Guinea Bissau) (Foley et al. 2007). On the Atlantic coast of Florida, a study on the foraging grounds off Hutchinson Island found that approximately 5% of the turtles sampled came from the Aves Island/Suriname nesting assemblage, which is part of the SA DPS (Bass and Witzell 2000). All of the individuals in both studies were benthic juveniles. Available information on green turtle migratory behavior indicates that long distance dispersal is only seen for juvenile turtles. This suggests that larger adult-sized turtles return to forage within the region of their natal rookeries, thereby limiting the potential for gene flow across larger scales (Monzón-Argüello et al. 2010). While all of the mainland U.S. nesting individuals are part of the NA DPS, the U.S. Caribbean nesting assemblages are split between the NA and SA DPS. Nesters in Puerto Rico are part of the NA DPS, while those in the U.S. Virgin Islands are part of the SA DPS. We do not currently have information on what percent of individuals on the U.S. Caribbean foraging grounds come from which DPS.

<u>North Atlantic DPS Distribution</u>

The NA DPS boundary is illustrated in Figure A1. Four regions support nesting concentrations of particular interest in the NA DPS: Costa Rica (Tortuguero), Mexico (Campeche, Yucatan, and Quintana Roo), U.S. (Florida), and Cuba. By far the most important nesting concentration for green turtles in this DPS is Tortuguero, Costa Rica. Nesting also occurs in the Bahamas, Belize, Cayman Islands, Dominican Republic, Haiti, Honduras, Jamaica, Nicaragua, Panama, Puerto Rico, Turks and Caicos Islands, and North Carolina, South Carolina, Georgia, and Texas, U.S.A. In the eastern North Atlantic, nesting has been reported in Mauritania (Fretey 2001).

The complete nesting range of NA DPS green sea turtles within the southeastern United States includes sandy beaches between Texas and North Carolina, as well as Puerto Rico (Dow et al. 2007; NMFS and USFWS 1991). The vast majority of green sea turtle nesting within the southeastern United States occurs in Florida (Johnson and Ehrhart 1994; Meylan et al. 1995). Principal U.S. nesting areas for green sea turtles are in eastern Florida, predominantly Brevard south through Broward counties.

In U.S. Atlantic and Gulf of Mexico waters, green sea turtles are distributed throughout inshore and nearshore waters from Texas to Massachusetts. Principal benthic foraging areas in the southeastern United States include Aransas Bay, Matagorda Bay, Laguna Madre, and the Gulf inlets of Texas (Doughty 1984; Hildebrand 1982; Shaver 1994), the Gulf of Mexico off Florida from Yankeetown to Tarpon Springs (Caldwell and Carr 1957), Florida Bay and the Florida Keys (Schroeder and Foley 1995), the Indian River Lagoon system in Florida (Ehrhart 1983), and the Atlantic Ocean off Florida from Brevard through Broward Counties (Guseman and Ehrhart 1992; Wershoven and Wershoven 1992). The summer developmental habitat for green sea turtles also encompasses estuarine and coastal waters from North Carolina to as far north as Long Island Sound (Musick and Limpus 1997). Additional important foraging areas in the western Atlantic include the Culebra archipelago and other Puerto Rico coastal waters, the south coast of Cuba, the Mosquito Coast of Nicaragua, the Caribbean coast of Panama, scattered areas along Colombia and Brazil (Hirth 1971), and the northwestern coast of the Yucatán Peninsula.

South Atlantic DPS Distribution

The SA DPS boundary is shown in Figure 1, and includes the U.S. Virgin Islands in the Caribbean. The SA DPS nesting sites can be roughly divided into four regions: western Africa, Ascension Island, Brazil, and the South Atlantic Caribbean (including Colombia, the Guianas, and Aves Island in addition to the numerous small, island nesting sites).

The in-water range of the SA DPS is widespread. In the eastern South Atlantic, significant sea turtle habitats have been identified, including green turtle feeding grounds in Corisco Bay, Equatorial Guinea/Gabon (Formia 1999); Congo; Mussulo Bay, Angola (Carr and Carr 1991); as well as Principe Island. Juvenile and adult green turtles utilize foraging areas throughout the Caribbean areas of the South Atlantic, often resulting in interactions with fisheries occurring in those same waters (Dow et al. 2007). Juvenile green turtles from multiple rookeries also frequently utilize the nearshore waters off Brazil as foraging grounds as evidenced from the frequent captures by fisheries (Lima et al. 2010; López-Barrera et al. 2012; Marcovaldi et al. 2009). Genetic analysis of green turtles on the foraging grounds off Ubatuba and Almofala, Brazil show mixed stocks coming primarily from Ascension, Suriname and Trindade as a secondary source, but also Aves, and even sometimes Costa Rica (North Atlantic DPS)(Naro-Maciel et al. 2007; Naro-Maciel et al. 2012). While no nesting occurs as far south as Uruguay and Argentina, both have important foraging grounds for South Atlantic green turtles (Gonzalez Carman et al. 2011; Lezama 2009; López-Mendilaharsu et al. 2006; Prosdocimi et al. 2012; Rivas-Zinno 2012).

Life History Information

Green sea turtles reproduce sexually, and mating occurs in the waters off nesting beaches and along migratory routes. Mature females return to their natal beaches (i.e., the same beaches where they were born) to lay eggs (Balazs 1982; Frazer and Ehrhart 1985) every 2-4 years while males are known to reproduce every year (Balazs 1983). In the southeastern United States, females generally nest between June and September, and peak nesting occurs in June and July (Witherington and Ehrhart 1989b). During the nesting season, females nest at approximately 2-week intervals, laying an average of 3-4 clutches (Johnson and Ehrhart 1996). Clutch size often varies among subpopulations, but mean clutch size is approximately 110-115 eggs. In Florida, green sea turtle nests contain an average of 136 eggs (Witherington and Ehrhart 1989b). Eggs incubate for approximately 2 months before hatching. Hatchling green sea turtles are approximately 2 inches (5 cm) in length and weigh approximately 0.9 ounces (25 grams). Survivorship at any particular nesting site is greatly influenced by the level of man-made stressors, with the more pristine and less disturbed nesting sites (e.g., along the Great Barrier Reef in Australia) showing higher survivorship values than nesting sites known to be highly disturbed (e.g., Nicaragua) (Campell and Lagueux 2005; Chaloupka and Limpus 2005).

After emerging from the nest, hatchlings swim to offshore areas and go through a post-hatchling pelagic stage where they are believed to live for several years. During this life stage, green sea turtles feed close to the surface on a variety of marine algae and other life associated with drift lines and debris. This early oceanic phase remains one of the most poorly understood aspects of green sea turtle life history (NMFS and USFWS 2007b). Green sea turtles exhibit particularly slow growth rates of about 0.4-2 inches (1-5 cm) per year (Green 1993), which may be attributed to their largely herbivorous, low-net energy diet (Bjorndal 1982). At approximately 8-10 inches (20-25 cm) carapace length, juveniles leave the pelagic environment and enter nearshore developmental habitats such as protected lagoons and open coastal areas rich in sea grass and marine algae. Growth studies using skeletochronology indicate that green sea turtles in the western Atlantic shift from the oceanic phase to nearshore developmental habitats after approximately 5-6 years (Bresette et al. 2006; Zug and Glor 1998). Within the developmental habitats, juveniles begin the switch to a more herbivorous diet, and by adulthood feed almost exclusively on seagrasses and algae (Rebel 1974), although some populations are known to also feed heavily on invertebrates (Carballo et al. 2002). Green sea turtles mature slowly, requiring 20-50 years to reach sexual maturity (Chaloupka and Musick 1997; Hirth 1997).

While in coastal habitats, green sea turtles exhibit site fidelity to specific foraging and nesting grounds, and it is clear they are capable of "homing in" on these sites if displaced (McMichael et al. 2003). Reproductive migrations of Florida green sea turtles have been identified through flipper tagging and/or satellite telemetry. Based on these studies, the majority of adult female Florida green sea turtles are believed to reside in nearshore foraging areas throughout the Florida Keys and in the waters southwest of Cape Sable, and some post-nesting turtles also reside in Bahamian waters as well (NMFS and USFWS 2007b).

Status and Population Dynamics

Accurate population estimates for marine turtles do not exist because of the difficulty in sampling turtles over their geographic ranges and within their marine environments. Nonetheless, researchers have used nesting data to study trends in reproducing sea turtles over time. A summary of nesting trends and nester abundance is provided in the most recent status review for the species (Seminoff et al. 2015), with information for each of the DPSs.

<u>North Atlantic DPS</u>

The NA DPS is the largest of the 11 green turtle DPSs, with an estimated nester abundance of over 167,000 adult females from 73 nesting sites. Overall, this DPS is also the most data rich. Eight of the sites have high levels of abundance (i.e., <1000 nesters), located in Costa Rica, Cuba, Mexico, and Florida. All major nesting populations demonstrate long-term increases in abundance (Seminoff et al. 2015).

Tortuguero, Costa Rica is by far the predominant nesting site, accounting for an estimated 79% of nesting for the DPS (Seminoff et al. 2015). Nesting at Tortuguero appears to have been increasing since the 1970's, when monitoring began. For instance, from 1971-1975 there were approximately 41,250 average annual emergences documented and this number increased to an average of 72,200 emergences from 1992-1996 (Bjorndal et al. 1999). Troëng and Rankin (2005) collected nest counts from 1999-2003 and also reported increasing trends in the population consistent with the earlier studies, with nest count data suggesting 17,402-37,290 nesting females per year (NMFS and USFWS 2007b). Modeling by Chaloupka et al. (2008) using data sets of 25 years or more resulted in an estimate of the Tortuguero, Costa Rica population is growing at 4.9% annually.

In the continental United States, green sea turtle nesting occurs along the Atlantic coast, primarily along the central and southeast coast of Florida where an estimated 200-1,100 females nest each year (Meylan et al. 1994; Weishampel et al. 2003). Occasional nesting has also been documented along the Gulf Coast of Florida (Meylan et al. 1995). Green sea turtle nesting is documented annually on beaches of North Carolina, South Carolina, and Georgia, though nesting is found in low quantities (nesting databases maintained on www.seaturtle.org).

In Florida, index beaches were established to standardize data collection methods and effort on key nesting beaches. Since establishment of the index beaches in 1989, the pattern of green sea turtle nesting has generally shown biennial peaks in abundance with a positive trend during the 10 years of regular monitoring (Figure 4). According to data collected from Florida's index nesting beach survey from 1989-2015, green sea turtle nest counts across Florida have increased approximately ten-fold from a low of 267 in the early 1990s to a high of 27,975 in 2015. Two consecutive years of nesting declines in 2008 and 2009 caused some concern, but this was followed by increases in 2010 and 2011, and a return to the trend of biennial peaks in abundance thereafter (Figure 4). Modeling by Chaloupka et al. (2008) using data sets of 25 years or more has resulted in an estimate of the Florida nesting stock at the Archie Carr National Wildlife Refuge growing at an annual rate of 13.9%.

Similar to the nesting trend found in Florida, in-water studies in Florida have also recorded increases in green turtle captures at the Indian River Lagoon site, with a 661 percent increase over 24 years (Ehrhart et al. 2007), and the St Lucie Power Plant site, with a significant increase in the annual rate of capture of immature green turtles (SCL<90 cm) from 1977 to 2002 or 26 years (3,557 green turtles total; M. Bressette, Inwater Research Group, unpubl. data; (Witherington et al. 2006).

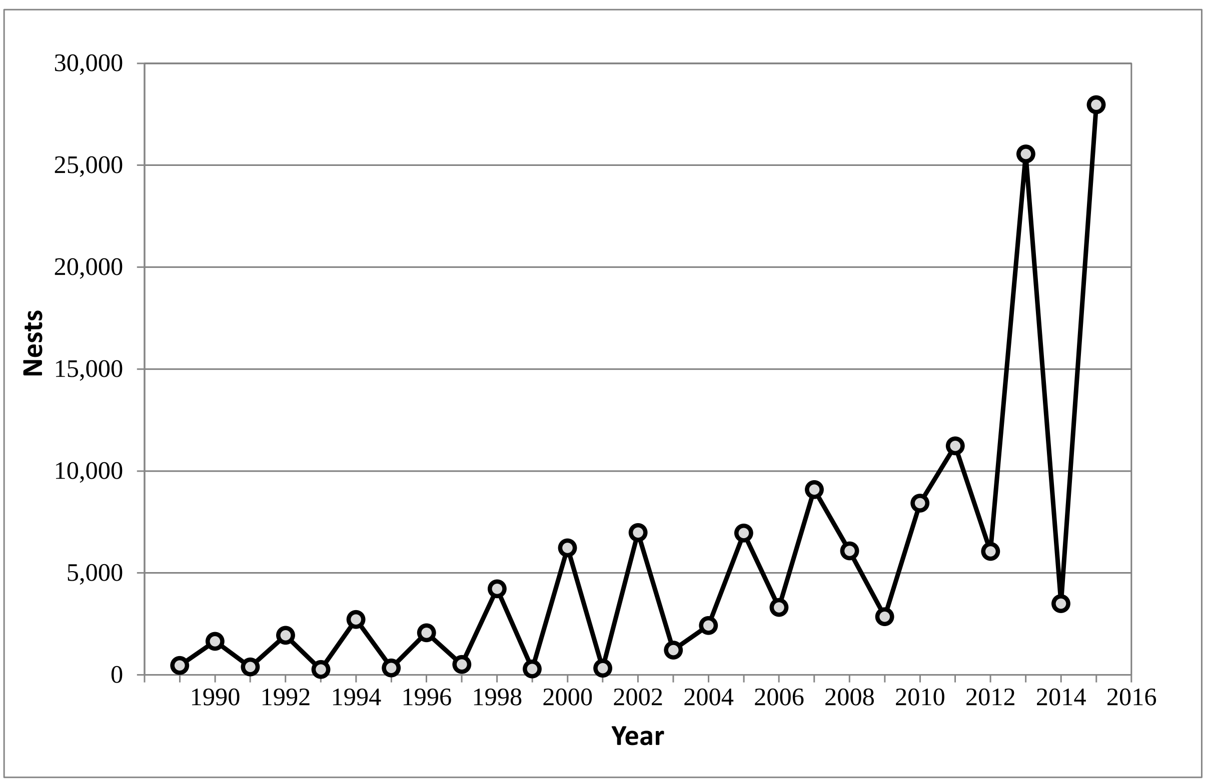


Figure S3. Green sea turtle nesting at Florida index beaches since 1989.

South Atlantic DPS

The SA DPS is large, estimated at over 63,000 nesters, but data availability is poor. More than half of the 51 identified nesting sites (37) did not have sufficient data to estimate number of nesters or trends (Seminoff et al. 2015). This includes some sites, such as beaches in French Guiana, which are suspected to have large numbers of nesters. Therefore, while the estimated number of nesters may be substantially underestimated, we also do not know the population trends at those data-poor beaches. However, while the lack of data was a concern due to increased uncertainty, the overall trend of the SA DPS was not considered to be a major concern as some of the largest nesting beaches such as Ascension Island, Aves Island (Venezuela), and Galibi (Suriname) appear to be increasing. Others such as Trindade (Brazil), Atol das Rocas (Brazil), and Poilão and the rest of Guinea-Bissau seem to be stable or do not have sufficient data to make a determination. Bioko (Equatorial Guinea) appears to be in decline but has less nesting than the other primary sites (Seminoff et al. 2015).

In the U.S., nesting of SA DPS green turtles occurs on the beaches of the U.S. Virgin Islands, primarily on Buck Island. There is insufficient data to determine a trend for Buck Island nesting, and it is a smaller rookery, with approximately 63 total nesters utilizing the beach (Seminoff et al. 2015).

Threats

The principal cause of past declines and extirpations of green sea turtle assemblages has been the overexploitation of the species for food and other products. Although intentional take of green sea turtles and their eggs is not extensive within the southeastern United States, green sea turtles that nest and forage in the region may spend large portions of their life history outside the region and outside U.S. jurisdiction, where exploitation is still a threat. Green sea turtles also face many of the same threats as other sea turtle species, including destruction of nesting habitat from storm events, oceanic events such as cold-stunning, pollution (e.g., plastics, petroleum products, petrochemicals), ecosystem alterations (e.g., nesting beach development, beach nourishment and shoreline stabilization, vegetation changes), poaching, global climate change, fisheries interactions, natural predation, and disease. A discussion on general sea turtle threats can be found in Section 6.2.1.

In addition to general threats, green sea turtles are susceptible to natural mortality from Fibropapillomatosis (FP) disease. FP results in the growth of tumors on soft external tissues (flippers, neck, tail, etc.), the carapace, the eyes, the mouth, and internal organs (gastrointestinal tract, heart, lungs, etc.) of turtles (Aguirre et al. 2002; Herbst 1994; Jacobson et al. 1989). These tumors range in size from 0.04 inches (0.1 cm) to greater than 11.81 inches (30 cm) in diameter and may affect swimming, vision, feeding, and organ function (Aguirre et al. 2002; Herbst 1994; Jacobson et al. 1989). Presently, scientists are unsure of the exact mechanism causing this disease, though it is believed to be related to both an infectious agent, such as a virus (Herbst et al. 1995), and environmental conditions (e.g., habitat degradation, pollution, low wave energy, and shallow water (Foley et al. 2005). FP is cosmopolitan, but it has been found to affect large numbers of animals in specific areas, including Hawaii and Florida (Herbst 1994; Jacobson 1990; Jacobson et al. 1991).

Cold-stunning is another natural threat to green sea turtles. Although it is not considered a major source of mortality in most cases, as temperatures fall below 46.4°-50°F (8°-10°C) turtles may lose their ability to swim and dive, often floating to the surface. The rate of cooling that precipitates cold-stunning appears to be the primary threat, rather than the water temperature itself (Milton and Lutz 2003). Sea turtles that overwinter in inshore waters are most susceptible to cold-stunning because temperature changes are most rapid in shallow water (Witherington and Ehrhart 1989a). During January 2010, an unusually large cold-stunning event in the southeastern United States resulted in around 4,600 sea turtles, mostly greens, found cold-stunned, and hundreds found dead or dying. A large cold-stunning event occurred in the western Gulf of Mexico in February 2011, resulting in approximately 1,650 green sea turtles found cold-stunned in Texas. Of these, approximately 620 were found dead or died after stranding, while approximately 1,030 turtles were rehabilitated and released. During this same time frame, approximately 340 green sea turtles were found cold-stunned in Mexico, though approximately 300 of those were subsequently rehabilitated and released.

Whereas oil spill impacts are discussed generally for all species in Section 6.2.1, specific impacts of the DWH spill on green sea turtles are considered here. Impacts to green sea turtles occurred to offshore small juveniles only. A total of 154,000 small juvenile greens (36.6% of the total small juvenile sea turtle exposures to oil from the spill) were estimated to have been exposed to oil. A large number of small juveniles were removed from the population, as 57,300 small juveniles greens are estimated to have died as a result of the exposure. A total of 4 nests (580 eggs) were also translocated during response efforts, with 455 hatchlings released (the fate of which is unknown) (DWH Trustees 2015). Additional unquantified effects may have included inhalation of volatile compounds, disruption of foraging or migratory movements due to surface or subsurface oil, ingestion of prey species contaminated with oil and/or dispersants, and loss of foraging resources which could lead to compromised growth and/or reproductive potential. There is no information currently available to determine the extent of those impacts, if they occurred.

While green turtles regularly use the northern Gulf of Mexico, they have a widespread distribution throughout the entire Gulf of Mexico, Caribbean, and Atlantic, and the proportion of the population using the northern Gulf of Mexico at any given time is relatively low. Although it is known that adverse impacts occurred and numbers of animals in the Gulf of Mexico were reduced as a result of the Deepwater Horizon oil spill of 2010 (DWH), the relative proportion of the population that is expected to have been exposed to and directly impacted by the DWH event, as well as the impacts being primarily to smaller juveniles (lower reproductive value than adults and large juveniles), reduces the impact to the overall population. It is unclear what impact these losses may have caused on a population level, but it is not expected to have had a large impact on the population trajectory moving forward. However, recovery of green turtle numbers equivalent to what was lost in the northern Gulf of Mexico as a result of the spill will likely take decades of sustained efforts to reduce the existing threats and enhance survivorship of multiple life stages (DWH Trustees 2015).

6.2.4 Kemp's Ridley Sea Turtle

The Kemp's ridley sea turtle was listed as endangered on December 2, 1970, under the Endangered Species Conservation Act of 1969, a precursor to the ESA. Internationally, the Kemp's ridley is considered the most endangered sea turtle (Groombridge 1982; TEWG 2000; Zwinenberg 1977).

Species Description and Distribution

The Kemp's ridley sea turtle is the smallest of all sea turtles. Adults generally weigh less than 100 lb (45 kg) and have a carapace length of around 2.1 ft (65 cm). Adult Kemp's ridley shells are almost as wide as they are long. Coloration changes significantly during development from the grey-black dorsum and plastron of hatchlings, a grey-black dorsum with a yellowish-white plastron as post-pelagic juveniles, and then to the lighter grey-olive carapace and cream-white or yellowish plastron of adults. There are 2 pairs of prefrontal scales on the head, 5 vertebral scutes, usually 5 pairs of costal scutes, and generally 12 pairs of marginal scutes on the carapace. In each bridge adjoining the plastron to the carapace, there are 4 scutes, each of which is perforated by a pore.

Kemp's ridley habitat largely consists of sandy and muddy areas in shallow, nearshore waters less than 120 ft (37 m) deep, although they can also be found in deeper offshore waters. These areas support the primary prey species of the Kemp's ridley sea turtle, which consist of swimming crabs, but may also include fish, jellyfish, and an array of mollusks.

The primary range of Kemp's ridley sea turtles is within the Gulf of Mexico basin, though they also occur in coastal and offshore waters of the U.S. Atlantic Ocean. Juvenile Kemp's ridley sea turtles, possibly carried by oceanic currents, have been recorded as far north as Nova Scotia. Historic records indicate a nesting range from Mustang Island, Texas, in the north to Veracruz, Mexico, in the south. Kemp's ridley sea turtles have recently been nesting along the Atlantic Coast of the United States, with nests recorded from beaches in Florida, Georgia, and the Carolinas. In 2012, the first Kemp's ridley sea turtle nest was recorded in Virginia. The Kemp's ridley nesting population had been exponentially increasing prior to the recent low nesting years, which may indicate that the population had been experiencing a similar increase. Additional nesting data in the coming years will be required to determine what the recent nesting decline means for the population trajectory.

Life History Information

Kemp's ridley sea turtles share a general life history pattern similar to other sea turtles. Females lay their eggs on coastal beaches where the eggs incubate in sandy nests. After 45-58 days of embryonic development, the hatchlings emerge and swim offshore into deeper, ocean water where they feed and grow until returning at a larger size. Hatchlings generally range from 1.65-1.89 in (42-48 mm) straight carapace length (SCL), 1.26-1.73 in (32-44 mm) in width, and 0.3-0.4 lb (15-20 g) in weight. Their return to nearshore coastal habitats typically occurs around 2 years of age (Ogren 1989), although the time spent in the oceanic zone may vary from 1-4 years or perhaps more (TEWG 2000). Juvenile Kemp's ridley sea turtles use these nearshore coastal habitats from April through November, but they move towards more suitable overwintering habitat in deeper offshore waters (or more southern waters along the Atlantic coast) as water temperature drops.

The average rates of growth may vary by location, but generally fall within 2.2-2.9 $\pm$ 2.4 in per year (5.5-7.5 $\pm$ 6.2 cm/year) (Schmid and Barichivich 2006; Schmid and Woodhead 2000). Age to sexual maturity ranges greatly from 5-16 years, though NMFS et al. (2011) determined the best estimate of age to maturity for Kemp's ridley sea turtles was 12 years. It is unlikely that most adults grow very much after maturity. While some sea turtles nest annually, the weighted mean remigration rate for Kemp's ridley sea turtles is approximately 2 years. Nesting generally occurs from April to July. Females lay approximately 2.5 nests per season with each nest containing approximately 100 eggs (Márquez M. 1994).

Population Dynamics

Of the 7 species of sea turtles in the world, the Kemp's ridley has declined to the lowest population level. Most of the population of adult females nest on the beaches of Rancho Nuevo, Mexico (Pritchard 1969). When nesting aggregations at Rancho Nuevo were discovered in 1947, adult female populations were estimated to be in excess of 40,000 individuals (Hildebrand 1963). By the mid-1980s, however, nesting numbers from Rancho Nuevo and adjacent Mexican beaches were below 1,000, with a low of 702 nests in 1985. Yet, nesting steadily increased through the 1990s, and then accelerated during the first decade of the twenty-first century (Figure 5), which indicates the species is recovering.

It is worth noting that when the Bi-National Kemp's Ridley Sea Turtle Population Restoration Project was initiated in 1978, only Rancho Nuevo nests were recorded. In 1988, nesting data from southern beaches at Playa Dos and Barra del Tordo were added. In 1989, data from the northern beaches of Barra Ostionales and Tepehuajes were added, and most recently in 1996, data from La Pesca and Altamira beaches were recorded. Currently, nesting at Rancho Nuevo accounts for just over 81% of all recorded Kemp's ridley nests in Mexico. Following a significant, unexplained 1-year decline in 2010, Kemp's ridley nests in Mexico reached a record high of 21,797 in 2012 (Gladys Porter Zoo 2013). From 2013 through 2014, there was a second significant decline, as only 16,385 and 11,279 nests were recorded, respectively. In 2015, nesting in Mexico improved to 14,006 recorded nests (J. Pena, Gladys Porter Zoo, pers. comm. to M. Barnette, NMFS PRD, October 19, 2015). At this time, it is unclear if future nesting will steadily and continuously increase, similar to what occurred from 1990-2009, or if nesting will continue to exhibit sporadic declines and increases as recorded in the past 5 years.

A small nesting population is also emerging in the United States, primarily in Texas, rising from 6 nests in 1996 to 42 in 2004, to a record high of 209 nests in 2012 (National Park Service data, http://www.nps.gov/pais/naturescience/strp.htm, http://www.nps.gov/pais/naturescience/current-season.htm). It is worth noting that nesting in Texas has paralleled the trends observed in Mexico, with a significant decline in 2010 followed by a second decline in 2013-2014. Nesting rebounded in 2015, as 159 nests were documented along the Texas coast (D. Shaver, National Park Service, pers. comm. to M. Barnette, NMFS PRD, October 28, 2015).

Through modelling, Heppell et al. (2005) predicted the population is expected to increase at least 12-16% per year and could reach at least 10,000 females nesting on Mexico beaches by 2015. NMFS et al. (2011) produced an updated model that predicted the population to increase 19% per year and to attain at least 10,000 females nesting on Mexico beaches by 2011. Approximately 25,000 nests would be needed for an estimate of 10,000 nesters on the beach, based on an average 2.5 nests/nesting female. While counts did not reach 25,000 nests by 2015, it is clear that the population has increased over the long term. The increases in Kemp's ridley sea turtle nesting over the last 2 decades is likely due to a combination of management measures including elimination of direct harvest, nest protection, the use of TEDs, reduced trawling effort in Mexico and the United States, and possibly other changes in vital rates (TEWG 1998; TEWG 2000). While these results are encouraging, the species' limited range as well as low global abundance makes it particularly vulnerable to new sources of mortality as well as demographic and environmental randomness, all factors which are often difficult to predict with any certainty. Additionally, the significant nesting declines observed in 2010 and 2013-2014 potentially indicate a serious population-level impact, and there is cause for concern regarding the ongoing recovery trajectory.

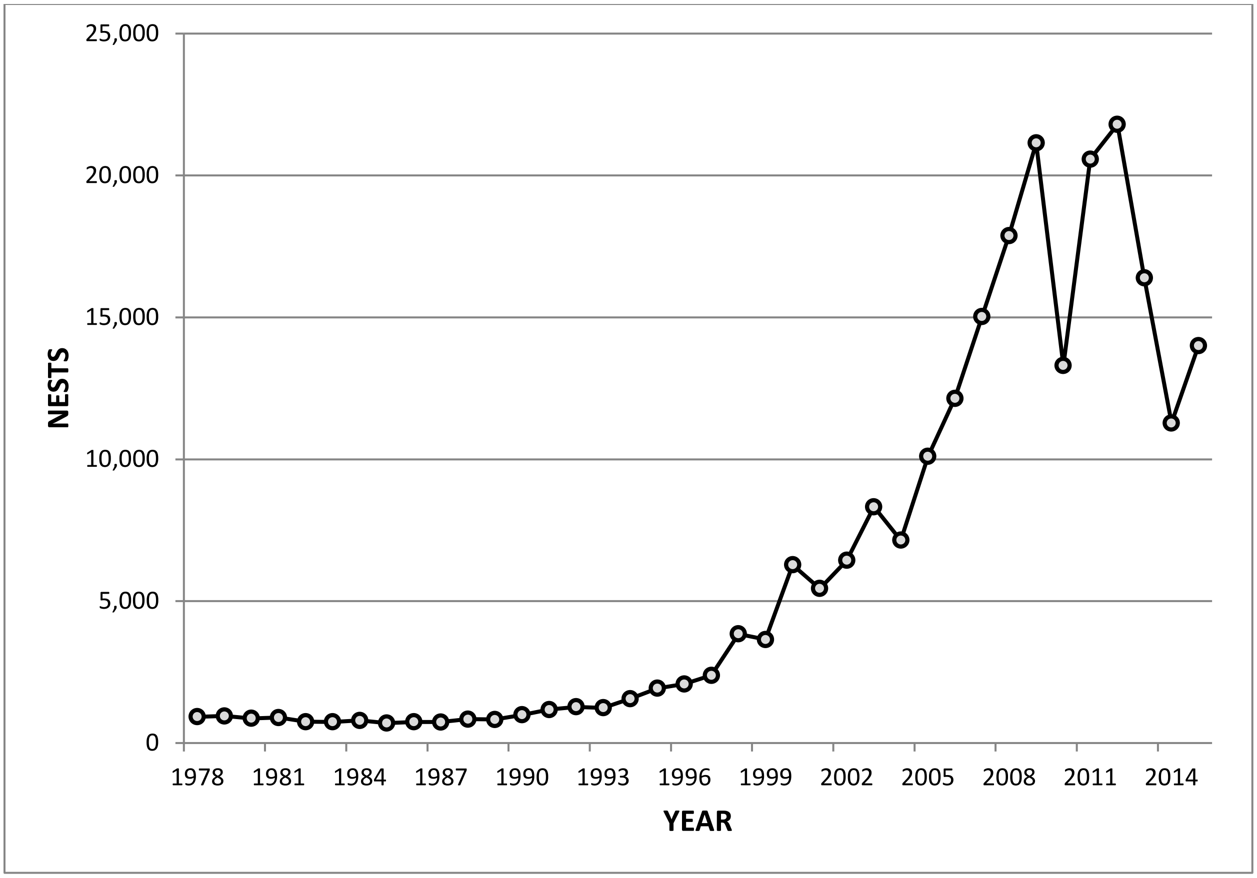


Figure S4. Kemp's ridley nest totals from Mexican beaches (Gladys Porter Zoo nesting database 2015)

Threats

Kemp's ridley sea turtles face many of the same threats as other sea turtle species, including destruction of nesting habitat from storm events, oceanic events such as cold-stunning, pollution (plastics, petroleum products, petrochemicals, etc.), ecosystem alterations (nesting beach development, beach nourishment and shoreline stabilization, vegetation changes, etc.), poaching, global climate change, fisheries interactions, natural predation, and disease. A discussion on general sea turtle threats can be found in Section 6.2.1; the remainder of this section will expand on a few of the aforementioned threats and how they may specifically impact Kemp's ridley sea turtles.

As Kemp's ridley sea turtles continue to recover and nesting arribadas[12] are increasingly established, bacterial and fungal pathogens in nests are also likely to increase. Bacterial and fungal pathogen impacts have been well documented in the large arribadas of the olive ridley at Nancite in Costa Rica (Mo 1988). In some years, and on some sections of the beach, the hatching success can be as low as 5% (Mo 1988). As the Kemp's ridley nest density at Rancho Nuevo and adjacent beaches continues to increase,

[12] Arribada is the Spanish word for "arrival" and is the term used for massive synchronized nesting within the genus *Lepidochelys.*

appropriate monitoring of emergence success will be necessary to determine if there are any density-dependent effects.

