NOAA Fisheries/Federal Highway Administration Best Management Practices Manual For Transportation Activities in the Greater Atlantic Region

NOAA Fisheries/FHWA Best Management Practices (BMPs) Manual for Transportation Actions in the Greater Atlantic Region

In fulfillment of Task 2 of Interagency Agreement No. DTFH61-13-X-30040, and as amended DTFH61-13-X00040-0001: Guidance document including:
1) a best management practice manual specific to transportation projects affecting EFH and ESA-listed species and their critical habitat in the Greater Atlantic Region and
2) a spreadsheet with project types, resource effects, and conservation measures

Prepared in Collaboration through an Interagency Agreement by:

National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office (GARFO)

55 Great Republic Drive, Gloucester, MA 01930

With and for:

Federal Highway Administration, Office of Project Development and Environmental Review

1200 New Jersey Avenue SE, Washington, DC 20590

Assisted by:

Volpe, The National Transportation Systems Center, U.S. Department of Transportation

55 Broadway, Kendall Square, Cambridge, MA 02142

VERSION 1.0: June 1, 2017

Table of Contents

Tables and Figures

1.0 Introduction

The Endangered Species Act (ESA), Magnuson-Stevens Fishery Conservation and Management Act (MSA), and the Fish and Wildlife Coordination Act (FWCA) require federal agencies, such as the Federal Highway Administration (FHWA) to consult with NOAA's National Marine Fisheries Service (NOAA Fisheries) on actions they fund, permit, or carry out that may adversely affect ESA-listed species and their critical habitat, essential fish habitat (EFH), and/or other NOAA-trust resources. These consultations between FHWA and NOAA Fisheries are conducted to minimize adverse effects from transportation projects on NOAA-trust resources. This Best Management Practices (BMP)[1] Manual provides a summary of the potential adverse effects produced by transportation projects as well as NOAA Fisheries' Greater Atlantic Regional Fisheries Office's (GARFO) recommended measures to avoid, minimize, and/or offset those adverse effects.

The guidance in this BMP Manual provides a consistent, biologically driven effects analysis for the full range of transportation projects affecting ESA-listed species and their critical habitats, designated EFH, and other NOAA-trust resources[2] under NOAA Fisheries' jurisdiction in the Greater Atlantic Region (GAR). GARFO's jurisdiction includes any coastal or riverine areas where ESA-listed species, EFH, and/or NOAA-trust resources may be present in the GAR. This Manual is applicable for transportation activities in Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, and Virginia.

The BMPs provided herein are recommended measures for transportation agencies to incorporate into their projects to avoid, minimize, and offset adverse effects to ESA-listed species and their critical habitat, EFH, and NOAA-trust resources. The BMPs provide more transparency and predictability to transportation agencies, including FHWA and state Departments of Transportation (DOTs) regarding species conservation, habitat needs, and GARFO's recommendations. This conservation strategy facilitates project approvals by enabling transportation agencies to incorporate impact avoidance and other minimization strategies during project planning. For transportation activities that cannot fully avoid impacts, project proponents can incorporate these BMPs in the design or planning phases to minimize impacts and future redesign of projects. The information in this document can also be used to inform transportation agencies of options that may be incorporated in design scenarios and alternatives development and in conducting biological evaluations and assessments. This approach is intended to improve predictability, increase consistency of project design and review, reduce consultation timeframes and delays, and contribute to the conservation of trust resources, leading to improved environmental outcomes.

[1] This manual uses the term "Best Management Practices (BMPs)" to represent the preferred practices, methods, actions, materials and other items that avoid and minimize impacts to ESA-listed species and their critical habitat, EFH, and NOAA-trust resources.
[2] Many NOAA-trust resources serve as prey for federally-managed species and are therefore a component of EFH.

2.0 ESA-Listed Species and Critical Habitat in the Greater Atlantic Region

The ESA provides protection to species listed as threatened and endangered. In most cases, once a species is listed as threatened or endangered, critical habitat[3] must also be designated. Critical habitat includes areas occupied by the species, in which are found physical and biological features (PBFs)[4] that are essential to the conservation of an ESA-listed species and which may require special management considerations or protection. Critical habitat may also include unoccupied habitat if it is essential for the conservation of the species. Some species are listed as one unit throughout their range and some species are listed as distinct population segments (DPSs) with each DPS treated as a separate species. An overview of the ESA-listed species under GARFO jurisdiction is provided below.[5]

More detailed information on species biology and site-specific distribution of these species is provided in NOAA Fisheries' species presence tables.[6] These tables provide specific information on locations of ESA-listed species including seasonality, life stages, and behaviors of the animals in distinct geographic areas. The GARFO ESA-Listed Species Maps provide a visual overview of the presence of a particular ESA-listed species using the best available knowledge, geographic factors, time of year, and the biology of that species. These tools allow for proactive conservation, prior to conducting ESA consultation. FHWA/DOT can use the site-specific information to inform preparation of a Biological Assessment, and ultimately avoid and minimize impacts to ESA-listed species by determining why and how stressors impact which species and connecting that to the appropriate BMPs to minimize their interaction.

2.1 Fish

2.1.1 Atlantic salmon (*Salmo salar*) – Endangered

The Gulf of Maine DPS of anadromous[7] Atlantic salmon was listed jointly by NOAA Fisheries and United States Fish and Wildlife Service (U.S. FWS) (the Services) as an endangered species on November 17, 2000. In 2009, the Services finalized an expanded listing of Atlantic salmon and its designated critical habitat (74 FR 29344, June 19, 2009). The current Gulf of Maine DPS includes all anadromous Atlantic salmon whose freshwater range occurs in the watersheds from the Androscoggin River northward along the Maine coast to the Dennys River and wherever these fish occur in estuarine and marine environments. The marine range of Gulf of Maine DPS

---

[3] Section 3(5)(A) of the ESA (16 U.S.C. 1532(5)) defines critical habitat as: (i) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 4 of the Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside of the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 4 of the Act, upon a determination by the Secretary that such areas are essential for the conservation of the species.

[4] "Physical or biological features" are the features that support the life-history needs of the species, including, but not limited to, water characteristics, soil type, geological features, sites, prey, vegetation, symbiotic species or other features.

[5] This guidance does not address Marine Mammal Protection Act (MMPA) concerns. For impacts to species covered under the MMPA that are not ESA-listed species, refer to NOAA Fisheries' website for further information.

[6] For actions incorporating this information including species information and BMPs, FHWA/DOT should first ensure that the most recent version is used (including any updates to the ESA section 7 maps).

[7] Anadromous fish are a subset of diadromous fish. Anadromous fish live as adults in saltwater and spawn in freshwater.

extends from the Gulf of Maine, throughout the Northwest Atlantic Ocean, to the coast of Greenland. Included in the Gulf of Maine DPS are all associated conservation hatchery populations used to supplement these natural populations; currently, such conservation hatchery populations are maintained at Green Lake National Fish Hatchery and Craig Brook National Fish Hatchery, both operated by U.S. FWS. Excluded from the Gulf of Maine DPS are landlocked Atlantic salmon and salmon raised in commercial hatcheries for the aquaculture industry.

2.1.1.1 Atlantic salmon critical habitat

With the June 19, 2009 endangered listing, the Services designated critical habitat for the Gulf of Maine DPS of Atlantic salmon. The final rule was revised on August 10, 2009 (74 FR 39003). In this revision, designated critical habitat for the expanded Gulf of Maine DPS of Atlantic salmon was updated to exclude trust and fee holdings of the Penobscot Indian Nation. The final rule identified 45 specific areas containing over 19,000 kilometers of rivers and streams and 799 square kilometers of lakes and ponds as having the PBFs essential to the conservation of the species, which may require special management or protections.

Within the occupied range of the Gulf of Maine DPS, Atlantic salmon PBFs include sites for spawning and incubation, sites for juvenile rearing, and sites for migration. The PBFs that allow these sites to be used successfully for spawning, incubation, rearing, and migration are the features of habitat within the Gulf of Maine DPS that are essential to the conservation of the species. A detailed review of the PBFs required by Atlantic salmon is provided in Kircheis and Liebich (2007). GIS layers for Atlantic salmon critical habitat are available at NOAA Fisheries' Geographic Information System website. Atlantic salmon is unique because in addition to having populations listed as endangered, it also has designated EFH. Atlantic salmon critical habitat and EFH may overlap in some areas.

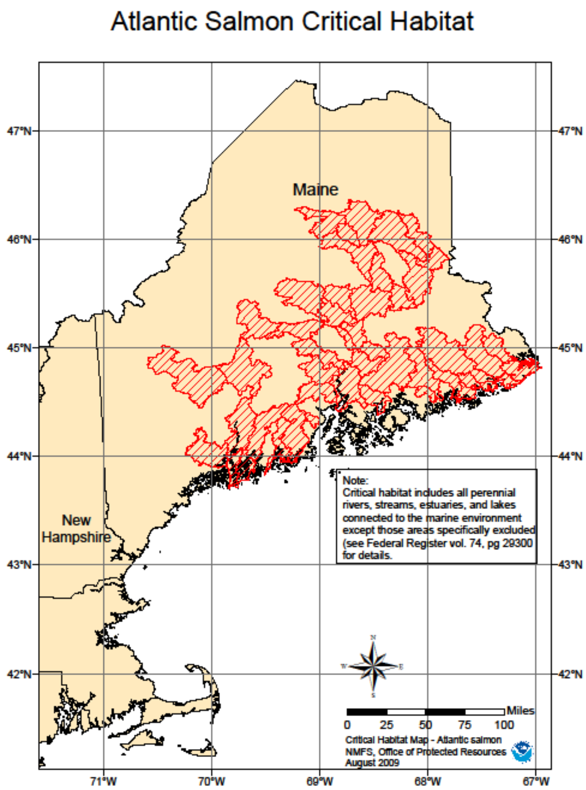

Figure 1. Atlantic Salmon Critical Habitat

2.1.2 Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) – Endangered and Threatened

- Gulf of Maine DPS – Threatened
- New York Bight DPS – Endangered
- Chesapeake Bay DPS – Endangered
- Carolina DPS – Endangered
- South Atlantic DPS – Endangered

On February 6, 2012, NOAA Fisheries listed four DPSs of Atlantic sturgeon as endangered (New York Bight, Chesapeake Bay, Carolina, and South Atlantic) and one DPS as threatened (Gulf of Maine) under the ESA (77 FR 5880 and 77 FR 5914). The marine range for all five DPSs includes all marine waters, coastal bays and estuaries, from Labrador Inlet, Labrador, Canada to Cape Canaveral, Florida. The ranges of all five DPSs overlap. Based on the best available information on the distribution of Atlantic sturgeon, NOAA Fisheries determined that Atlantic sturgeon from any of the five DPSs may be present in the GAR. Atlantic sturgeon migrate into the ocean from the river they were born, at two or three years old ("subadults"); they occur along the U.S. Atlantic coast using rivers and estuaries. Spawning most often occurs in late spring or early summer (April to June), and fall spawning occurs in some rivers (e.g., James and York Rivers). Spawning typically occurs in flowing water between the salt front and fall line of large rivers.

2.1.2.1. Atlantic sturgeon proposed critical habitat

NOAA Fisheries issued two proposed rules to designate critical habitat for the five listed DPSs of Atlantic sturgeon in U.S. waters: 1) Gulf of Maine, New York Bight, and Chesapeake Bay DPSs (81 FR 35701; June 3, 2016); and 2) Carolina and South Atlantic DPSs (81 FR 41926; June 28, 2016). The proposed rules identified four PBFs necessary for the conservation of the species:

1. Hard bottom substrate (e.g., rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (i.e., 0.0 to 0.5 parts per thousand (ppt) range) for settlement of fertilized eggs, refuge, growth, and development of early life stages;
2. Aquatic habitat with a gradual downstream salinity gradient of 0.5 to 30 ppt and soft substrate (e.g., sand, mud) downstream of spawning sites for juvenile foraging and physiological development;
3. Water of appropriate depth and absent physical barriers to passage (e.g., locks, dams, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support: 1) unimpeded movement of adults to and from spawning sites; 2) seasonal and physiologically dependent movement of juveniles to appropriate salinity zones within the river estuary; and 3) staging, resting, or holding of subadults or spawning condition adults. Water depths in main river channels must also be deep enough (e.g., ≥1.2 m) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river; and
4. Water, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support: 1) spawning; 2) annual and inter-annual adult, subadult, larval, and juvenile survival; and 3) larval, juvenile, and subadult growth, development, and recruitment (e.g., 13°C to 26°C for spawning habitat and no more than 30°C for juvenile rearing habitat, and 6 mg/L DO for juvenile rearing habitat).

GARFO is leading the rulemaking for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs, while the Southeast Regional Office is leading the Carolina and South Atlantic DPSs. The public comment period on NOAA Fisheries' proposed rule for the critical habitat designation closed on September 1, 2016. During the proposed rule period, FHWA is required to confer with NOAA Fisheries on any activities that could destroy or adversely modify the proposed critical habitat.[8] NOAA Fisheries is expected to publish the final rule by July 18, 2017. In the GAR, critical habitat for Atlantic sturgeon is proposed within the following river systems: 1) Penobscot, 2) Kennebec, 3) Androscoggin, 4) Piscataqua, 5) Merrimack, 6) Connecticut, 7) Housatonic, 8) Hudson, 9) Delaware, 10) Susquehanna, 11) Potomac, 12) Rappahannock, 13) York, and 14) James. The habitat containing the physical features essential to the conservation of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs and that may require special management or protection is aquatic habitat of main stem rivers flowing into a coastal estuary.

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

Atlantic sturgeon typically cannot pass dams or natural features such as waterfalls and rapids found at the fall line of rivers from Maine through Virginia. Therefore, NOAA Fisheries defined each critical habitat unit for these three DPSs by an upriver landmark on the main stem river (e.g., the most downriver dam or a bridge immediately downriver of the fall line of that river) and all waters of the main stem downriver of that landmark to where the waters empty at its mouth into an identified water body (81 FR 35701).

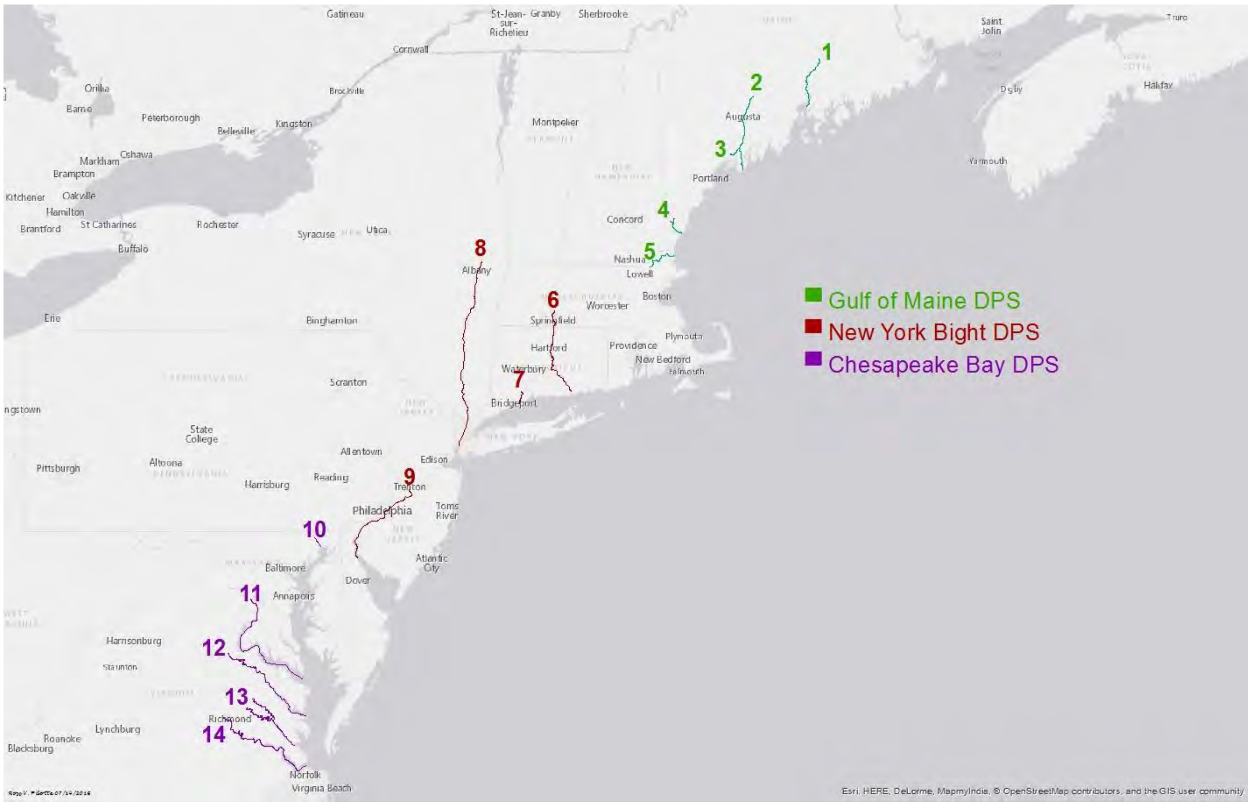

Figure 2. Atlantic Sturgeon Proposed Critical Habitat in the GAR

2.1.3 Shortnose sturgeon (*Acipenser brevirostrum*) – Endangered

Shortnose sturgeon are listed as endangered by NOAA Fisheries (32 FR 4001, March 11, 1967). Shortnose sturgeon occur in most major Atlantic river systems from the Minas Basin in Nova Scotia, Canada, to the St. Johns River, Florida. Spawning populations have been documented in the following large coastal river systems: the Penobscot, Kennebec, Androscoggin, Merrimack, Connecticut, Hudson, Delaware, and Potomac Rivers. Unlike adult Atlantic sturgeon that range widely along the coast, most adult shortnose sturgeon remain in their natal river or estuary. While movements between river systems have been documented in the Gulf of Maine, between the Connecticut and Hudson Rivers, and in the Southeast, interbreeding between river populations is limited to very few individuals per generation; this results in morphological and genetic variation between most river populations (Walsh *et al.* 2001; Grunwald *et al.* 2002; Waldman *et al.* 2002; Wirgin *et al.* 2005). Many of the river systems within the range are separated by considerable distances, while others are geographically close and sometimes share a river mouth or estuary.

2.2 Sea Turtles

- North Atlantic DPS of green sea turtles – Threatened
- Kemp's ridley sea turtles – Endangered
- Leatherback sea turtles– Endangered
- Northwest Atlantic DPS of loggerhead sea turtles – Threatened

All four species of sea turtles are highly migratory and travel widely throughout the GAR. While sea turtles may occur year-round off the southeastern U.S., they are generally present in marine and estuarine waters of the GAR from May through November. As water temperatures rise in the spring, sea turtles begin to migrate to nearshore waters and up the U.S. Atlantic coast, occurring in Virginia as early as April/May and in the Gulf of Maine in June. The trend is reversed in the fall with some animals remaining in the GAR until late fall. Nesting is extremely limited in the region; typically, juveniles and, to a lesser extent, adults are present in the GAR.

2.2.1 North Atlantic DPS of green sea turtle (*Chelonia mydas*) – Threatened

On April 6, 2016, NOAA Fisheries and the U.S. Fish and Wildlife Service issued a final rule to list 11 DPSs of the green sea turtle under the ESA (81 FR 20057). The final rule became effective on May 6, 2016. Based on the best available scientific and commercial data, and after considering comments on the proposed rule, the Services listed three DPSs as endangered and eight DPSs as threatened. The North Atlantic DPS, the only DPS of green sea turtles found in the GAR, is listed as threatened. In the U.S. Atlantic Ocean, green sea turtles are occasionally found as far north as New England, but are more commonly seen from New York south. They occur seasonally in GAR waters, including but not limited to Chesapeake Bay and Long Island Sound, which serve as foraging and developmental habitats.

2.2.2 Kemp's ridley sea turtle (*Lepidochelys kempii*) – Endangered

The Kemp's ridley turtle was first listed under the Endangered Species Conservation Act of 1970 on December 2, 1970 (35 FR 18319), and subsequently under the ESA. On March 23, 1999 NOAA Fisheries revised and consolidated the initial regulation (64 FR 14052). The endangered Kemp's ridley sea turtle is one of the least abundant of the world's sea turtle species. In contrast to loggerhead, leatherback, and green sea turtles, which are found in multiple oceans of the world, Kemp's ridley sea turtles typically occur only in the Gulf of Mexico and the northwestern waters of the Atlantic Ocean. Adult Kemp's ridley sea turtles are rare in the northeastern U.S. waters of the Atlantic, although juveniles venture as far north as New England, as demonstrated by the cold stunning events that occur in Cape Cod Bay each fall when temperatures drop. Foraging areas in the GAR include, but are not limited to, Chesapeake Bay, Delaware Bay, Cape Cod Bay, and Long Island Sound.

2.2.3 Leatherback sea turtle (*Dermochelys coriacea*) – Endangered

Leatherback sea turtles, listed as endangered (35 FR 8491, June 2, 1970), are the largest living turtles, and range farther than any other sea turtle species. Leatherback sea turtles are considered a pelagic species that feed on jellyfish and tunicates; however, they are also known to use coastal waters of the U.S. continental shelf on a seasonal basis. Their large size and tolerance of relatively low water temperatures allow them to occur in boreal waters such as those off

Labrador. The distribution of the leatherback sea turtle includes the Gulf of Maine northward to Nova Scotia and the Labrador coast during the summer and late summer months. Leatherbacks are also known to aggregate in and at the mouth of Chesapeake Bay during warmer months, presumably taking advantage of large jellyfish populations that breed in the bay.