Over the past 6 years, NMFS has documented (via the Sea Turtle Stranding and Salvage Network data, http://www.sefsc.noaa.gov/species/turtles/strandings.htm) elevated sea turtle strandings in the Northern Gulf of Mexico, particularly throughout the Mississippi Sound area. In the first 3 weeks of June 2010, over 120 sea turtle strandings were reported from Mississippi and Alabama waters, none of which exhibited any signs of external oiling to indicate effects associated with the DWH oil spill event. A total of 644 sea turtle strandings were reported in 2010 from Louisiana, Mississippi, and Alabama waters, 561 (87%) of which were Kemp's ridley sea turtles. During March through May of 2011, 267 sea turtle strandings were reported from Mississippi and Alabama waters alone. A total of 525 sea turtle strandings were reported in 2011 from Louisiana, Mississippi, and Alabama waters, with the majority (455) having occurred from March through July, 390 (86%) of which were Kemp's ridley sea turtles. During 2012, a total of 384 sea turtles were reported from Louisiana, Mississippi, and Alabama waters. Of these reported strandings, 343 (89%) were Kemp's ridley sea turtles. During 2014, a total of 285 sea turtles were reported from Louisiana, Mississippi, and Alabama waters, though the data is incomplete. Of these reported strandings, 229 (80%) were Kemp's ridley sea turtles. These stranding numbers are significantly greater than reported in past years; Louisiana, Mississippi, and Alabama waters reported 42 and 73 sea turtle strandings for 2008 and 2009, respectively. It should be noted that stranding coverage has increased considerably due to the DWH oil spill event.

Nonetheless, considering that strandings typically represent only a small fraction of actual mortality, these stranding events potentially represent a serious impact to the recovery and survival of the local sea turtle populations. While a definitive cause for these strandings has not been identified, necropsy results indicate a significant number of stranded turtles from these events likely perished due to forced submergence, which is commonly associated with fishery interactions (B. Stacy, NMFS, pers. comm. to M. Barnette, NMFS PRD, March 2012). Yet, available information indicates fishery effort was extremely limited during the stranding events. The fact that 80% or more of all Louisiana, Mississippi, and Alabama stranded sea turtles in the past 5 years were Kemp's ridleys is notable; however, this could simply be a function of the species' preference for shallow, inshore waters coupled with increased population abundance, as reflected in recent Kemp's ridley nesting increases.

In response to these strandings, and due to speculation that fishery interactions may be the cause, fishery observer effort was shifted to evaluate the inshore skimmer trawl fishery during the summer of 2012. During May-July of that year, observers reported 24 sea turtle interactions in the skimmer trawl fishery. All but a single sea turtle were identified as Kemp's ridleys (1 sea turtle was an unidentified hardshell turtle). Encountered sea turtles were all very small juvenile specimens, ranging from 7.6-19.0 in (19.4-48.3 cm) curved carapace length (CCL). All sea turtles were released alive. The small average size of encountered Kemp's ridleys introduces a potential conservation issue, as over 50% of these reported sea turtles could potentially pass through the maximum 4-in bar spacing of TEDs currently required in the shrimp fishery. Due to this issue, a proposed 2012 rule to require TEDs in the skimmer trawl fishery (77 FR 27411) was not implemented. Based on anecdotal information, these interactions were a relatively new issue for the inshore skimmer trawl fishery. Given the nesting trends and habitat utilization of Kemp's ridley sea turtles, it is likely that fishery interactions in the Northern Gulf of Mexico may continue to be an issue of concern for the species, and one that may potentially slow the rate of recovery for Kemp's ridley sea turtles.

While oil spill impacts are discussed generally for all species in Section 6.2.1, specific impacts of the DWH oil spill event on Kemp's ridley sea turtles are considered here. Kemp's ridleys experienced the greatest negative impact stemming from the DWH oil spill event of any sea turtle species. Impacts to Kemp's ridley sea turtles occurred to offshore small juveniles, as well as large juveniles and adults. Loss of hatchling production resulting from injury to adult turtles was also estimated for this species. Injuries to adult turtles of other species, such as loggerheads, certainly would have resulted in unrealized nests and hatchlings to those species as well. Yet, the calculation of unrealized nests and hatchlings was limited to Kemp's ridleys for several reasons. All Kemp's ridleys in the Gulf belong to the same population (NMFS et al. 2011), so total population abundance could be calculated based on numbers of hatchlings because all individuals that enter the population could reasonably be expected to inhabit the northern Gulf of Mexico throughout their lives (DWH Trustees 2015).

A total of 217,000 small juvenile Kemp's ridleys (51.5% of the total small juvenile sea turtle exposures to oil from the spill) were estimated to have been exposed to oil. That means approximately half of all small juvenile Kemp's ridleys from the total population estimate of 430,000 oceanic small juveniles were exposed to oil. Furthermore, a large number of small juveniles were removed from the population, as up to 90,300 small juveniles Kemp's ridleys are estimated to have died as a direct result of the exposure. Therefore, as much as 20% of the small oceanic juveniles of this species were killed during that year. Impacts to large juveniles (>3 years old) and adults were also high. An estimated 21,990 such individuals were exposed to oil (about 22% of the total estimated population for those age classes); of those, 3,110 mortalities were estimated (or 3% of the population for those age classes). The loss of near-reproductive and reproductive-stage females would have contributed to some extent to the decline in total nesting abundance observed between 2011 and 2014. The estimated number of unrealized Kemp's ridley nests is between 1,300 and 2,000, which translates to between approximately 65,000 and 95,000 unrealized hatchlings (DWH Trustees 2015). This is a minimum estimate, however, because the sublethal effects of the DWH oil spill event on turtles, their prey, and their habitats might have delayed or reduced reproduction in subsequent years, which may have contributed substantially to additional nesting deficits observed following the DWH oil spill event. These sublethal effects could have slowed growth and maturation rates, increased remigration intervals, and decreased clutch frequency (number of nests per female per nesting season). The nature of the DWH oil spill event effect on reduced Kemp's ridley nesting abundance and associated hatchling production after 2010 requires further evaluation. It is clear that the DWH oil spill event resulted in large losses to the Kemp's ridley population across various age classes, and likely had an important population-level effect on the species. Still, we do not have a clear understanding of those impacts on the population trajectory for the species into the future.

6.2.5 Leatherback Sea Turtle

The leatherback sea turtle was listed as endangered throughout its entire range on June 2, 1970, (35 FR 8491) under the Endangered Species Conservation Act of 1969.

Species Description and Distribution

The leatherback is the largest sea turtle in the world, with a curved carapace length (CCL) that often exceeds 5 ft (150 cm) and front flippers that can span almost 9 ft (270 cm) (NMFS and USFWS 1998a). Mature males and females can reach lengths of over 6 ft (2 m) and weigh close to 2,000 lb (900 kg). The leatherback does not have a bony shell. Instead, its shell is approximately 1.5 in (4 cm) thick and consists of a leathery, oil-saturated connective tissue overlaying loosely interlocking dermal bones. The ridged shell and large flippers help the leatherback during its long-distance trips in search of food.

Unlike other sea turtles, leatherbacks have several unique traits that enable them to live in cold water. For example, leatherbacks have a countercurrent circulatory system (Greer et al. 1973),[13] a thick layer of insulating fat (Davenport et al. 1990; Goff and Lien 1988), gigantothermy (Paladino et al. 1990),[14] and they can increase their body temperature through increased metabolic activity (Bostrom and Jones 2007; Southwood et al. 2005). These adaptations allow leatherbacks to be comfortable in a wide range of temperatures, which helps them to travel further than any other sea turtle species (NMFS and USFWS 1995). For example, a leatherback may swim more than 6,000 miles (10,000 km) in a single year (Benson et al. 2007a; Benson et al. 2011; Eckert 2006; Eckert et al. 2006). They search for food between latitudes 71°N and 47°S in all oceans, and travel extensively to and from their tropical nesting beaches. In the Atlantic Ocean, leatherbacks have been recorded as far north as Newfoundland, Canada, and Norway, and as far south as Uruguay, Argentina, and South Africa (NMFS 2001).

While leatherbacks will look for food in coastal waters, they appear to prefer the open ocean at all life stages (Heppell et al. 2003). Leatherbacks have pointed tooth-like cusps and sharp-edged jaws that are adapted for a diet of soft-bodied prey such as jellyfish and salps. A leatherback's mouth and throat also have backward-pointing spines that help retain jelly-like prey. Leatherbacks' favorite prey are jellies (e.g., medusae, siphonophores, and salps), which commonly occur in temperate and northern or sub-arctic latitudes and likely has a strong influence on leatherback distribution in these areas (Plotkin 2003). Leatherbacks are known to be deep divers, with recorded depths in excess of a half-mile (Eckert et al. 1989), but they may also come into shallow waters to locate prey items.

Genetic analyses using microsatellite markers along with mitochondrial DNA and tagging data indicate there are 7 groups or breeding populations in the Atlantic Ocean: Florida, Northern Caribbean, Western Caribbean, Southern Caribbean/Guianas, West Africa, South Africa, and Brazil (TEWG 2007). General differences in migration patterns and foraging grounds may occur between the 7 nesting assemblages, although data to support this is limited in most cases.

Life History Information

The leatherback life cycle is broken into several stages: (1) egg/hatchling, (2) post-hatchling, (3) juvenile, (4) subadult, and (5) adult. Leatherbacks are a long-lived species that delay age of maturity, have low and variable survival in the egg and juvenile stages, and have relatively high and constant annual survival in the subadult and adult life stages (Chaloupka 2002; Crouse 1999; Heppell et al. 1999; Heppell et al. 2003; Spotila et al. 1996; Spotila et al. 2000). While a robust estimate of the leatherback sea turtle's life span does not exist, the current best estimate for the maximum age is 43 (Avens et al. 2009). It is still unclear when leatherbacks first become sexually mature. Using skeletochronological data, Avens et al. (2009) estimated that leatherbacks in the western North Atlantic may not reach maturity until 29 years of age, which is longer than earlier estimates of 2-3 years by Pritchard and Trebbau (1984), of 3-6 years by

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[13] Countercurrent circulation is a highly efficient means of minimizing heat loss through the skin's surface because heat is recycled. For example, a countercurrent circulation system often has an artery containing warm blood from the heart surrounded by a bundle of veins containing cool blood from the body's surface. As the warm blood flows away from the heart, it passes much of its heat to the colder blood returning to the heart via the veins. This conserves heat by recirculating it back to the body's core.

[14] "Gigantothermy" refers to a condition when an animal has relatively high volume compared to its surface area, and as a result, it loses less heat.

Rhodin (1985), of 13-14 years for females by Zug and Parham (1996), and 12-14 years for leatherbacks nesting in the U.S. Virgin Islands by Dutton et al. (2005). A more recent study that examined leatherback growth rates estimated an age at maturity of 16.1 years (Jones et al. 2011).

The average size of reproductively active females in the Atlantic is generally 5-5.5 ft (150-162 cm) CCL (Benson et al. 2007a; Hirth et al. 1993; Starbird and Suarez 1994). Still, females as small as 3.5-4 ft (105-125 cm) CCL have been observed nesting at various sites (Stewart et al. 2007).

Female leatherbacks typically nest on sandy, tropical beaches at intervals of 2-4 years (Garcia M. and Sarti 2000; McDonald and Dutton 1996; Spotila et al. 2000). Unlike other sea turtle species, female leatherbacks do not always nest at the same beach year after year; some females may even nest at different beaches during the same year (Dutton et al. 2005; Eckert 1989; Keinath and Musick 1993; Steyermark et al. 1996). Individual female leatherbacks have been observed with fertility spans as long as 25 years (Hughes 1996). Females usually lay up to 10 nests during the 3-6 month nesting season (March through July in the United States), typically 8-12 days apart, with 100 eggs or more per nest (Eckert et al. 2012; Eckert 1989; Maharaj 2004; Matos 1986; Stewart and Johnson 2006; Tucker 1988). Yet, up to approximately 30% of the eggs may be infertile (Eckert 1989; Eckert et al. 1984; Maharaj 2004; Matos 1986; Stewart and Johnson 2006; Tucker 1988). The number of leatherback hatchlings that make it out of the nest on to the beach (i.e., emergent success) is approximately 50% worldwide (Eckert et al. 2012), which is lower than the greater than 80% reported for other sea turtle species (Miller 1997). In the United States, the emergent success is higher at 54-72% (Eckert and Eckert 1990; Stewart and Johnson 2006; Tucker 1988). Thus the number of hatchlings in a given year may be less than the total number of eggs produced in a season. Eggs hatch after 60-65 days, and the hatchlings have white striping along the ridges of their backs and on the edges of the flippers. Leatherback hatchlings weigh approximately 1.5-2 oz (40-50 g), and have lengths of approximately 2-3 in (51-76 mm), with fore flippers as long as their bodies. Hatchlings grow rapidly, with reported growth rates for leatherbacks from 2.5-27.6 in (6-70 cm) in length, estimated at 12.6 in (32 cm) per year (Jones et al. 2011).

In the Atlantic, the sex ratio appears to be skewed toward females. The Turtle Expert Working Group (TEWG) reports that nearshore and onshore strandings data from the U.S. Atlantic and Gulf of Mexico coasts indicate that 60% of strandings were females (TEWG 2007). Those data also show that the proportion of females among adults (57%) and juveniles (61%) was also skewed toward females in these areas (TEWG 2007). James et al. (2007) collected size and sex data from large subadult and adult leatherbacks off Nova Scotia and also concluded a bias toward females at a rate of 1.86:1.

The survival and mortality rates for leatherbacks are difficult to estimate and vary by location. For example, the annual mortality rate for leatherbacks that nested at Playa Grande, Costa Rica, was estimated to be 34.6% in 1993-1994, and 34.0% in 1994-1995 (Spotila et al. 2000). In contrast, leatherbacks nesting in French Guiana and St. Croix had estimated annual survival rates of 91% (Rivalan et al. 2005) and 89% (Dutton et al. 2005), respectively. For the St. Croix population, the average annual juvenile survival rate was estimated to be approximately 63% and the total survival rate from hatchling to first year of reproduction for a female was estimated to be between 0.4% and 2%, assuming age at first reproduction is between 9-13 years (Eguchi et al. 2006). Spotila et al. (1996) estimated first-year survival rates for leatherbacks at 6.25%.

Migratory routes of leatherbacks are not entirely known; however, recent information from satellite tags have documented long travels between nesting beaches and foraging areas in the Atlantic and Pacific

Ocean basins (Benson et al. 2007a; Benson et al. 2011; Eckert 2006; Eckert et al. 2006; Ferraroli et al. 2004; Hays et al. 2004; James et al. 2005). Leatherbacks nesting in Central America and Mexico travel thousands of miles through tropical and temperate waters of the South Pacific (Eckert and Sarti 1997; Shillinger et al. 2008). Data from satellite tagged leatherbacks suggest that they may be traveling in search of seasonal aggregations of jellyfish (Benson et al. 2007b; Bowlby et al. 1994; Graham 2009; Shenker 1984; Starbird et al. 1993; Suchman and Brodeur 2005).

Status and Population Dynamics

The status of the Atlantic leatherback population has been less clear than the Pacific population, which has shown dramatic declines at many nesting sites (Santidrián Tomillo et al. 2007; Sarti Martínez et al. 2007; Spotila et al. 2000). This uncertainty has been a result of inconsistent beach and aerial surveys, cycles of erosion, and reformation of nesting beaches in the Guianas (representing the largest nesting area). Leatherbacks also show a lesser degree of nest-site fidelity than occurs with the hardshell sea turtle species. Coordinated efforts of data collection and analyses by the leatherback Turtle Expert Working Group have helped to clarify the understanding of the Atlantic population status (TEWG 2007).

The Southern Caribbean/Guianas stock is the largest known Atlantic leatherback nesting aggregation (TEWG 2007). This area includes the Guianas (Guyana, Suriname, and French Guiana), Trinidad, Dominica, and Venezuela, with most of the nesting occurring in the Guianas and Trinidad. The Southern Caribbean/Guianas stock of leatherbacks was designated after genetics studies indicated that animals from the Guianas (and possibly Trinidad) should be viewed as a single population. Using nesting females as a proxy for population, the TEWG (2007) determined that the Southern Caribbean/Guianas stock had demonstrated a long-term, positive population growth rate. TEWG observed positive growth within major nesting areas for the stock, including Trinidad, Guyana, and the combined beaches of Suriname and French Guiana (TEWG 2007). More specifically, Tiwari et al. (2013) report an estimated three-generation abundance change of +3%, +20,800%, +1,778%, and +6% in Trinidad, Guyana, Suriname, and French Guiana, respectively.

Researchers believe the cyclical pattern of beach erosion and then reformation has affected leatherback nesting patterns in the Guianas. For example, between 1979 and 1986, the number of leatherback nests in French Guiana had increased by about 15% annually (NMFS 2001). This increase was then followed by a nesting decline of about 15% annually. This decline corresponded with the erosion of beaches in French Guiana and increased nesting in Suriname. This pattern suggests that the declines observed since 1987 might actually be a part of a nesting cycle that coincides with cyclic beach erosion in Guiana (Schulz 1975). Researchers think that the cycle of erosion and reformation of beaches may have changed where leatherbacks nest throughout this region. The idea of shifting nesting beach locations was supported by increased nesting in Suriname,[15] while the number of nests was declining at beaches in Guiana (Hilterman et al. 2003). Though this information suggested the long-term trend for the overall Suriname and French Guiana population was increasing.

The Western Caribbean stock includes nesting beaches from Honduras to Colombia. Across the Western Caribbean, nesting is most prevalent in Costa Rica, Panama, and the Gulf of Uraba in Colombia (Duque et al. 2000). The Caribbean coastline of Costa Rica and extending through Chiriquí Beach, Panama, represents the fourth largest known leatherback rookery in the world (Troëng et al. 2004). Examination

[15] Leatherback nesting in Suriname increased by more than 10,000 nests per year since 1999 with a peak of 30,000 nests in 2001.

of data from index nesting beaches in Tortuguero, Gandoca, and Pacuaré in Costa Rica indicate that the nesting population likely was not growing over the 1995-2005 time series (TEWG 2007). Other modeling of the nesting data for Tortuguero indicates a possible 67.8% decline between 1995 and 2006 (Troëng et al. 2007). Tiwari et al. (2013) report an estimated three-generation abundance change of -72%, -24%, and +6% for Tortuguero, Gandoca, and Pacuare, respectively.

Nesting data for the Northern Caribbean stock is available from Puerto Rico, St. Croix (U.S. Virgin Islands), and the British Virgin Islands (Tortola). In Puerto Rico, the primary nesting beaches are at Fajardo and on the island of Culebra. Nesting between 1978 and 2005 has ranged between 469-882 nests, and the population has been growing since 1978, with an overall annual growth rate of 1.1% (TEWG 2007). Tiwari et al. (2013) report an estimated three-generation abundance change of -4% and +5,583% at Culebra and Fajardo, respectively. At the primary nesting beach on St. Croix, the Sandy Point National Wildlife Refuge, nesting has varied from a few hundred nests to a high of 1,008 in 2001, and the average annual growth rate has been approximately 1.1% from 1986-2004 (TEWG 2007). From 2006-2010, Tiwari et al. (2013) report an annual growth rate of +7.5% in St. Croix and a three-generation abundance change of +1,058%. Nesting in Tortola is limited, but has been increasing from 0-6 nests per year in the late 1980s to 35-65 per year in the 2000s, with an annual growth rate of approximately 1.2% between 1994 and 2004 (TEWG 2007).

The Florida nesting stock nests primarily along the east coast of Florida. This stock is of growing importance, with total nests between 800-900 per year in the 2000s following nesting totals fewer than 100 nests per year in the 1980s (Florida Fish and Wildlife Conservation Commission, unpublished data). Using data from the index nesting beach surveys, the TEWG (2007) estimated a significant annual nesting growth rate of 1.17% between 1989 and 2005. FWC Index Nesting Beach Survey Data generally indicates biennial peaks in nesting abundance beginning in 2007 (Figure 6 and Table A4). A similar pattern was also observed statewide (Table A4). This up-and-down pattern is thought to be a result of the cyclical nature of leatherback nesting, similar to the biennial cycle of green turtle nesting. Overall, the trend shows growth on Florida’s east coast beaches. Tiwari et al. (2013) report an annual growth rate of 9.7% and a three-generation abundance change of +1,863%.

Table A4. Number of Leatherback Sea Turtle Nests in Florida.

Nests Recorded	2011	2012	2013	2014	2015
Index Nesting Beaches	625	515	322	641	489
Statewide	1,653	1,712	896	1,604	NA

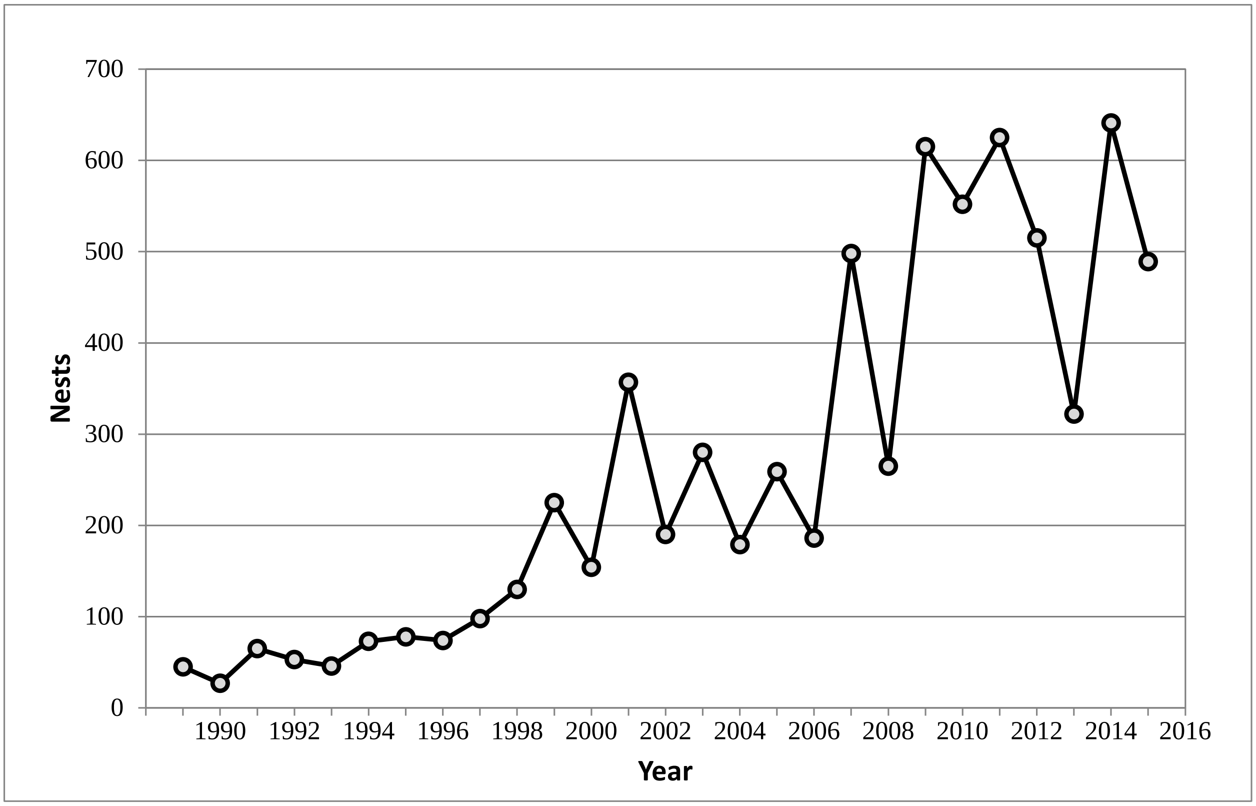

Figure S5. Leatherback sea turtle nesting at Florida index beaches since 1989.

The West African nesting stock of leatherbacks is large and important, but it is a mostly unstudied aggregation. Nesting occurs in various countries along Africa's Atlantic coast, but much of the nesting is undocumented and the data are inconsistent. Gabon has a very large amount of leatherback nesting, with at least 30,000 nests laid along its coast in a single season (Fretey et al. 2007). Fretey et al. (2007) provide detailed information about other known nesting beaches and survey efforts along the Atlantic African coast. Because of the lack of consistent effort and minimal available data, trend analyses were not possible for this stock (TEWG 2007).

Two other small but growing stocks nest on the beaches of Brazil and South Africa. Based on the data available, TEWG (2007) determined that between 1988 and 2003, there was a positive annual average growth rate between 1.07% and 1.08% for the Brazilian stock. TEWG (2007) estimated an annual average growth rate between 1.04% and 1.06% for the South African stock.

Because the available nesting information is inconsistent, it is difficult to estimate the total population size for Atlantic leatherbacks. Spotila et al. (1996) characterized the entire Western Atlantic population as stable at best and estimated a population of 18,800 nesting females. Spotila et al. (1996) further estimated that the adult female leatherback population for the entire Atlantic basin, including all nesting beaches in the Americas, the Caribbean, and West Africa, was about 27,600 (considering both nesting and interesting females), with an estimated range of 20,082-35,133. This is consistent with the estimate of 34,000-95,000 total adults (20,000-56,000 adult females; 10,000-21,000 nesting females) determined by the TEWG (2007). The TEWG (2007) also determined that at of the time of their publication, leatherback sea turtle populations in the Atlantic were all stable or increasing with the exception of the

Western Caribbean and West Africa populations. The latest review by NMFS USFWS (2013) suggests the leatherback nesting population is stable in most nesting regions of the Atlantic Ocean.

Threats

Leatherbacks face many of the same threats as other sea turtle species, including destruction of nesting habitat from storm events, oceanic events such as cold-stunning, pollution (plastics, petroleum products, petrochemicals, etc.), ecosystem alterations (nesting beach development, beach nourishment and shoreline stabilization, vegetation changes, etc.), poaching, global climate change, fisheries interactions, natural predation, and disease. A discussion on general sea turtle threats can be found in Section 6.2.1; the remainder of this section will expand on a few of the aforementioned threats and how they may specifically impact leatherback sea turtles.

Of all sea turtle species, leatherbacks seem to be the most vulnerable to entanglement in fishing gear, especially gillnet and pot/trap lines. This vulnerability may be because of their body type (large size, long pectoral flippers, and lack of a hard shell), their attraction to gelatinous organisms and algae that collect on buoys and buoy lines at or near the surface, their method of locomotion, and/or their attraction to the lightsticks used to attract target species in longline fisheries. From 1990-2000, 92 entangled leatherbacks were reported from New York through Maine and many other stranded individuals exhibited evidence of prior entanglement (Dwyer et al. 2003). Zug and Parham (1996) point out that a combination of the loss of long-lived adults in fishery-related mortalities and a lack of recruitment from intense egg harvesting in some areas has caused a sharp decline in leatherback sea turtle populations. This represents a significant threat to survival and recovery of the species worldwide.

Leatherback sea turtles may also be more susceptible to marine debris ingestion than other sea turtle species due to their predominantly pelagic existence and the tendency of floating debris to concentrate in convergence zones that adults and juveniles use for feeding and migratory purposes (Lutcavage et al. 1997; Shoop and Kenney 1992). The stomach contents of leatherback sea turtles revealed that a substantial percentage (33.8% or 138 of 408 cases examined) contained some form of plastic debris (Mrosovsky et al. 2009). Blocking of the gut by plastic to an extent that could have caused death was evident in 8.7% of all leatherbacks that ingested plastic (Mrosovsky et al. 2009). Mrosovsky et al. (2009) also note that in a number of cases, the ingestion of plastic may not cause death outright, but could cause the animal to absorb fewer nutrients from food, eat less in general, etc.– factors which could cause other adverse effects. The presence of plastic in the digestive tract suggests that leatherbacks might not be able to distinguish between prey items and forms of debris such a plastic bags (Mrosovsky et al. 2009). Balazs (1985) speculated that the plastic object might resemble a food item by its shape, color, size, or even movement as it drifts about, and therefore induce a feeding response in leatherbacks.

As discussed in Section 6.2.1, global climate change can be expected to have various impacts on all sea turtles, including leatherbacks. Global climate change is likely to also influence the distribution and abundance of jellyfish, the primary prey item of leatherbacks (NMFS and USFWS 2007a). Several studies have shown leatherback distribution is influenced by jellyfish abundance ((Houghton et al. 2006; Witt et al. 2007; Witt et al. 2006); however, more studies need to be done to monitor how changes to prey items affect distribution and foraging success of leatherbacks so population-level effects can be determined.

While oil spill impacts are discussed generally for all species in Section 6.2.1, specific impacts of the DWH oil spill on leatherback sea turtles are considered here. Available information indicates leatherback sea turtles (along with hawksbill turtles) were likely directly affected by the oil spill. Leatherbacks were documented in the spill area, but the number of affected leatherbacks was not estimated due to a lack of information compared to other species. But given that the northern Gulf of Mexico is important habitat for leatherback migration and foraging (TEWG 2007), and documentation of leatherbacks in the DWH oil spill zone during the spill period, it was concluded that leatherbacks were exposed to DWH oil, and some portion of those exposed leatherbacks likely died. Potential DWH-related impacts to leatherback sea turtles include direct oiling or contact with dispersants from surface and subsurface oil and dispersants, inhalation of volatile compounds, disruption of foraging or migratory movements due to surface or subsurface oil, ingestion of prey species contaminated with oil and/or dispersants, and loss of foraging resources which could lead to compromised growth and/or reproductive potential. There is no information currently available to determine the extent of those impacts, if they occurred. Although adverse impacts likely occurred to leatherbacks, the relative proportion of the population that is expected to have been exposed to and directly impacted by the DWH event may be relatively low. Thus, a population-level impact may not have occurred due to the widespread distribution and nesting location outside of the Gulf of Mexico for this species.

1.1.1.6 Hawksbill Sea Turtle

The hawksbill sea turtle was listed as endangered throughout its entire range on June 2, 1970 (35 FR 8491), under the Endangered Species Conservation Act of 1969, a precursor to the ESA. Critical habitat was designated on June 2, 1998, in coastal waters surrounding Mona and Monito Islands in Puerto Rico (63 FR 46693).

Species Description and Distribution

Hawksbill sea turtles are small- to medium-sized (99-150 lb on average [45-68 kg]) although females nesting in the Caribbean are known to weigh up to 176 lb (80 kg) (Pritchard et al. 1983). The carapace is usually serrated and has a tortoise-shell" coloring, ranging from dark to golden brown, with streaks of orange, red, and/or black. The plastron of a hawksbill turtle is typically yellow. The head is elongated and tapers to a point, with a beak-like mouth that gives the species its name. The shape of the mouth allows the hawksbill turtle to reach into holes and crevices of coral reefs to find sponges, their primary adult food source, and other invertebrates. The shells of hatchlings are 1.7 in (42 mm) long, are mostly brown, and are somewhat heart-shaped (Eckert 1995; Hillis and Mackay 1989; van Dam and Sarti 1989).

Hawksbill sea turtles have a circumtropical distribution and usually occur between latitudes 30°N and 30°S in the Atlantic, Pacific, and Indian Oceans. In the western Atlantic, hawksbills are widely distributed throughout the Caribbean Sea, off the coasts of Florida and Texas in the continental United States, in the Greater and Lesser Antilles, and along the mainland of Central America south to Brazil (Amos 1989; Groombridge and Luxmoore 1989; Lund 1985; Meylan and Donnelly 1999; NMFS and USFWS 1998b; Plotkin and Amos 1990; Plotkin and Amos 1988). They are highly migratory and use a wide range of habitats during their lifetimes (Musick and Limpus 1997; Plotkin 2003). Adult hawksbill sea turtles are capable of migrating long distances between nesting beaches and foraging areas. For instance, a female hawksbill sea turtle tagged at Buck Island Reef National Monument (BIRNM) in St. Croix was later identified 1,160 miles (1,866 km) away in the Miskito Cays in Nicaragua (Spotila 2004).

Hawksbill sea turtles nest on sandy beaches throughout the tropics and subtropics. Nesting occurs in at least 70 countries, although much of it now only occurs at low densities compared to that of other sea turtle species (NMFS and USFWS 2007c). Meylan and Donnelly (1999) believe that the widely dispersed nesting areas and low nest densities is likely a result of overexploitation of previously large colonies that have since been depleted over time. The most significant nesting within the United States occurs in Puerto Rico and the U.S. Virgin Islands, specifically on Mona Island and BIRNM, respectively. Although nesting within the continental United States is typically rare, it can occur along the southeast coast of Florida and the Florida Keys. The largest hawksbill nesting population in the western Atlantic occurs in the Yucatán Peninsula of Mexico, where several thousand nests are recorded annually in the states of Campeche, Yucatán, and Quintana Roo (Garduño-Andrade et al. 1999; Spotila 2004). In the U.S. Pacific, hawksbills nest on main island beaches in Hawaii, primarily along the east coast of the island. Hawksbill nesting has also been documented in American Samoa and Guam. More information on nesting in other ocean basins may be found in the 5-year status review for the species (NMFS and USFWS 2007c).

Mitochondrial DNA studies show that reproductive populations are effectively isolated over ecological time scales (Bass et al. 1996). Substantial efforts have been made to determine the nesting population origins of hawksbill sea turtles assembled in foraging grounds, and genetic research has shown that hawksbills of multiple nesting origins commonly mix in foraging areas (Bowen and Witzell 1996). Since hawksbill sea turtles nest primarily on the beaches where they were born, if a nesting population is decimated, it might not be replenished by sea turtles from other nesting rookeries (Bass et al. 1996).

Life History Information

Hawksbill sea turtles exhibit slow growth rates although they are known to vary within and among populations from a low of 0.4-1.2 in (1-3 cm) per year, measured in the Indo-Pacific (Chaloupka and Limpus 1997; Mortimer et al. 2003; Mortimer et al. 2002; Whiting 2000), to a high of 2 in (5 cm) or more per year, measured at some sites in the Caribbean (Diez and Van Dam 2002; León and Diez 1999). Differences in growth rates are likely due to differences in diet and/or density of sea turtles at foraging sites and overall time spent foraging (Bjorndal and Bolten 2002; Chaloupka et al. 2004). Consistent with slow growth, age to maturity for the species is also long, taking between 20 and 40 years, depending on the region (Chaloupka and Musick 1997; Limpus and Miller 2000). Hawksbills in the western Atlantic are known to mature faster (i.e., 20 or more years) than sea turtles found in the Indo-Pacific (i.e., 30-40 years) (Boulan 1983; Boulon Jr. 1994; Diez and Van Dam 2002; Limpus and Miller 2000). Males are typically mature when their length reaches 27 in (69 cm), while females are typically mature at 30 in (75 cm) (Eckert et al. 1992; Limpus 1992).

Female hawksbills return to the beaches where they were born (natal beaches) every 2-3 years to nest (Van Dam et al. 1991; Witzell 1983) and generally lay 3-5 nests per season (Richardson et al. 1999). Compared with other sea turtles, the number of eggs per nest (clutch) for hawksbills can be quite high. The largest clutches recorded for any sea turtle belong to hawksbills (approximately 250 eggs per nest) ((Hirth and Latif 1980), though nests in the U.S. Caribbean and Florida more typically contain approximately 140 eggs (USFWS hawksbill fact sheet, http://www.fws.gov/northflorida/SeaTurtles/Turtle%20Factsheets/hawksbill-sea-turtle.htm). Eggs incubate for approximately 60 days before hatching (USFWS hawksbill fact sheet). Hatchling hawksbill sea turtles typically measure 1-2 in (2.5-5 cm) in length and weigh approximately 0.5 oz (15 g).

Hawksbills may undertake developmental migrations (migrations as immatures) and reproductive migrations that involve travel over many tens to thousands of miles (Meylan 1999a). Post-hatchlings (oceanic stage juveniles) are believed to live in the open ocean, taking shelter in floating algal mats and drift lines of flotsam and jetsam in the Atlantic and Pacific oceans (Musick and Limpus 1997) before returning to more coastal foraging grounds. In the Caribbean, hawksbills are known to almost exclusively feed on sponges (Meylan 1988; Van Dam and Diez 1997), although at times they have been seen foraging on other food items, notably corallimorphs and zooanthids (León and Diez 2000; Mayor et al. 1998; Van Dam and Diez 1997).

Reproductive females undertake periodic (usually non-annual) migrations to their natal beaches to nest and exhibit a high degree of fidelity to their nest sites. Movements of reproductive males are less certain, but are presumed to involve migrations to nesting beaches or to courtship stations along the migratory corridor. Hawksbills show a high fidelity to their foraging areas as well (Van Dam and Diez 1998). Foraging sites are typically areas associated with coral reefs, although hawksbills are also found around rocky outcrops and high energy shoals which are optimum sites for sponge growth. They can also inhabit seagrass pastures in mangrove-fringed bays and estuaries, particularly along the eastern shore of continents where coral reefs are absent (Bjorndal 1997; Van Dam and Diez 1998).

Status and Population Dynamics

There are currently no reliable estimates of population abundance and trends for non-nesting hawksbills at the time of this consultation; therefore, nesting beach data is currently the primary information source for evaluating trends in global abundance. Most hawksbill populations around the globe are either declining, depleted, and/or remnants of larger aggregations (NMFS and USFWS 2007c). The largest nesting population of hawksbills occurs in Australia where approximately 2,000 hawksbills nest off the northwest coast and about 6,000-8,000 nest off the Great Barrier Reef each year (Spotila 2004). Additionally, about 2,000 hawksbills nest each year in Indonesia and 1,000 nest in the Republic of Seychelles (Spotila 2004). In the United States, hawksbills typically laid about 500-1,000 nests on Mona Island, Puerto Rico in the past (Diez and Van Dam 2007), but the numbers appear to be increasing, as the Puerto Rico Department of Natural and Environmental Resources counted nearly 1,600 nests in 2010 (PRDNER nesting data). Another 56-150 nests are typically laid on Buck Island off St. Croix (Meylan 1999b; Mortimer and Donnelly 2008). Nesting also occurs to a lesser extent on beaches on Culebra Island and Vieques Island in Puerto Rico, the mainland of Puerto Rico, and additional beaches on St. Croix, St. John, and St. Thomas, U.S. Virgin Islands.

Mortimer and Donnelly (2008) reviewed nesting data for 83 nesting concentrations organized among 10 different ocean regions (i.e., Insular Caribbean, Western Caribbean Mainland, Southwestern Atlantic Ocean, Eastern Atlantic Ocean, Southwestern Indian Ocean, Northwestern Indian Ocean, Central Indian Ocean, Eastern Indian Ocean, Western Pacific Ocean, Central Pacific Ocean, and Eastern Pacific Ocean). They determined historic trends (i.e., 20-100 years ago) for 58 of the 83 sites, and also determined recent abundance trends (i.e., within the past 20 years) for 42 of the 83 sites. Among the 58 sites where historic trends could be determined, all showed a declining trend during the long-term period. Among the 42 sites where recent (past 20 years) trend data were available, 10 appeared to be increasing, 3 appeared to be stable, and 29 appeared to be decreasing. With respect to regional trends, nesting populations in the Atlantic (especially in the Insular Caribbean and Western Caribbean Mainland) are generally doing better than those in the Indo-Pacific regions. For instance, 9 of the 10 sites that showed recent increases are located in the Caribbean. Buck Island and St. Croix's East End beaches support 2 remnant populations of between 17-30 nesting females per season (Hillis and Mackay 1989; Mackay 2006). While the proportion of hawksbills nesting on Buck Island represents a small proportion of the total hawksbill nesting occurring in the greater Caribbean region, Mortimer and Donnelly (2008) report an increasing trend in nesting at that site based on data collected from 2001-2006. The conservation measures implemented when BIRNM was expanded in 2001 most likely explains this increase.

Nesting concentrations in the Pacific Ocean appear to be performing the worst of all regions despite the fact that the region currently supports more nesting hawksbills than either the Atlantic or Indian Oceans (Mortimer and Donnelly 2008). While still critically low in numbers, sightings of hawksbills in the eastern Pacific appear to have been increasing since 2007, though some of that increase may be attributable to better observations (Gaos et al. 2010). More information about site-specific trends can be found in the most recent 5-year status review for the species (NMFS and USFWS 2007c).

Threats

Hawksbills are currently subjected to the same suite of threats on both nesting beaches and in the marine environment that affect other sea turtles (e.g., interaction with federal and state fisheries, coastal construction, oil spills, climate change affecting sex ratios) as discussed in Section 6.2.1. There are also specific threats that are of special emphasis, or are unique, for hawksbill sea turtles discussed in further detail below.

While oil spill impacts are discussed generally for all species in Section 6.2.1, specific impacts of the DWH spill on hawksbill turtles have been estimated. Hawksbills made up 2.2% (8,850) of small juvenile sea turtle (of those that could be identified to species) exposures to oil in offshore areas, with an estimate of 615 to 3,090 individuals dying as a result of the direct exposure (DWH Trustees 2015). No quantification of large benthic juveniles or adults was made. Additional unquantified effects may have included inhalation of volatile compounds, disruption of foraging or migratory movements due to surface or subsurface oil, ingestion of prey species contaminated with oil and/or dispersants, and loss of foraging resources which could lead to compromised growth and/or reproductive potential. There is no information currently available to determine the extent of those impacts, if they occurred. Although adverse impacts occurred to hawksbills, the relative proportion of the population that is expected to have been exposed to and directly impacted by the DWH event is relatively low, and thus a population-level impact is not believed to have occurred due to the widespread distribution and nesting location outside of the Gulf of Mexico for this species.

The historical decline of the species is primarily attributed to centuries of exploitation for the beautifully patterned shell, which made it a highly attractive species to target (Parsons 1972). The fact that reproductive females exhibit a high fidelity for nest sites and the tendency of hawksbills to nest at regular intervals within a season made them an easy target for capture on nesting beaches. The shells from hundreds of thousands of sea turtles in the western Caribbean region were imported into the United Kingdom and France during the nineteenth and early twentieth centuries (Parsons 1972). Additionally, hundreds of thousands of sea turtles contributed to the region's trade with Japan prior to 1993 when a zero quota was imposed (Milliken and Tokunaga 1987), as cited in Brautigam and Eckert (2006).

The continuing demand for the hawksbills' shells as well as other products derived from the species (e.g., leather, oil, perfume, and cosmetics) represents an ongoing threat to its recovery. The British Virgin Islands, Cayman Islands, Cuba, Haiti, and the Turks and Caicos Islands (United Kingdom) all permit some form of legal take of hawksbill sea turtles. In the northern Caribbean, hawksbills continue to be harvested for their shells, which are often carved into hair clips, combs, jewelry, and other trinkets (Márquez M. 1990; Stapleton and Stapleton 2006). Additionally, hawksbills are harvested for their eggs and meat, while whole, stuffed sea turtles are sold as curios in the tourist trade. Hawksbill sea turtle products are openly available in the Dominican Republic and Jamaica, despite a prohibition on harvesting hawksbills and their eggs (Fleming 2001). Up to 500 hawksbills per year from 2 harvest sites within Cuba were legally captured each year until 2008 when the Cuban government placed a voluntary moratorium on the sea-turtle fishery (Carillo et al. 1999; Mortimer and Donnelly 2008). While current nesting trends are unknown, the number of nesting females is suspected to be declining in some areas (Carillo et al. 1999; Moncada et al. 1999). International trade in the shell of this species is prohibited between countries that have signed the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), but illegal trade still occurs and remains an ongoing threat to hawksbill survival and recovery throughout its range.

Due to their preference to feed on sponges associated with coral reefs, hawksbill sea turtles are particularly sensitive to losses of coral reef communities. Coral reefs are vulnerable to destruction and degradation caused by human activities (e.g., nutrient pollution, sedimentation, contaminant spills, vessel groundings and anchoring, recreational uses) and are also highly sensitive to the effects of climate change (e.g., higher incidences of disease and coral bleaching) (Crabbe 2008; Wilkinson 2004). Because continued loss of coral reef communities (especially in the greater Caribbean region) is expected to impact hawksbill foraging, it represents a major threat to the recovery of the species.

6.3 Sturgeon

There are 2 species of sturgeon (Atlantic and shortnose) that travel widely through the South Atlantic. These species are highly mobile and therefore could occur within the action areas of transportation projects in NC, SC, and GA. Section 6.3.1 and 6.3.2 will address information on the distribution, life history, population structure, abundance, population trends, and threats to each species of sturgeon.

6.3.1 Atlantic Sturgeon

Five separate DPSs of Atlantic sturgeon were listed under the ESA by NMFS effective April 6, 2012 (77 FR 5880 and 5914, February 6, 2012). The New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs were listed as endangered. The Gulf of Maine DPS was listed as threatened.

Species Descriptions and Distributions

Atlantic sturgeon are long-lived, late-maturing, estuarine-dependent, anadromous fish distributed along the eastern coast of North America (Waldman and Wirgin 1998). Historically, sightings have been reported from Hamilton Inlet, Labrador, south to the St. Johns River, Florida (Murawski et al. 1977; Smith and Clugston 1997). Atlantic sturgeon may live up to 60 years, reach lengths up to 14 ft, and weigh over 800 lb (ASSRT 2007; Collette and Klein-MacPhee 2002). They are distinguished by armor-like plates (called scutes) and a long protruding snout that has 4 barbels (slender, whisker-like feelers extending from the head used for touch and taste). Atlantic sturgeon spend the majority of their lives in nearshore marine waters, returning to their natal rivers to spawn (Wirgin et al. 2002). Young sturgeon may spend the first few years of life in their natal river estuary before moving out to sea (Wirgin et al. 2002). Sturgeon are omnivorous benthic (bottom) feeders and filter quantities of mud along with their food. Adult sturgeon diets include mollusks, gastropods, amphipods, isopods, and small fishes, especially sand lances (*Ammodytes* sp.) (Scott and Crossman 1973). Juvenile sturgeon feed on aquatic insects and other invertebrates (Smith 1985).

Historically, Atlantic sturgeon were present in approximately 38 rivers in the United States from the St. Croix River, Maine to the St. Johns River, Florida, of which 35 rivers have been confirmed to have had a historical spawning population. Atlantic sturgeon are currently present in approximately 32 of these rivers, and spawning occurs in at least 20 of them. The marine range of Atlantic sturgeon extends from the Hamilton Inlet, Labrador, Canada, to Cape Canaveral, Florida. Because adult Atlantic sturgeon from all DPSs mix extensively in marine waters, we expect fish from all DPSs to be found in the action areas of transportation projects in NC, SC, and GA.

Life History Information

Atlantic sturgeon populations show clinal variation, with a general trend of faster growth and earlier age at maturity in more southern systems. Atlantic sturgeon mature between the ages of 5-19 years in South Carolina (Smith et al. 1982), between 11-21 years in the Hudson River (Young et al. 1988), and between 22-34 years in the St. Lawrence River (Scott and Crossman 1973). Most Atlantic sturgeon adults likely do not spawn every year. Multiple studies have shown that spawning intervals range from 1-5 years for males (Caron et al. 2002; Collins et al. 2000c; Smith 1985) and 2-5 years for females (Stevenson and Secor 1999; Van Eenennaam et al. 1996; Vladykov and Greely 1963). Fecundity of Atlantic sturgeon has been correlated with age and body size, with egg production ranging from 400,000 to 8,000,000 eggs per year (Dadswell 2006; Smith et al. 1982; Van Eenennaam and Doroshov 1998). The average age at which 50% 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 adult Atlantic sturgeon generally migrate upriver in spring/early summer, which occurs in February-March in southern systems, April-May in mid-Atlantic systems, and May-July in Canadian systems (Bain 1997; Caron et al. 2002; Murawski et al. 1977; Smith 1985; Smith and Clugston 1997). In some southern rivers, a fall spawning migration may also occur (Moser et al. 1998; Rogers and Weber 1995; Weber and Jennings 1996). In the fall, Hager et al. (2014) captured an Atlantic sturgeon identified as a spawned-out female due to her size and concave stomach and also noted capture of other fish showing signs of wear suggesting males had been engaging in spawning behavior. In Virginia's James River, Balazik et al. (2012) captured 1 fish identified as a female in the fall during the 3-year study with a concave condition of the abdomen consistent with female sturgeon that have spawned recently. In addition, postovulated eggs recovered from the urogenital opening were in an early degradation stage, suggesting the fish had spawned within days (Balazik et al. 2012). Further physiological support for fall spawning is provided by the 9 spermiating males captured along with the female and a grand total of 106 different spermiating males captured during August–October (Balazik et al. 2012). Randall and Sulak (2012) reported similar evidence for fall spawning of the closely related Gulf sturgeon, which included multiple captures of sturgeon in September–November that were ripe or exhibited just-spawned characteristics.

Atlantic sturgeon spawning occurs in fast-flowing water between the salt front and fall line of large rivers (Bain et al. 2000; Borodin 1925; Crance 1987; Leland 1968; Scott and Crossman 1973) over hard substrate, such as cobble, gravel, or boulders, to which the highly adhesive sturgeon eggs adhere (Gilbert 1989; Smith and Clugston 1997). Hatching occurs approximately 94-140 hours after egg deposition and larvae assume a demersal existence (Smith et al. 1980). The yolk sac larval stage is completed in about 8-12 days, during which time the larvae move downstream to rearing grounds (Kynard and Horgan 2002). During the first half of their migration downstream, movement is limited to night. During the day, larvae use benthic structure (e.g., gravel matrix) as refugia (Kynard and Horgan 2002). During the latter half of migration, when larvae are more fully developed, movement to rearing grounds occurs both day and night. Juvenile sturgeon continue to move further downstream into brackish waters, and eventually become residents in estuarine waters for months or years.

Juvenile and adult Atlantic sturgeon occupy upper estuarine habitat where they frequently congregate around the saltwater/freshwater interface. Estuarine habitats are important for juveniles, serving as nursery areas by providing abundant foraging opportunities, as well as thermal and salinity refuges, for facilitating rapid growth. Some juveniles will take up residency in non-natal rivers that lack active spawning sites (Bain 1997). Residency time of young Atlantic sturgeon in estuarine areas varies between 1-6 years (Schueller and Peterson 2010; Smith 1985), after which Atlantic sturgeon start out-migration to the marine environment. Out-migration of adults from the estuaries to the sea is cued by water temperature and velocity. Adult Atlantic sturgeon will reside in the marine habitat during the non-spawning season and forage extensively. Coastal migrations by adult Atlantic sturgeon are extensive and are known to occur over sand and gravel substrate (Greene et al. 2009). Atlantic sturgeon remain in the marine habitat until the waters begin to warm, at which time ripening adults migrate back to their natal rivers to spawn.

Upstream migration to the spawning grounds is cued primarily by water temperature and velocity. Therefore, fish in the southern portion of the range migrate earlier than those to the north do (Kieffer and Kynard 1993; Smith 1985). In Georgia and South Carolina, migration begins in February or March (Collins et al. 2000a). Males commence upstream migration to the spawning sites when waters reach around 6°C (Dovel and Berggren 1983; Smith 1985; Smith et al. 1982), with females following a few weeks later when water temperatures are closer to 12° or 13°C (Collins et al. 2000a; Dovel and Berggren 1983; Smith 1985). In some rivers, predominantly in the south, a fall spawning migration may also occur (Moser et al. 1998; Rogers and Weber 1995), with running ripe males found August through October and post-spawning females captured in late September and October (Collins et al. 2000c).

Status and Population Dynamics

At the time Atlantic sturgeon were listed, the best available abundance information for each of the 5 DPSs was the estimated number of adult Atlantic sturgeon spawning in each of the rivers on an annual basis. The estimated number of annually spawning adults in each of the river populations is insufficient to quantify the total population numbers for each DPS of Atlantic sturgeon due to the lack of other necessary accompanying life history data. A recently Atlantic sturgeon population estimate was derived from the Northeast Area Monitoring and Assessment Program (NEAMAP). NEAMAP trawl surveys were conducted from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina, in nearshore waters to depths of 60 ft from fall 2007 through spring 2012. The results of these surveys, assuming 50% gear efficiency (i.e., assumption that the gear will capture some, but not all, of the sturgeon in the water column along the tow path, and the survey area is only a portion of Atlantic sturgeon habitat), are presented in Table A5. It is important to note that the NEAMAP surveys were conducted primarily in the Northeast and may underestimate the actual population abundances of the Carolina and South Atlantic DPSs, which are likely more concentrated in the Southeast since they originated from and spawn there. However, the total ocean population abundance estimates listed in Table A5 currently represent the best available population abundance estimates for the 5 U.S. Atlantic sturgeon DPSs.

Table A5. Summary of Calculated Population Estimates based upon the NEAMAP Survey Swept Area, Assuming 50% Efficiency (NMFS 2013).

DPS	Estimated Ocean Population Abundance	Estimated Ocean Population of Adults	Estimated Ocean Population of Subadults (of size vulnerable to capture in fisheries)
South Atlantic	14,911	3,728	11,183
Carolina	1,356	339	1,017
Chesapeake Bay	8,811	2,203	6,608
New York Bight	34,566	8,642	25,925
Gulf of Maine	7,455	1,864	5,591

South Atlantic DPS

The South Atlantic DPS includes all Atlantic sturgeon that spawn or are spawned in the watersheds (including all rivers and tributaries) of the Ashepoo, Combahee, and Edisto River (ACE) Basins southward along the South Carolina, Georgia, and Florida coastal areas to the St. Johns River, Florida. Rivers known to have current spawning populations within the range of the South Atlantic DPS include the Combahee, Edisto, Savannah, Ogeechee, Altamaha, and Satilla Rivers. We determined spawning was occurring if young-of-the-year (YOY) were observed, or mature adults were present, in freshwater portions of a system. However, in some rivers, spawning by Atlantic sturgeon may not be contributing to population growth because of lack of suitable habitat and the presence of other stressors on juvenile survival and development.

Historically, both the Broad-Coosawatchie and St. Marys Rivers were documented to have spawning populations; there is also evidence that spawning may have occurred in the St. Johns River or one of its tributaries. The spawning population in the St. Marys River, as well as any historical spawning population in the St. Johns, are believed to be extirpated, and the status of the spawning population in the Broad-Coosawatchie is unknown. Both the St. Marys and St. Johns rivers are used as nursery habitat by young Atlantic sturgeon originating from other spawning populations. The use of the Broad-Coosawatchie by sturgeon from other spawning populations is unknown at this time. The presence of historical and current spawning populations in the Ashepoo River has not been documented; however, this river may currently be used for nursery habitat by young Atlantic sturgeon originating from other spawning populations. This represents our current knowledge of the river systems utilized by the South Atlantic DPS for specific life functions, such as spawning, nursery habitat, and foraging. Still, fish from the South Atlantic DPS likely use other river systems than those listed here for their specific life functions.

Prior to the collapse of the fishery in the late 1800s, the sturgeon fishery was the third largest fishery in Georgia. Secor (2002) estimated from U.S. Fish Commission landing reports that approximately 11,000 spawning females were likely present in Georgia and 8,000 adult females were present in South Carolina prior to 1890. The Altamaha River population of the South Atlantic DPS, with an estimated 343 adults spawning annually, is believed to be the largest remaining population in the Southeast, yet is estimated to be only 6% of its historical population size. The abundances of the remaining river populations within the South Atlantic DPS, each estimated to have fewer than 300 annually spawning adults, are estimated to be less than 1% of what they were historically (ASSRT 2007). The NEAMAP model estimates a minimum ocean population of 14,911 South Atlantic DPS Atlantic sturgeon, of which 3,728 are adults.

Carolina DPS

The Carolina DPS includes all Atlantic sturgeon that are spawned in the watersheds (including all rivers and tributaries) from the Albemarle Sound southward along the southern Virginia, North Carolina, and South Carolina coastal areas to Charleston Harbor. Rivers known to have current spawning populations within the range of the Carolina DPS include the Roanoke, Tar-Pamlico, Cape Fear, Waccamaw, and Yadkin-Pee Dee Rivers. We determined spawning was occurring if YOY were observed, or mature adults were present, in freshwater portions of a system. In some rivers, though, spawning by Atlantic sturgeon may not be contributing to population growth because of lack of suitable habitat and the presence of other stressors on juvenile survival and development. There may also be spawning populations in the Neuse, Santee, and Cooper Rivers, though it is uncertain.

Historically, both the Sampit and Ashley Rivers in South Carolina were documented to have spawning populations at one time, although the spawning population in the Sampit River is believed to be extirpated and the current status of the spawning population in the Ashley River is unknown. Both rivers may be used as nursery habitat by young Atlantic sturgeon originating from other spawning populations. This represents our current knowledge of the river systems utilized by the Carolina DPS for specific life functions, such as spawning, nursery habitat, and foraging. Still, fish from the Carolina DPS likely use other river systems than those listed here for their specific life functions.

Historical landings data indicate that between 7,000 and 10,500 adult female Atlantic sturgeon were present in North Carolina prior to 1890 (Armstrong and Hightower 2002; Secor 2002). Secor (2002) estimates that 8,000 adult females were present in South Carolina during that same time frame. The Atlantic sturgeon spawning population in at least 1 river system (the Sampit River) within the Carolina DPS has been extirpated, and the statuses of 4 additional spawning populations are uncertain. There are believed to be only 5 of 7-10 historical spawning populations remaining in the Carolina DPS. In some rivers, spawning by Atlantic sturgeon may not be contributing to population growth because of lack of suitable habitat and the presence of other stressors on juvenile survival and development. The abundances of the remaining river populations within the DPS, each estimated to have fewer than 300 spawning adults, are estimated to be less than 3% of what they were historically (ASSRT 2007). The NEAMAP model estimates a minimum ocean population of 1,356 Carolina DPS Atlantic sturgeon, of which 339 are adults.

Chesapeake Bay DPS

The Chesapeake Bay DPS includes all anadromous Atlantic sturgeons that are spawned in the watersheds that drain into the Chesapeake Bay and into coastal waters from the Delaware-Maryland border on Fenwick Island to Cape Henry, Virginia. Within this range, Atlantic sturgeon historically spawned in the Susquehanna, Potomac, James, York, Rappahannock, and Nottoway Rivers (ASSRT 2007). Spawning still occurs in the James River, and the presence of juvenile and adult sturgeon in the York River suggests that spawning may occur there as well (ASSRT 2007; Greene et al. 2009; Musick et al. 1994). However, conclusive evidence of current spawning is available for the James River, only. Atlantic sturgeon that are spawned elsewhere are known to use waters of the Chesapeake Bay for other life functions, such as foraging and as juvenile nursery habitat, before entering the marine system as subadults (ASSRT 2007; Grunwald et al. 2008; Vladykov and Greely 1963; Wirgin et al. 2007).

Historically, the Chesapeake Bay DPS likely supported more than 10,000 spawning adults (ASSRT 2007; KRRMP 1993; Secor 2002). Current estimates of the Chesapeake Bay DPS from the NEAMAP model (Table A6) indicate the current number of spawning adults is likely an order of magnitude lower than historical levels (ASSRT 2007; Kahnle et al. 2007). The NEAMAP model estimates a minimum ocean population of 8,811 Chesapeake Bay DPS Atlantic sturgeon, of which 2,319 are adults.

New York Bight DPS

The New York Bight DPS includes all anadromous Atlantic sturgeon that spawn in the watersheds that drain into coastal waters from Chatham, Massachusetts, to the Delaware-Maryland border on Fenwick Island. Within this range, Atlantic sturgeon historically spawned in the Connecticut, Delaware, Hudson, and Taunton Rivers (ASSRT 2007; Murawski et al. 1977; Secor 2002). Spawning still occurs in the Delaware and Hudson Rivers, but there is no recent evidence (within the last 15 years) of spawning in the Connecticut and Taunton Rivers (ASSRT 2007). Atlantic sturgeon that are spawned elsewhere continue to use habitats within the Connecticut and Taunton Rivers for other life functions (ASSRT 2007; Savoy 2007; Wirgin and King 2011).

Prior to the onset of expanded fisheries exploitation of sturgeon in the 1800s, a conservative historical estimate for the Hudson River Atlantic sturgeon population was 10,000 adult females (Secor 2002). Current population abundance is likely at least one order of magnitude smaller than historical levels (ASSRT 2007; Kahnle et al. 2007; Secor 2002). Based on data collected from 1985-1995, there are 870 spawning adults per year in the Hudson River (Kahnle et al. 2007). Kahnle (2007; 1998) also showed that the level of fishing mortality from the Hudson River Atlantic sturgeon fishery during the period of 1985-1995 exceeded the estimated sustainable level of fishing mortality for the riverine population, and may have led to reduced recruitment. All available data on abundance of juvenile Atlantic sturgeon in the Hudson River Estuary indicate a substantial drop in production of young since the mid-1970s (Kahnle et al. 1998). A decline appeared to occur in the mid- to late 1970s followed by a secondary drop in the late 1980s (ASMFC 2010; Kahnle et al. 1998; Sweka et al. 2007). Catch-per-unit-effort (CPUE) data suggest that recruitment has remained depressed relative to catches of juvenile Atlantic sturgeon in the estuary during the mid- to late 1980s (ASMFC 2010; Sweka et al. 2007). From 1985-2007, there were significant fluctuations in CPUE. The number of juveniles appears to have declined between the late 1980s and early 1990s. While the CPUE is generally higher in the 2000s as compared to the 1990s, significant annual fluctuations make it difficult to discern any trend. The CPUEs from 2000-2007 are generally higher than those from 1990-1999; however, they remain lower than the CPUEs observed in the late 1980s. There is currently not enough information regarding any life stage to establish a trend for the Hudson River population (ASMFC 2010; Sweka et al. 2007).

There is no abundance estimate for the Delaware River population of Atlantic sturgeon. Harvest records from the 1800s indicate that this was historically a large population, with an estimated 180,000 adult females prior to 1890 (Secor 2002; Secor and Waldman 1999). Fisher (2009) sampled the Delaware River in 2009 to target YOY Atlantic sturgeon. The effort captured 34 YOY. Brundage and O'Herron (2003) also collected 32 YOY Atlantic sturgeon from the Delaware River in a separate study. Fisher (2011) reports that genetics information collected from 33 of the 2009 year class YOY indicates that at least 3 females successfully contributed to the 2009 year class. The capture of YOY in 2009 shows that successful spawning is still occurring in the Delaware River, but the relatively low numbers suggest the existing riverine population is limited in size. Similar to the Hudson River, there is currently not enough information to determine a trend for the Delaware River population. The ASSRT (2007) suggested that there may be less than 300 spawning adults per year for the Delaware River portion of the New York Bight DPS. The NEAMAP model estimates a minimum ocean population of 34,566 Atlantic sturgeon, of which 8,642 are adults.

Gulf of Maine DPS

The Gulf of Maine DPS includes all anadromous Atlantic sturgeons that are spawned in the watersheds from the Maine/Canadian border and, extending southward, all watersheds draining into the Gulf of Maine as far south as Chatham, Massachusetts. Within this range, Atlantic sturgeon historically spawned in the Androscoggin, Kennebec, Merrimack, Penobscot, and Sheepscot Rivers (ASSRT 2007). Spawning still occurs in the Kennebec and Androscoggin Rivers, and may still occur in the Penobscot River. Atlantic sturgeon continue to be present in the Kennebec River; in addition, they are captured in directed research projects in the Penobscot River. They are also observed in the Saco, Presumpscot, and Charles rivers where they were unknown to occur before or had not been observed to occur for many years. These observations suggest that the abundance of the Gulf of Maine DPS of Atlantic sturgeon is large enough that recolonization to rivers historically suitable for spawning may be occurring.

Historically, the Gulf of Maine DPS likely supported more than 10,000 spawning adults (ASSRT 2007; KRRMP 1993; Secor 2002), suggesting the recent estimate of spawning adults within the DPS is 1-2 orders of magnitude smaller than historical levels (i.e., hundreds to low thousands) (ASSRT 2007; Kahnle et al. 2007). The CPUE of subadult Atlantic sturgeon in a multifilament gillnet survey conducted on the Kennebec River was considerably greater for the period of 1998-2000 (CPUE = 7.43) compared to the CPUE for the period 1977-1981 (CPUE = 0.30). The CPUE of adult Atlantic sturgeon showed a slight increase over the same time period (1977-1981 CPUE = 0.12 versus 1998-2000 CPUE = 0.21) (Squiers 2004). There is also new evidence of Atlantic sturgeon presence in rivers (e.g., the Saco River) where they have not been observed for many years. Still, there is not enough information to establish a trend for this DPS. The NEAMAP model estimates a minimum ocean population of 7,455 Atlantic sturgeon, of which 1,864 are adults.