2.2.4 Northwest Atlantic DPS of loggerhead sea turtle (*Caretta caretta*) – Threatened

The Northwest Atlantic DPS of loggerhead sea turtles is listed as threatened (76 FR 58868, September 22, 2011) and is the most abundant species of sea turtle in U.S. waters. They are found in temperate and subtropical waters and occupy a range of habitats including offshore waters, continental shelves, bays, estuaries, and lagoons. Loggerhead sea turtles occur year-round in ocean waters of the South Atlantic Bight where water temperature is influenced by the proximity of the Gulf Stream. As coastal water temperatures warm in the spring, loggerheads begin to migrate to inshore waters of the southeast U.S. and also move up the U.S. Atlantic coast, occurring in Virginia foraging areas as early as April/May and on the most northern foraging grounds in the Gulf of Maine in June. The trend is reversed in the fall as water temperatures cool. Most loggerheads leave the Gulf of Maine by mid-September, but some may remain in the Mid-Atlantic and Northeast until late fall.

2.2.4.1 Northwest Atlantic DPS of loggerhead sea turtle critical habitat

On July 10, 2014, the Services published two separate final rules designating critical habitat for the Northwest Atlantic DPS of loggerhead sea turtles (79 FR 39755 for nesting beaches under U.S. FWS jurisdiction; 79 FR 39856 for marine areas under NOAA Fisheries' jurisdiction). Effective August 11, 2014, NOAA Fisheries' final rule for marine areas designated 38 occupied areas within the at-sea range of the Northwest Atlantic DPS. These designated marine areas of critical habitat contain one or more of: nearshore reproductive habitat, overwintering habitat, breeding habitat, migratory habitat, and *Sargassum* habitat. In the GAR, the only critical habitat for loggerheads is *Sargassum* habitat which occurs far offshore (beyond the continental shelf break) of the Delmarva Peninsula.

2.3 Whales

- North Atlantic right whale – Endangered
- Fin whale – Endangered
- Sei whale – Endangered
- Sperm whale – Endangered
- Blue whale – Endangered

Right and fin whales occur in Mid-Atlantic and New England waters over the continental shelf. In general, these two species follow a similar pattern of foraging at high latitudes (e.g., New England and Canadian waters) in the spring and summer months and calving in lower latitudes (i.e., off of Florida for right whales) in the winter months. These species make rare appearances in bays and estuaries of the GAR; their presence is typically restricted to offshore waters. Sei, sperm, and blue whales typically occur in deeper waters beyond the continental shelf and are rare within state waters where most FHWA transportation activities occur. As a result, this Manual does not discuss them in detail.

2.3.1 North Atlantic right whale (*Eubalaena glacialis*) – Endangered

Northern right whales were originally listed December 2, 1970 (35 FR 18319) and the North Atlantic right whale was subsequently listed as a separate species (73 FR 12024, March 6, 2008). North Atlantic right whales are the most endangered large whale species in the GAR. The population ranges primarily from calving grounds in coastal waters of the southeastern U.S. to feeding grounds in New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence. The distribution of right whales seems linked to the distribution of their principal zooplankton prey, calanoid copepods. Right whales are most abundant in Cape Cod Bay between February and April and in the Great South Channel in May and June where they are observed feeding predominantly on copepods of the genera *Calanus* and *Pseudocalanus*. Right whales also frequent Stellwagen Bank and Jeffreys Ledge, as well as Canadian waters including the Bay of Fundy, and Browns and Baccaro Banks in summer through fall.

2.3.1.1 North Atlantic right whale critical habitat

On January 27, 2016, NOAA Fisheries published a final rule (81 FR 4837) to replace the critical habitat for right whales in the North Atlantic, originally designated in 1994, with two new areas. The effective date for this final rule is February 26, 2016. The areas designated as critical habitat contain approximately 29,763 square nautical miles of marine habitat in the Gulf of Maine and Georges Bank region (Unit 1, Northeastern U.S. Foraging Area) and off the Southeast U.S. coast (Unit 2, Southeastern U.S. Calving Area). GIS layers for right whale critical habitat are available on the NOAA Fisheries GIS website. The final rule identifies the following four PBFs of the Northeastern U.S. foraging habitat that are essential to conservation of the species:

1. The physical oceanographic conditions and structures of the Gulf of Maine and Georges Bank region that combine to distribute and aggregate *Calanus finmarchicus* for right whale foraging, namely prevailing currents and circulation patterns, bathymetric features (basins, banks, and channels), oceanic fronts, density gradients, and temperature regimes;
2. Low flow velocities in Jordan, Wilkinson, and Georges Basins that allow diapausing *C. finmarchicus* to aggregate passively below the convective layer so that the copepods are retained in the basins;
3. Late stage *C. finmarchicus* in dense aggregations in the Gulf of Maine and Georges Bank region; and
4. Diapausing *C. finmarchicus* in aggregations in the Gulf of Maine and Georges Bank region.

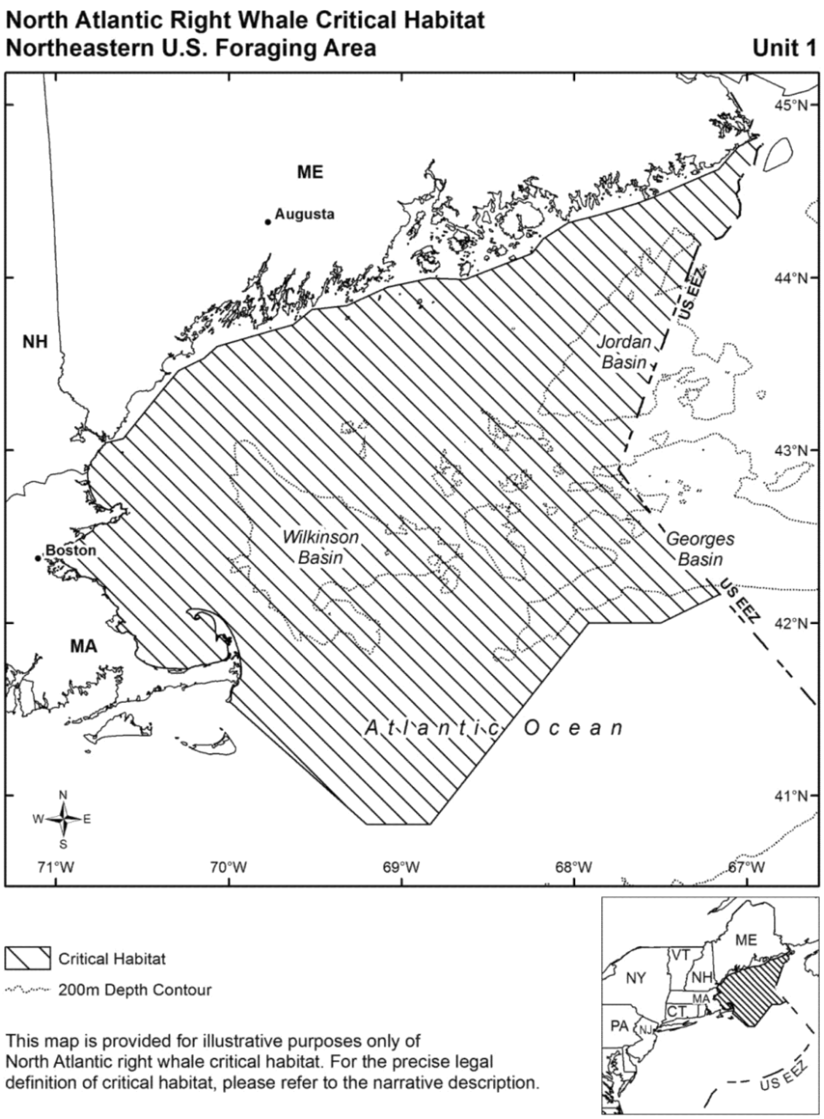

Figure 3. North Atlantic Right Whale Critical Habitat in the GAR

2.3.2 Fin whale (*Balaenoptera physalus*) – Endangered

Fin whales were listed as endangered on December 2, 1970 (35 FR 18319) and are common in waters of the U.S. Atlantic from Cape Hatteras northward. Fin whales are migratory, moving seasonally into and out of high-latitude feeding areas, but the overall migration pattern is complex and specific routes are not documented. However, acoustic recordings from passive-listening hydrophone arrays indicate that a southward "flow pattern" occurs in the fall from the Labrador-Newfoundland region, past Bermuda, and into the West Indies. The most important area for this species on the Northeast U.S. continental shelf appears to be from the Great South Channel, along the 50-meter isobath past Cape Cod, over Stellwagen Bank, and past Cape Ann to Jeffreys Ledge.

3.0 Essential Fish Habitat (EFH) in the Greater Atlantic Region

Habitat has an essential role in supporting the productivity of a species. EFH includes all types of aquatic habitat where fish spawn, breed, feed, or grow to maturity. Such habitats include, but are not limited to, wetlands, mudflats, seagrasses, sand, cobble, bays, rivers, and estuaries. In the GAR, NOAA Fisheries and the New England, Mid-Atlantic, and South Atlantic fishery management councils (FMCs) identify and designate EFH for life stages of each federally-managed species and habitat areas of particular concern (HAPCs) using the best available scientific information. HAPCs are considered high priority areas for conservation, management, or research because they are rare, sensitive, stressed by development, or important to ecosystem function.

3.1 EFH Designations for Federally-Managed Species

The official EFH designation language for federally-managed species in the GAR, including text descriptions and information on life history stages and habitat preferences for each species, is provided in the Guide to Essential Fish Habitat Designations in the Northeastern United States.[9] The designations describe the geographic extent in which EFH is found and the type of habitats used by each life stage. The Essential Fish Habitat Mapper provides a spatial representation of EFH and HAPCs by species and life stage.

In the GAR, EFH is designated for the following species:

American plaice, Atlantic cod, Atlantic halibut, Atlantic herring, Atlantic mackerel, Atlantic salmon, Atlantic sea scallop, Atlantic wolffish, black sea bass, bluefish, butterfish, cobia, golden crab, haddock, king mackerel, longfin squid, monkfish, ocean pout, ocean quahog, offshore hake, pollock, red hake, redfish, scup, shortfin squid, skates (barndoor, clearnose, little, rosette, smooth, thorny, winter), Spanish mackerel, spiny dogfish, summer flounder, surf clam, tilefish, white hake, whiting, windowpane flounder, winter flounder, witch flounder, and yellowtail flounder.

EFH is also designated for the following highly migratory species and billfish in the GAR:

Albacore tuna, Atlantic angel shark, Atlantic bigeye tuna, Atlantic bluefin tuna, Atlantic sharpnose, Atlantic skipjack tuna, Atlantic swordfish, Atlantic yellowfin tuna, basking shark, bigeye thresher shark, blue marlin, blue shark, common thresher shark, dusky shark, longbill spearfish, longfin mako shark, porbeagle shark, roundscale spearfish, sand tiger shark, sandbar shark, scalloped hammerhead shark, shortfin mako shark, silky shark, smooth dogfish, tiger shark, white marlin, and white shark.

3.1.1 Habitat Areas of Particular Concern (HAPCs)

HAPCs are a subset of EFH and are depicted on the EFH Mapper. In the GAR, HAPCs include:

[9] Note that the description of EFH in the fishery management plans takes precedence over any information on the website and the EFH mapper.