Viability of Atlantic Sturgeon DPSs

The concept of a viable population able to adapt to changing environmental conditions is critical to Atlantic sturgeon, and the low population numbers of every river population in the 5 DPSs on the East Coast put them in danger of extinction throughout their range. None of the riverine spawning populations are large or stable enough to provide with any level of certainty for continued existence of any of the DPSs. Although the largest impact that caused the precipitous decline of the species has been prohibited (directed fishing), the Atlantic sturgeon population sizes within each DPS have remained relatively constant at greatly reduced levels for 100 years. The largest Atlantic sturgeon population in the United States, the Hudson River population within the New York Bight DPS, is estimated to have only 870 spawning adults each year. The Altamaha River population within the South Atlantic DPS is the largest Atlantic sturgeon population in the Southeast and only has an estimated 343 adults spawning annually. All other Atlantic sturgeon river populations in the U.S. are estimated to have less than 300 spawning adults annually.

Small numbers of individuals resulting from drastic reductions in populations, such as occurred with Atlantic sturgeon due to the commercial fishery, can remove the buffer against natural demographic and environmental variability provided by large populations (Berry 1971; Shaffer 1981; Soulé 1980). Recovery of depleted populations is an inherently slow process for a late-maturing species such as Atlantic sturgeon, and they continue to face a variety of other threats that contribute to their risk of extinction. Their late age at maturity provides more opportunities for individual Atlantic sturgeon to be removed from the population before reproducing. While a long life span allows multiple opportunities to contribute to future generations, it also increases the time frame over which exposure to the multitude of threats facing Atlantic sturgeon can occur.

The viability of the Atlantic sturgeon DPSs depends on having multiple self-sustaining riverine spawning populations and maintaining suitable habitat to support the various life functions (spawning, feeding, growth) of Atlantic sturgeon populations. Because a DPS is a group of populations, the stability, viability, and persistence of individual populations affects the persistence and viability of the larger DPS. The loss of any population within a DPS will result in: (1) a long-term gap in the range of the DPS that is unlikely to be recolonized; (2) loss of reproducing individuals; (3) loss of genetic biodiversity; (4) potential loss of unique haplotypes; (5) potential loss of adaptive traits; (6) reduction in total number; and (7) potential for loss of population source of recruits. The loss of a population will negatively impact the persistence and viability of the DPS as a whole, as fewer than 2 individuals per generation spawn outside their natal rivers (King et al. 2001; Waldman et al. 2002; Wirgin et al. 2000). The persistence of individual populations, and in turn the DPS, depends on successful spawning and rearing within the freshwater habitat, the immigration into marine habitats to grow, and then the return of adults to natal rivers to spawn.

Threats

Atlantic sturgeon were once numerous along the East Coast until fisheries for their meat and caviar reduced the populations by over 90% in the late 1800s. Fishing for Atlantic sturgeon became illegal in state waters in 1998 and in remaining U.S. waters in 1999. Dams, dredging, poor water quality, and accidental catch (bycatch) by fishers continue to threaten Atlantic sturgeon. Though Atlantic sturgeon populations appear to be increasing in some rivers, other river populations along the East Coast continue to struggle and some have been eliminated entirely. The 5 DPSs of Atlantic sturgeon were listed as threatened or endangered under the ESA primarily as a result of a combination of habitat restriction and modification, overutilization (i.e., being taken as bycatch) in commercial fisheries, and the inadequacy of regulatory mechanisms in ameliorating these impacts and threats.

<u>Dams</u>

Dams for hydropower generation, flood control, and navigation adversely affect Atlantic sturgeon by impeding access to spawning, developmental, and foraging habitat, modifying free-flowing rivers to reservoirs, physically damaging fish on upstream and downstream migrations, and altering water quality in the remaining downstream portions of spawning and nursery habitat (ASSRT 2007). Attempts to minimize the impacts of dams using measures such as fish passage have not proven beneficial to Atlantic sturgeon, as they do not regularly use existing fish passage devices, which are generally designed to pass pelagic fish (i.e., those living in the water column) rather than bottom-dwelling species, like sturgeon. Within the range occupied by the Carolina DPS, dams have restricted Atlantic sturgeon spawning and juvenile developmental habitat by blocking over 60% of the historical sturgeon habitat upstream of the dams in the Cape Fear and Santee-Cooper River systems. Water quality (velocity, temperature, and DO downstream of these dams, as well as on the Roanoke River, has been reduced, which modifies and restricts the extent of spawning and nursery habitat for the Carolina DPS.

Within the range of the New York Bight DPS, the Holyoke Dam on the Connecticut River blocks further upstream passage; however, the extent that Atlantic sturgeon historically would have used habitat upstream of Holyoke is unknown. Connectivity may be disrupted by the presence of dams on several smaller rivers in the New York Bight region. Connectivity is disrupted by the presence of dams on several rivers in the range of the Gulf of Maine DPS. Within the Gulf of Maine DPS, access to historical spawning habitat is most severely impacted in the Merrimack River (ASSRT 2007). Construction of the Essex Dam blocked the migration of Atlantic sturgeon to 58% of its historically available habitat (ASSRT 2007). The extent that Atlantic sturgeon are affected by operations of dams in the Gulf of Maine region is currently unknown, although Atlantic sturgeon larvae have been found downstream of the Brunswick Dam in the Androscoggin River. This suggests that Atlantic sturgeon spawning may be occurring in the vicinity of at least 1 hydroelectric project and may be affected by its operations.

Dredging

Riverine, nearshore, and offshore areas are often dredged to support commercial shipping and recreational boating, construction of infrastructure, and marine mining. Environmental impacts of dredging include the direct removal/burial of prey species; turbidity/siltation effects; contaminant resuspension; noise/disturbance; alterations to hydrodynamic regime and physical habitat; and actual loss of riparian habitat (Chytalo 1996; Winger et al. 2000). According to Smith and Clugston (1997), dredging and filling impact important habitat features of Atlantic sturgeon as they disturb benthic fauna, eliminate deep holes, and alter rock substrates.

In the South Atlantic DPS, maintenance dredging is currently modifying Atlantic sturgeon nursery habitat in the Savannah River. Modeling indicates that the proposed deepening of the navigation channel will result in reduced DO and upriver movement of the salt wedge, restricting spawning habitat. Dredging is also modifying nursery and foraging habitat in the St. Johns River. For the Carolina DPS, dredging in spawning and nursery grounds modifies the quality of the habitat and is further restricting the extent of available habitat in the Cape Fear and Cooper Rivers, where Atlantic sturgeon habitat has already been modified and restricted by the presence of dams. Dredging for navigational purposes is suspected of having reduced available spawning habitat for the Chesapeake Bay DPS in the James River (ASSRT 2007; Bushnoe et al. 2005; Holton and Walsh 1995). Both the Hudson and Delaware rivers have navigation channels that are maintained by dredging. Dredging is also used to maintain channels in the nearshore marine environment. Many rivers in the range of the Gulf of Maine DPS also have navigation channels that are maintained by dredging. Dredging outside of federal channels and in-water construction occurs throughout the range of the New York Bight and Gulf of Maine DPSs.

Water Quality

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 2009a; Niklitschek and Secor 2009c) 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 (Niklitschek and Secor 2005; Niklitschek and Secor 2009a; Niklitschek and Secor 2009c; Secor and Gunderson 1998).

Reductions in water quality from terrestrial activities have modified habitat utilized by the South Atlantic DPS. Low DO is modifying sturgeon habitat in the Savannah due to dredging, and non-point source inputs are causing low DO in the Ogeechee River and in the St. Marys River, which completely eliminates juvenile nursery habitat in summer. Low DO has also been observed in the St. Johns River in the summer. In the Pamlico and Neuse systems occupied by the Carolina DPS, nutrient-loading and seasonal anoxia are occurring, associated in part with concentrated animal feeding operations (CAFOs). Heavy industrial development and CAFOs 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. Decreased water quality also threatens Atlantic sturgeon of the Chesapeake Bay DPS, especially since the Chesapeake Bay system is vulnerable to the effects of nutrient enrichment due to a relatively low tidal exchange and flushing rate, large surface-to-volume ratio, and strong stratification during the spring and summer months (ASMFC 1998; ASSRT 2007; Pyzik et al. 2004). These conditions contribute to reductions in DO levels throughout the bay. The availability of nursery habitat, in particular, may be limited given the recurrent hypoxia (low DO) conditions within the Bay (Niklitschek and Secor 2005; Niklitschek and Secor 2010). Both the Hudson and Delaware Rivers, as well as other rivers in the New York Bight region, were heavily polluted in the past from industrial and sewer discharges. In the past, many rivers in Maine, including the Androscoggin River, were heavily polluted from industrial discharges from pulp and paper mills. While water quality has improved and most discharges are limited through regulations, many pollutants persist in the benthic environment of the New York Bight and Gulf of Maine DPSs. It is particularly problematic if pollutants are present on spawning and nursery grounds, as developing eggs and larvae are particularly susceptible to exposure to contaminants.

Water Quantity

Water allocation issues are a growing threat in the Southeast and exacerbate existing water quality problems. Taking water from one basin and transferring it to another fundamentally and irreversibly alters natural water flows in both the originating and receiving basins, which can affect DO levels, temperature, and the ability of the basin of origin to assimilate pollutants

(GWC 2006). Water quality within the river systems in the range of the South Atlantic and Carolina DPSs is negatively affected by large water withdrawals. Known water withdrawals of over 240 million gallons per day are permitted from the Savannah River for power generation and municipal uses. However, permits for users withdrawing less than 100,000 gallons per day are not required, so actual water withdrawals from the Savannah and other rivers within the range of the South Atlantic DPS are likely much higher. In the range of the Carolina DPS, 20 interbasin water transfers in existence prior to 1993, averaging 66.5 million gallons per day (mgd), were authorized at their maximum levels without being subjected to an evaluation for certification by the North Carolina Department of Environment and Natural Resources or other resource agencies. Since the 1993 legislation requiring certificates for transfers, almost 170 mgd of interbasin water withdrawals have been authorized, with an additional 60 mgd, pending certification. The removal of large amounts of water from these systems will alter flows, temperature, and DO. Water shortages and “water wars” are already occurring in the rivers occupied by the South Atlantic and Carolina DPSs and will likely be compounded in the future by population growth and potentially by climate change.

Climate Change

The Intergovernmental Panel on Climate Change (IPCC) projects with high confidence that higher water temperatures and changes in extremes, including floods and droughts, will affect water quality and exacerbate many forms of water pollution—from sediments, nutrients, dissolved organic carbon, pathogens, pesticides, and salt, as well as thermal pollution—with possible negative impacts on ecosystems (IPCC 2008). In addition, sea level rise is projected to extend areas of salinization of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas. Some of the most heavily populated areas are low-lying, and the threat of salt water entering into its aquifers with projected sea level rise is a concern (USGRG 2004). Existing water allocation issues would be exacerbated, leading to an increase in reliance on interbasin water transfers to meet municipal water needs, further stressing water quality.

Dams, dredging, and poor water quality have already modified and restricted the extent of suitable habitat for Atlantic sturgeon spawning and nursery habitat. Changes in water availability (depth and velocities) and water quality (temperature, salinity, DO, contaminants, etc.) in rivers and coastal waters inhabited by Atlantic sturgeon resulting from climate change will further modify and restrict the extent of suitable habitat for Atlantic sturgeon. Effects could be especially harmful since these populations have already been reduced to low numbers, potentially limiting their capacity for adaptation to changing environmental conditions (Belovsky 1987; Salwasser et al. 1984; Soulé 1987; Thomas 1990).

The effects of changes in water quality (temperature, salinity, DO, contaminants, etc.) in rivers and coastal waters inhabited by Atlantic sturgeon are expected to be more severe for those populations that occur at the southern extreme of the Atlantic sturgeon's range, and in areas that are already subject to poor water quality as a result of eutrophication. The South Atlantic and Carolina DPSs are within a region the IPCC predicts will experience overall climatic drying (IPCC 2008). Atlantic sturgeon from these DPSs are already susceptible to reduced water quality resulting from various factors: inputs of nutrients; contaminants from industrial activities and non-point sources; and interbasin transfers of water. In a simulation of the effects of water temperature on available Atlantic sturgeon habitat in Chesapeake Bay, Niklitschek and Secor (2005) found that a 1°C increase of water temperature in the bay would reduce available sturgeon habitat by 65%.

Vessel Strikes

Vessel strikes are a threat to the Chesapeake Bay and New York Bight DPSs. Eleven Atlantic sturgeon were reported to have been struck by vessels on the James River from 2005 through 2007. Several of these were mature individuals. From 2004-2008, 29 mortalities believed to be the result of vessel strikes were documented in the Delaware River; at least 13 of these fish were large adults. The time of year when these events occurred (predominantly May through July, with 2 in August), indicate the animals were likely adults migrating through the river to the spawning grounds. Because we do not know the percent of total vessel strikes that these observed mortalities represent, we are not able to quantify the number of individuals likely killed as a result of vessel strikes in the Chesapeake and New York Bight DPSs.

Bycatch Mortality

Overutilization of Atlantic sturgeon from directed fishing caused initial severe declines in Atlantic sturgeon populations, from which they have never rebounded. Further, continued overutilization of Atlantic sturgeon as bycatch in commercial fisheries is an ongoing impact to Atlantic sturgeon in all 5 DPSs. Atlantic sturgeon are more sensitive to bycatch mortality because they are a long-lived species, have an older age at maturity, have lower maximum reproductive rates, and a large percentage of egg production occurs later in life. Based on these life history traits, Boreman (1997) calculated that Atlantic sturgeon can only withstand the annual loss of up to 5% of their population to bycatch mortality without suffering population declines. Mortality rates of Atlantic sturgeon taken as bycatch in various types of fishing gear range between 0% and 51%, with the greatest mortality occurring in sturgeon caught by sink gillnets. Currently, there are estimates of the number of Atlantic sturgeon captured and killed in sink gillnet and otter trawl fisheries authorized by Fishery Management Plans (FMPs) in the Northeast Region (Miller and Shepherd 2011). Those estimates indicate from 2006-2010, on average there were 1,548 and 1,569 encounters per year in observed gillnet and trawl fisheries, respectively, with an average of 3,118 encounters combined annually. Mortality rates in gillnet gear were approximately 20%, while mortality rates in otter trawl gear are generally lower, at approximately 5%. Atlantic sturgeon are particularly vulnerable to being caught in sink gillnets; therefore, fisheries using this type of gear account for a high percentage of Atlantic sturgeon bycatch. Atlantic sturgeon are incidentally captured in state and federal fisheries, reducing survivorship of subadult and adult Atlantic sturgeon (ASMFC 2007; Stein et al. 2004). Little data exists on bycatch in the Southeast and high levels of bycatch underreporting are suspected. However, fisheries known to incidentally catch Atlantic sturgeon occur throughout the marine range of the species and in some riverine waters as well. Because Atlantic sturgeon mix extensively in marine waters and may access multiple river systems, they are subject to being caught in multiple fisheries throughout their range. In addition, stress or injury to Atlantic sturgeon taken as bycatch but released alive may result in increased susceptibility to other threats, such as poor water quality (e.g., exposure to toxins and low DO). This may result in reduced ability to perform major life functions, such as foraging and spawning, or even post-capture mortality.

6.3.2 Shortnose sturgeon

Shortnose sturgeon were initially listed as an endangered species by USFWS on March 11, 1967, under the Endangered Species Preservation Act (32 FR 4001). Shortnose sturgeon continued to meet the listing criteria as "endangered" under subsequent definitions specified in the 1969 Endangered Species Conservation Act and remained on the list with the inauguration of the ESA in 1973. NMFS assumed jurisdiction for shortnose sturgeon from USFWS in 1974 (39 FR 41370). The shortnose sturgeon currently remains listed as an endangered species throughout all of its range along the east coast of the United States and Canada. A recovery plan for shortnose sturgeon was published by NMFS in 1998 (NMFS 1998).

Species Description and Distribution

The shortnose sturgeon (*Acipenser brevirostrum)* is the smallest of the 3 sturgeon species that occur in eastern North America. They attain a maximum length of about 6 feet, and a weight of about 55 lbs. Shortnose sturgeon inhabit large coastal rivers of eastern North America. Although considered an anadromous species,[16] shortnose sturgeon are more properly characterized as "freshwater amphidromous," meaning that they move between fresh and salt water during some part of their life cycle, but not necessarily for spawning. Shortnose sturgeon rarely leave the rivers where they were born ("natal rivers"). Shortnose sturgeon feed opportunistically on benthic insects, crustaceans, mollusks, and polychaetes (Dadswell et al. 1984).

[16] One that lives primarily in marine waters and breeds in freshwater

Historically, shortnose sturgeon were found in the coastal rivers along the east coast of North America from the Saint John River, New Brunswick, Canada, to the St. Johns River, Florida, and perhaps as far south as the Indian River in Florida (Evermann and Bean 1898; Gilbert 1989). Currently, the distribution of shortnose sturgeon across their range is disconnected, with northern populations separated from southern populations by a distance of about 250 miles (400 km) near their geographic center in Virginia (see Figure 7). In the southern portion of the range, they are currently found in the Edisto, Cooper, Altamaha, Ogeechee, and Savannah Rivers in Georgia. Sampling has also found shortnose in the Roanoke River, Albemarle Sound, and Cape Fear Rivers, while fishers have reported the species in Neuse River and Pamlico Sound (SSSRT 2010). Females bearing eggs have been collected in the Cape Fear River (Moser and Ross 1995). Spawning is known to be occurring in the Cooper River, the Congaree River, and the Yadkin-Pee Dee River (IUCN Species Assessment, in press). While it had been concluded that shortnose sturgeon are extinct from the Satilla River in Georgia, the St. Marys River along the Florida and Georgia border, and the St. Johns River in Florida (Rogers and Weber; 1995, Kahnle et al.; 1998, and Collins et al. 2000), recent targeted surveys in both the Satilla and St. Mary's have captured shortnose sturgeon. A single specimen was found in the St. Johns River by the Florida Fish and Wildlife Conservation Commission during extensive sampling of the river in 2002 and 2003.

Life History Information

Shortnose sturgeon populations show clinal variation, [17] with a general trend of faster growth and earlier age at maturity in more southern systems. Fish in the southern portion of the range grow the fastest, but growth appears to plateau over time. Conversely, fish in the northern part of the range tend to grow more slowly, but reach a larger size because they continue to grow throughout their lives. Male shortnose sturgeon mature at 2-3 years of age in Georgia, 3-5 years of age in South Carolina, and 10-11 years of age in the Saint John River, Canada. Females mature at 4-5 years of age in Georgia, 7-10 years of age in the Hudson River, New York, and 12-18 years of age in the Saint John River, Canada. Males begin to spawn 1-2 years after reaching sexual maturity and spawn every 1-2 years (Dadswell 1979; Kieffer and Kynard 1996; NMFS 1998). Age at first spawning for females is about 5 years post-maturation with spawning occurring every 3-5 years (Dadswell 1979). Fecundity of shortnose sturgeon ranges between approximately 30,000-200,000 eggs per female (Gilbert 1989).

Adult shortnose sturgeon spawn in the rivers where they were born. Initiation of the upstream movement of shortnose sturgeon to spawn is likely triggered partially by water temperatures. Shortnose sturgeon captured in 5 coastal river systems of South Carolina all spawned during temperatures ranges from 5–18°C (Post et al. 2014), which is similar to what has been documented throughout the range (Duncan et al. 2004; Hall et al. 1991; Kieffer and Kynard 1996; NMFS 1998; Taubert 1980). In the Altamaha River, Georgia, adults began their upstream migrations during likely spawning runs during the late-winter months when water temperatures declined to 11.6–16.9 °C (Post et al. 2014). Water depth and flow are also important at spawning sites (Kieffer and Kynard 1996). Spawning sites are characterized by moderate river flows with average bottom velocities between 1-2.5 ft (0.4-0.8 m) per second (Hall et al. 1991; Kieffer and Kynard 1996; NMFS 1998). Shortnose sturgeon tend to spawn on rubble, cobble, or large rocks (Buckley and Kynard 1985; Dadswell 1979; Kynard 1997; Taubert 1980), timber, scoured clay, or gravel (Hall et al. 1991). Southern populations of shortnose sturgeon usually spawn at least 125

[17] A gradual change in a character or feature across the distributional range of a species or population, usually correlated with an environmental or geographic transition

miles (200 km) upriver (Kynard 1997) or throughout the fall line[18] zone if they are able to reach it. Adults typically spawn in the late winter to early spring (December-March) in southern rivers (i.e., North Carolina and south) and the mid to late spring in northern rivers. They spend the rest of the year in the vicinity of the saltwater/freshwater interface (Collins and Smith 1993).

Little is known about YOY behavior and movements in the wild, but shortnose sturgeon at this age are believed to remain in channel areas within freshwater habitats upstream of the saltwater/freshwater interface for about 1 year, potentially due to their low tolerance for salinity (Dadswell et al. 1984; Kynard 1997). Residence of YOY in freshwater is supported by several studies on cultured shortnose sturgeon (Jarvis et al. 2001; Jenkins et al. 1993; Ziegeweid et al. 2008). In most rivers, juveniles aged 1 and older join adults and show similar patterns of habitat use (Kynard 1997). In the Southeast, juveniles aged 1 year and older make seasonal migrations like adults, moving upriver during warmer months where they shelter in deep holes, before returning to the fresh/saltwater interface when temperatures cool (Collins et al. 2002; Flournoy et al. 1992). Due to their low tolerance for high temperatures, warm summer temperatures (above 82°F) may severely limit available juvenile rearing habitat in some rivers in the southeastern United States. Juveniles in the Saint John, Hudson, and Savannah Rivers use deep channels over sand and mud substrate for foraging and resting (Dovel et al. 1992; Hall et al. 1991; Pottle and Dadswell 1979).

Status and Population Dynamics

The 1998 shortnose sturgeon recovery plan identified 19 distinct shortnose sturgeon populations based on natal rivers. Since 1998, significantly more tagging/tracking data on straying rates to adjacent rivers has been collected, and several genetic studies have determined where coastal migrations and effective movement (i.e., movement with spawning) are occurring. Genetic analyses aided in identifying population structure across the range of shortnose sturgeon. Several studies indicate that most, if not all, shortnose sturgeon riverine populations are statistically different ($p < 0.05$) (King et al. 2001; Waldman et al. 2002; Wirgin et al. 2005; Wirgin et al. 2010; Wirgin et al. 2000). Gene flow is low between riverine populations indicating that while shortnose sturgeon tagged in one river may later be recaptured in another, it is unlikely the individuals are spawning in those non-natal rivers. This is consistent with our knowledge that adult shortnose sturgeon are known to return to their natal rivers to spawn. However, Fritts et al. (2016) provide evidence that greater mixing of riverine populations occurs in areas where the distance between adjacent river mouths is relatively close, such as in the Southeast.

A side from genetic differences associated with shortnose sturgeon only spawning in their natal rivers, researchers have also identified levels of genetic differentiation that indicate high degrees of reproductive isolation in at least 3 groupings (i.e., metapopulations) (Figure 7). Shortnose sturgeon in the Southeast comprise a single metapopulation, the “Carolinian Province” (Figure 7) Wirgin et al. (2010) note that genetic differentiation among populations within the Carolinian Province was considerably less pronounced than among those in the other 2 metapopulations (i.e., Virginian Province and Acadian Province) and contemporary genetic data suggest that reproductive isolation among these populations is less than elsewhere. In other words, the shortnose sturgeon populations within the Carolinian Province are more closely related to each other, than the populations that make up either the Virginian or Acadian Provinces.

[18] The fall line is the boundary between an upland region of continental bedrock and an alluvial coastal plain, sometimes characterized by waterfalls or rapids.

The 3 shortnose sturgeon metapopulations should not be considered collectively but as individual units of management because each is reproductively isolated from the other and constitutes an evolutionarily (and likely an adaptively) significant lineage. The loss of any metapopulation would result in the loss of evolutionarily significant biodiversity and would result in a significant gap(s) in the species' range. Loss of the southern shortnose sturgeon metapopulation would result in the loss of the southern half of the species' range (i.e., there is no known reproduction south of the Delaware River). Loss of the mid-Atlantic metapopulation (Virginian Province) would create a conspicuous discontinuity in the range of the species from the Hudson River to the northern extent of the Southern metapopulation. The northern metapopulation constitutes the northernmost portion of the U.S. range. Loss of this metapopulation would result in a significant gap in the range that would serve to isolate the shortnose sturgeon that reside in Canada from the remainder of the species' range in the United States. The loss of any metapopulation would result in a decrease in spatial range, biodiversity, unique haplotypes, adaptations to climate change, and gene plasticity. Loss of unique haplotypes that may carry geographic specific adaptations would lead to a loss of genetic plasticity and, in turn, decrease adaptability. The loss of any metapopulation would increase species' vulnerability to random events.

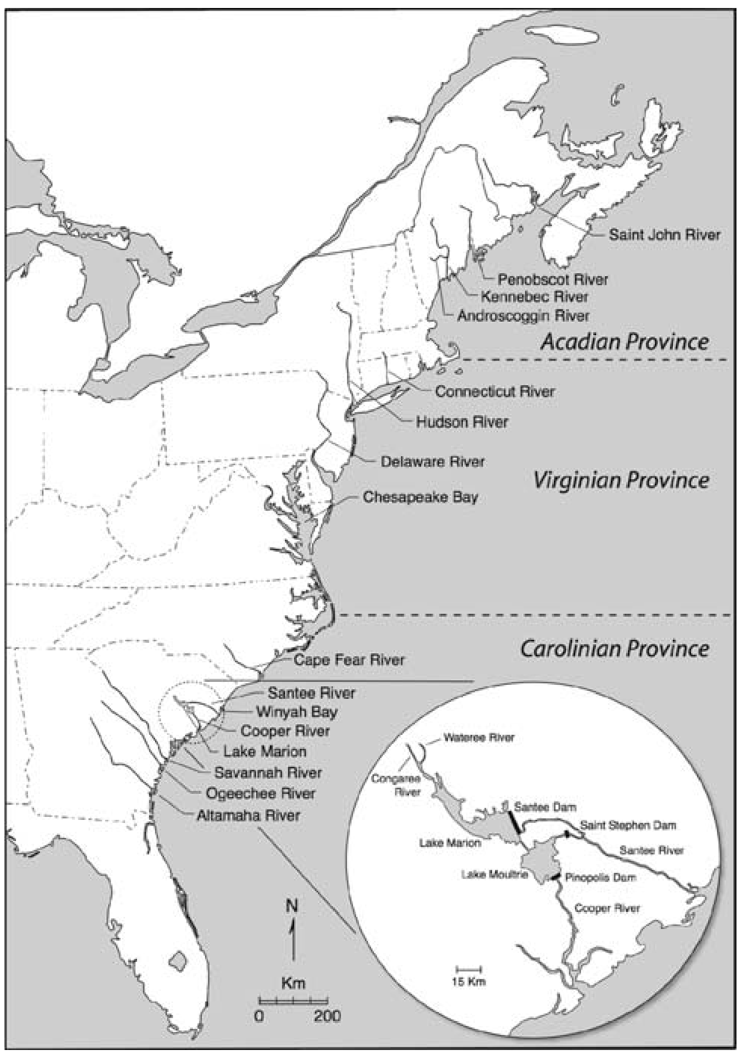

Figure A2. The North American Atlantic coast depicting three shortnose sturgeon metapopulations based on mitochondrial DNA control region sequence analysis (Wirgin et al. 2010).

The current status of the shortnose sturgeon in the Southeast is variable. Populations within the southern metapopulation are relatively small compared to their northern counterparts. Table A6 shows available abundance estimates for rivers in the Southeast. The Altamaha River supports the largest known shortnose sturgeon population in the Southeast with successful self-sustaining recruitment. Total population estimates in the Altamaha show large interannual variation is occurring; estimates have ranged from as low as 468 fish in 1993 to over 5,550 fish in 2006 (NMFS 1998; Peterson and Bednarski 2013). Abundance estimates for the Ogeechee River indicate the shortnose sturgeon population in this river is considerably smaller than in the Altamaha River. The highest point estimate since 1993 occurred in 2007 and resulted in a total Ogeechee River population estimate of 404 shortnose sturgeon (95% confidence interval [CI]: 175-633) (Peterson and Farrae 2011). However, subsequent sampling in 2008 and 2009 resulted in point estimates of 264 (95% CI: 126-402) and 203 (95% CI: 32-446), respectively (Peterson and Farrae 2011), suggesting the population may be declining. Spawning is also occurring in the Savannah, Cooper, Congaree, and Yadkin-Pee Dee Rivers. The Savannah River shortnose sturgeon population is possibly the second largest in the Southeast with an estimated 1,000-3,000 adults, but faces many environmental stressors and spawning is likely occurring in only a very small area. While active spawning is occurring in South Carolina's Winyah Bay complex (Black, Sampit, Yadkin-Pee Dee, and Waccamaw Rivers) the population status there is unknown. The most recent estimate for the Cooper Rivers suggests a population of approximately 220 spawning adults (Cooke et al. 2004). Status of the other riverine populations supporting the southern metapopulation is unknown due to limited survey effort, with capture in some rivers limited to less than 5 specimens.

Table A6. Shortnose Sturgeon Populations and Their Estimated Abundances.

Population (Location)	Data Series	Abundance Estimate (CI)[a]	Population Segment	Reference
Cape Fear River (NC)		>50	Total	
Winyah Bay (NC, SC)		unknown		
Santee River (SC)		unknown		
Cooper River (SC)	1996-1998	220 (87-301)	Adults	(Cooke et al. 2004)
ACE Basin (Ashepoo, Combahee, and Edisto Rivers) (SC)		unknown		
Savannah River (SC, GA)		1,000 - 3,000	Adults	B. Post, SCDNR 2003; NMFS unpublished
Ogeechee River (GA)	1993	361 (326-400)	Total	Rogers and Weber 1994; NMFS 1998b
	1999-2000	147 (104-249)	Total	(Fleming et al. 2003)
	2007	404 (175-633)	Total	(Peterson and Farrae 2011)
	2008	264 (126-402)	Total	
	2009	203 (32-446)	Total	
Altamaha River (GA)	1988	2,862 (1,069-4,226)	Total	NMFS 1998a
	1990	798 (645-1,045)	Total	NMFS 1998a
	1993	468 (316-903)	Total	NMFS 1998a
	2006	5,551 (2,804–11,304)	Total	(Peterson and Bednarski 2013)
	2009	1,206 (566–2,759)	Total	
Satilla River (GA)		N/A		

Saint Marys River (FL)		N/A		
St. Johns River (FL)		unknown		FFWCC 2007c

[a] Population estimates (with confidence intervals [CIs]) are established using different techniques and should be viewed with caution. In some cases, sampling biases may have violated the assumptions of the procedures used or resulted in inadequate representation of a population segment. Some estimates (e.g., those without CIs or those that are depicted by ranges only) are the "best professional judgment" of researchers based on their sampling effort and success.

Annual variation in population estimates in many basins is due to changes in yearly capture rates that are strongly correlated with weather conditions (e.g., river flow, water temperatures). In "dry years," fish move into deep holes upriver of the saltwater/freshwater interface, which can make them more susceptible to gillnet sampling. Consequently, rivers with limited data sets among years and limited sampling periods within a year may not offer a realistic representation of the size or trend of the shortnose sturgeon population in the basin. As a whole, the data on shortnose sturgeon populations is rather limited and some of the differences observed between years may be an artifact of the models and assumptions used by the various studies.

Threats

The shortnose sturgeon was listed as endangered under the ESA as a result of a combination of habitat degradation or loss (resulting from dams, bridge construction, channel dredging, and pollutant discharges), mortality (from impingement on cooling water intake screens, turbines, climate change, dredging, and incidental capture in other fisheries), and the inadequacy of regulatory mechanisms in ameliorating these impacts and threats. The primary threats to the species today are described below.

<u>Dams</u>

Dams for hydropower generation, flood control, and navigation adversely affect shortnose sturgeon habitat by impeding access to spawning, developmental, and foraging habitat, modifying free-flowing rivers to reservoirs, physically damaging fish on upstream and downstream migrations, and altering water quality in the remaining downstream portions of spawning and nursery habitat. Fish passage has not proven very successful in minimizing the impacts of dams on shortnose sturgeon, as they do not regularly use existing fish passage devices, which are generally designed to pass pelagic fish (i.e., those living in the water column) rather than bottom-dwelling species like sturgeon. Dams have separated the shortnose sturgeon population in the Cooper River, trapping some above the structure while blocking access upstream to sturgeon below the dam. Telemetry studies indicate that some shortnose sturgeon do pass upriver through the vessel lock in the Pinopolis Dam on the Cooper River in the Santee Cooper Lakes (Post et al. 2014). In 2011, 2 tagged shortnose sturgeon used the vessel lock in the Pinopolis Dam to pass upstream of the dam. One of the sturgeon was still inhabiting the lakes as of 2013, while the other sturgeon entered Lake Moultrie in March and returned to the Cooper River in April, either through the Pinopolis Lock or through the turbines at Jefferies Power Station (Post et al. 2014). Shortnose sturgeon inhabit only Lake Marion, the upper of the 2 reservoirs. There is currently no estimate for the portion of the population that inhabits the reservoirs and rivers above the dam.

Additional impacts from dams include the Kirkpatrick Dam (aka Rodman Dam) located about ~12.9 km upstream from the St. Johns River, Florida on the Ocklawaha River (the largest tributary) as part of the Cross Florida Barge Canal. The Ocklawaha River has been speculated as the spawning area for shortnose sturgeon (SSSRT 2010). The New Savannah Bluff Lock and Dam located on the Savannah River on the

South Carolina and Georgia border also impedes shortnose sturgeon from accessing upstream shoal areas (IUCN Species Assessment, in press).

Dredging

Riverine, nearshore, and offshore areas are often dredged to support commercial shipping and recreational boating, construction of infrastructure, and marine mining. Environmental impacts of dredging include the direct removal/burial of prey species; turbidity/siltation effects; contaminant resuspension; noise/disturbance; alterations to hydrodynamic regime and physical habitat; and actual loss of riparian habitat (Chytalo 1996; Winger et al. 2000). Dredging in spawning and nursery grounds modifies the quality of the habitat and further restricts the extent of available habitat in the Cooper and Savannah Rivers, where shortnose sturgeon habitat has already been modified and restricted by the presence of dams.

Water Quality

Shortnose sturgeon rely on a variety of water quality parameters to successfully carry out their life functions. Low dissolved oxygen (DO) and the presence of contaminants modify the quality of 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 shortnose sturgeon in the Southeast. For example, shallow water in many of the estuaries and rivers in North Carolina and South Carolina will reach temperatures nearing 30ºC in the summer months. Both low flow and high water temperatures can cause DO levels to drop to less than 3.0 mg/L (IUCN Species Assessment, in press). Sturgeon are more sensitive to low DO than other fish species (Niklitschek and Secor 2009b; Niklitschek and Secor 2009a), and low DO in combination with high temperature is particularly problematic.

Water Quantity

Water allocation issues are a growing threat in the Southeast and exacerbate existing water quality problems. Taking water from one basin and transferring it to another fundamentally and irreversibly alters natural water flows in both the originating and receiving basins. This transfer can affect DO levels, temperature, and the ability of the basin of origin to assimilate pollutants (GWC 2006). Water quality within the river systems in the range of the shortnose sturgeon is negatively affected by large water withdrawals. Known water withdrawals of over 240 million gallons per day are permitted from the Savannah River for power generation and municipal uses. However, permits for users withdrawing less than 100,000 gallons per day are not required, so actual water withdrawals from the Savannah River and other rivers within the range of the shortnose sturgeon are likely much higher. The removal of large amounts of water from the system alters flows, temperature, and DO. Water shortages and “water wars” are already occurring in the rivers occupied by the shortnose sturgeon and will likely be compounded in the future by human population growth and potentially by climate change.

Climate Change

Shortnose sturgeon in the Southeast are within a region the Intergovernmental Panel on Climate Change (IPCC) predicts will experience overall climatic drying (IPCC 2007). The Southeast has experienced an ongoing period of drought since 2007. During this time, South Carolina experienced drought conditions that ranged from moderate to extreme (SCSCO 2008). From 2006 until mid-2009, Georgia experienced the worst drought in its history. In September 2007, many of Georgia’s rivers and streams were at their lowest levels ever recorded for the month, and new record low daily stream flows were recorded at 15 rivers with 20 or more years of data in Georgia (USGS 2007). The drought worsened in September 2008. All streams in Georgia except those originating in the extreme southern counties were extremely low. While Georgia has periodically undergone periods of drought—there have been 6 periods of drought lasting from 2-7 years since 1903 (USGS 2000)—drought frequency appears to be increasing (Ruhl 2003). Abnormally low stream flows can restrict access by sturgeon to habitat areas and exacerbate water quality issues such as water temperature, reduced DO, nutrient levels, and contaminants.

Shortnose sturgeon are already susceptible to reduced water quality resulting from dams, inputs of nutrients, contaminants from industrial activities and nonpoint sources, and interbasin transfers of water. The IPCC report projects with high confidence that higher water temperatures and changes in extremes in this region, including floods and droughts, will affect water quality and exacerbate many forms of water pollution from sediments, nutrients, dissolved organic carbon, pathogens, pesticides, and salt, as well as thermal pollution, with possible negative impacts on ecosystems (IPCC 2007). In addition, sea level rise is projected to extend areas of salinization of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas. Some of the most populated areas of this region are low-lying; the threat of saltwater entering into this region's aquifers with projected sea level rise is a concern (USGRG 2004). Existing water allocation issues would be exacerbated, leading to an increase in reliance on interbasin water transfers to meet municipal water needs, further stressing water quality. Dams, dredging, and poor water quality have already modified and restricted the extent of suitable habitat for shortnose sturgeon spawning and nursery habitat. Changes in water availability (depth and velocities) and water quality (temperature, salinity, DO, contaminants, etc.) in rivers and coastal waters inhabited by shortnose sturgeon resulting from climate change will further modify and restrict the extent of suitable habitat for shortnose sturgeon. Effects could be especially harmful since these populations have already been reduced to low numbers, potentially limiting their capacity for adaptation to changing environmental conditions (Belovsky 1987; Salwasser et al. 1984; Soulé 1987; Thomas 1990).

Bycatch

Overutilization of shortnose sturgeon from directed fishing caused initial severe declines in shortnose sturgeon populations in the Southeast, from which they have never rebounded. Further, continued collection of shortnose sturgeon as bycatch in commercial fisheries is an ongoing impact. Shortnose sturgeon are incidentally caught in state shad gillnet fisheries is occurring in the Ogeechee and Altamaha rivers (IUCN Species Assessment, in press). Shortnose sturgeon are sensitive to bycatch mortality because they are a long-lived species, have an older age at maturity, have lower maximum reproductive rates, and a large percentage of egg production occurs later in life. In addition, stress or injury to shortnose sturgeon taken as bycatch but released alive may result in increased susceptibility to other threats, such as poor water quality (e.g., exposure to toxins and low DO). This may result in reduced ability to perform major life functions, such as foraging and spawning, or even post-capture mortality.

As a wide-ranging anadromous species, shortnose sturgeon are subject to numerous federal (United States and Canadian), state, provincial, and interjurisdictional laws, regulations, and agencies' activities. While these mechanisms have addressed impacts to shortnose sturgeon through directed fisheries, there are currently no mechanisms in place to address the significant risk posed to shortnose sturgeon from commercial bycatch. Though statutory and regulatory mechanisms exist that authorize reducing the impact of dams on riverine and anadromous species, such as shortnose sturgeon, and their habitat, these mechanisms have proven inadequate for preventing dams from blocking access to habitat upstream and degrading habitat downstream. Further, water quality continues to be a problem in the historical spawning rivers along the Atlantic coast, even with existing controls on some pollution sources. Current regulatory authorities are not necessarily effective in controlling water allocation issues (e.g., no restrictions on interbasin water transfers in South Carolina, the lack of ability to regulate non-point source pollution).

6.4 Designated Atlantic Sturgeon Critical Habitat

In August 2017, the NMFS issued the final rule to designate critical habitat for the threatened Gulf of Maine distinct population segment (DPS) of Atlantic sturgeon, the endangered New York Bight DPS of Atlantic sturgeon, the endangered Chesapeake Bay DPS of Atlantic sturgeon, the endangered Carolina DPS of Atlantic sturgeon and the endangered South Atlantic DPS of Atlantic sturgeon pursuant to the Endangered Species Act (ESA). Specific occupied areas designated as critical habitat for the Carolina DPS of Atlantic sturgeon contain approximately 1,939 km (1,205 miles) of aquatic habitat in the following rivers of North Carolina and South Carolina: Roanoke, Tar-Pamlico, Neuse, Cape Fear, Northeast Cape Fear, Waccamaw, Pee Dee, Black, Santee, North Santee, South Santee, and Cooper, and the following other water body: Bull Creek. Specific occupied areas designated as critical habitat for the South Atlantic DPS of Atlantic sturgeon contain approximately 2,883 km (1,791 miles) of aquatic habitat in the following rivers of South Carolina, Georgia, and Florida: Edisto, Combahee-Salkehatchie, Savannah, Ogeechee, Altamaha, Ocmulgee, Oconee, Satilla, and St. Marys Rivers.

Essential Features of Critical Habitat

The NMFS determined that the key conservation objectives for the Carolina and South Atlantic DPSs of Atlantic sturgeon are to increase the abundance of each DPS by facilitating increased survival of all life stages and facilitating adult reproduction and juvenile and subadult recruitment into the adult population. We determined the physical features essential to the conservation of the species and that may require special management considerations or protection, which support the identified conservation objectives, are:

(1) Hard bottom substrate (*e.g.*, rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (*i.e.*, 0.0-0.5 ppt range) for settlement of fertilized eggs 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 30 ppt and soft substrate (*e.g.*, sand, mud) between the river mouths 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 mouths 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 m) 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, between the river mouths and spawning sites 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. Appropriate temperature and oxygen values will vary interdependently, and depending on salinity in a particular habitat. For example, 6.0 mg/L DO or greater likely supports juvenile rearing habitat, whereas DO less than 5.0 mg/L for longer than 30 days is less likely to support rearing when water temperature is greater than 25 °C. In temperatures greater than 26 °C, DO greater than 4.3 mg/L is needed to protect survival and growth. Temperatures of 13 to 26 °C likely to support spawning habitat.

Further Information

Further information on designated critical habitat for the endangered Carolina distinct population segment of the Atlantic sturgeon (Carolina DPS of Atlantic sturgeon) and the endangered South Atlantic distinct population segment of the Atlantic sturgeon (South Atlantic DPS of Atlantic sturgeon) can be found at: 82 FR 39160. Additionally, *Appendix B* shows all critical habitat units of Carolina and South Atlantic DPSs.

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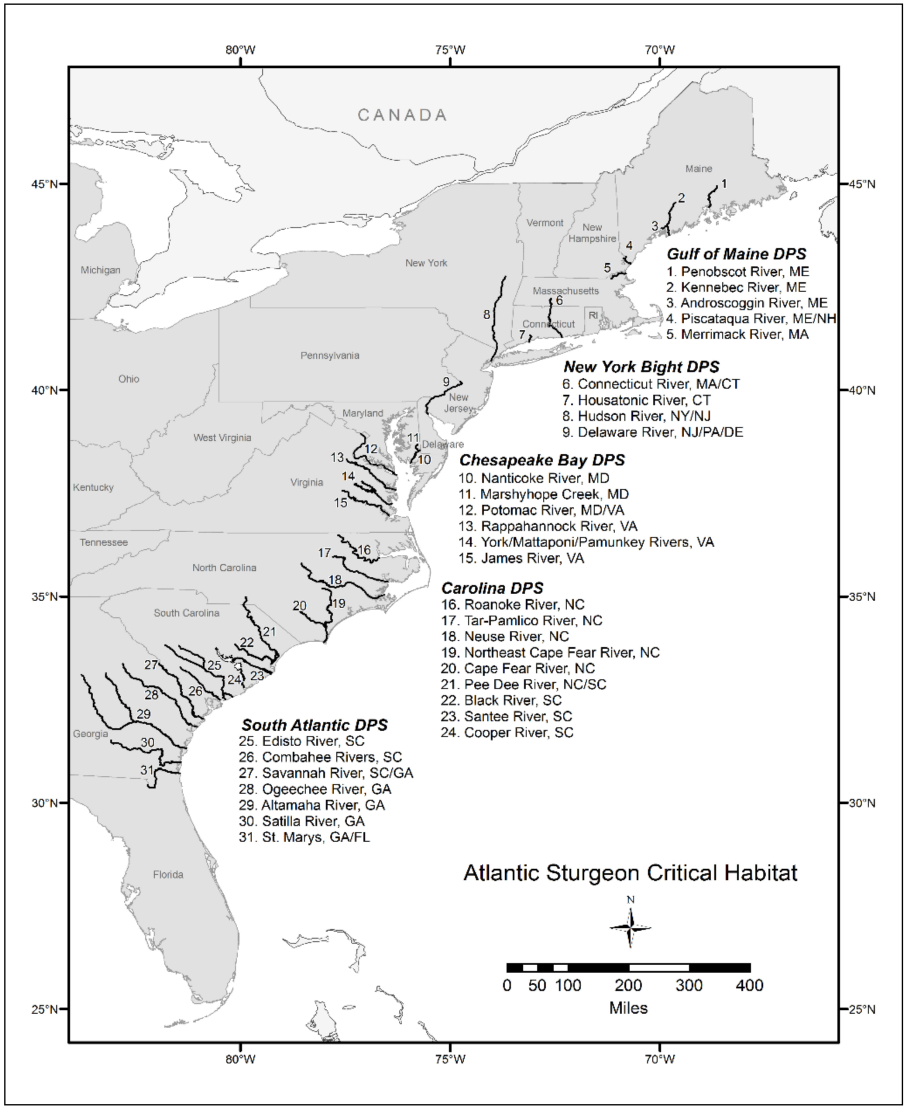
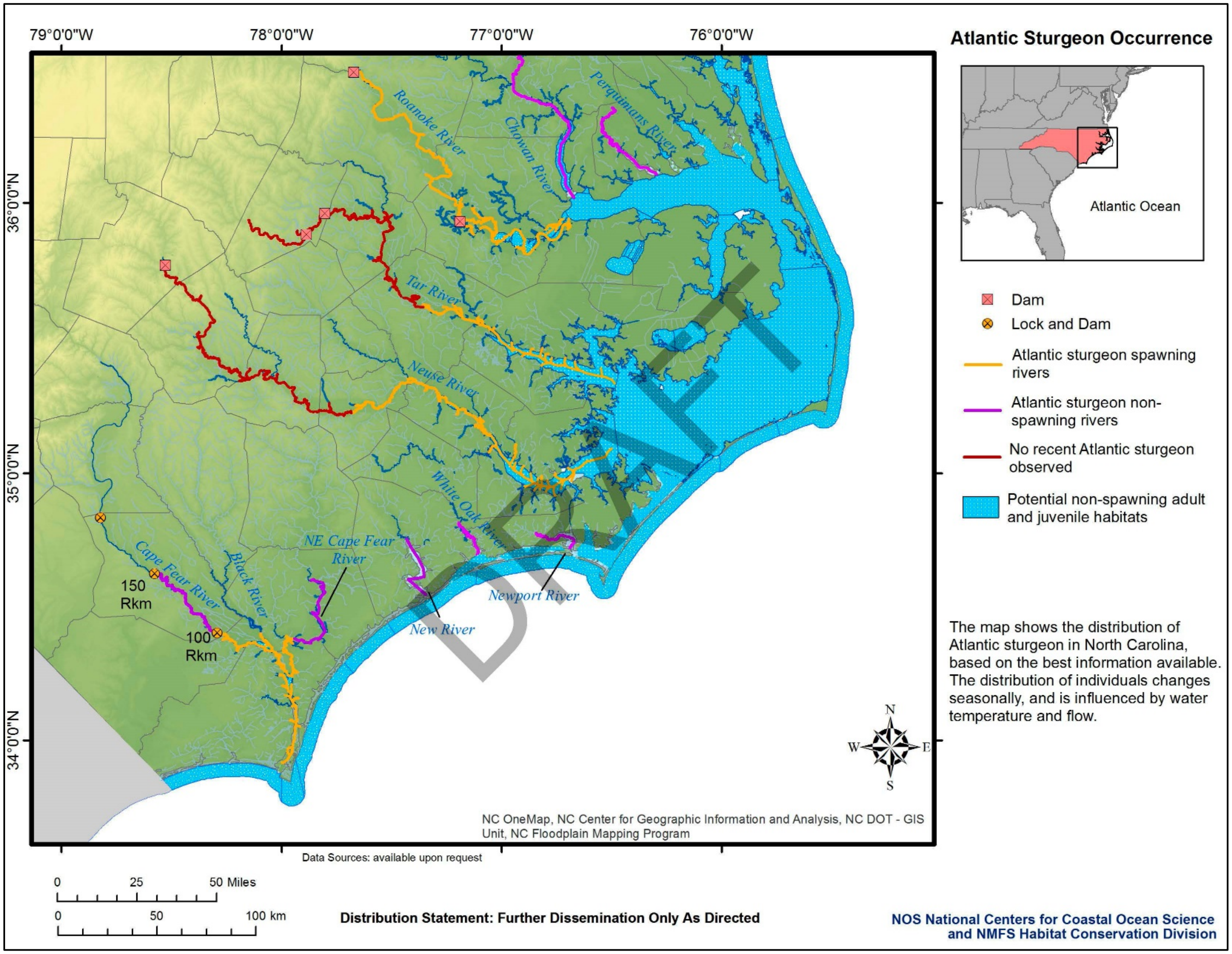
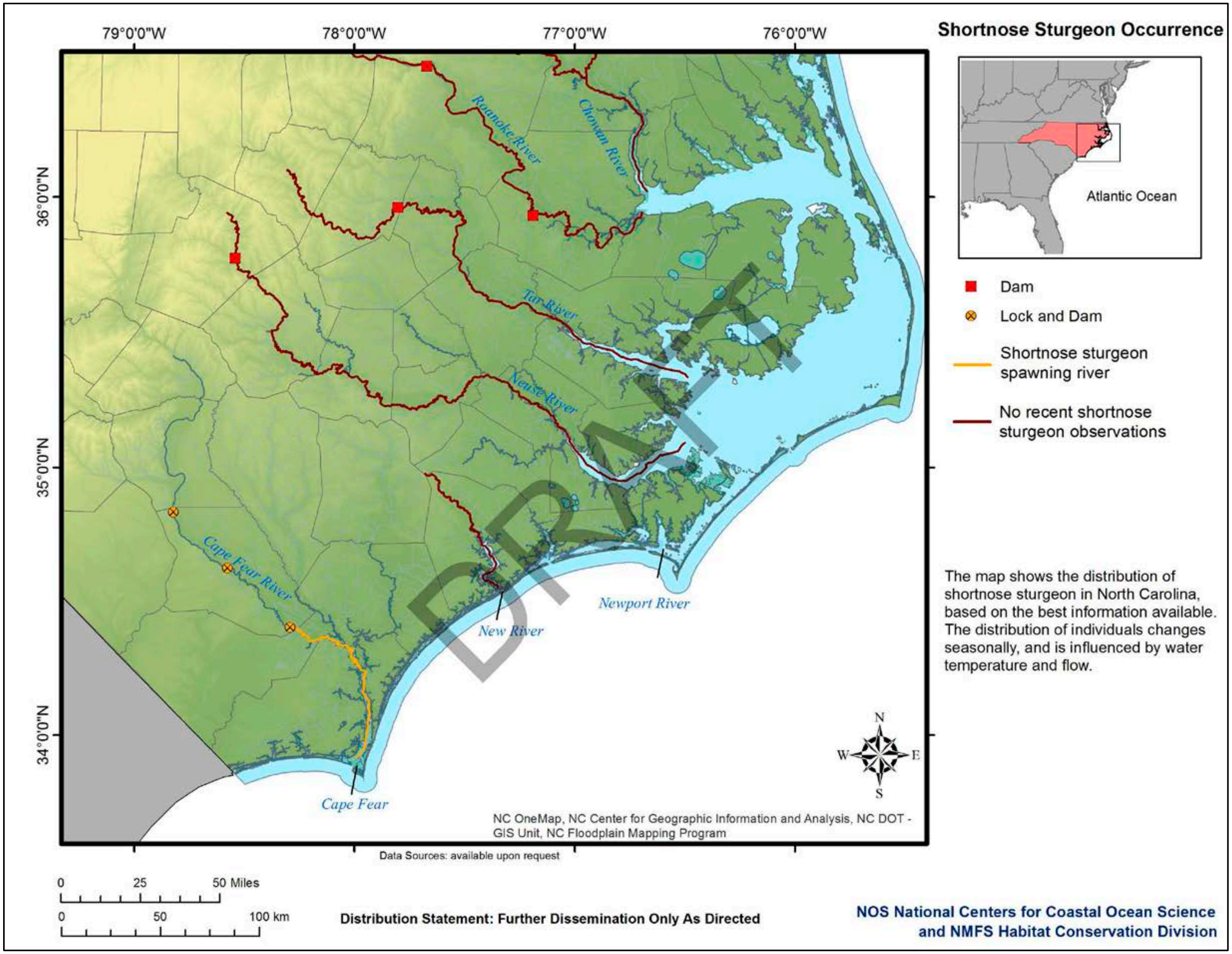
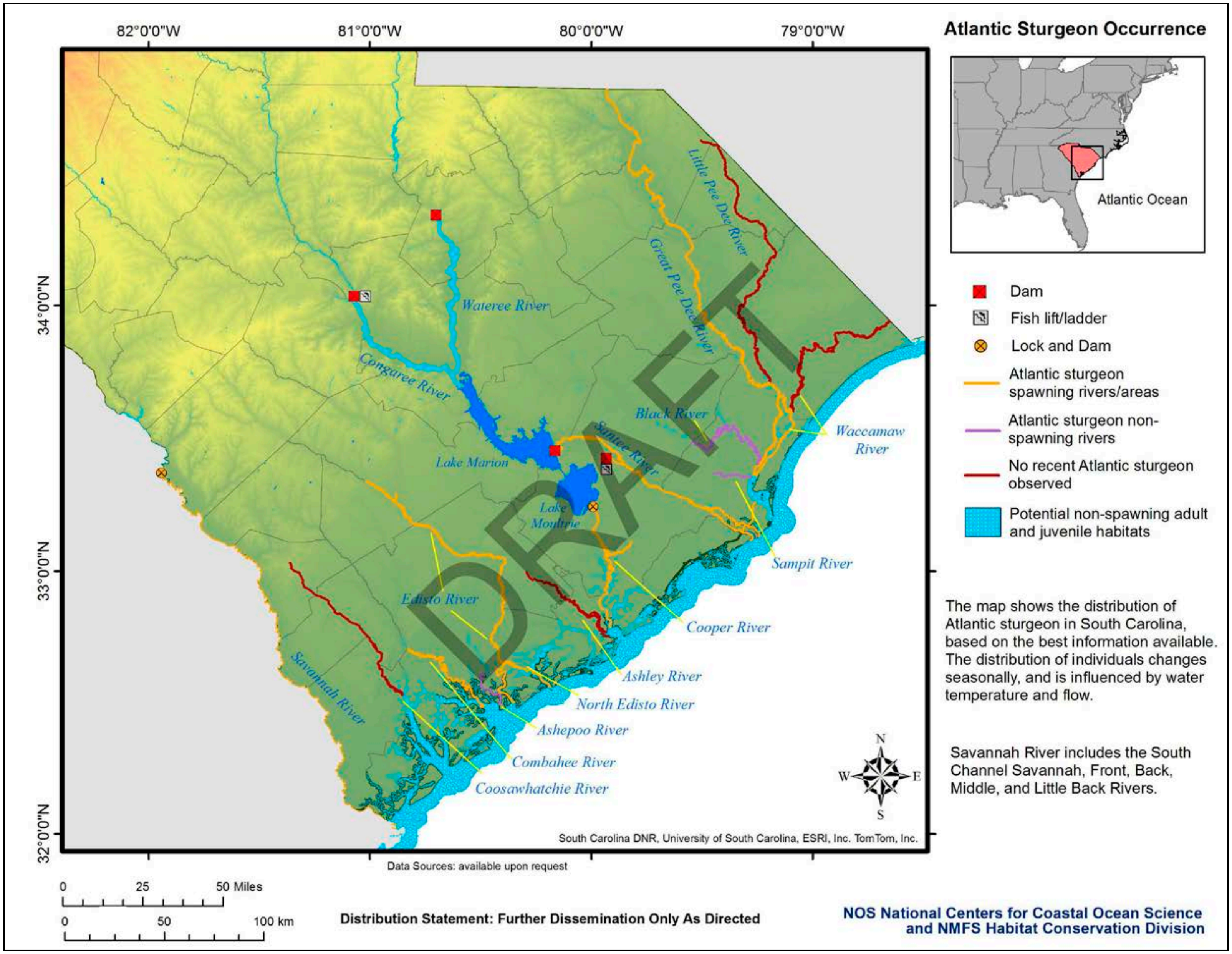
7 Appendix B - Designated Atlantic sturgeon Critical Habitat

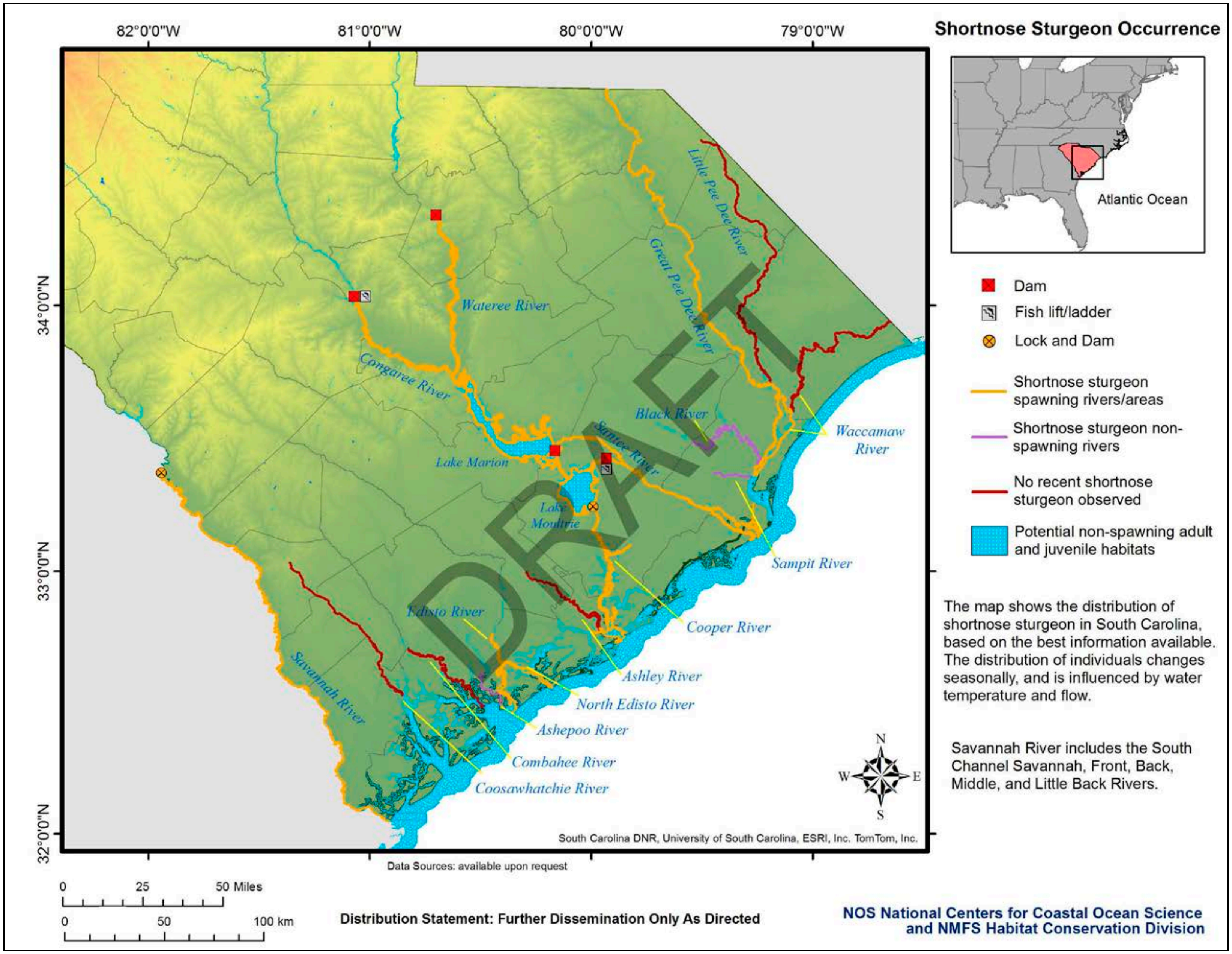


8 Appendix C – Sturgeon Occurrence in NC, SC, and GA



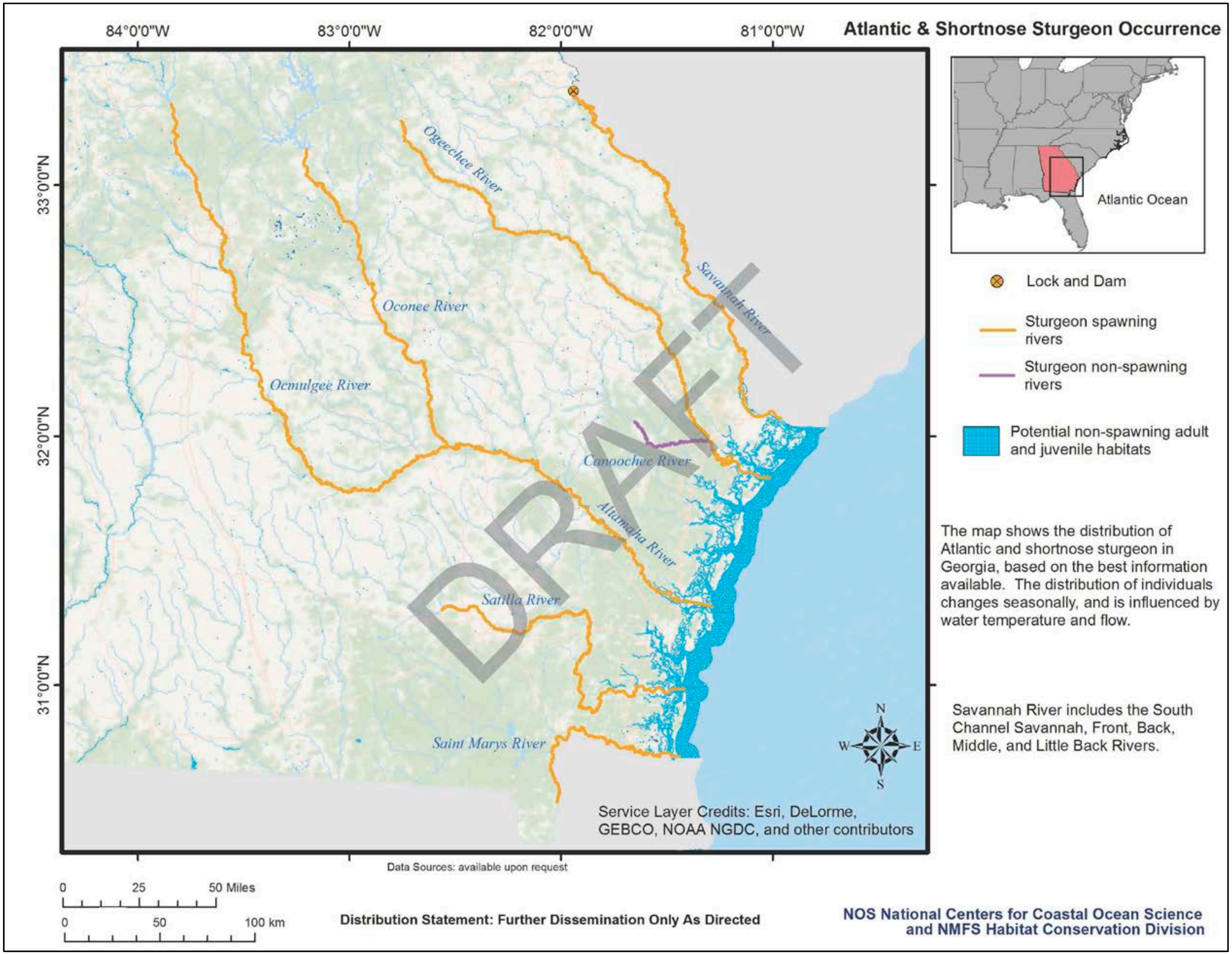

Shortnose Sturgeon Occurrence
79°0'0"W
78°0'0"W
77°0'0"W
76°0'0"W
36°0'0"N
35°0'0"N
34°0'0"N
Roanoke River
Chowan River
Tar River
Neuse River
Cape Fear River
New River
Newport River
Cape Fear
Atlantic Ocean
Dam
Lock and Dam
Shortnose sturgeon spawning river
No recent shortnose sturgeon observations
The map shows the distribution of shortnose sturgeon in North Carolina, based on the best information available. The distribution of individuals changes seasonally, and is influenced by water temperature and flow.
NC OneMap, NC Center for Geographic Information and Analysis, NC DOT - GIS Unit, NC Floodplain Mapping Program
Data Sources: available upon request
0 25 50 Miles
0 50 100 km
Distribution Statement: Further Dissemination Only As Directed
NOS National Centers for Coastal Ocean Science and NMFS Habitat Conservation Division
DRAFT


Atlantic Sturgeon Occurrence
82°0'0"W
81°0'0"W
80°0'0"W
79°0'0"W
34°0'0"N
33°0'0"N
32°0'0"N
Atlantic Ocean
Dam
Fish lift/ladder
Lock and Dam
Atlantic sturgeon spawning rivers/areas
Atlantic sturgeon non-spawning rivers
No recent Atlantic sturgeon observed
Potential non-spawning adult and juvenile habitats
The map shows the distribution of Atlantic sturgeon in South Carolina, based on the best information available. The distribution of individuals changes seasonally, and is influenced by water temperature and flow.
Savannah River includes the South Channel Savannah, Front, Back, Middle, and Little Back Rivers.
Little Pee Dee River
Great Pee Dee River
Wateree River
Congaree River
Black River
Santee River
Waccamaw River
Lake Marion
Lake Moultrie
Sampit River
Edisto River
Cooper River
Savannah River
Ashley River
North Edisto River
Ashepoo River
Combahee River
Coosawhatchie River
DRAFT
N
W
E
S
South Carolina DNR, University of South Carolina, ESRI, Inc. TomTom, Inc.
Data Sources: available upon request
0
25
50 Miles
0
50
100 km
Distribution Statement: Further Dissemination Only As Directed
NOS National Centers for Coastal Ocean Science and NMFS Habitat Conservation Division



The map shows the distribution of shortnose sturgeon in South Carolina, based on the best information available. The distribution of individuals changes seasonally, and is influenced by water temperature and flow.