1. Juvenile Atlantic cod: an area on Georges Bank of approximately 300 square nautical miles along the northern edge of Georges Bank and the Hague Line containing gravel cobble substrate;
2. Adult Atlantic salmon: 11 rivers in Maine (Dennys, Machias, East Machias, Pleasant, Narraguagus, Ducktrap, Kennebec, Penobscot, St. Croix, Tunk Stream, and Sheepscot);
3. Summer flounder: all native species of macroalgae, seagrasses, and freshwater and tidal macrophytes in any size bed, as well as loose aggregations within adult and juvenile summer flounder EFH;[10]
4. Tilefish: substrate between the 250- and 1200-foot isobath, adjacent to Veatch, Oceanographer, and Lydonia Canyons; and
5. Sandbar shark: areas at the mouth of Great Bay, NJ, in Delaware Bay, and lower Chesapeake Bay.

3.2 Major Habitat Types

The aquatic habitats in the GAR contain varying physical and biological properties from the cold waters of the Gulf of Maine south to the more temperate climate of the Mid-Atlantic Bight. In this region, the oceanographic and physical processes interact to form a network of expansively to narrowly distributed habitat types (Stevenson *et al*. 2004). The GAR contains freshwater rivers and streams that flow towards the sea into numerous bays and estuaries that serve as important refuge and nursery areas for marine species. The major systems include riverine/ freshwater, estuarine/nearshore, and marine/offshore environments. FHWA/DOT's transportation activities are generally limited to riverine and estuarine locations. Some of the diadromous[11] fish in the GAR include striped bass, alewife, blueback herring, American shad, and American eel. Other NOAA-trust resources, including American lobster, blue crab, black sea bass, cunner, tautog, mummichog, and silversides, provide valuable recreational and commercial fisheries and are critical to a healthy marine ecosystem. Many of these species serve as the forage base for federally-managed fisheries, and are considered a component of EFH. SAV and shellfish maps may be available from state environmental agencies. A list of the electronic sources of this information is provided in Appendix B.

3.2.1 Riverine/Freshwater

Riverine and riparian habitats in the northeastern coastal U.S. are important for the growth, survival, and reproduction of diadromous fish and are critical to maintaining healthy estuarine ecosystems. These habitats include freshwater streams, rivers, streamside wetlands, freshwater submerged aquatic vegetation (SAV), and banks and associated vegetation bordered by other freshwater habitats (NEFMC 1998). Depending on water velocity and other physical characteristics, riverine systems include benthic substrates ranging from exposed bedrock, cobble, and other hard bottom types to extremely unconsolidated, soft materials. These features largely determine the fish and invertebrates present.

[10] These areas are not shown on the EFH mapper. SAV maps may be found in the links in Appendix B or may need to be collected at the project site.
[11] Diadromous fish are those that spend part of their lives in saltwater and part in freshwater.

Free flowing waters act as migratory corridors and spawning, nursery, and rearing areas and provide forage and refuge for different life stages of fish. Riparian corridors provide shade, nutrients, and habitat-enhancing debris in riverine systems (Bilby and Ward 1991), which are essential elements for these aquatic resources to thrive. Freshwater wetlands and SAV perform important ecological functions by reducing erosion, attenuating floodwater velocity and volume, improving water quality by the uptake of nutrients, and reducing sediment loads (Howard-Williams 1985; De Laney 1995; Fletcher 2003). Freshwater habitats are vulnerable to anthropogenic disturbances that alter the functions, values, quantity, and accessibility of freshwater wetlands used by diadromous fish (Beschta *et al*. 1987; Naiman 1992).

3.2.2 Estuarine/Nearshore

Estuaries are bays and inlets influenced by oceans and rivers, serving as the transition zone between fresh and salt water. In the northeastern U.S., estuaries include inland reaches of large river systems where salinities exceed 0.5 ppt. They support communities of plants and animals adapted to the mixing zone. These habitats support reproduction, feeding, refuge, and other physiological necessities (NEFMC 1998). Coastal and estuarine features such as salt marshes, mud flats, rocky intertidal zones, sandy beaches, and SAV are critical to nearshore and offshore habitats and fishery resources of the northeastern U.S. (Stevenson *et al*. 2004; Kritzer *et al*. 2016). Nearshore habitats are dynamic environments that support most marine and diadromous fish at some stage of development (NEFMC 1998). Mud flats, salt marshes, and creeks provide productive shallow water habitat for forage species. These valuable habitats are some of the most vulnerable to alterations through coastal development, including transportation actions.

Shallow estuarine waters provide refuge from predation and foraging areas for juvenile fish during high tides (Helfman *et al*. 2009). Each shallow water habitat type provides EFH for multiple federally-managed fish species. SAV beds are highly productive, produce a structural matrix on which many other species depend, improve water quality, and stabilize sediments (Fonseca *et al.* 1998). Larvae and juveniles of commercial and sport fish such as bluefish, summer flounder, spot, Atlantic croaker, and herring appear in SAV beds in the spring and early summer (Fonseca *et al*. 1992). Mud and sand substrates serve as EFH during spawning, juvenile and/or adult stages for species, including, but not limited to, juvenile pollock, juvenile little skate, juvenile hake species, juvenile and adult windowpane flounder, and all life stages of winter flounder (Cargnelli *et al*. 1999; Chang *et al*. 1999; Pereira *et al*. 1999; Stevenson *et al*. 2014). Mixed gravel substrate habitats provide structural complexity for managed fish species that require shelter and seek refuge from predation, including, but not limited to, juvenile stages of cod, ocean pout, and Atlantic herring (Auster 1998; Auster and Langton 1999; NRC 2002; Stevenson *et al*. 2006 and 2014). The structural complexity of rocky substrates with attached macroalgae and macrofauna mediate the spatial distribution of juvenile cod and provide additional refuge from predation, significantly increasing their survival (Fraser *et al*. 1996; Gotceitas *et al*. 1997; Lindholm *et al*. 1999 and 2001).

3.2.3 Marine/Offshore

The Northeast U.S. Continental Shelf Ecosystem (Sherman *et al*. 1996) is composed of four distinct sub-regions: the Gulf of Maine, Georges Bank, the Mid-Atlantic Bight, and the continental slope (Stevenson *et al*. 2004). The Gulf of Maine is an enclosed coastal sea, with relatively cold waters and deep basins with various sediment types. Georges Bank is a relatively shallow coastal plateau that slopes gently from north to south with steep submarine canyons on its eastern and southeastern edge. It is characterized by highly productive, well-mixed waters and strong currents. The Mid-Atlantic Bight contains sandy, relatively flat, gently sloping continental shelf habitat from southern New England to Cape Hatteras, North Carolina. The continental slope is fairly homogenous, with exceptions at the shelf break, some of the canyons, the Hudson Shelf Valley, and areas of hard bottom (Stevenson *et al*. 2004). Offshore benthic habitat features include sand waves, shell aggregates, gravel beds, boulder reefs, and submerged canyons which provide nursery areas for many fish species (NEFMC 1998). Many marine organisms inhabit the stable offshore environment for multiple stages of their life history. It is unlikely that transportation activities under the purview of this manual would occur in or directly impact these marine/offshore habitats.

4.0 Stressors and Effects

Stressors produced by transportation activities may affect ESA-listed species and their critical habitat, EFH, and other NOAA-trust resources. An action may adversely affect an ESA-listed species if they are exposed to any potentially harmful elements of the action or if actions diminish the value of critical habitat. An adverse effect on EFH is any impact that reduces the quality and/or quantity of EFH and may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components. Transportation activities occurring within or adjacent to aquatic areas can cause site-specific or habitat-wide adverse effects, including individual, cumulative, or synergistic consequences of actions. Transportation activities could have positive effects on ESA-listed species and their critical habitat, EFH, and NOAA-trust resources either by design or coincidentally. For example, upgrading a culvert with a larger diameter opening could result in better environmental outcomes than replacement in-kind. However, temporary adverse effects from construction itself and adverse effects from the presence of any structure would result regardless of any minimization measures used.

This section provides detailed information on how stressors are produced by transportation actions and how those stressors affect ESA-listed species and their critical habitat, EFH, and other NOAA-trust resources. FHWA/DOT can use this information to develop biological evaluations/assessments and EFH assessments. Aspects of transportation actions can have complex interrelated effects. Effects can cascade through a system, and the responses by individuals and populations can vary. For example, while excavation for the installation of bridge abutments can cause increased turbidity, measures to contain those sediments can create a barrier to fish. All of the stressors presented here are also considered habitat alteration; however, the stressors were sectioned out to best reflect the mechanism leading to the effect. The BMPs provided in Section 6.0 of this guidance include measures to minimize these stressors or minimize exposure of species and habitat to these stressors. To avoid interactions with ESA-listed species and their critical habitat and EFH altogether, refer to the ESA tables for information on spawning areas and other important habitats and the EFH Mapper for spatial data on EFH and HAPCs by species and life stage.

4.1 Underwater Noise/Hydroacoustic Energy

Transportation activities involving in-water work may produce underwater noise and acoustic impacts. The duration of acoustic impacts is typically limited to the construction phases. Demolition may introduce significant acoustic impacts to the aquatic environment. Blasting represents a single point of disturbance with a restricted, and often predictable, mortality zone. Blast energy is generally focused towards fracturing rock substrate, preventing excess energy from releasing into the water column (Keevin *et al*. 1999). Baker (2008) describes how detonations in open water produce both higher amplitude and higher frequency shock waves than contained detonations; thus, the use of stemming charges results in reduced pressures and lower aquatic organism mortality compared with an equivalent explosive charge weight detonated in open water (Nedwell and Thandavamoorthy 1992; Hempen *et al*. 2007).

Unlike blasting, pile driving and mechanical demolition create repeating sound disturbances that can last for extended periods of time. Factors that affect the type and intensity of sound pressure waves include the size and type of pile or material, firmness of the substrate, and the type of equipment/hammer used (Hanson *et al*. 2003; Johnson *et al.* 2008). Wood and concrete piles produce lower sound pressures than do steel piles. Pile driving in firmer substrates requires more energy and produces more intense sound pressures (Hanson *et al*. 2003; Johnson *et al.* 2008). As the distance from the source increases, underwater sound levels dissipate rapidly.

Dredging and disposal can produce continuous noise impacts for extended periods of time (Nightingale and Simenstad 2001b). The acoustic frequencies and sound attenuation depend on the type of equipment used, the depth and thermal variations in the surrounding water, bathymetry, and sediment composition (Nightingale and Simenstad 2001b; Stocker 2002). Mechanical and hydraulic dredges produce underwater sounds that are strongest at low frequencies and because of rapid attenuation of low frequencies in shallow water, dredge noise normally is undetectable underwater at ranges beyond 20 to 25 kilometers (Richardson *et al*. 1995). Although the noise levels from large vessels may exceed those from dredging, single vessels usually do not produce strong noise in one area for a prolonged period of time (Richardson *et al*. 1995). Vessel noise may reverberate or scatter off geological features and anthropogenic structures in the water (Stocker 2002).