Savannah River includes the South Channel Savannah, Front, Back, Middle, and Little Back Rivers.


Atlantic & Shortnose Sturgeon Occurrence
84°0'0"W
83°0'0"W
82°0'0"W
81°0'0"W
33°0'0"N
32°0'0"N
31°0'0"N
Ogeechee River
Oconee River
Ocmulgee River
Savannah River
Canoochee River
Altamaha River
Satilla River
Saint Marys River
DRAFT
Atlantic Ocean
Lock and Dam
Sturgeon spawning rivers
Sturgeon non-spawning rivers
Potential non-spawning adult and juvenile habitats
The map shows the distribution of Atlantic and shortnose sturgeon in Georgia, based on the best information available. The distribution of individuals changes seasonally, and is influenced by water temperature and flow.
Savannah River includes the South Channel Savannah, Front, Back, Middle, and Little Back Rivers.
N
S
E
W
Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors
Data Sources: available upon request
0 25 50 Miles
0 50 100 km
Distribution Statement: Further Dissemination Only As Directed
NOS National Centers for Coastal Ocean Science and NMFS Habitat Conservation Division

9 Appendix D: Federally Managed Species Relevant to Transportation Projects in North Carolina, South Carolina, and Georgia

Common Name	Species	Fishery Management Council
Penaeid shrimp		
Brown shrimp	*Farfantepenaeus aztecus*	SAFMC
White shrimp	*Litopenaeus setiferus*	SAFMC
Pink shrimp	*Farfantepenaeus duorarum*	SAFMC
Snapper-Grouper Complex		
Gag grouper	*Mycteroperca microlepis*	SAFMC
Red grouper	*Epinephelus morio*	SAFMC
Black grouper	*Mycteroperca bonaci*	SAFMC
Goliath grouper	*Epinephelus itajara*	SAFMC
Black sea bass	*Centropristis striata*	SAFMC/MAFMC
Gray snapper	*Lutjanus griseus*	SAFMC
Lane snapper	*Lutjanus synagris*	SAFMC
Atlantic spadefish	*Chaetodipterus faber*	SAFMC
Coastal Migratory Pelagics		
Spanish mackerel	*Scomberomorus maculatus*	SAFMC
King mackerel	*Scomberomorus cavalla*	SAFMC
Cobia	*Rachycentron canadum*	SAFMC
Highly Migratory Species		
Bonnethead shark (Atlantic stock)	*Sphyrna tiburo*	NMFS - HMS
Finetooth shark	*Carcharhinus isodon*	NMFS – HMS
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	NMFS – HMS

Blacktip shark	*Carcharhinus limbatus*	NMFS – HMS
Bull shark	*Carcharhinus leucas*	NMFS – HMS
Lemon shark	*Negaprion brevirostris*	NMFS – HMS
Sandbar shark	*Carcharhinus plumbeus*	NMFS – HMS
Scalloped Hammerhead shark	*Sphyrna lewini*	NMFS - HMS
Other Species		
Bluefish	*Pomatomus saltatrix*	MAFMC
Scup	*Stenotomus chrysops*	MAFMC
Summer flounder	*Paralichthys dentatus*	MAFMC

Other NOAA-trust resources (Atlantic Coastal Fisheries Cooperative Management Act & Fish and Wildlife Coordination Act) relevant to transportation projects in NC, SC, and GA

Common Name	**Species**
Alewife	*Alosa pseudoharengus*
American shad	*Alosa sapidissima*
Atlantic menhaden	*Brevoortia tyrannus*
American eel	*Anguilla rostrata*
Blueback herring	*Alosa aestivalis*
Striped bass	*Morone saxatilis*
Red drum	*Sciaenops ocellatus*
Blue crab	*Callinectes sapidus*
Eastern oyster	*Crassostrea virginica*
Horseshoe crab	*Limulus polyphemus*

10 Appendix E: Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) Relevant to Transportation Projects in North Carolina, South Carolina, and Georgia

Essential Fish Habitat Designations by the South Atlantic Fishery Management Council (SAFMC)

To aid in understanding EFH and EFH-HAPC, the SAFMC has produced the *Users Guide to Essential Fish Habitat Designations by the South Atlantic Fishery Management Council,* November 2016: http://safmc.net/download/SAFMCEFHUsersGuideFinalNov16.pdf

Fishery Management Plan	Essential Fish Habitat	Habitat Areas of Particular Concern
SAFMC - Fishery Management Plan for the Shrimp Fishery of the South Atlantic Region (SAFMC)	EFH for penaeid shrimp includes inshore estuarine nursery areas, offshore marine habitats used for spawning and growth to maturity, and all interconnecting water bodies as described in the Habitat Plan. Inshore nursery areas include tidal freshwater (palustrine), estuarine, and marine emergent wetlands (e.g., intertidal marshes); tidal palustrine forested areas; mangroves; tidal freshwater, estuarine, and marine submerged aquatic vegetation (e.g., seagrass); and subtidal and intertidal non-vegetated flats. This applies from North Carolina through the Florida Keys.	All coastal inlets, all state-designated nursery habitats of particular importance to shrimp (e.g., in North Carolina this would include all Primary Nursery Areas and all Secondary Nursery Areas), and state-identified overwintering areas.
SAFMC - Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region	For specific life stages of estuarine dependent and nearshore snapper-grouper species, EFH includes areas inshore of the 100-foot contour, such as attached macroalgae; submerged rooted vascular plants (e.g., seagrass); estuarine emergent vegetated wetlands (saltmarshes, brackish marsh); tidal creeks; estuarine scrub/shrub (mangrove fringe); oyster reefs and shell banks; unconsolidated bottom (soft sediments); artificial reefs; and coral reefs and live/hard bottom.	Medium to high profile offshore hard bottoms where spawning normally occurs; localities of known or likely periodic spawning aggregations; nearshore hard bottom areas; The Point, The Ten Fathom Ledge, and Big Rock (North Carolina); The Charleston Bump (South Carolina); mangrove habitat; seagrass habitat; oyster/shell habitat; all coastal inlets; all state-designated nursery habitats of particular importance to snapper grouper (e.g., Primary and Secondary Nursery Areas designated in North Carolina); pelagic and benthic *Sargassum*; Hoyt Hills for wreckfish; the Oculina Bank Habitat Area of Particular Concern; all hermatypic coral habitats and reefs; manganese outcroppings on the Blake Plateau; and Council-designated Artificial Reef Special Management Zones.
SAFMC - Fishery Management Plan for the Coastal Migratory Pelagic	EFH for coastal migratory pelagic species includes sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters, from the surf to the shelf break zone, but from the Gulf stream	Sandy shoals of Capes Lookout, Cape Fear, and Cape Hatteras from shore to the ends of the respective shoals, but shoreward of the Gulf stream; The Point, The Ten-Fathom Ledge, and Big Rock (North Carolina); The Charleston

Resources (Mackerels)	shoreward, including *Sargassum*. In addition, all coastal inlets, all state-designated nursery habitats of particular importance to coastal migratory pelagics (for example, in North Carolina this would include all Primary Nursery Areas and all Secondary Nursery Areas). For cobia, EFH also includes high salinity bays, estuaries, and seagrass habitat. In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse coastal migratory pelagic larvae. For king and Spanish mackerel and cobia essential fish habitat occurs in the South Atlantic and Mid-Atlantic Bights.	Bump and Hurl Rocks (South Carolina); The Point off Jupiter Inlet (Florida); *Phragmatopoma* (worm reefs) reefs off the central east coast of Florida; nearshore hard bottom south of Cape Canaveral; The Hump off Islamorada, Florida; The Marathon Hump off Marathon, Florida; The "Wall" off of the Florida Keys; Pelagic *Sargassum*; and Atlantic coast estuaries with high numbers of Spanish mackerel and cobia based on abundance data from the ELMR Program. Estuaries meeting these criteria for Cobia include Broad River, South Carolina.

Essential Fish Habitat Designations by the Mid-Atlantic Fishery Management Council (MAFMC)

MAFMC - Fishery Management Plan for the Bluefish Fishery

Life Stage	Geographic Area	Salinity	Seasonality	Comments
Eggs	North of Cape Hatteras, found over Continental Shelf from Montauk Point, NY south to Cape Hatteras, South of Cape Hatteras, found over Continental Shelf through Key West, Florida	>31ppt	Apr. to Aug.	No EFH designation inshore
Larvae	North of Cape Hatteras, found over Continental Shelf from Montauk Point, NY south to Cape Hatteras, South of Cape Hatteras, found over Continental Shelf through Key West, Florida, the slope sea and Gulf Stream between latitudes 29N and 40N; includes the following estuaries: Narragansett Bay	>30ppt	Apr. to Sept.	No EFH designation inshore
Juveniles	North of Cape Hatteras, found over Continental Shelf from Nantucket Island, MA south to Cape Hatteras,South of Cape Hatteras, found over Continental Shelf through Key West, Florida, the slope sea and Gulf Stream between latitudes 29N and 40N also includes estuaries between Penobscot Bay to Great Bay; Mass Bay to James R.; Albemarle Sound to St. Johns River, FL	23-26 ppt Freshwater zone in Albemarle Sound	N. Atlantic estuaries from June to Oct. Mid-Atlantic estuaries from May to Oct. S. Atlantic estuaries from March to Dec.	Use estuaries as nursery areas; can intrude into areas with salinities as low as 3 ppt.

Adults	North of Cape Hatteras, found over Continental Shelf from Cape Cod Bay, MA south to Cape Hatteras,South of Cape Hatteras, found over Continental Shelf through Key West, Florida also includes estuaries between Penobscot Bay to Great Bay; Mass Bay to James R.; Albemarle Sound to Pamlico/ Pungo R., Bougue Sound, Cape Fear R., St. Helena Sound, Broad R., St. Johns R., & Indian R.	>25ppt	N. Atlantic estuaries from June to Oct. Mid-Atlantic estuaries from Apr. to Oct. S. Atlantic estuaries from May to Jan.	Highly Migratory

Adapted from Summary of Essential Fish Habitat (EFH) and General Habitat Parameters for Federally Managed Species (EFH Tables) – Greater Atlantic Regional Fisheries Office. Please see the EFH Tables at https://www.greateratlantic.fisheries.noaa.gov/ for complete information and descriptions.

MAFMC - Fishery Management Plan for Summer Flounder, Scup, and Black Sea Bass

Summer Flounder

Life Stage	Geographic Area	Salinity	Seasonality	Comments
Eggs	Over Continental Shelf from GOME to Cape Hatteras, NC; South of Cape Hatteras to Florida		Oct. to May	
Larvae	Over Continental Shelf from GOME to Cape Hatteras, NC; South of Cape Hatteras to Florida; also includes estuaries from Waquoit Bay to Narragansett Bay; Hudson River/ Raritan Bay; Barnegat Bay, Chesapeake Bay, Rappahannock R., York R., James R., Albemarle Sound, Pamlico Sound, Neuse R. to Indian R.	23 – 33ppt Fresh in Hudson River Raritan Bay Area	Mid-Atlantic Bight from Sept. to Feb.; Southern part from Nov. to May at depths 9-30m.	High use of tidal creeks and creek mouths
Juveniles	Over Continental Shelf from GOME to Cape Hatteras, NC; South of Cape Hatteras to Florida; also includes estuaries from Waquoit Bay to James R.; Albemarle Sound to Indian R.	10 – 30ppt Fresh in Narrag Bay, Albe/Pamlico Sound & St. Johns River		HAPC – All native species of macroalgae, seagrasses and freshwater and tidal macrophytes in any size bed as well as loose aggregations, within adult and juvenile EFH. (major prey: mysid shrimp)
Adults	Over Continental Shelf from GOME to Cape Hatteras, NC; South of Cape Hatteras to Florida; also includes estuaries from Buzzards Bay, Narragansett Bay,	Fresh in Albemarle Sound, Pamlico	Wintering adults (Nov. to Apr.) offshore, south of NY to NC. Inshore, estuaries from May to Oct.	HAPC – All native species of macroalgae, seagrasses and freshwater and tidal

	Conn. R. to James R.; Albemarle Sound to Broad R.; St. Johns R., & Indian R.	Sound & St. Johnson River.		macrophytes in any size bed as well as loose aggregations, within adult and juvenile EFH. (major prey: fish, shrimp, squid, polychaetes)

Adapted from Summary of Essential Fish Habitat (EFH) and General Habitat Parameters for Federally Managed Species (EFH Tables) – Greater Atlantic Regional Fisheries Office. Please see the EFH Tables at https://www.greateratlantic.fisheries.noaa.gov/ for complete information and descriptions.

Scup

Life Stage	Geographic Area	Salinity	Seasonality	Comments
Eggs	Southern NE to coastal Virginia includes the following estuaries: Waquoit Bay to Long Island Sound; Gardiners Bay, Hudson R./Raritan Bay	>15	May to August	
Larvae	Southern NE to coastal Virginia includes the following estuaries: Waquoit Bay to Long Island Sound; Gardiners Bay, Hudson R./Raritan Bay	>15	May – Sept.	
Juveniles	The Continental Shelf from GOME to Cape Hatteras, NC includes the following estuaries: Mass Bay, Cape Cod Bay to Long Island Sound; Gardiners Bay to Delaware Inland Bays; & Chesapeake Bay	>15	Spring and summer in estuaries and bays	
Adults	The Continental Shelf from GOME to Cape Hatteras, NC includes the following estuaries: Cape Cod Bay to Long Island Sound; Gardiners Bay to Hudson R./Raritan Bay; Delaware Inland Bays; & Chesapeake Bay	>15	Wintering adults (November – April) are usually offshore, south of NY to NC	(spawn < 30m during inshore migration – May 0 Aug; prey: small benthic inverts)

Adapted from Summary of Essential Fish Habitat (EFH) and General Habitat Parameters for Federally Managed Species (EFH Tables) – Greater Atlantic Regional Fisheries Office. Please see the EFH Tables at https://www.greateratlantic.fisheries.noaa.gov/ for complete information and descriptions.

Black Sea Bass

Life Stage	Geographic Area	Salinity	Seasonality	Comments
Eggs	Continental Shelf and estuaries from southern NE to North Carolina, also includes Buzzards Bay		May to Oct.	

Larvae	Pelagic waters over Continental Shelf from GOME to Cape Hatteras, NC, also includes Buzzards Bay	30 – 35ppt	May – Nov.; peak June - July	
Juveniles	Demersal waters over Continental Shelf from GOME to Cape Hatteras, NC, also includes estuaries from Buzzards Bay to Long Island Sound; Gardiners Bay, Barnegat Bay to Chesapeake Bay; Tangier/ Pocomoke Sound and James River	>18 ppt	Found in coastal areas (Apr. – Dec.; peak June-Nov.) between VA and MA, but winter offshore from NJ and south; estuaries in summer and spring.	YOY use salt marsh edges and channels; high habitat fidelity
Adults	Demersal waters over Continental Shelf from GOME to Cape Hatteras, NC, also includes estuaries: Buzzards Bay, Narragansett Bay, Gardiners Bay, Great South Bay, Barnegat Bay to Chesapeake Bay; Tangier/ Pocomoke Sound and James River	>20ppt	Wintering adults (Nov. to Apr.) offshore, south of NY to NC. Inshore, estuaries from May to Oct.	Spawn in coastal bays but not estuaries; change sex to males with growth; prey: benthic and near bottom inverts, small fish, and squid

Adapted from Summary of Essential Fish Habitat (EFH) and General Habitat Parameters for Federally Managed Species (EFH Tables) – Greater Atlantic Regional Fisheries Office. Please see the EFH Tables at https://www.greateratlantic.fisheries.noaa.gov/ for complete information and descriptions.

NMFS Consolidated Atlantic Highly Migratory Species (HMS) Fishery Management Plan Essential Fish Habitat Designations

NMFS is currently in the process of amending the 2006 Consolidated Atlantic Highly Migratory Species (HMS) Fishery Management Plan (FMP) based on a review of Atlantic HMS Essential Fish Habitat (EFH). The Draft Environmental Assessment for Amendment 10 to the 2006 Consolidated Atlantic HMS FMP can be found at 81 FR 62100. The final version of the BMP Manual and Appendices will reflect any updates to EFH and HAPC.

Species	Life Stage	EFH
Blacktip shark (Atlantic stock) - *Carcharhinus limbatus*	Neonate/YOY (≤ 59 cm FL)	In Atlantic coastal areas out to 30 m depth contour from norther Florida through areas with muddy bottoms in Georgia and the seaward side of coastal islands of the Carolinas, at depths of 2 to 4 m. Found in estuary systems of Sapelo Island, Georgia.
	Juvenile (60-125 cm FL) and Adult (≥ 126 cm FL)	In Atlantic coastal areas from Florida to the Maryland/Virginia line (northern extent of EFH is Chincoteague Island). Localized off of the southeast Florida coast, from northern Cape Canaveral (28°40' N) south to the Jupiter Island area (27°04' N) in water depths of 3 to 11 m.. Found in South Carolina Inlets, estuarine, and nearshore waters (including Winyah Bay and North Inlet) with water temperatures ranging from 19 to 33 °C, salinities ranging from 13 to 37 ppt, water depth ranging from 2.4 to 12.8 m, and dissolved oxygen ranging from 4.3-6.1 mg/L in shell, sand, rocky habitats.

Bull shark - *Carcharhinus leucas*	Juvenile (78-188 cm FL) and Adult (≥ 189 cm FL)	Gulf of Mexico coastal areas along the Texas coast, including Matagorda Bay and San Antonio Bays, eastern Louisiana, including the west side of Mississippi River Delta and around the Chandeluer Sound on the east side of the Mississippi River Delta, and interior of Lake Pontchartrain, the Pearl River system, Little Lake/Barataria Bay and its inland waters, the Terrebonne/Timbalier Bay system, and the Atchafalaya/Vermilion Bay system in the coastal waters off Louisiana, Mississippi Sound and Mobile Bay off the coasts of Mississippi and Alabama, to the Florida Panhandle, and the west coast of Florida, including Pine Island Sound, Yankeetown, Tampa Bay, Charlotte Harbor, Ten Thousand Islands, and through the Florida Keys. Atlantic coastal areas localized from the mid-east coast of Florida, including northern Cape Canaveral (28°40' N) south to the Jupiter Island area (27°04' N) in water depths of 3 to 11 m, Altamaha River Estuary in Georgia, to South Carolina: freshwater creeks, power plant outfalls, ocean inlets, and seagrass habitats with temperatures as low as 16.4°C, salinities 1.7 to 41.1 ppt and dissolved oxygen concentrations between 4 and 7 mg/L; shallow depths less than 9 m. Adults are usually found in higher salinities than juvenile and neonate/YOY sharks out to the shelf edge but not in slope waters.
Lemon shark – *Negaprion brevirostris*	Juveniles (76 to 200 cm FL)	Gulf of Mexico coastal areas along Texas, eastern Louisiana the Chandeleur Islands off Louisiana, and off Florida from Naples through the Florida Keys, especially areas where temperatures ranged between 26.4 to 31.3 °C, salinities of 23.2 to 31.2 ppt, depth of 0.9-5.4 m and DO of 5.2 to 6.7 mL/L in mud and seagrass areas. Atlantic coastal areas of Florida through Charleston, South Carolina. Coastal waters off of Puerto Rico and the U.S. Virgin Islands.
	Adults (≥ 201 cm TL)	Gulf of Mexico coastal areas along the east coast of Louisiana and the west coast of Florida through the Florida Keys, especially in areas where temperatures ranged between 29.3 to 29.9 °C, salinities of 25.7 to 29.8 ppt, depth of 2.1 to 4.3 m and DO of 5.2 to 6.7 mL/L in mud and seagrass areas. Atlantic coastal areas extending from the east coast of Florida to Charleston, South Carolina, where adults can be found during the summer months. Eastern Puerto Rico.
Sandbar shark - *Carcharhinus plumbeus*	Neonate/YOY (<66 cm FL)	Localized coastal area in the Gulf of Mexico on the Florida Panhandle in an area between Indian Pass and St. Andrew Sound, Florida in water temperatures from 20 to 31 °C at salinities from 19-39 ppt and depths of 2.1-5.2 m in silt/clay habitats. Atlantic coastal areas from Cape Lookout, North Carolina, to Long Island, New York. Important primary nurseries exist in Delaware Bay, Delaware, Chesapeake Bay; Maryland, where the principal nursery is limited to the southeastern portion of the estuary when the salinity is greater than 20.5 ppt and depth is greater than 5.5 m; Great Bay, New Jersey; and the waters off Cape Hatteras, North Carolina in water temperatures ranging from 15 to 30 °C, salinities at least from 15-35 ppt, and water depth ranging from 0.8 to 23 m in sand, mud, shell and rocky habitats from New York to North Carolina.
	Juvenile (67 to 154 cm FL)	Localized area in the Gulf of Mexico off Cape San Blas,Florida. Localized areas along the Atlantic coast of Georgia to southern New England, such as Nantucket Sound, Massachusetts in water temperatures ranging from 20 to 24 °C and depths from 2.4 to 6.4 m. Important secondary nurseries in Delaware Bay, Delaware, Chesapeake

		Bay, Maryland, Great Bay, New Jersey, and the waters off Cape Hatteras, North Carolina in water temperatures ranging from 15 to 30 °C, salinities at least from 15 to 35 ppt, and water depth ranging from 0.8 to 23 m in sand, mud, shell and rocky habitats from Massachusetts to North Carolina.
	Adult (> 154 cm FL)	In the Gulf of Mexico off Texas north through the Florida Panhandle and south to the Florida Keys. Adults common in the West Florida Shelf, particularly off Cape San Blas, and cool, deep, clear water offshore of Texas and Louisiana. Atlantic coastal areas from Florida to southern New England.
	Habitat areas of particular concern (HAPC)	Important nursery and pupping grounds have been identified in shallow areas and at the mouth of Great Bay, New Jersey, in lower and middle Delaware Bay, Delaware, lower Chesapeake Bay, Maryland, and near the Outer Banks, North Carolina, and in areas of Pamlico Sound and adjacent to Hatteras and Ocracoke Islands, North Carolina, and offshore of those islands in water temperatures ranging from 15 to 30 °C, salinities at least from 15 to 35 ppt, and water depth ranging from 0.8 to 23 m in sand and mud habitats.
Scalloped Hammerhead shark - *Sphyrna lewini*	Neonate/YOY (≤45 cm TL)	Coastal areas in the Gulf of Mexico from Texas to the southern west coast of Florida. Atlantic east coast from the mid-east coast of Florida to southern North Carolina. They prefer temperatures of 23.2 to 30.2 °C, salinities of 27.6 to 36.3 ppt, and DO of 5.1 to 5.5 mL/L and depths in the 5 to 6 meter range and prefer mud and seagrass bottoms.
	Juveniles and Adults (>45 cm FL)	Coastal areas in the Gulf of Mexico from the southern to mid- coast of Texas, eastern Louisiana to the southern west coast of Florida, and the Florida Keys. Offshore from the mid-coast of Texas to eastern Louisiana. Atlantic east coast of Florida through New Jersey.
Bonnethead shark (Atlantic Stock) - *Sphyrna tiburo*	Neonate/YOY (≤31 cm FL)	Atlantic east coast inshore and nearshore waters from Cape Hatteras to Holden Beach, North Carolina (temperature 19-33°C, depth 0.6-11.6 m); coastal and estuarine waters of South Carolina and Georgia (temperature 23-31 °C, salinity 22-36.6 ppt, depth 0.5-13.1 m); and coastal waters from the tip of Georgia to Cape Canaveral, Florida.
	Juveniles (32 to 81 cm FL)	Atlantic east coast inshore and nearshore waters from Cape Hatteras to Holden Beach, North Carolina (temperature 19-33°C, depth 0.6-11.6 m); coastal and estuarine waters of South Carolina and Georgia (temperature 23-31 °C, salinity 22-36.6 ppt, depth 0.5-13.1 m); and coastal waters from the tip of Georgia to Cape Canaveral, Florida.
Finetooth Shark – *Carcharhinus isodon*		Along the Gulf of Mexico coast of Texas, eastern Louisiana, Mississippi, Alabama, and the Florida Panhandle. Atlantic east coast along Georgia and South Carolina. Important pupping and nursery habitat is located in South Carolina in Bulls Bay and nearshore habitats of South Carolina (arrival when temperatures reach 22 °C in spring and departure in fall when temperatures drop to 20 °C), GA estuarine and coastal waters specifically lower Duplin River/Doboy Sound (25-30 °C, salinity 23-26 ppt, depth 3-5 m); Apalachicola Bay and Crooked Island Sound (temperature 26.4-31.4 °C, salinity 25- 36 ppt, depth 3-3.5 m); Terrebonne and Timbalier bay system, Louisiana (25.3-32.1 °C, 0.6 - 4.9 m depth); the Mississippi Sound, specifically off western Horn, Sound, and Round Islands (YOY); and Galveston, Matagorda, Aransas, Corpus Christi and the lower Laguna Madre bay systems of

		Texas (19.2-30.6 °C, 16-36 m depth). Important secondary nursery habitats include coastal areas between Cape Hatteras to Holden Beach, North Carolina (3.1-10.7 m depth, 22-30.6 °C); South Carolina estuarine and coastal waters (including Wynah Bay and North Inlet) (20-28 °C, salinity 23.5 ppt or higher); Georgia estuarine waters (25-28.2 °C, 23-32.1 ppt salinity, 0.5-4.3 m depth); shallow coastal waters of the northeastern Gulf of Mexico with muddy bottom (Apalachicola Bay, Crooked Island Sound, St. Andrew Bay) (19.5-31.4 °C, 19-38 ppt, 2.3-5.3 m depth); seaward side of coastal islands from Apalachee Bay to St. Andrews Bay, Florida, especially around the mouth of the Apalachicola River; Terrebone/Timbalier Bay system, Louisiana (25.3-32.1 °C, 19-34.3 ppt salinity, 0.6-4.9 m depth); Bay St. Louis, Mississippi to Perdido Sound, Alabama; Galveston, Matagorda, Aransas, Corpus Christi and the lower Laguna Madre bay systems of Texas; beaches of the southeastern Texas coast (2.1-5.5 m depth). Localized coastal areas along southern Texas and from eastern Louisiana through the Florida Panhandle in the Gulf of Mexico. Atlantic east coast from Key West through Florida Bay to Cape Hatteras. Important habitats include: Wynah Bay and North Inlet, South Carolina (salinity higher than 23.5 ppt); Terrebone and Timballier bay system, Lousiana; Mississippi Sound north of Cat, Ship, Horn, and Petit Bois Islands between the islands and the coast of Louisiana; shallow coastal waters of the northeastern Gulf of Mexico (Crooked Island Sound, gulf side of St. Vincent Island).
Atlantic Sharpnose shark (Atlantic Stock) – *Rhizoprionodon terraenovae*	Neonate/YOY (24 - 51 cm FL)	Mid-coast of Florida to Cape Hatteras, with seasonal summer distribution in the northern part of the range. Important pupping and nursery habitats include inshore and nearshore waters from Cape Hatteras to Holden Beach, North Carolina; estuarine and nearshore waters of South Carolina (21-29 °C, 24-37 ppt salinity, pupping activity May-June, nursery occupation through October); and estuarine and coastal waters of Georgia (26.4 – 30.8 °C, 21.6 – 36.4 ppt salinity, 2.7 – 13.1 m depth). The northeastern coast of Florida to Cape Canaveral is an important primary nursery and pupping area (18.4 – 30.7°C, 22.8-33.7 ppt salinity, 0.9-4 m depth).
	Juvenile (52 - 59 cm FL)	Mid-coast of Florida to Cape Hatteras, with seasonal summer distribution in the northern part of the range and a localized area off of Delaware. Important secondary nursery areas for juveniles include: inshore and nearshore waters from Cape Hatteras to Holden Beach, North Carolina (17.3 – 33 °C, 1.4 – 16.5m depth); estuarine and nearshore waters of South Carolina (21-29 °C, 24-37 ppt salinity, pupping activity May- June, nursery occupation through October); and estuarine and coastal waters of Georgia (26.4 – 30.8 °C, 21.6 – 36.4 ppt salinity, 2.7 – 13.1 m depth).

11 Appendix F: Effects Analysis for Transportation Actions in the Southeast Region

The table presents a comparison of transportation project types (actions and activities) and links between project components with resource effects and best management practices.

Stressors generated from transportation projects affect species and habitats in various ways. In order for adverse effects to occur, species and habitats must be exposed and respond to stressors. For species, responses are generally characterized (increasing in severity) as behavioral, sub-lethal, or lethal. Behavioral responses may include startle, alarm, altered behavioral displays, avoidance, abandonment, and displacement. Sub-lethal and lethal responses can be collectively grouped as "reduced fitness" (an effect). The sub-lethal responses that lead to reduced fitness include increased respiration, reduced feeding success, reduced growth rates, delayed age at sexual maturity, depressed immune responses, and reduced fecundity. These can also be referred to as stress effects. Lethal responses include reproductive failure, and direct or indirect mortality. There is considerable overlap in various responses and effects (e.g., numerous behavioral, sub-lethal, and lethal responses and effects can reduce fitness). Best management practices are not intended to change how a species or habitat responds to a stressor, but are designed to change how they are exposed (avoid or minimize the plausible route of effect).