4.1.1 Effects

In addition to physiological effects, underwater noise can interrupt migrating, foraging, overwintering/ sheltering, or spawning by ESA-listed species, managed species, and/or forage species such as diadromous fish. This can temporarily cause aquatic organisms to avoid an area that would normally serve as foraging, spawning, nursery, or refuge habitat. Interruption of basic biological life stages could have cascading effects by reducing population levels or viability.

4.1.1.1 ESA-listed species

Effects to ESA-listed species may include behavioral modifications, such as avoidance or decreased foraging activity, injury (e.g., hearing loss), or in extreme cases, mortality, depending on the distance from the activity. Injury can occur from a single noise event exceeding the threshold for direct physical injury, constituting an immediate adverse effect; or from prolonged exposure to noise levels that exceed the daily cumulative exposure threshold, constituting adverse effects if the species are exposed to the noise levels for prolonged periods. The noise could deter ESA-listed species from an area, and these behavioral effects can prevent the species from migrating, foraging, sheltering, or spawning. Pressure oscillations created by blasting cause a rapid contraction and over-extension of gas-filled cavities (e.g., swim bladders and lungs) which may result in internal damage or mortality (Wiley *et al*. 1981).

Table 1. GARFO Sound Thresholds for ESA-Listed Species

Species Classification	Size	Injury Threshold	Behavioral Modification Threshold
FISH	> 2g	206 dBpeak/187 cSEL[12]	150 dB re 1 µPa RMS
	< 2g	206 dBpeak/183 cSEL	150 dB re 1 µPa RMS
SEA TURTLES	all	180 dB re 1µPa RMS	166 dB re 1 µPa RMS
WHALES	all	See below[13]	
Impulsive noise			160 re 1µPa RMS
Non-pulse noise			120 re 1µPa RMS

4.1.1.1.1 ESA-listed fish

Sound waves can cause temporary or permanent damage to hearing and swim bladders of ESA-listed fish. Sturgeon and salmon exposed to elevated levels of underwater noise can experience injury or behavioral disturbance. A conservative indicator of the noise level at which there is the potential for behavioral effects to ESA-listed fish is 150 decibels relative to one micro-Pascal (dB re 1 µPa) root-mean-square (RMS). Upon exposure to noise at this level, there is the potential to experience some behavioral response. Behavioral responses could range from a temporary startle to avoidance of an ensonified area; fish may leave an area for more suitable spawning grounds or avoid natural migration paths. Pile-driving operations may affect the distribution and behavior of juvenile pink salmon and chum salmon (Feist *et al*. 1996).

At ranges beyond those causing injury, ESA-listed fish are susceptible to behavioral disturbances from underwater noise in the frequencies of their hearing range. Explosions produce loud, broadband noise audible to many species, but the main frequencies produced are often influenced by the blasted material and blasting technique. Based on the duration of noise, repeated exposure to acoustic energy (e.g., pile driving, dredging, and vessel noise) could result in a wider range of behavioral effects than single, impulsive energy waves. Project areas in or near known spawning grounds, important foraging areas, migration corridors, or designated critical habitat may be more likely to disturb ESA-listed species, depending on when the action occurs (Baker 2008).

Fish with swim bladders, such as salmon and sturgeon, are generally more susceptible to mortality and injury from explosions than sea turtles and whales, as they are difficult to see from above the surface of the water and due to their relatively greater numbers and physiological differences. Fish with swim bladders are more likely to be killed or injured than fish without swim bladders, as mortality from explosions usually results from tissue damage to gas filled

[12] The sound exposure level (SEL) is defined as that level which, lasting for one second, has the same acoustic energy as the transient and is expressed as dB re: 1µPa2•sec.

[13] Please refer to NOAA Fisheries' 2016 Marine Mammal Acoustic Technical Guidance document and user spreadsheet for assessing whether a project creates underwater noise that exceeds the permanent threshold shift (PTS) (i.e., considered injury) or temporary threshold shift (TTS) limits for listed cetaceans.

organs, such as the intestinal tract and swim bladders. Internal injuries to other organ systems have occurred from the rapid expansion of the swim bladder resulting from exposure to negative pressures from a shock wave. Smaller fish are expected to incur greater blast injury than larger fish at the same exposure level (Yelverton *et al*. 1975; Goertner 1978; Wiley *et al*. 1981; O'Keefe 1984; Munday *et al*. 1986; Moser 1999; Baker 2008).

4.1.1.1.2 Sea turtles

Sound waves can cause temporary or permanent damage to hearing and the lungs of sea turtles. The sea turtle ear appears to be adapted to both aerial and aquatic environments (Baker 2008). Currently, there are no established thresholds for injury or behavioral disturbance for sea turtles. Behavioral reactions of sea turtles (McCauley *et al*. 2000a and 2000b; DeRuiter and Doukara 2012) were reported for sea turtles in response to airgun noise. McCauley *et al*. (2000b) noted that decibel levels of 166 dB re 1µPa RMS were required before behavioral reactions (e.g., increased swimming speed) were observed in sea turtles. Based on this, sea turtles exposed to underwater noise greater than 166 dB re 1µPa RMS may be expected to experience behavioral disturbance and actively avoid an area with noise levels greater than 166 dB re 1µPa RMS. While information suggests the noise levels that might result in injury to sea turtles from exposure to underwater explosives, no such information is available for non-explosive sound sources. However, all available information indicates that injury is not expected upon exposure to impulsive noises less than 180 dB re 1µPa RMS.

4.1.1.1.3 Whales

Sound waves can cause temporary or permanent damage to hearing and the lungs of whales. Underwater noise may also mask sounds whales use for communication across long distances. Whales are at greatest risk of injury when they are at the same depth as, or slightly above, an explosion (Keevin and Hempen 1997). Risks decrease above and below the depth of an explosion; however, the pressure waves from an explosion may propagate differently, depending on environmental factors. Frequently occurring or repeated detonations over a given time period may cause behavioral changes that disrupt biologically important behaviors.

4.1.1.2 EFH and other NOAA-trust resources

Pressure waves generated during transportation activities may affect managed species, temporarily damage EFH, and/or disrupt NOAA-trust resources. Fish detect and respond to sounds for many life history requirements, including locating prey, avoiding predation, spawning, and various social interactions (Myrberg 1972; Myrberg and Riggio 1985; Kalmijn 1988). Noise can cause fish to disperse from the acoustic source and may disrupt their feeding patterns (Marten *et al.* 2001). Fish use sound for both prey/predator detection and social interaction (Richard 1968; Myrberg 1972; Myrberg and Riggio 1985; Hawkins 1986; Kalmijn 1988), and underwater blasting and noise within EFH may alter fish distribution and behavior (Feist *et al.* 1996). Managed fish with air cavities are generally more susceptible to underwater blasts than those without (Keevin *et al*. 1999); smaller fish are more likely to be impacted by the shock wave of underwater blasts than are larger fish, and the eggs and embryos tend to be particularly sensitive. Fish larvae tend to be less sensitive to blasts than eggs or post-larvae fish, likely because the larvae do not yet possess air bladders (Wright 1982; Keevin *et al*. 1999; Johnson *et al*. 2008); however, acoustic impact studies on larval fish are limited. A study by

Govoni *et al.* (2008) found mortality in two larval marine fish species at peak pressures as low as 16.2 pounds per square inch (psi) in pinfish and 17.9 psi for spot fish. Larval pinfish mortality did not reach 50% until 43.1 psi, but spot fish experienced 100% mortality at 40.3 psi (Govoni *et al.* 2008).

The behavioral response elicited by fish differs depending on the range of sound frequencies present within the water column. Fish respond to lower frequency sounds by displaying an avoidance response and not habituating to the sound despite repeated exposure (Dolat 1997; Knudsen *et al*. 1997; Sand *et al*. 2000). Fish may be initially startled by higher frequency sounds but eventually become habituated and no longer respond to the stimuli. Acclimation to the sound may place fish in more danger as they remain in range of potentially harmful sound pressure waves (Dolat 1997; Johnson *et al*. 2008). Temporary or permanent hearing loss may also result from loud underwater sounds, which can lead to reduced fitness and may increase vulnerability to predators. It can also result in reduced success in locating prey, an inability to communicate, or an inability to sense their physical environment (Illingworth and Rodkin, Inc. and Jones and Stokes 2009). Acoustic impacts also negatively affect the distribution of forage fish.

4.2 Impingement/Entrainment and Entanglement

Entrainment is the voluntary or involuntary movement of aquatic organisms from a water body into a surface diversion or through, under, or around screens and results in the loss of the organisms from the population. Impingement is the involuntary contact and entrapment of aquatic organisms on the surface of intake screens caused when the approach velocity exceeds the swimming capability of the organism (WDFW 1998). Entanglement may result from transportation activities that involve vertical in-water lines such as buoy lines, turbidity curtains, scientific measurement devices, cables, or other objects associated with the construction of transportation projects.

4.2.1 Effects

Dredges and water diversions can impinge or entrain and cofferdams can entrap invertebrates and ESA-listed species and managed species during routine operation. Sessile organisms and some less mobile organisms, such as crustaceans and larval and juvenile fish, may be more susceptible (Nightingale and Simenstad 2001b). The susceptibility to entrainment for some pelagic species may be related to the degree of waterway constriction in the area, which makes it more difficult to avoid the dredge operation (Larson and Moehl 1990; McGraw and Armstrong 1990). Impingement/entrainment may cause injury or death in certain cases, such as by becoming entrapped in a dredge bucket or buried in sediment during dredging or when sediment is deposited into a dredge scow. Fish captured and emptied out of a dredge bucket can suffer stress or injury, which can lead to mortality. Hydraulic dredging can lead to entrainment of aquatic species in suction hoses and hydraulic intake equipment, such as dragheads.

Water diversions and dewatering activities also may entrain and impinge aquatic species. These activities have been identified as a source of fish mortality and injury, with egg and larval stages of aquatic organisms being the most susceptible (Moazzam and Rizvi 1980; NOAA 1994; Richkus and McLean 2000). Entrainment can subject early life stages of fish to adverse conditions such as increased heat, physical abrasion, and rapid pressure changes. Although some temperate species of fish can tolerate exposure to extreme temperatures for short durations (Brawn 1960; Barker *et al*. 1981), fish and invertebrates entrained experience nearly 100% mortality from the stresses associated with altered temperatures, toxic effects of chemical exposure, and mechanical and pressure-related injuries from diversions/intakes (Enright 1977; Moazzam and Rizvi 1980; Barker *et al*. 1981; Richkus and McLean 2000; Johnson *et al.* 2008).

Entanglement in vertical in-water lines can cause serious injury or mortality to ESA-listed species, managed species, and NOAA-trust resources. Mismanaged or poorly designed turbidity curtains can become detached and entrap or entangle organisms. Entanglement can cause aquatic organisms to become impaired or incapacitated, leading to starvation, drowning, increased vulnerability to predators, and physical wounds (Milliken and Lee 1990; Johnson *et al.* 2008).

4.2.1 ESA-listed fish

During culvert or water intake installation, such as for bypass pumps or diversions, small fish (young of the year, larvae, and juveniles) are most susceptible to entrainment or impingement. Juvenile and adult shortnose sturgeon have demonstrated avoidance of impingement and entrainment at intakes with velocities as high as 3.0 feet per second (ft/s) (Kynard *et al.* 2005), but earlier life stages would not be able to withstand such velocities. Studies have shown that yearling or older shortnose sturgeon (> 28 cm) are likely to avoid impingement when intake velocities are 1 ft/s or less; the same is thought to be true for Atlantic sturgeon (Kynard *et al*. 2005).

Salmon and sturgeon may be impinged or entrained in dredges. Hopper dredges operate for prolonged periods underwater, with minimal disturbance, but generate continuous flow fields of suction forces while dredging. Entrainment is believed to occur when the draghead is not in firm contact with the substrate, so sturgeon feeding or resting on or near the bottom may be vulnerable to entrainment. In addition, the size and flow rates produced by the suction power of the dredge, the condition of the channel, and the method of operation of the dredge and draghead all relate to the potential of the dredge to entrain sturgeon (Reine and Clarke 1998). Sturgeon entrainment in cutterhead dredges is unlikely. A risk of sturgeon entrainment exists only within one meter of a cutterhead dredge head with a 36-inch pipe diameter and suction of 4.6 meters per second. Smaller diameter pipes have lower risk of entrainment (Clarke 2011).

Sturgeon and salmon are not typically susceptible to entrainment in mechanical dredges because bucket dredges are relatively stationary and the dredge operation entails the bucket moving at a slow pace. Atlantic salmon are top swimmers that generally migrate at night, when dredges do not typically operate. Additionally, mechanical dredging lacks suction, and the culmination of these factors allows fast, strong-swimming fish such as sturgeon and salmon to move away from dredging activities. The risk of interactions between sturgeon and dredges is thought to be highest in areas where large numbers of sturgeon are known to aggregate, such as overwintering sites or foraging concentrations. The risk of capture may also be related to the behavior of the sturgeon in the area. Sturgeon are at the bottom of the river interacting with the sediment while foraging. Overwintering sturgeon may be less responsive to stimuli, which could reduce their ability to avoid an oncoming dredge bucket.

Sturgeon and salmon may be susceptible to entanglement in vertical lines if buoys or other anchored items are sited too densely or there are large areas with vertical lines leaving limited passage in important migratory and foraging pathways. Lines could potentially catch the gills or scutes of these fish causing them to become entrained and drown.

4.2.1.2 Sea turtles

Sea turtles are large, strong swimmers and unlikely to be affected by water intakes; however, they may be impinged or entrained in dredges. Hopper dredges move relatively rapidly and can entrain and kill sea turtles. Loggerhead, Kemp's ridley, and green sea turtles are vulnerable to entrainment in the draghead of the hopper dredge, as the draghead moves along the bottom. Given their large size, leatherback sea turtles are not vulnerable to entrainment. Entrainment occurs when sea turtles do not or cannot escape from the suction of the hopper dredge. Mortality most often occurs when turtles are sucked into the dredge draghead, pumped through the intake pipe and then killed as they cycle through the centrifugal pump and into the hopper. Sea turtles are not known to be vulnerable to entrainment in cutterhead dredges. This is likely due to the size of sea turtles and their swimming ability that allows them to escape the intake velocity near a cutterhead. Sea turtles are also not susceptible to entrainment in mechanical dredges, because bucket dredges are relatively stationary, and the operation entails moving the dredge bucket at a slow pace. Mechanical dredging lacks suction, and the culmination of these factors allows fast, strong-swimming sea turtles to move away from dredging activities.

Sea turtles may become entangled in vertical lines and loose lines may become wrapped around their flippers. Once entangled, turtles may not surface to breathe, thus drowning.

4.2.1.3 Whales

Whales are typically present offshore and away from the estuarine and riverine areas where transportation activities occur. In addition, due to their large size and fast swimming ability, impingement or entrainment of whales from transportation actions is unlikely to occur. Whales may become entangled in vertical lines if the lines are located in areas where whales may be foraging or migrating. Vertical lines may pull whales down, or slow them down to the point where they cannot escape the lines to feed.

4.2.1.4 EFH and other NOAA-trust resources

Benthic infauna, which serve as forage for some managed species, are particularly vulnerable to entrainment by dredging, although some mobile epibenthic and demersal species, such as shrimp, crabs, and fish, are susceptible to entrainment as well (Nightingale and Simenstad 2001b). Avoidance responses to suction dredge entrainment have been reported for some demersal and pelagic mobile species. The susceptibility to entrainment for some pelagic species may be related to the degree of waterway constriction in the area of the dredging, which makes it more difficult for fish to avoid the dredge operation (Larson and Moehl 1990; McGraw and Armstrong 1990). Entrainment and impingement of fish and invertebrates in water intake structures have immediate and future impacts to the riverine, estuarine, and marine ecosystems. Not only is fish and invertebrate biomass removed from the aquatic system, but the biomass that would be produced in the future is no longer available to predators (Rago 1984; Johnson *et al.* 2008); this negatively impacts the quality of EFH, as less forage is available. Fish and invertebrate populations may be adversely affected by intakes, as less mobile early life stages are particularly vulnerable and mortality of the early life stage often determines recruitment and strength of the year-class. Important habitat for aquatic organisms around water intakes may also become unavailable for recruitment and settlement (Travnichek *et al*. 1993; Johnson *et al.* 2008).

Vertical lines or other devices, such as turbidity curtains, may temporarily impact to EFH and other NOAA-trust resources. Lines or curtains could prevent managed species from accessing spawning or forage areas. This impact is expected to be temporary, as access would be restored once the lines or curtains are removed.

4.3 Turbidity and Sedimentation

Transportation actions in or near aquatic habitats including cofferdam/pile installation and removal, bridge construction, riprap installation/removal, and demolition activities may increase rates of erosion, debris loads, turbidity, and sedimentation in streams, wetlands, or other aquatic habitats, and diminish flood plain storage capacity. Increased sedimentation can also result from changes in hydraulics caused by wave energy reflection in the nearshore coastal area. This can result in scour, and increased turbidity can reduce or eliminate SAV and other sensitive habitats adjacent to the structures (Williams and Thom 2001; Johnson *et al*. 2008).

Roads introduce an impervious surface into the landscape, which intercepts rain and increases runoff, carrying soil, sand, and other sediments (Ziegler *et al*. 2001) more readily into aquatic habitats. Sedimentation in aquatic habitats can be acute following precipitation events or chronic from improper road maintenance (Hanson *et al*. 2003). Road maintenance, including sanding to prevent icing or routine road repair, can also cause sedimentation in adjacent aquatic habitats. Sedimentation and turbidity impacts on riverine and estuarine habitats can be worsened by the loss and replacement of wetlands with impervious surfaces.

Transportation projects may include dredging for debris removal, channel restoration, or other maintenance during construction. Dredging and excavation result in greatly elevated levels of turbidity in the water column. Mechanical dredging techniques such as clam shell or bucket dredges cause turbidity as sediment spills through the tops and sides of the dredge bucket when it contacts the bottom, during withdrawal of the bucket through the water column, and when it breaks the water's surface (Nightingale and Simenstad 2001b). Closed or environmental buckets are designed to reduce the sediment spill from the bucket through modifications, such as rubber seals or overlapping plates, and are often used in contaminated sediments (Johnson *et al.* 2008). Turbidity from dredging is expected to rapidly decrease with distance from the project area. Mechanical dredging generally produces more turbidity than hydraulic dredging techniques, such as hopper or cutterheads. However, hydraulic dredging can cause significant turbidity if the slurry is allowed to overflow from the barge and into the water column. This technique, called "economic loading," is often used to reduce the number of barge trips (Wilber and Clarke 2001).

Suspended sediment levels from conventional mechanical clamshell bucket dredging operations range from 105 milligrams per liter (mg/L) in the middle of the water column to 445 mg/L near the bottom (210 mg/L, depth-averaged) (U.S. ACOE 2001). 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 detected 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 a 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 a clamshell dredge.

Turbidity plumes produced by dredging are highly variable and dependent upon grain size and the type of dredge used. Modeling results of cutterhead dredging indicate that elevated total suspended solids (TSS) concentrations would be present throughout the bottom six feet of the water column for a distance of approximately 1,000 feet (U.S. ACE 1983) from the activity. Based on these analyses, elevated suspended sediment levels are expected to be present within a 1,000-foot radius of the cutterhead dredge. Turbidity levels associated with cutterhead dredge sediment plumes range from 11.5 to 282 mg/L, with the highest levels detected next to the cutterhead dredge and decreasing with greater distance from the dredge (Nightingale and Simenstad 2001b).

The extent of turbidity impacts depends on disposal methodology, physical characteristics of the material (particle size), and hydrodynamics at a disposal site. Near-bottom turbidity plumes caused by hopper dredges may extend approximately 2,300 to 2,400 feet down current from the dredge, and approximately 1,000 feet behind the dredge the two plumes merge into a single plume (U.S. ACOE 1983). Suspended solid concentrations may be as high as several tens of ppt near the discharge port and as high as a few ppt near the draghead. A study by Anchor Environmental (2003) shows nearfield concentrations ranged from 80.0 to 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 most cases, the majority of resuspended sediments resettle close to the dredge within one hour, and only a small fraction takes longer to resettle (Anchor Environmental 2003).

Pile installation and removal disturbs bottom sediments and may temporarily increase suspended sediment. Directly pulling broken piles may suspend large amounts of sediment, as sediments clinging to the pile slough off as it is raised through the water column. Clamshell buckets may suspend additional sediment if they penetrate the substrate while grabbing the pile (Hanson *et al*. 2003). Vibratory pile removal can cause the sediments to slough off within the substrate, resulting in relatively lower levels of suspended sediments (Hanson *et al*. 2003). Breaking or cutting the pile below the mudline may suspend small amounts of sediment, if the stub is left in place and little digging is required. Sediment plumes may also occur around the piles during installation, although it is usually much less than the turbidity created during removal. The TSS levels expected for pile driving range from 5.0 to 120.0 mg/L above background levels (U.S. EPA 1986). Some turbidity may be generated when piles are installed or removed with hydraulic jets, although this technique is not widely used with piles in the GAR (Johnson *et al.* 2008).

Vessels, such as barge-mounted cranes, may be used to conduct general construction activities associated with transportation projects. Construction vessels operating in shallow water at a transportation project site may cause resuspension of bottom sediments and may physically disrupt shallow aquatic habitats, such as bank and shoreline through prop dredging (Barr 1993). The degree of sediment resuspension and turbidity produced in the water column from vessel activity is generally dependent on the wave energy and wake produced by the vessel, size of the sediment particles, water depth, and number of vessels passing through an area (Karaki and vanHoften 1975; Barr 1993). Sedimentation and turbidity impacts associated with vessel traffic may be more pronounced in shallow water habitats with fine sediments (Klein 1997; Johnson *et al.* 2008).

Improper design or use of certain erosion and sedimentation control measures can also result in increased turbidity and sedimentation. Turbidity/silt curtains may not be appropriate in some situations if the water velocity is too high. In some cases, the curtains can be pulled loose and do more damage to habitats than the turbidity it was meant to control. Pumping turbid water out of a dewatered area or sediment basin can also contribute to increased turbidity and sedimentation.