Activity/Sub-Activity					
General/Incidental Construction	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
General and incidental construction activities for roadway construction, maintenance, and demolition.					See chapters and sections on underwater noise, turbidity and sedimentation, reduced water quality, habitat alteration, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Heavy equipment & vehicles	Erosion, turbidity, and sedimentation	Behavior modification	Minor localized water quality impacts	See Chapter 1 & 2
	Temporary access roads/work areas	Erosion, turbidity, and sedimentation	Behavior modification	Affected water quality, localized degradation, and affected prey resources	See Chapter 1 & 2

	Stabilization/riprap placement	Habitat loss and degradation, turbidity and sedimentation, altered sediment deposition	Behavior modification, reduced fitness	Shoreline and nearshore habitat loss, affected foraging, sheltering, and spawning habitat, and affected prey resources	See Chapter 5
	Barges & crane/timber mats	Habitat loss and degradation: vegetation smother and sediment compaction	Behavior modification, reduced fitness	Loss of bottom habitat and vegetation, altered sediment transport, affected foraging, sheltering, and spawning habitat, and affected prey resources	See Chapter 1
		Habitat loss and degradation: shading	Behavior modification, reduced fitness	Reduced light levels and altered ambient light patterns, limited plan growth and recruitment, altered plant and animal assemblages, and affected prey resources	See Chapter 1 & 4
	Spuds/spudding	Habitat loss and degradation, vegetation smother and sediment compact, turbidity and sedimentation	Physical injury, behavior modification, reduced fitness	Altered bottom habitat and vegetation, altered sediment transport, affected foraging, sheltering, and spawning habitat, and affected prey resources	See Chapter 1
		Hydroacoustic impacts	Physical injury, behavior modification, reduced fitness	Temporary localized habitat degradation and affected prey resources	See Chapter 3
	Earthwork	Erosion, turbidity, and sedimentation	Physical injury, behavior modification, reduced fitness	Affected water quality and affected prey resources	See Chapter 2
		Decreased water quality and contaminant/pollutant introduction or resuspension	Hazardous material exposure, physical injury and mortality, behavior modification, reduced fitness	Affected water quality, localized degradation, and affected prey resources	See Chapter 1
	Substructures	Habitat loss and degradation, hydroacoustic impacts, turbidity and sedimentation	Behavior modification, reduced fitness	Loss of bottom habitat and vegetation, altered sediment transport, altered hydrodynamics, affected foraging, sheltering, and spawning habitat, and affected prey resources	See Chapter 3

	Superstructure	Habitat loss and degradation: shading	Behavior modification, reduced fitness	Reduced light levels and altered ambient light patterns, limited plan growth and recruitment, altered plant and animal assemblages, and affected prey resources	See Chapter 4
New Bridge, Bridge Replacement, and Bridge Widening & Repair, Maintenance and Retrofit of Bridges	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Bridge work may include structural repairs; pile driving and removal; demolition; excavation for and installation of bridge abutments; temporary fills; riprap placement; constructing bridge columns; constructing stormwater facilities; approach widening; paving with asphalt concrete; and complete replacement. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See chapters and sections on underwater noise, turbidity and sedimentation, reduced water quality, habitat alteration, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Substructures/footings	Habitat alteration and loss	Behavior modification, reduced fitness	Habitat loss & alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapters 1 & 3
		Reduced water quality/ pollutant materials discharge	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized habitat alteration, affected prey resources	Chapter 1
	Superstructures	Habitat alteration/shading	Behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, affected prey resources	Chapter 4
	Beam/deck panel placement	Underwater noise	Temporary behavior modification/ avoidance, reduced fitness	Temporary localized habitat alteration, affected prey resources	Chapter 3
	Deck pour/paving and painting	Reduced water quality/ pollutant materials discharge	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized habitat alteration, affected prey resources	Chapter 1

	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2
	Barges/vessels & crane/timber mats	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4
	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2
	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Stabilization/riprap placement	Habitat alteration/altered connectivity, turbidity and sedimentation/altered sediment deposition	Behavior modification/avoidance, reduced fitness	Shoreline & nearshore habitat loss, affected foraging, sheltering and spawning habitat, localized habitat alteration, affected prey resources	Chapter 1, 2 & 5
	Pile installation via vibratory or impact hammer, water jetting	Underwater noise	Physical injury and mortality, temporary behavior modification, reduced fitness	Temporary localized habitat alteration, affected prey resources	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2

		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Excavation/drilled-shafts/columns/piers	Underwater noise	Physical injury and mortality; temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2
	Removal via direct pull/clam shell	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2
	Removal via vibratory hammer	Underwater noise	Physical injury, temporary behavior modification, reduced fitness	Temporary localized habitat alteration	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2
	Pile-cutting	Underwater noise	Physical injury, temporary behavior modification, reduced fitness	Temporary localized habitat alteration	Chapter 3
	Post-piling removal	Habitat alteration/altered bottom habitat	Physical injury and mortality, avoidance	Habitat alteration	Chapter 1 & 3
	Fill/disposal	Turbidity and sedimentation	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1

		Habitat alteration/altered bottom habitat	Physical injury and mortality, temporary behavior modification, reduced fitness	Habitat loss & alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/altered connectivity, altered sediment deposition	Temporary behavior modification/avoidance, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1 and 2
		Vessel interaction	Physical injury, temporary behavior modification, reduced fitness	Affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
Docks, Piers, and Waterway Access Projects	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Docks, piers, and waterway access projects may be associated with boardwalks, bicycle/pedestrian paths or bridges, other docks and piers, boat ramps, overlooks, viewpoints, and/or historical markers. These activities may include at-grade or elevated trails including boardwalks (piles with decking), fill/ stabilization, and excavation. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See chapters and sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, docks, piers and bridges, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Stabilization/riprap placement	Habitat alteration/altered connectivity, turbidity and sedimentation/altered sediment deposition	Behavior modification, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 5
	Substructures	Habitat alteration, turbidity and sedimentation	Behavior modification, reduced fitness	Habitat loss & alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapter 2 & 3
	Superstructures	Habitat alteration/shading	Behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, affected prey resources	Chapter 3 & 4
	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2

	Barges/vessels & crane/timber mats	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 2
		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4
	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2
	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 3
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Pile installation via vibratory or impact hammer, water jetting	Underwater noise	Physical injury and mortality, temporary behavior modification, reduced fitness	Temporary localized habitat alteration, affected prey resources	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1

	Excavation/drilled-shafts/columns/piers	Underwater noise	Physical injury and mortality; temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2
	Removal via direct pull/clam shell	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2
	Removal via vibratory hammer	Underwater noise	Physical injury, temporary behavior modification, reduced fitness	Temporary localized habitat alteration	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2
	Pile-cutting	Underwater noise	Physical injury, temporary behavior modification, reduced fitness	Temporary localized habitat alteration	Chapter 3
	Post-piling removal	Habitat alteration/altered bottom habitat	Physical injury and mortality, avoidance	Habitat alteration	Chapter 1, 2 & 3
Culvert Installation, Replacement, Repair, Maintenance, and Cleaning	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Work on culverts may involve vegetation and sediment removal, pavement, roadbed, and embankment removal, culvert extraction, placing new culverts or outflow pipes, backfilling and patching the pavement, installing armoring and headwalls, planting, and dewatering the work area and establishing a flow bypass prior to initiating work. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See chapters and sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, culverts, and habitat alteration. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Culvert footers/supports	Habitat alteration and loss	Behavior modification, reduced fitness	Loss of habitat, altered flow dynamics, affected prey resources	Chapter 3 & 4
		Reduced water quality/ pollutant materials discharge	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized habitat alteration, affected prey resources	Chapter 1 and 4

	Paving	Reduced water quality/ pollutant materials discharge	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized habitat alteration, affected prey resources	Chapter 1
	Culvert placement	Habitat alteration/altered connectivity, turbidity and sedimentation/altered sediment deposition	Behavior modification, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, localized habitat alteration, affected prey resources	Chapter 4
	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2
	Timber mats	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/ altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4
	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Stabilization/riprap placement	Habitat alteration/altered connectivity, turbidity and sedimentation/altered sediment deposition	Behavior modification/avoidance, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, localized habitat alteration, affected prey resources	Chapter 1 & 5
	Fill/disposal	Turbidity and sedimentation	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2

		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
		Habitat alteration/altered bottom habitat	Physical injury and mortality, temporary behavior modification, reduced fitness	Habitat loss & alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 4
		Habitat alteration/altered connectivity, altered sediment deposition	Temporary behavior modification/avoidance, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1, 2 & 4
		Vessel interaction	Physical injury, temporary behavior modification, reduced fitness	Affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
Shoreline Stabilization	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Stabilization techniques include placing or resetting riprap, abutment caps, bulkheads, scour countermeasures, concrete mattresses, or other structures to protect and restore eroded slopes or to protect slopes that are vulnerable to erosion. Non-structural shoreline stabilization measures that do not use hard components such as the placement of sand fill, coir logs, and/or native shell may also be incorporated. Stabilization structures can be installed from land, temporary structures, or water via shallow-draft barges. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See chapters sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, vessel interaction, and shoreline stabilization. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Removal/excavation of structures & riprap	Turbidity and sedimentation	Physical injury and mortality, temporary behavior modification/avoidance, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2

	Barges/vessels & crane/timber mats	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4
	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2
	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 3
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Stabilization/riprap placement	Habitat alteration/altered connectivity, altered sediment deposition	Behavior modification/avoidance, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 5
	Fill/disposal	Turbidity and sedimentation	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chpater 2 & 5
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1 & 5
		Habitat alteration/altered bottom habitat	Physical injury and mortality, temporary behavior modification, reduced fitness	Habitat loss & alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 5

		Habitat alteration/altered connectivity, altered sediment deposition	Temporary behavior modification/avoidance, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1 & 5
		Vessel interaction	Physical injury, temporary behavior modification, reduced fitness	Affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
Staging Area Establishment	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Staging areas may need to be established for delivery and storage of construction materials and equipment, contractor office and storage trailers, and parking. Staging areas vary in size and may require vegetation clearing, grubbing, grading, or excavation to level the site, and installation of drainage improvements. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, and vessel interaction.Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Stabilization/riprap placement	Habitat alteration/altered connectivity, turbidity and sedimentation/altered sediment deposition	Behavior modification, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1
	Substructures	Habitat alteration, turbidity and sedimentation	Behavior modification, reduced fitness	Loss of habitat, altered flow dynamics, affected prey resources	Chapter 1 & 2
	Superstructures	Habitat alteration/shading	Behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, affected prey resources	Chapter 4
	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2
	Barges/vessels & crane/timber mats	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 4
		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/ altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4

	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2
	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
Water Diversions/Cofferdams	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Cofferdams create isolated work areas that can be dewatered to allow work to be done in-the-dry. Cofferdams may consist of sandbags, causeways/ earthen structures, and/or large casings or structures created out of sheet piles. They may be installed with hammers, by crane and excavator, or placed by hand, depending on size. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, culverts, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Cofferdam construction/ installation	Underwater noise	Physical injury and mortality, temporary behavior modification, reduced fitness	Temporary localized habitat alteration, affected prey resources	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2
	Cofferdam in place	Habitat alteration/barriers	Temporary behavior modification, delayed movements	Temporary localized habitat loss	Chapter 2 & 4
	Cofferdam removal	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2

		Reduced water quality/ pollutant materials discharge	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized habitat alteration, affected prey resources	Chapter 1
	Dewatering, cofferdam pump-out	Impingement/entrainment, turbidity and sedimentation, reduced water quality	Physical injury and mortality, trapping/harassment, temporary behavior modification, reduced fitness	Temporarily affected water quality, temporary localized habitat alteration	Chapter 2 & 4
	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2
	Barges/vessels & cranes	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4
	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2
	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 3
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
Fill/Stabilization	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**

Fill and grading may be required prior to stabilization. Construction of temporary access fills and roads may be required to provide a working platform or access for machinery. Scour repair measures including fill and stabilization structures may be necessary. Fill may also be associated with disposal of excavated or dredged material. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, shoreline stabilization, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Fill/disposal	Turbidity and sedimentation	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
		Habitat alteration/altered bottom habitat	Physical injury and mortality, temporary behavior modification, reduced fitness	Habitat loss & alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/altered connectivity, altered sediment deposition	Temporary behavior modification/avoidance, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1 & 4
		Vessel interaction	Physical injury, temporary behavior modification, reduced fitness	Affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2
	Barges/vessels & crane/timber mats	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 4
		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4

	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2
	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 4
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
		Impingement and entrainment	Physical injury and mortality, trapping/ harassment, temporary behavior modification, reduced fitness	Temporarily affected water quality, temporary localized habitat alteration	Chapter 1 & 4
Demolition	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Demolition occurs by mechanical dismantling of structures from an adjacent structure or barge, or via land or through blasting. Structural components may be removed using a variety of methods such as cutting/sawing, blasting/chemical expansion (bentonite), hydraulic drilling, excavating, or by using a hoe ram, wrecking ball, clamshell dredge, or splitting wedges and hydraulic impact hammer. Demolition debris is typically mechanically removed and demolished structures are typically barged or trucked offsite for disposal. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, pile removal and blasting, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Mechanical removal or blasting	Underwater noise	Physical injury and mortality, temporary behavior modification, reduced fitness	Temporary localized habitat alteration, affected prey resources	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2

		Reduced water quality/ resuspended contaminants and pollutant materials discharge	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Excavation	Turbidity and sedimentation	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
		Habitat alteration/altered bottom habitat	Physical injury and mortality, temporary behavior modification, reduced fitness	Habitat loss & alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/altered connectivity, altered sediment deposition	Temporary behavior modification, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1
		Impingement and entrainment	Physical injury and mortality, trapping/harassment, temporary behavior modification, reduced fitness	Temporarily affected water quality, temporary localized habitat alteration	Chapter 4
		Vessel interaction	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
Pile Installation/Removal	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**

Piles support decking, provide temporary support during construction, serve as fenders and dolphins to protect structures, support navigation markers, and may support cofferdams, breakwaters, and bulkheads. They can be made of steel, concrete, wood, or plastic, and may be in the form of single piles or sheets. Piles can be driven into the substrate by impact or vibratory hammers, water jetting, or drilled/augured in by drilled shafts or rock sockets and may be removed by vibratory hammer, direct pull, clamshell bucket grab, cutting/breaking below the mudline, or mechanical demolition. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, pile installation, removal and blasting, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Pile installation via vibratory or impact hammer, water jetting	Underwater noise	Physical injury and mortality, temporary behavior modification, reduced fitness	Temporary localized habitat alteration, affected prey resources	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Excavation/drilled-shafts/columns/piers	Underwater noise	Physical injury and mortality; temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2
	Removal via direct pull/clam shell	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2

	Removal via vibratory hammer	Underwater noise	Physical injury, temporary behavior modification, reduced fitness	Temporary localized habitat alteration	Chapter 3
		Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, temporary localized habitat alteration, affected prey resources	Chapter 2
	Pile-cutting	Underwater noise	Physical injury, temporary behavior modification, reduced fitness	Temporary localized habitat alteration	Chapter 3
	Post-piling removal	Habitat alteration/altered bottom habitat	Physical injury and mortality, avoidance	Habitat alteration	Chapter 1 &3
	Barges/vessels	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4
	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
Dredging/Excavation	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Dredging is typically done with hydraulic or mechanical equipment to remove naturally accreting sediment, deepen or widen a waterway, or to return an area to pre-construction conditions. Dredging or excavation may be associated with the installation of sub-structures, placement of erosion and scour control measures or utility lines or cables, or to remove debris. Excavation is often necessary to key in stabilization materials. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, dredging, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.

	Dredging/excavation	Turbidity and sedimentation	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1 & 2
		Habitat alteration/altered bottom habitat	Physical injury and mortality, temporary behavior modification, reduced fitness	Habitat alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 2
		Habitat alteration/altered connectivity, altered sediment deposition	Temporary behavior modification, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 2
		Impingement and entrainment	Physical injury and mortality, trapping/harassment, temporary behavior modification, reduced fitness	Temporarily affected water quality, temporary localized habitat alteration	Chapter 2 & 4
		Vessel interaction	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2
	Barges/vessels & crane/timber mats	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1 & 2
		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4
	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2

	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
		Impingement and entrainment	Physical injury and mortality, trapping/ harassment, temporary behavior modification, reduced fitness	Temporarily affected water quality, temporary localized habitat alteration	Chapter 2 & 4
Vessel Activities	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Construction and maintenance of transportation projects can increase vessel traffic. Equipment access may be from barges, depending on site characteristics. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Vessel traffic/activity	Underwater noise	Physical injury, temporary behavior modification/avoidance, reduced fitness	Temporary localized habitat alteration, affected prey resources	Chapter 3
		Reduced water quality/ pollutant materials discharge	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
		Habitat alteration, turbidity and sedimentation/altered sediment deposition	Temporary behavior modification/avoidance, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1

		Impingement and entrainment	Physical injury and mortality, harassment, temporary behavior modification, reduced fitness	Temporary localized habitat alteration	Chapter 1
		Vessel interaction	Physical injury, temporary behavior modification, reduced fitness	Affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
Habitat Restoration, Establishment, and Enhancement	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
Habitat restoration, establishment, or enhancement may be done to restore areas impacted temporarily during the construction of a project, or as compensatory mitigation or to create mitigation banks. This may include excavation, fill, planting, invasive plant removal, channel reconstruction, shell placement, and living shorelines. Habitat restoration may also include demolition of abandoned or obsolete structures, debris removal, and/or sediment remediation. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Stabilization/riprap placement	Habitat alteration/altered connectivity, turbidity and sedimentation/altered sediment deposition	Behavior modification, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 5
	Substructures	Habitat alteration, turbidity and sedimentation	Behavior modification, reduced fitness	Loss of habitat, altered flow dynamics, affected prey resources	Chapter 1 & 2
	Superstructures	Habitat alteration/shading	Behavior modification, reduced fitness	Reduced light levels/ altered ambient light patterns, affected prey resources	Chapter 4
	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2
	Barges/vessels & crane/timber mats	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1, 2 & 4

		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/ altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4
	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2
	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Dredging/excavation/fill	Turbidity and sedimentation	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
		Habitat alteration/altered bottom habitat	Physical injury and mortality, temporary behavior modification, reduced fitness	Habitat alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/altered connectivity, altered sediment deposition	Temporary behavior modification, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1, 2 & 4

		Impingement and entrainment	Physical injury and mortality, trapping/harassment, temporary behavior modification, reduced fitness	Temporarily affected water quality, temporary localized habitat alteration	Chapter 2 & 4
		Vessel interaction	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
Scientific Measurement Devices/Survey Activities	**Components**	**Stressors**	**Species Effects**	**Habitat Effects**	**Best Management Practices**
The use of scientific measurement devices or survey activities may be necessary to collect data at a project site in advance of project design or construction or as a part of required monitoring. Such devices or survey activities may include staff or current gages, water recording and biological observation devices, soil borings, core sampling, historic resource surveys, and side scan sonar. Refer to the other applicable activities/sub-activities to ensure all aspects of a project are included.					See sections on underwater noise, impingement/entrainment, turbidity and sedimentation, reduced water quality, habitat alteration, and vessel interaction. Many chapters and sections provide important information and recommendations, but the chapters/sections indicated below are the most relevant to the particular stressors and effects.
	Stabilization/riprap placement	Habitat alteration/altered connectivity, turbidity and sedimentation/altered sediment deposition	Behavior modification, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1, 2 & 5
	Substructures	Habitat alteration, turbidity and sedimentation	Behavior modification, reduced fitness	Loss of habitat, altered flow dynamics, affected prey resources	Chapter 2
	Superstructures	Habitat alteration/shading	Behavior modification, reduced fitness	Reduced light levels/ altered ambient light patterns, affected prey resources	Chapter 4
	Temporary access roads/work areas	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 2
	Barges/vessels & crane/timber mats	Habitat alteration/vegetation smothering and sediment compaction, vessel interation	Temporary behavior modification, reduced fitness	Loss of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1, 2 & 4

		Habitat alteration/shading	Temporary behavior modification, reduced fitness	Reduced light levels/ altered ambient light patterns, limited plant growth/recruitment, altered plant/animal assemlages, altered behavior, affected prey resources	Chapter 4
	Heavy equipment & vehicles	Turbidity and sedimentation	Temporary behavior modification, reduced fitness	Minor localized water quality impacts	Chapter 2
	Spuds/spudding	Habitat alteration/vegetation smothering and sediment compaction	Temporary behavior modification, reduced fitness	Alteration of bottom habitat, altered sediment transport, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1, 2 & 4
	Earthwork	Turbidity and sedimentation	Physical injury, temporary behavior modification, reduced fitness	Affected water quality, affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
	Excavation	Turbidity and sedimentation	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected water quality, localized habitat loss and alteration (burying/covering), affected prey resources	Chapter 2
		Reduced water quality/ resuspended contaminants	Hazardous material exposure, physical injury, and mortality, temporary behavior modification, reduced fitness	Affected water quality, localized alteration, affected prey resources	Chapter 1
		Habitat alteration/altered bottom habitat	Physical injury and mortality, temporary behavior modification, reduced fitness	Habitat alteration, affected water quality, affected prey resources, foraging, sheltering and spawning habitat	Chapter 1
		Habitat alteration/altered connectivity, altered sediment deposition	Temporary behavior modification, reduced fitness	Shoreline habitat loss, affected foraging, sheltering and spawning habitat, affected prey resources	Chapter 1 & 2

		Impingement and entrainment	Physical injury and mortality, trapping/harassment, temporary behavior modification, reduced fitness	Temporarily affected water quality, temporary localized habitat alteration	Chapter 2 & 4
		Vessel interaction	Physical injury, temporary behavior modification/avoidance, reduced fitness	Affected prey resources, foraging, sheltering and spawning habitat	Chapter 1

12 Appendix G: Consolidated List of Recommended Best Management Practices for Transportation Projects in North Carolina, South Carolina, and Georgia

Implementing recommended best management practices (BMPs) will aid FHWA/state DOTs in avoiding and minimizing impacts to NMFS-trust resources by reducing the exposure of species and habitats to stressors and eliminating the plausible routes of effects. Projects that cannot avoid or sufficiently minimize impacts to species or habitats may need to implement mitigation measures. Though a comprehensive list of BMPs is provided, innovative techniques and methodologies may lead to the development of additional BMPs, but their use should be coordinated with NMFS on a case-by-case basis.

The BMPs are discretionary measures that transportation agencies can incorporate during project planning to avoid and minimizing potential impacts to NOAA-trust resources. The BMPs provide more transparency and predictability to FHWA and State DOTs regarding species conservation, habitat needs, and NMFS'recommendations. Frontloading BMPs into early design phases of projects will likely lead to reduced consultation timeframes, reduced delays, and could reduce the potential for future redesign of projects. Many BMPs can be incorporated into the design of projects, while others may be addressed as environmental commitments for contractors.

***** *All best management practices related to structural project components and construction techniques are contingent upon engineering feasibility and other design considerations.*

Environmental Windows/Moratoria

EW1 Activities should be timed and located in ways that avoid and minimize potential adverse impacts to NOAA-trust resources. This includes reducing or avoiding impacts to sensitive life history stages of organisms, and times of the year when critical activities such as migration, spawning, or egg and young-of-the-year development are occurring.

EW2 To the maximum extent practicable[19], activities should be conducted when species are not present in the project area, or are present in low densities.

EW3 Seasonal work windows are specific to regional environmental conditions, specific locations and waterbodies, and species requirements, therefore specific work windows should be coordinated with NMFS.

General and Incidental Project Activities

GP1 To the maximum extent practicable, projects should be designed in ways that avoid and minimize impacts to aquatic habitats, aquatic life, and their movements.

GP2 Non water-dependent actions should not be located in aquatic areas if such actions may have adverse impacts on NOAA-trust resources.

[19] Practicability is generally defined as feasibility as it relates to technology, cost, and logistics viewed in terms of the overall project purpose.

GP3 Activities that may result in significant adverse effects on fishery habitat should be avoided where less environmentally harmful alternatives are available. If alternatives do not exist, impacts of these actions should be minimized to the maximum extent practicable.

GP4 To the maximum extent practicable, projects should avoid filling aquatic habitats, minimize any permanent fill in aquatic areas, and avoid temporary fills for construction purposes; only clean fill should be used when fill is necessary.

GP5 Project footprints, including secondary areas for staging and other purposes, should be minimized to the maximum extent practicable.

GP6 All activities should be confined to construction work areas, as indicated on plans and drawings. This includes active right-of-way, staging areas, and access areas.

GP7 Temporary or permanent project elements should not impede or obstruct movement of any NOAA-trust resources.

GP8 All activities in shallow water habitats and sensitive habitats such as streams and tidal creeks, salt marsh, submerged aquatic vegetation (SAV), salt marsh, shellfish beds, and intertidal areas should be avoided and minimized to the maximum extent practicable (including work footprint, structures, temporary and permanent fill, excavation, etc.)

GP9 Construction in and shading of SAV, areas which historically supported SAV, and/or areas which are potential habitat for recolonization by SAV should be avoided; consult historic SAV surveys and conduct new pre-construction SAV surveys in the growing season.

GP10 Sensitive habitats, including SAV, shellfish beds, and saltmarsh, should be identified and marked in the field by a qualified, professional biologist prior to the start of any work activities to aid on-site personnel in avoiding unintended impacts to these habitats.

GP11 Permanent elevated structures should span aquatic environments to the maximum extent practicable; causeways and causeway fill should be minimized to the maximum extent practicable by extending bridges, steepening side slopes, using mechanically stabilized earth (MSE) walls, and other techniques.

GP12 Temporary water crossings should be minimized to the maximum extent practicable; temporary water crossings should be located in areas that disturb the least amount of area.

- Elevated bridges that minimize fill should be used for temporary water crossings.
- Environmental windows apply to in-water temporary water crossings.

GP13 In-water work areas should be isolated to minimize and avoid sediments and noise in the water (e.g., use siltation curtains, bubble curtains, isolation casings, etc.).

GP14 Appropriate water quality Best Management Practices (BMPs) for erosion and turbidity control should be used during all stages of construction and in all construction areas; inspect and maintain water quality BMPs regularly.

GP15 To the maximum extent practicable, all erosion, and sedimentation control measures should be installed prior to land clearing/disturbing activities (e.g., clearing and grubbing). Minimal land clearing may be necessary to install erosion and sedimentation control devices.

GP16 To the maximum extent practicable, all refueling, maintenance, and staging of equipment and vehicles should occur in locations where spills would not drain directly into aquatic habitat. All reasonable precautions should be taken to prevent spills from entering aquatic habitats during refueling and maintenance of machinery located on barges or trestles. Refueling should not take place on temporary rock jetties when the equipment can be moved into upland areas.

- To the maximum extent practicable, refueling should be done at least 250 feet from any water body and be outside of active stream channels, outside of any tidal areas, and away from ditches or channels that enter flowing waters; designated refueling sites in upland areas at least 250 feet away from receiving waters are preferred.

GP 17 All materials that will be placed in the water, including sheet piles, concrete piles, and erosion control materials, should be free of sediments and/or contaminants.

GP18 A spill response plan should be created for each project/activity. The plan and all materials necessary for its implementation should be accessible on-site. Toxicant input into any waters of the U.S. should be avoided; petroleum products, chemicals, live or raw concrete (freshly poured or concrete that has not yet set), or water contaminated by the aforementioned should not be allowed to enter flowing waters.

- To the maximum extent practicable, concrete washout pits/pans/pools should be located at least 500 feet from any water body and be outside of active stream channels, outside of any tidal areas, and away from ditches or channels that enter flowing waters; designated sites in upland areas at least 500 feet away from receiving waters are preferred.

GP19 A Spill Prevention, Control, and Countermeasure Plan (SPCC Plan; Section 311(j)(1)(C) of the Clean Water Act as amended by the Oil Pollution Act of 1990) should be created when appropriate. The rule may be found at Title 40, Code of Federal Regulations, Part 112.

GP20 To the maximum extent practicable, upland areas should be used for all general and incidental construction, including temporary construction access roads, SCEs, staging areas, and other secondary construction areas.

GP22 To the maximum extent practicable, all waste/borrow areas should be located in upland areas; spoils and stockpiles should be placed in upland areas and properly contained (e.g., with erosion and sedimentation controls).

GP22 Any work in wetlands or intertidal areas should be done using low ground pressure vehicles or temporary work trestles, to the maximum extent practicable. If necessary, crane/timber mats should only be used for short periods. Barge grounding should be avoided.

GP23 When practicable, existing ingress or egress points should be used to access work areas or work should be performed from the top of banks.

GP24 Measures that avoid tracking sediments out of the project area, such as stabilized construction entrances/exits, should be used.

GP25 Work pads, falsework (e.g., braces and scaffolding), and other construction items within wetlands or over water should be removed prior to the end of any construction window and as soon as work is complete.

GP26 A project schedule and plan should be developed prior to construction that avoids and minimizes impacts to NOAA-trust resources. Once initiated, projects should be carried to completion in an expeditious manner to minimize disturbance.

GP27 Upon completion, or where there is an extended work stoppage, all disturbed areas should be stabilized with vegetative cover and/or riprap, as appropriate. Locally native vegetation and/or native seed mixtures for the stabilization and landscaping should be used, to the maximum extent practicable. Planting media should be free of all debris and non-native or invasive species.

GP28 Placement or removal of fill and other structures should avoid impacts to sensitive habitats such as SAV and oyster aggregations. If avoiding SAV or oyster aggregations is not practicable, a relocation plan should be developed for the oyster aggregations and SAV within the project area. Any potential SAV or oyster relocation should be discussed and coordinated with NMFS (state agencies are generally included in this coordination). Compensatory mitigation should be provided for any unavoidable impacts.

GP29 All buffer areas, including riparian buffers, should be maintained to avoid and minimize disturbance. Buffer areas should not be used for general or incidental project construction if it can be avoided.

GP30 Watercourse diversions shall be minimized to the maximum extent practicable; all water bodies should be managed to minimize flooding of construction sites/work areas.

GP31 If temporary fills are unavoidable, geotextile fabric should be placed first to ensure that any fill will be removed completely at the end of construction. Clean riprap, free of debris, is the preferred material for temporary fills.

GP32 The use of temporary work platforms/trestles should follow the recommendations/guidance outlined in Chapter 4 for piling installation and removal.

GP33 Methods that smother marsh vegetation and compact sediments should be avoided, to the extent practical (e.g., crane/timber mats and barge grounding). Floating barges, temporary work platforms/trestles, and low ground pressure vehicles (vehicles that exert low pressure on the soil/substrate) should be utilized.

GP34 In-water lines, ropes, or chains should be made of materials and installed in a manner (properly spaced) to minimize the risk of entanglement by using thick, heavy, and taut lines that do not loop or entangle. Lines can be enclosed in a rigid sleeve.

GP35 Turbidity controls should be properly designed and implemented in a way that does not block entry to/from habitats. Turbidity controls should be monitored to ensure aquatic species do not become entangled or entrapped.

GP36 Cofferdams should be constructed and removed in accordance with Chapter 4 and should be placed to avoid main channels of streams, rivers, and tidal creeks.

GP37 Structures (temporary and permanent) should not impede or obstruct movement of species; individuals should not be prevented from accessing areas and habitats up and downstream of the project potentially used for spawning, foraging, resting, and migration.

GP38 Temporary scientific monitoring devices should be removed and the substrate restored to pre-construction elevations no later than 24 months from initial installation, or upon completion of data acquisition.

GP39 Monitoring devices should be used to ensure temperature and dissolved oxygen levels remain within the appropriate ranges for NOAA-trust species during project construction.

GP40 All obsolete and temporary structures and fill should be removed and areas restored to their pre-construction state. Any disturbed areas should be restored to pre-construction conditions.

GP41 All sedimentation and erosion control devices should be removed following final grading and stabilization of the project area.

GP42 In areas where listed species are expected, an observer plan should be discussed with and submitted to NMFS SERO PRD for review.

GP43 All vessels should be operated in adequate water depths to avoid scour or grounding and should travel at low speeds to avoid wake damage to shorelines and other habitats. Additional precautions, such as operating at no-wake speeds, should be taken if ESA-listed species may be present in the area.

GP44 The size/footprint of temporary rock jetties and rock platforms and time they are placed in the water should be minimized to the maximum extent practicable.

GP45 Temporary rock jetties and rock platforms should not exceed 50% of the width of the waterbody at a given time. In tidal areas, the width of the water body should be considered/measured at mean low water (MLW).

GP46 Temporary rock jetties and rock platforms that are greater than 25% of the width of the waterbody should have culvert(s) installed to allow for aquatic organism passage.

GP47 For temporary rock jetties, work at the terminal ends of the jetties should be proioritized for completion; removal of the jetties should then begin from the terminal ends to the extent practicable, working back towards the shoreline, allowing for stepwise widening of the passable opening in the waterbody.

GP48 Geotextile fabric should be placed first to ensure that any riprap from temporary rock jetties and rock platforms will be removed completely at the end of construction.

GP49 Any habitat restoration, such as restoring temporary impact areas to pre-construction conditions or removing and grading old-approach fill areas should be done by using systematic onsite surveys of pre-construction conditions and/or adjacent habitat conditions. Additionally, monitoring should occur following completion of restoration activities.