4.3.1 Effects

4.3.1.1 ESA-listed fish

Depending on the time of year and typical behavior of the species, in-water sediment plumes caused by transportation activities may interrupt migrating, foraging, overwintering/sheltering, or spawning by ESA-listed fish species. Interruption of basic biological life stages could have cascading effects by reducing population levels or viability. Studies on anadromous fish indicated that adverse effects to fish from exposure to elevated turbidity could occur at 580 mg/L for the most sensitive species, with 1,000 mg/L as a more typical threshold (Burton 1993), and effects to benthic communities could occur at 390 mg/L (EPA 1986). Atlantic and shortnose sturgeon are thought to be at least as tolerant of elevated turbidity as other anadromous fish. Turbidity is most likely to affect sturgeon if a plume causes a barrier to normal behaviors. However, sturgeon are highly mobile and individuals may navigate around sediment plumes and continue normal movements. Sturgeon eggs and early life stages are less tolerant to increased sediment levels than juveniles and adults. Observations in the Delaware River indicated that larval populations may be smothered when suspended material settles out of the water column (Hastings 1983). Larval survival studies conducted by Auld and Schubel (1978) showed that striped bass larvae tolerated 50 and 100 mg/L suspended sediment concentrations and that survival was significantly reduced at 1,000 mg/L. 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. In a study on the effects of suspended sediment on white perch and striped bass eggs and larvae (Morgan *et al*. 1973), sediment adhered to the eggs when sediment levels over 1,000 parts per million were reached. No adverse effects to demersal eggs and larvae were documented at levels of 45 mg/L or less.

4.3.1.2 Sea turtles and whales

Sea turtles and whales breathe air and direct effects of elevated turbidity levels from transportation actions are not likely to occur. However, increased turbidity levels described above for fish, may cause adverse effects if large plumes affect the prey base or, if plumes present a barrier to migration or movement.

4.3.1.3 EFH and other NOAA-trust resources

Shoreline alterations that occur as part of transportation activities can redirect wave energy, causing scouring and loss of adjacent areas including salt marsh vegetation or other sensitive habitats. Suspended sediments reduce the availability of sunlight to SAV, cover fish spawning areas and food supply, alter foraging patterns and success (Breitburg 1988), interfere with filtering capacity of filter feeders, clog and harm the gills of fish (U.S. EPA 2003), or lead to death (Wilber and Clark 2001). The severity suspended sediments effects on aquatic organisms often increases as a function of sediment concentration and duration of exposure (Newcombe and Jensen 1996), and the sensitivity of species to suspended sediments depends on the nature of the sediment and the life history stage of the species. Early life stages and sessile organisms are the most sensitive to sedimentation impacts (Barr 1987; Wilber *et al*. 2005). Some habitats are prone to natural sediment loads and sediment resuspension because of the dynamic nature of the ecosystems; therefore, most organisms adapted to these environments have tolerance to some level of suspended sediments and sedimentation (Nightingale and Simenstad 2001b).

Increased turbidity and sedimentation can bury benthic organisms and demersal fish eggs. The depth of burial and the density of the substrate may limit the natural escape response of some organisms that are capable of migrating vertically through the substrate (Barr 1987; Wilber *et al*. 2005). In addition, anoxic conditions in the disturbed sediments may decrease the ability of benthic organisms to escape burial (Barr 1987). Short-term burial, where sediment deposits are promptly removed by tides or storm events, may have minimal effects on some species (Wilber *et al*. 2005); however, even thin layers of fine sediment have been documented to decrease gas exchange in fish eggs and adversely affect the settlement and recruitment of bivalve larvae (Wilber *et al*. 2005). An experiment with winter flounder eggs exposed to sediment deposition found a lower larval survival rate compared to control sites (Klein-MacPhee *et al*. 2004). Similarly, laboratory experiments with winter flounder eggs buried to various depths indicated a decreased hatch success and delayed hatch with increasing depth (Berry *et al*. 2004 and 2011). Berry *et al.* (2011) reported little or no hatch in eggs exposed to greater than 2.5 mm of sediment and delayed hatch in eggs exposed to as little as 0.6 mm of sediment.

Turbidity can adversely affect diadromous fish, particularly during spring and fall migrations. Sedimentation may also adversely affect invertebrates that serve as prey for managed species (Greene 2002; Johnson *et al.* 2008). Increased suspended sediments may degrade or eliminate spawning and rearing habitats, impede feeding, negatively affect the food sources of fish, severely alter the aquatic food web, and thus negatively affect the growth and survival of diadromous fish. Studies indicate that adverse effects to benthic communities could occur at 390 mg/L (EPA 1986). Sedimentation can affect Atlantic salmon habitat. Changes in stream morphology, such as the frequency and extent of bedload movement and the introduction of sediments, can remove spawning substrates, scour redds or “nests,” result in a direct loss of eggs and young, or reduce their quality by deposition of increased amounts of fine sediments. These changes can affect the early life stages of Atlantic salmon, which show an affinity for specific habitat types (Fitzsimons *et al*. 1999; Hedger *et al.* 2005; Johnson *et al.* 2008). Sediments can eliminate refuge used by juvenile stages of salmon 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 (Danie *et al*. 1984; Fay *et al*. 2006).

4.4 Reduced Water Quality (Dissolved oxygen, Temperature, and Pollutants)

Transportation activities can degrade water quality through increased run-off, and therefore pollutants, entering the aquatic environment and concentrated flow on the road surfaces or in adjacent ditches/channels, which could increase velocity of runoff into receiving waters (Hanson *et al*. 2003). Water quality may be temporarily impacted by transportation actions through a localized increase in suspended sediments, as discussed in Section 4.3. Lowered dissolved oxygen (DO), changes in temperature, and addition of pollutants may interrupt the basic life history functions of aquatic species and contribute to the reduced productivity of fishery resources. The solubility of oxygen decreases with increased temperature and oxygen can be consumed by aerobic organisms faster than it is replenished by the air. Both of these mechanisms can be caused by transportation activities. This can contribute to eutrophic conditions that already exist in many estuaries and marine waters in the northeastern U.S. (Johnson *et al.* 2008).

Roads can alter the hydrology of a watershed. Altered hydrology around estuaries can effect water residence time, temperature, and salinity and increase vertical stratification of the water column, inhibiting the diffusion of oxygen into deeper water leading to lowered DO concentrations (Kennedy *et al*. 2002; Johnson *et al.* 2008). Undersized and/or improperly placed crossings can restrict tidal flow and cause flooding upstream, affecting upland and riparian habitat and can affect water quality by acting as dams, impounding water and increasing water temperature. As water flows through a structure, the temperature of the water can also rise, affecting aquatic organisms downstream; such effects can be exacerbated by climate change.

Projects conducted next to streams can also impact water temperature. Roads can alter natural temperature regimes in riverine and estuarine ecosystems because of radiant heating effect from the road surfaces (Johnson *et al.* 2008). Loss of riparian and salt marsh vegetation from transportation actions can increase the amount of solar radiation reaching streams and rivers and results in an increase in water temperatures of those water bodies (Moring 2005). Conversely, increased shading from transportation structures may unnaturally reduce local light levels, primary production rates, and water temperatures adjacent to the structures (Williams and Thom 2001; Johnson *et al.* 2008).

Transportation projects can alter water quality parameters and release contaminants and nutrients into the water column (Messieh *et al*. 1991; Newell *et al*. 1998; Johnson *et al.* 2008). Roads near aquatic habitats can be a source of chemical contaminants, such as deicing chemicals or salt, fertilizers, herbicides to control roadside vegetation, rubber/graphite residue from the wearing of tires, deposition from vehicle exhaust, heavy metals from brakes, and petroleum products from vehicles or from the road asphalt itself (Furniss *et al*. 1991; U.S. EPA 2005). Contaminants such as ammonia can also be released in the water column with the use of certain types of explosives. Other contaminants can be released from piles treated with creosote or other preservatives (Poston 2001; Kennish 2002; Weis and Weis 2002). The rate of preservatives leaching is highly variable and dependent on the age of the treated wood and other factors. Concrete or steel are relatively inert and do not leach contaminants into the water (Johnson *et al.* 2008); however, the interaction of raw concrete or grout and the water is a concern. Vessels and construction equipment can release oil or other pollutants into the aquatic environment. These hazardous materials can be released into the environment from fuel and oil related to vessel or equipment operations. Nutrients and contaminants can bind to fine particles in bottom sediments (Messieh *et al*. 1991; Newell *et al*. 1998) and the disturbance of these sediments can release metals, hydrocarbons, hydrophobic organics, pesticides, pathogens, and nutrients into the water column and allow them to become biologically available in the water column or through trophic transfer (Wilbur and Pentony 1999; U.S. EPA 2000; Nightingale and Simenstad 2001b).

4.4.1 Effects

Changes in water quality parameters including velocity, volume, temperature, and chemical constituents from discharges and other activities may adversely affect ESA-listed species, EFH, and NOAA-trust resources. Reductions in water quality can impair and limit the ability of aquatic organisms to grow, feed, and reproduce (Deegan and Buchsbaum 2005; Johnson *et al.* 2008). Changes in the water velocity, volume, temperature, and chemical constituents all represent impacts on water quality as well as habitat (see section 4.5). Hydrological modifications from transportation activities can increase the quantity and quality of run-off entering the aquatic environment and may contribute to reduced fisheries productivity. Altered temperature regimes can affect the distribution, growth rates, survival, migration patterns, egg maturation and incubation success, competitive ability, and disease/parasite resistance of aquatic organisms (U.S. EPA 2003). In-water plumes (e.g., toxic chemical and thermal) resulting from transportation activities may interrupt migrating, foraging, overwintering/sheltering, or spawning by ESA-listed species, managed species, and/or forage species, such as diadromous fish, if aquatic organisms avoid an area that would normally serve as habitat. Interruption of basic biological life stages may also be caused by the physical presence of water quality containment measures (including turbidity curtains and cofferdams) (Spence *et al*. 1996), which could have cascading effects by reducing population levels or viability.

4.4.1.1 ESA-listed fish

Atlantic and shortnose sturgeon are similarly sensitive to certain water quality parameters. DO levels below 4.0 mg/L and temperatures above 28° C may have deleterious effects on sturgeon. Sturgeon may also be impacted by the uptake of heavy metals, other chemicals, or areas of low dilution. The release of water with altered temperatures, low DO, and the presence of toxins affects migration and migrating behavior. Both water quantity and quality can greatly affect the usable zone of passage within a channel (Haro *et al*. 2004).

4.4.1.2 Sea turtles and whales

Sea turtles and whales can be affected by impaired water quality through the reduction of their forage base. Low DO levels, high temperatures, or release of pollutants that do not adhere to water quality standards may all detrimentally affect benthic communities and small pelagic fish that serve as forage. Because sea turtles and whales breathe air, many pollutants are not absorbed through sensitive gill structures or during development phases as is the case for fish.