GP50 If no mitigation banks are available with credits suitable for offsetting impacts to EFH, mitigation for unavoidable impacts to EFH should occur on-site and be in-kind.

GP51 All projects should adhere to NMFS's *Sea Turtle and Smalltooth Sawfish Construction Conditions*, dated March 23, 2006. These conditions should also apply to Atlantic and shortnose sturgeon, including the requirement that construction stops temporarily if an ESA-listed species is sighted within 50 feet of mechanical construction equipment. The document can be found at: http://sero.nmfs.noaa.gov/protected_resources/section_7/guidance_docs/documents/

General Erosion, Turbidity, and Sedimentation

ETS1 Project elements should be located in ways that avoid and minimize long-term alterations to erosion, turbidity, and sedimentation; in-water project elements (e.g., pilings) should be placed in areas that avoid or minimize long-term scour (e.g., piles should not be placed in the center of channels).

ETS2 The amount and extent of erosion, turbidity, and sedimentation should be avoided and minimized by using appropriate controls such as sediment control fence, silt curtains, settling basins, cofferdams, isolation casings, and operational (equipment and timing) modifications; all measures to be used should be specified in construction plans.

ETS3 Stormwater BMPs should be used in accordance with National Pollution Discharge Elimination System (NPDES) Stormwater Pollution Prevention Plans (SWPPP) and other local/regional/state guidelines.

ETS4 When working in, or adjacent to, sensitive habitats such a submerged aquatic vegetation (SAV) or shellfish/oyster areas, multiple erosion, turbidity, and sedimentation controls should be used to minimize or avoid habitat impacts.

ETS5 To the maximum extent practicable, erosion control measures should be installed prior to ground-disturbance; erosion control measures should be used on any disturbed land not actively under construction (e.g., temporary seeding).

ETS6 Erosion and sediment control measures should be surveyed regularly for deficiencies. All deficiencies should be repaired or replaced immediately.

ETS7 Pumping turbid (sediment-laden) water directly into receiving waters without treatment should be avoided (e.g., settling basins, filter bags should be used).

ETS8 In intertidal areas, activities that disturb sediments should be conducted during low tide periods when sediments are exposed to reduce impacts of turbidity and sedimentation, to the maximum extent practicable.

ETS9 Aquatic turbidity and sedimentation control measures should be properly secured and monitored to ensure aquatic species are not entangled or trapped in the project area.

ETS10 Fills (temporary and permanent) should be placed in ways that will not be eroded by high water flows, storm flows, or chance (stochastic) events.

ETS11 Any fill material stockpiled for later use should be located in upland areas and surrounded by appropriate controls to avoid migration of material into nearby waterbodies.

ETS12 All erosion, turbidity, and sedimentation control measures should be promptly removed upon project completion.

ETS13 Measures to avoid tracking sediments out of the project area should be used, such as stabilized construction entrances/exits.

ETS14 Stormwater treatment facilities including ponds, swales, and retention/detention areas should be placed in low quality uplands if possible and avoid wetlands, salt marsh, tidal creek, and estuarine waters.

Dredging

DR1 New dredging should be avoided to the maximum extent practicable. Activities commonly requiring dredging such as the placement of piles/columns should be designed to eliminate the need for any maintenance dredging.

DR2 Dredging area and volume should be reduced to the maximum extent practicable that will still accomplish the project goal(s); areas that are within the project area, but are deeper than the target dredge depth should be avoided.

DR3 Dredge disposal sites should be appropriately considered (using the volumes of proposed dredged material) prior to dredging so disposal sites will adequately contain dredge material.

DR4 For maintenance dredging, sources of erosion in the watershed should be identified that may be contributing to excessive siltation and sedimentation and the need for maintenance dredging. To the maximum extent practicable, techniques or programs should be implemented that reduce erosion and sedimentation.

DR5 Silt or turbidity curtains should be used during dredging to reduce the impact of suspended sediments and potential for siltation of adjacent habitats.

DR6 For any dredging operations conducted during sea turtle nesting and emergence season, all lighting aboard dredging vessels/equipment near sea turtle nesting beaches should be limited to the minimum lighting necessary to comply with U.S. Coast Guard and/or Occupational Safety and Health Administration requirements. All non-essential lighting on dredging vessels/equipment should be minimized through reduction, shielding, lowering, and appropriate placement of lights to minimize illumination of the water to reduce potential disorientation effects on female sea turtles approaching the nesting beaches and sea turtle hatchlings making their way seaward from their natal beaches.

DR7 To the maximum extent practicable, dredging should be avoided in areas with fine sediments to reduce turbidity plumes and the release of nutrients and contaminants.

DR8 To the maximum extent practicable, dredging should be avoided in shellfish areas, intertidal and wetland habitats, in areas with SAV, areas that historically supported SAV, and areas, which are potential habitat for SAV. Surveys of historic and current SAV should be conducted to determine distribution and potential for recolonization of SAV.

DR9 To the maximum extent practicable, the use of suction/hopper dredges should be avoided.

DR10 If suction/hopper dredging is necessary, operations should be conducted in accordance with the regional biological opinion concerning the use of hopper dredges in channels and borrow areas along the Southeast U.S. Atlantic coast (referred to as SARBO).

DR11 Specialized equipment to avoid and minimize impacts to species should be used during dredging activities. These include, but are not limited to, sea turtle deflector dragheads and floating pipelines. Inflow screening baskets should be installed to monitor the intake and overflow of the dredge.

DR12 Operational modifications should be used to minimize turbidity and sedimentation during dredging. This could include using an environmental bucket, reducing lift speeds, and using small diameter cutterhead dredges.

DR13 Relocation trawling or scare/deterrence methods should be used to minimize impacts to species that may be present in the dredging project area.

DR14 Beneficial uses of uncontaminated sediments should be considered whenever practicable; materials that contribute to habitat restoration and enhancement should be prioritized.

DR15 Contaminant testing should be conducted on sediments prior to dredging and disposal and should meet U.S. Environmental Protection Agency requirements and standards.

DR16 Any accessory equipment such as pipelines associated with dredging activities should be placed to avoid sensitive habitats including shellfish areas, intertidal and wetland habitats, and in areas with SAV.

DR17 All work crews and personnel should be informed about any ESA-listed species that could occur in the dredge area. An action plan (typically in the species watch plan) should be available to all personnel, which outlines their responsibilities.

DR18 Dredge disposal areas should be properly sited, managed, and monitored to avoid impacts associated with dredge material placement.

Pile and Footing Installation

Pile selection

PI1 *Pile Type* - Driving steel piles results in more sound from individual pile strikes than concrete or wood piles of the same size. To the maximum extent practicable, concrete or wood piles should be used to reduce underwater sound levels from individual pile strikes.

PI2 *Pile Size* – Reducing pile size may reduce peak sound pressure levels, however, the use of smaller piles may require more piles be driven – potentially resulting in accumulated SEL values greater than with larger piles. For piles in or near sensitive habitats (such as areas where species are known to spawn, rest, or forage), the use of smaller piles should be analyzed as an avoidance and minimization measure.

Site Selection/Pile Placement

PI3 The number of piles installed and removed should be the minimum number necessary to accomplish the project purpose.

PI4 To the maximum extent practicable, piles should not be placed in streams, tidal creeks, and entrances to tidal creeks.

PI5 To the maximum extent practicable, pile installation, and removal should be avoided in shellfish areas and in areas with submerged aquatic vegetation (SAV), areas that historically supported SAV, and areas, which are potential habitat for SAV. Surveys of historic and current SAV should be conducted to determine distribution and potential for recolonization of SAV.

Pile installation Equipment

PI6 To the maximum extent practicable, vibratory hammers should be used to install driven piles, including metal sheet piles.

PI7 CIP piles (drilled-shaft methods) generate less underwater noise than impact hammers and, when possible, should also be used in lieu of pile driving with impact hammers (if vibratory hammers are not feasible).

PI8 If/when an impact hammer is necessary, a vibratory hammer should be used to first drive the pile as deep as possible.

PI9 When an impact hammer is necessary, cushions blocks (pile caps) should be placed between the top of the pile and the hammer (typical of many projects).

PI10 Water jetting should be avoided in areas with fine sediments to reduce turbidity plumes and the release of nutrients and contaminants. Jetting should also be avoided when in or adjacent to sensitive habitats, including shellfish areas and SAV.

Sound Attenuation Devices/Methods

PI11 Sound attenuation devices/methods should be used to reduce in-water noise levels generated by pile installation activities.

- *Air bubble curtains* - Air bubble curtains create a bubble screen, which can reduce or inhibit the propagation of sound from a pile. Effectiveness is largely based on the proper design and implementation of the bubble curtain. Bubble curtains are not effective in areas with strong currents.
- *Cofferdams* – Cofferdams can be used to isolate an area of the water column. Cofferdams are typically constructed of metal sheet pile and are dewatered to isolate the pile from the water, which attenuates sound by providing an air space between the pile and aquatic environment, although sound can still propagate through the ground and into the water column.
- *Isolation casings* – Isolation casings are typically hollow piles slightly larger in diameter than the pile to be installed. The casing is installed, then dewatered and permanent pile installed. The small air space between the pile and aquatic environment attenuates sound. Alternatively, the casing can be filled with sound-absorbing materials or bubbles.
- *Proprietary devices/methods* – Uncommon or proprietary attenuation devices/methods may be used following coordination/consultation with the NMFS.
- Attenuation devices/methods used in combination may have additive effects, further reducing sound generated during pile driving activities.

PI12 To the maximum extent practicable, pile installation activities should be limited to no more than 12 hours per day to allow species to move through an area during quiet periods.

PI13 Silt or turbidity curtains should be used to reduce the impact of suspended sediments and the potential for siltation/sedimentation of adjacent habitats. Curtains can also exclude species from an area.

PI14 In intertidal areas, piles should be installed during low tide periods when sediments are exposed.

PI15 Construction practices or equipment used for installing piles that smother vegetation should be avoided (e.g., barge mats placed on marsh vegetation for extended periods). Barge grounding should be avoided.

PI16 One of the following methods should be used to give animals the opportunity to leave an area prior to full-force pile driving when injurious noise levels may occur. When possible, these procedures should be used for a minimum of 10 minutes prior to full-force pile driving:

- “Ramp up” method (i.e., pile driving starts at a very low force and gradually builds up to full force),
- “Dry firing” method (i.e., operating the pile hammer by dropping the hammer with no compression), or
- “Soft start” method (i.e., noise from hammers is initiated for a short period (1 strike or 15 seconds), followed by a 1 to 3-minute waiting period – this sequence is repeated multiple times).

PI17 All pile installation activities should aim to keep acoustic levels below the behavioral and injurious thresholds for NOAA-trust resources.

Pile and Footing Installation

PR1 To the maximum extent practicable, the entirety of deficient or obsolete piles should be removed. If entire piles cannot be removed, piles should be cut at or below the mudline/stream bottom/substrate when possible.

PR2 To the maximum extent practicable, a vibratory hammer should be used (rather than direct pull or other methods) to remove piles, allowing sediments to slough off near the mudline. Piles should be removed slowly to give sediments a chance to slough off. Direct pull can be used if a vibratory hammer is not an option; however, the repeated movement or shaking of piles typically used during direct pull method can lead to increased turbidity and sedimentation, can alter the bottom topography near the pile, and could physically injure or kill NOAA-trust resources or their prey.

PR3 The the maximum extent practicable, holes left by removed piles should be filled with clean native sediments if they willt not fill on their own within two weeks. Consideration of this potential is important early in the coordination and permit processes, as this is typically a permitted action.

PR4 In intertidal areas, piles should be removed during low tide periods when sediments are exposed.

PR5 Construction practices or equipment used for removing piles that smother vegetation should be avoided (e.g., barge mats placed on marsh vegetation for extended periods). Barge grounding should be avoided.

PR6 To the maximum extent practicable, blasting should be avoided to remove piles and footings. Mechanical methods should be used instead of blasting.

PR7 To the maximum extent practicable, pile removal activities should be limited to no more than 16 hours per day to allow species to move through an area during quiet periods.

PR87 All pile removal activities should aim to keep acoustic levels below the behavioral and injurious thresholds for NOAA-trust resources.

Blasting

BL1 To the maximum extent practicable, confined blasts with stemmed charges should be used to focus/contain blast energy into the structure rather than being released into the water column.

BL2 Blast mats should be used and placed on top of structures to reduce debris ("fly rock") and lessen the acoustic signature during blasting operations.

BL3 If practical (hammers are on-site), dry-firing, ramping-up, and soft-start measured employed by pile driving hammers (if pile hammers are available on-site) should be used immediately prior to any blasting to reduce potential impacts to wildlife.

BL4 In some situations, pre-blast monitoring of the Danger Zone using nets (gill nets, trammel nets), tag receptors, and/or sonar to detect the presence/absence of listed species (e.g., shortnose and Atlantic sturgeon) may be necessary, particularly in known spawning habitats.

BL5 Noise attenuating devices, such as bubble curtains, should be employed to reduce the potential impacts of blasting activities and to reduce shockwave duration and intensity.

BL6 Blasting should be conducted during periods of low-water or low-tide to reduce impacts to habitats and species.

BL7 When ESA-listed species are known to be present, or could potentially be present, delays that turn the overall blast into a series of lesser-charged explosions should be used. The minimum delay between individual charges should be at least 9 milliseconds.

BL8 In areas where ESA-listed species are present, or are suspected to be present, detailed blasting plans should be submitted to NMFS for review and final approval prior to the commencement of blasting activities. In areas where ESA-listed species are not present, but EFH or federally managed fisheries are present, detailed blasting plans should be submitted to NMFS for review and comment prior to the commencement of blasting activities. Appropriate acoustic monitoring devices should be installed to adaptively manage the blasting plan.

BL9 In areas where ESA-listed species are present, or are suspected to be present, a weighted turbidity curtain should be placed around blast areas to act as a barrier. The area should be cleared of all ESA-listed species prior to closing the curtain by qualified fisheries biologists. If ESA-listed species are present (most likely Atlantic or shortnose sturgeon), or suspected to be present, the head fishery biologist must hold a current Section 10 permit for capturing and handling the species. If injury/mortality thresholds are expected, the turbidity curtain should be placed at a distance from the source beyond where injury thresholds would occur.

BL10 Pre-blast meetings should be held to discuss all requirements, concerns, and procedures prior to the commencement of blasting activities.

BL11 A Danger Zone around the blast area should be determined based on the maximum explosive weight per delay. A buffer zone beyond the zone of influence should also be considered (as a "heads-up" zone).

BL12 A "Species Watch Plan" should be implemented and include pre-, during, and post-blast monitoring by qualified fisheries personnel within and adjacent to the established zone of influence. Monitoring may be conducted from the air, atop elevated structures, and/or from boats or land.

BL13 All work crews and personnel should be informed about any ESA-listed species in the blast area. An action plan (typically in the species watch plan) should be available to all personnel.

BL14 Demolished materials should be removed from the aquatic environment as soon as is practicable following blasting and adhere to the Recommended Best Management Practices related to dredging in Chapter 2.

Bridges and Piers

BP1 Fill should be limited to the minimum amount necessary to complete the project.

BP2 Activities should be limited to the minimum amounts necessary to build new structures, replace functionally obsolete and/or structurally deficient structures, or to expand, restore or improve safety and functionality of existing structures.

BP3 To the maximum extent practicable, reduce the width, increase the height, and minimize the number of in-water substructures of bridges, piers, or docks to reduce the impacts of shading.

BP4 The height-width (HW) ratio of newly constructed (new or replacement) bridges, piers, or docks should be 0.7 or great.

BP5 To the maximum extent practicable, structures should be oriented in an N-S direction to reduce the impacts of shading.

BP6 For pedestrian and cyclist bridges and for piers and docks, the use of solid decking (concrete) should be avoided or minimized, to the extent practicable. Wood or composite planking with a consistent spacing of 0.5 inches between deck boards or grated decking with maximal open spacing should be used to minimize shading impacts. Other measures to reduce shading may exist, and their use should be coordinated with NMFS.

BP7 To the maximum extent practicable, bridges should be designed (mainly the height of the bridge) to accommodate a 100-year flow event, and allow for unimpeded tidal and storm flows without encroachment into stream or tidal creek channels (e.g., superstructure components should not impede or obstruct flows).

BP8 New and replacement bridges should be evaluated in reference to projected sea level rise relating to the design life of the structure. The range of sea level rise scenarios considered should be between three and six feet by 2100, as described in The Third National Climate Assessment, 2014 (U.S. Global Change Research Program).

BP9 For twin-span bridge expansion, space between the spans should be used first before expanding outward, to the maximum extent practicable.

BP10 For bridge replacements on existing or parallel alignments, approach-fills no longer used due to modifications of the bridge design (e.g., lengthening) or fills not intended to be used for stormwater treatment, should be removed to the maximum extent practical and graded to adjacent habitat levels, as determined through on-site surveys.

- o Monitoring should be done to verify establishment of target species occurs within one or two growing seasons.
- o Monitoring and performance standards should be proposed if the areas will be used for mitigation; a mitigation plan should be developed.
- o A functional assessment should be used to deduct all or a portion of the fill removal when determining total project impacts.
- o Restoration of existing approach-fill removal areas should be coordinated with the NMFS and state resource agencies. Living shorelines should be prioritized in these areas (refer to Guidance for Considering the Use of Living Shorelines, NOAA 2015, discussed in Chapter 5).

BP11 To the maximum extent practicable, top-down construction methodologies should be used to avoid and minimize impacts.

BP12 The use of temporary work trestles, floating barges, and low ground bearing pressure track equipment should be maximized for access to construction areas. The use of temporary fills and timber/crane mats should be avoided, to the maximum extent practicable.

BP13 Work areas should be isolated from adjacent streams, tidal creeks, wetlands or other waters of the U.S. by placing silt fences, silt curtains, or other approved sediment and erosion control devices on the perimeter of the work area to prevent sediment input into any waters of the United States.

BP14 Any shoreline stabilization and placement of new material for shoreline stabilization should be minimized to amounts necessary to construct or protect a structure. See Chapter 5 for additional recommendations.

BP15 To reduce impacts to sea turtles, fishing from roadway, pedestrian, and cycling bridges should be prevented where sea turtles may occur.

BP16 In areas where sea turtles occur, artificial lighting associated with bridges should be oriented to avoid and minimize illumination of the surrounding waters at night.

BP17 Structures should be designed to minimize the need and frequency for future maintenance dredging.

BP18 For bridge maintenance activities such as scraping and painting that may result in debris or contaminants falling directly into the water, full containment measures, such as diaper curtains, should be used.

BP19 A combination of structural (post-construction in-situ and end-of-pipe controls) and non-structural (source control, design-related, and maintenance) stormwater control measures should be used to minimize or mitigate the effects of bridge runoff.

BP20 To the maximum extent practicable, stormwater systems should be designed to accommodate increased precipitation events, including heavy/intense precipitation events, which have increased as a result of climate change.

BP21 To the maximum extent practicable, systems that redirect runoff through constructed infrastructure that includes both closed (typically pipes) and open systems should be used.

BP22 To the maximum extent practicable, the use of direct systems that allow runoff to discharge freely to the surface waters below bridges through deck drains or scuppers should be avoided.

Culverts

CU1 Culvert installation, construction, maintenance, and demolition activities should be timed and located in ways that avoid and minimize potential adverse impacts to NOAA-trust resources. This should include implementing seasonal work windows.

CU2 The number of crossings where culverts would be necessary should be minimized by realigning roadways and consolidating water crossings.

CU3 Culvert size should accommodate a 100-year flow event and allow unimpeded tidal and storm flows without encroachment into stream or tidal creek channels.

CU4 Culverts should allow for normative physical processes within the stream-floodplain corridor by promoting natural sediment transport patterns, providing unaltered fluvial debris movement, and restoring or maintaining functional longitudinal continuity and connectivity of the stream-floodplain system. Culverts should be designed to maintain or replicate natural stream channel and flow conditions; the structure should allow unimpeded base flows, peaks flows, stormflows, and the full-range of tidal flows.

CU5 Culvert design and alternative selection should be based on the biological significance and ecological risk of a particular site – culverts should be designed with the focus on facilitating aquatic organism passage through a culvert and maintaining overall ecological connectivity.

CU6 To the maximum extent practicable, the preferred alternatives for water body crossings outlined below for both new culverts and culvert replacement projects should be followed. The alternatives and structure types should be considered in order of preference:

- Nothing – Road abandonment and reclamation; realignment to avoid crossing water bodies altogether.
- Bridge – spanning the entire water body and flood plain to allow for long-term dynamic channel stability, floodplain connectivity, retention of existing habitat, maintenance of food (primary producers and benthic invertebrate) production, and minimized risk of failure.
- Active channel design – culverts are sized sufficiently large enough and/or embedded deep enough into the channel to allow the natural movement of bedload and formation of a stable bed inside the culvert.
- Stream simulation strategies – Embedded culverts, bottomless culverts or non-floodplain spanning stream simulation.
- Hydraulic design methods/non-embedded culvert – associated with more traditional culvert design approaches limited to low slopes for fish passage.
- Culvert designed with fishway (including roughened channels) – for areas with steeper slopes.
- Baffled culvert/internal weir– for use only when other alternatives are infeasible.

CU7 Culverts should maintain low flow conditions at all times; multiple small, parallel culverts should be avoided.

CU8 Culvert replacements should be “in-kind” or follow the order of preference listed above.

CU9 To the maximum extent practicable, undersized and perched culverts should be replaced as soon as possible, following the order of preference listed above.

CU10 Damaged or poorly functioning culverts should be replaced as soon as possible, following the order of preference listed above.

CU11 For projects that may affect fish passage, project documents should describe how the proposed structure would meet the active channel design, stream simulation, or hydraulic design criteria. These criteria are described in the publications listed below. The included analysis should evaluate the existing and proposed channel conditions within the action area and vicinity. Types of analysis used to assess fish passage conditions include hydraulic, geomorphic, and sediment and debris transport.

CU12 For work on crossings with known or potential tidal restrictions, tide gauge data should be collected to quantify the restriction and develop alternatives that can be evaluated prior to and during the design phase of the project.

CU13 Unimpeded water flows to adjoining habitats should be allowed throughout all construction phases (including maintenance and demolition) of culvert projects; cofferdams may restrict or reduce flows during construction, but should not block or inhibit all flow, to the maximum extent practicable. If flow must be blocked or inhibited, the duration should be minimized to the maximum extent practicable.

CU14 Cofferdams required for culvert projects should be placed in ways that avoid sensitive habitats (e.g., submerged aquatic vegetation and oyster reefs) and do not block passage of aquatic organisms; individual stressors and effects generated from coffer dam construction should be avoided and minimized as described in other chapters (e.g., Chapter 3 for hydroacoustic effects). If flow must be blocked or inhibited, the duration should be minimized to the maximum extent practicable.

CU15 All fish, and any managed or listed species, should be removed prior to dewatering cofferdams. Removal should only be undertaken by qualified fisheries biologists. If ESA-listed species are present (most likely Atlantic or shortnose sturgeon), or suspected to be present, the head fishery biologist must hold a current Section 10 permit for capturing and handling the species.

CU16 Upstream and downstream channel and bank conditions should be maintained and stabilized if the crossing structure causes erosion or accretion problems.

CU17 Shoreline stabilization and placement of new material for shoreline stabilization associated with culverts should be limited to the minimum amounts necessary to protect culverts. See Chapter 5 for additional recommendations.

CU18 Structures should be designed and located to avoid or minimize the need and frequency for future maintenance activities, including dredging.

CU19 For culvert maintenance, removal of sediment and debris should be limited to the minimum amount necessary to restore normal flows of the waterway. Normally, this removal would be within 100 feet of the culvert. Removed sediments and debris should be placed in an upland location isolated from streams, tidal creeks, road drainages, or other waters of the United States.

CU20 All fish passage projects in NMFS' jurisdiction should be coordinated with NMFS SERO PRD and HCD biologists as early in the process as possible.

The majority of peer-reviewed and technical literature recommends that bridges should be used in lieu of culverts whenever possible. If bridges are not feasible, numerous publications provide planning and design recommendations, as well as construction specifications for the construction and placement of culverts in aquatic environments. Though numerous publications focus on salmonid passage, the principles described for salmonids are broadly applicable for the passage of most aquatic organisms. The most relevant publications include[1]:

Anadromous salmonid passage facility design. NMFS, 2011; Guidelines for salmonid passage at stream crossings. NMFS, 2001. http://www.westcoast.fisheries.noaa.gov/publications/

Design of road culverts for fish passage. Washington Department of Fish and Wildlife (WDFW). 2003. http://wdfw.wa.gov/publications/00049/

Culvert design for aquatic organism passage. Federal Highway Administration (FHWA). 2010. https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=204&id=145

Hydraulic design of highway culverts, Third Edition. Federal Highway Administration (FHWA). 2012. https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=7&id=13

Relevant publications related to the impacts of climate change and SLR should be used when developing bridges, piers, and culvert projects. These publications include, but are not limited to:

HEC-25. Highways in the coastal environment – assessing extreme events. 2014. Hydraulic Engineering Circular No. 25. https://www.fhwa.dot.gov/engineering/hydraulics/

HEC-17. Highways in the river environment – floodplains, extreme events, risk, and resilience. 2016. Hydraulic Engineering Circular No. 17, 2nd edition. https://www.fhwa.dot.gov/engineering/hydraulics

Shoreline Stabilization Installation

SSI1 Activities should be limited to the minimum amount necessary for the erosion prevention/stabilization needed to accomplish the project purpose. For maintenance of existing shoreline stabilization – activities should be limited to those within the same footprint of the original permitted shoreline stabilization.

SSI2 Shoreline stabilization projects should be coordinated with the NMFS and local resource agencies to determine if living shorelines are feasible.

SSI3 To the maximum extent practicable, living shorelines should be prioritized for shoreline stabilization projects. This includes new shoreline stabilization and repairing, replacing, or maintaining existing shoreline stabilization.

SSI4 Shoreline stabilization projects emphasizing living shorelines should utilize structural and local building materials, including wetlands plants, oyster reefs, and sand fills.

SSI5 Shoreline stabilization installation projects occurring in flowing or standing water should be isolated from the rest of the waterbody by using silt fences (with sand bags on the toe), turbidity curtains, or other methods in order to prevent sediment input into the water. Work operations should cease if water rises above the silt fence. Cofferdams may also be used, but are recommended for smaller work areas.

SSI6 When riprap is required, clean rock or masonry riprap (free of pollutants, debris, soil or other materials) should be used.

SSI7 To the maximum extent practicable, materials, such as treated wood, that could leach chemicals into waters adjacent to shoreline stabilization projects should be avoided.

SSI8 To the maximum extent practicable, shoreline stabilization material related to traditional (hardened) structures, including rock riprap and armorstone, should not be placed below the water line.

SSI9 If the project involves the installation of any piles or foundations, including metal sheet piling, Chapter 3 should be used for guidance.

SSI10 If the use of metal sheet piling or piles is unavoidable, a vibratory hammer should be used for installation to reduce hydroacoustic impacts.

SSI11 Concrete mats, debris, metal sheet piling, or other similar material should not be used for shoreline stabilization, as these materials adversely impacts quality and quantity of habitats.

SSI12 To the maximum extent practicable, shoreline stabilization in streams, tidal creeks, and entrances to tidal creeks should be avoided.

SSI13 To the maximum extent practicable, shoreline stabilization should be avoided in, or adjacent to, shellfish areas and in areas with submerged aquatic vegetation (SAV), areas which historically supported SAV, and areas which are potential habitat for SAV. Surveys of historic and current SAV should be conducted to determine distribution and potential for recolonization of SAV.

SSI14 All work crews and personnel should be informed about any ESA-listed species in the area and should have a designated individual (typically environmental manager) to contact when listed species are observed.

SSI15 Work should not begin if ESA-listed species are observed in the area prior to commencement of work; Work should not begin until ESA-listed species have not been observed for a 30-minute period.

Shoreline Stabilization Removal

SSR1 If the project involves the removal of any piles or foundations, including metal sheet piling, Chapter 3 should be used for guidance.

SSR2 Shoreline stabilization removal projects occurring in flowing or standing water should be isolated from the rest of the waterbody by using silt fences (with sand bags on the toe), turbidity curtains, or other methods in order to prevent sediment input into the water. Work operations should cease if water rises above the silt fence. Cofferdams may also be used, but are recommended for smaller work areas.

SSR3 Failing shoreline stabilization structures/materials should be removed and disposed of off-site and/or in upland areas, where there is no chance for migration into aquatic areas.

SSR4 Following shoreline stabilization removal, areas should be restored to natural conditions. Areas that previously had shoreline stabilization should be graded to match adjacent elevations and revegetated with native vegetation, including native species that are found adjacent to the site.

SSR5 All work crews and personnel should be informed about any ESA-listed species in the area and should have a designated individual (typically environmental manager) to contact when listed species are observed.

SSR6 Work should not begin if ESA-listed species are observed in the area prior to commencement of work; Work should not begin until ESA-listed species have not been observed for a 30-minute period.

13 Appendix H: Atlantic sturgeon and shortnose sturgeon Migration and Spawning Timeframes in the Southeast Region

To avoid potential adverse impacts to migrating and spawning sturgeon, in-water work moratoria (times of year where in-water work is prohibited) may be adopted in known spawning/migration rivers. Moratoria prohibit in-water work when species are most likely to be present in a project area, based on life-history information, habitat requirements, recent research, publications, and reports. Due to species and regional differences in NC, SC, and GA, moratoria are not identical across the states. Moratoria can be suggested/included in the project-level submission documents (e.g., biological evaluation) transmitted from FHWA/state DOTs to NMFS as a measure to avoid and minimize potential impacts to sturgeon. Small variations (e.g., 10 days) in the moratoria dates can be proposed by FHWA/state DOTs in submission documents for NMFS consideration, if warranted by the specific project.

This table only applies to portions of rivers where migration and spawning occur. Shortnose sturgeon (of all age classes) and juvenile Atlantic sturgeon generally occupy lower portions of rivers and estuaries throughout the year. Therefore, there is no definable moratoria for these portions of rivers and estuaries. Examples of these rivers include the Waccamaw River (up to Bull Creek) in South Carolina, the Savannah River in Georgia from Millstone Landing south to the Atlantic Ocean, and the Cape Fear River (including the Brunswick River) from the US-76 Bridge south to the Atlantic Ocean in North Carolina.

State	River	Atlantic sturgeon present?	Shortnose sturgeon present?	Recommended Moratoria (no in-water work)
NC	Roanoke	Y	N	August 15 – October 31
NC	Tar	Y	N	August 15 – October 31 (none documented)
NC	Neuse	Y	N	August 15 – October 31
NC	NE Cape Fear	Y	N	March 1 - May 30 & August 15 – October 31
NC	Cape Fear	Y	Y	February 15 – May 15 & August 15 – November 15
SC	Great Pee Dee	Y	Y	September 1 – November 30 & January 16 – May 30
SC	Santee	Y	Y	September 1 – November 30 & January 16 – April 30

SC	Cooper	Y	Y	September 1 – November 30 & – January 16 - April 30
SC	Wateree	N	Y	January 16 – April 30
SC	Congaree (including Broad River to Columbia Diversion Dam)	N	Y	January 16 – April 30
SC	Edisto River	Y	N	September 1 – November 30 & March 1 – May 30
SC	North Fork Edisto River	Y	N	September 1 – November 30 & March 1 – May 30
SC	South Fork Edisto River	Y	N	September 1 – November 30 & March 1 – May 30
SC	Combahee	Y	N	September 1 – November 30 & March 1 – May 30
SC/GA	Savannah	Y	Y	August 1 – November 30 & January 16 – April 30
GA	Ogeechee	Y	Y	August 1 – November 30 & January 16 – April 30
GA	Altamaha	Y	Y	No definable moratoria; year-round presence
GA	Oconee	Y	Y	August 16 – November 15 January 16 – April 15
GA	Ocmulgee	Y	Y	August 16 – November 15 January 16 – April 15
GA	Satilla	Y	Y	No definable moratoria due to lack of data, but likely year-round presence in lower river. Suggested moratoria similar to the Ocmulgee River (see above).
GA/FL	Saint Marys	Y	N	No definable moratoria due to lack of data, but likely year-round presence in lower river. Suggested moratoria similar to the Ocmulgee River (see above).