4.4.1.3 EFH and other NOAA-trust resources

Reduced water quality can cause habitat destruction in the case of prolonged stressors, as the habitat may no longer be useable or may become severely degraded. Temperature effects, biochemical processes, and the behavior and physiology of aquatic organisms (Blaxter 1969), and long-term thermal pollution may change natural community dynamics of aquatic habitats. Elevated water temperatures in streams and rivers in the GAR may be responsible for increased algal growth, which is a possible factor in the diminished stocks of rainbow smelt (Moring 2005; Johnson *et al.* 2008). This may be exacerbated by climate change. In freshwater habitats of the GAR, rising water temperatures could lead to local extirpation of cold-water fish if temperature tolerance ranges are exceeded. Riparian vegetation removal can also have the effect of lowering water temperatures during winter, which can increase the formation of ice and delay the development of incubating fish eggs and alevins in salmonids (Hanson *et al*. 2003). Riparian vegetation is important to salmonids, providing shade for maintaining cool water temperatures, food supply, and channel stability and structure (Furniss *et al*. 1991).

Reduced DO concentrations can kill aquatic organisms or result in sub-acute effects such as reduced growth and reproductive success. Juvenile winter flounder growth was significantly reduced when DO levels were maintained at 2.2 mg/L or when DO varied diurnally between 2.5 and 6.4 mg/L (Bejda *et al*. 1992). Contaminated sediments can build up in aquatic organisms through bioaccumulation and biomagnification (Nightingale and Simenstad 2001b). These contaminants can affect marine organisms through uptake by wetland vegetation, adsorption by adjacent sediments, or directly through the water column (Weis and Weis 2002). They also affect the growth, reproduction and survival of shellfish, which provide forage for managed species. The presence of wood preservatives in the food chain can reduce local species richness and diversity (Weis and Weis 2002).

Water quality issues such as eutrophication, pollution, and sedimentation resulted in large-scale declines to SAV in some areas of the northeastern U.S. (Goldsborough 1997; Deegan and Buchsbaum 2005; Wilber *et al*. 2005; Costello and Kenworthy 2011). Environmental effects of excess nutrients and sediments are the most common and significant causes of SAV decline worldwide (Orth *et al*. 2006). The resuspension of nutrients creates turbid conditions and decreases photosynthesis. The combination of decreased photosynthesis and release of organic material with high biological oxygen demand can result in short-term oxygen depletion to aquatic resources (Nightingale and Simenstad 2001b). The loss of SAV is linked to poor water quality from increased turbidity and nutrient loading (Deegan and Buchsbaum 2005; Wilber *et al*. 2005). Coastal wetlands reduce the risk of eutrophication in estuaries and nearby coastal waters (Tyrrell 2005) by absorbing nutrients in groundwater and storm water.

4.5 Habitat Alteration

Transportation activities may cause habitat alteration through increased suspended sediment loading, fill, excavation, shading, and introduction of chemical contamination (Robinson and Pederson 2005). Habitat conversion or loss can result if hard substrates are removed, resulting in deeper habitats, scour, loss of bottom structure and complexity, and altered substrate type (Johnson *et al.* 2008). Dredging and disposal can decrease the amount of detrital food source, important for aquatic invertebrates (Mitsch and Gosselink 1993; Johnson *et al.* 2008). Disposal and fill activities can also directly eliminate sessile or semi-mobile aquatic organisms by smothering (Larson and Moehl 1990; McGraw and Armstrong 1990; Barr 1993; Newall *et al.* 1998). Habitats can also be temporarily or permanently impacted by the physical presence of construction materials (e.g., turbidity curtains, cofferdams, piles, bridge piers and abutments, machinery) in the water (Spence *et al.* 1996). Habitat alteration may not be reversible and recovery times for degraded habitat depend on the nature of the agent causing the degradation and the physical characteristics of the habitat (Deegan and Buchsbaum 2005).

If improperly designed, stream crossings can alter, degrade, fragment, or eliminate aquatic habitat and potentially impede or eliminate passage for resident and migratory species (Evans and Johnston 1980; Belford and Gould 1989; Clancy and Reichmuth 1990; Furniss *et al*. 1991; U.S. GAO 2001; Jackson 2003). Scour protection around overwater structures can also lead to a conversion and loss of habitat (Johnson *et al*. 2008). As described by FHWA (2010), many culverts currently in place were designed primarily with hydraulic conveyance in mind (Normann *et al.* 2005) and the culverts largely present barriers to fish passage and cause fragmentation and loss of ecological connectivity (Trombulak and Frissell 2000). Stream crossings and water diversions can alter natural freshwater flows (Boesch *et al*. 1997), reduce natural tidal flushing and interfere with natural nutrient and sediment-transport processes and sediment and nutrient transport processes (Christie *et al*. 1993; Fajen and Layzer 1993, Tyrell 2005), hindering benthic processes and communities. Water diversions can create a physical barrier to fish (Spence *et al*. 1996), and excessive water withdrawal can greatly reduce the usable river channel. Rapid reductions or increases in water flow can greatly affect fish migratory patterns. This can be exacerbated by climate change. Depending on the timing of reduced flows, fish can become stranded within a stream channel, in pools, or just below the river in an estuary system (Johnson *et al.* 2008).

Overwater structures create shade which reduces the light levels below and around the structure. The size, shape, and intensity of the shadow cast by a structure depend on its height, width, construction materials, and orientation (Johnson *et al.* 2008). Piles can alter adjacent substrates by increased deposition of sediment from changes in current fields or shell material deposition from pile communities. Around piles, native dominant communities typically associated with sand, gravel, mud, and SAV may be replaced by shell hash communities (Penttila and Doty 1990; Nightingale and Simenstad 2001a; Haas *et al*. 2002). In addition, changes to current fields around structures alter sediment distribution and topography creating depressions along pile lines (Penttila and Doty 1990). Pile extraction can result in altered sediment composition and depressions, which may cause erosion and sediment loss. Bottom depressions may fill in with fine sediments and silt, changing the characteristics of the benthic habitat (Johnson *et al.* 2008).

Climate change has wide-ranging impacts on all natural and human systems (Doll *et al.* 2012), including aquatic habitats. Climate change can result in changes such as sea level rise (SLR), increased temperatures, changes in precipitation and water quality, and flooding. These impacts are widespread and vary by region, but SLR is of primary importance to transportation projects in coastal areas of the GAR where NOAA-trust resources are present. Transportation projects that fail to incorporate SLR can lead to inadequately designed bridges and highways, resulting in significant costs due to redesigning, retrofitting, and potentially having to relocate or protect transportation infrastructure; this can also lead to increased impacts to environmental resources (TRB 2008; U.S. GCRP 2014). Changes due to climate change are expected to occur within the timeframe of the life expectancy of many transportation projects.

Adequately incorporating potential climate change effects including SLR into transportation projects can improve the resilience of systems and maximize performance over time (U.S. ACOE 2014). A goal of NOAA Fisheries is to avoid and minimize impacts, including climate change related impacts, to NOAA-trust resources through interagency consultations. NOAA Fisheries' Office of Protected Resources issued National Marine Fisheries Service Procedural Instruction 02-110-18, *Guidance for Treatment of Climate Change in NMFS Endangered Species Act Decisions*, on September 27, 2016 to support GARFO PRD in decision-making. The guidance provides policy considerations, some of which directly impact ESA section 7 consultations. Policy considerations 6 and 7 describe incorporating adaptive management approaches to climate variables and ensuring project design is adequate to protect ESA-listed species under future climate conditions.

Using consistent emissions scenarios, SLR projections, and approaches to the use of downscaled models in climate assessments will ensure appropriate protections throughout the GAR. GARFO HCD is currently developing a Climate Change Guidance Document to provide such consistent recommendations as well as a thorough summary of effects on NOAA-trust resources and existing tools and resources.

4.5.1 Effects

Transportation activities may affect the migration of mobile species and temporarily prohibit an area from use as foraging, spawning, nursery, or refuge habitat. Mobile species may leave an area for more suitable feeding or spawning grounds, or avoid migration paths because of turbidity plumes or noise created during construction activities. In-water construction activities could also impede species movement depending on the size of the work footprint and the presence of turbidity curtains or other exclusionary devices.

Reduced habitat quality may be equally damaging to the biological community as a loss in habitat quantity. Gradual declines in habitat quality can result in complete loss of habitat structure and function (Deegan and Buchsbaum 2005). Losses of habitat quantity and quality may reduce the ability of an area to support healthy and productive fish populations and lead to stressed populations (Robinson and Pederson 2005). The impacts to benthic communities vary greatly with the type of sediment, the degree of disturbance to the substrate, the intrinsic rate of reproduction of the species, and the potential for recruitment of adults, juveniles, eggs, and larvae (Newell *et al*. 1998). After dredging, sediments may be nearly devoid of benthic infauna, and those that are the first to recolonize are typically opportunistic species which may have less nutritional value for consumers (Allen and Hardy 1980; Newell *et al*. 1998). Dredging can result in a 30 to 70% decrease in the benthic species diversity and 40 to 95% reduction in number of individuals and biomass (Newell *et al*. 1998). Rates of benthic infauna recovery for disturbed habitats depend on the amount of material removed, the habitat affected and the fauna present at the site prior to dredging, the frequency of disturbances, and the degree of sedimentation that occurs following dredging (Greene 2002). Benthic infauna recovery rates may be less than one year for some fine-grained mud and clay deposits, where frequent disturbance is common, while gravel and sand substrates, which typically experience more stability, may take many years to recover (Newell *et al*. 1998). Post-dredging recovery in cold waters at high latitudes may require additional time because these benthic communities can include large, slow-growing species

(Newell *et al*. 1998). The post-dredging benthic community may function very differently than the pre-dredging community (Greene 2002; Johnson *et al.* 2008).

Overwater crossings can alter plant and animal assemblages in intertidal and shallow subtidal areas and interfere with key ecological functions such as spawning, rearing, and use of refuge sites. Site-specific factors such as water clarity, current, and depth, as well as the type and use of a given crossing determine the occurrence and magnitude of these impacts (Hanson *et al*. 2003; Johnson *et al.* 2008).

The failure to properly locate and design transportation infrastructure can lead to repeated adverse impacts on habitats of ESA-listed species, managed species, and NOAA-trust resources (Johnson *et al.* 2008). Integrating SLR into transportation projects can reduce, and in some cases eliminate, the need for various adaptation measures, which can reduce their associated adverse impacts on aquatic habitats. Furthermore, siting and locating transportation infrastructure in ways that avoid and minimize impacts to NOAA-trust resources may also reduce or eliminate climate change and SLR-related impacts.

Design strategies for climate change including SLR can also have direct, beneficial effects. For example, designing culverts to accommodate increased frequency, duration, and quantity of stormflows from climate change related impacts will protect transportation infrastructure. These designs may reduce adverse impacts to NOAA-trust resources resulting from inadequate culverts. Increasing bridge elevations to accommodate SLR, increased storm surge, and other climate stressors may also reduce adverse impacts to NOAA-trust resources. For example, bridges designed with increased elevations may minimize increased erosion and scour to shoreline and benthic habitats as a result of the bridge becoming a constriction to flow and result in reduced shading impacts to habitats below the bridge.

4.5.1.1 ESA-listed fish

Sturgeon are opportunistic feeders that forage over large areas and are expected to locate prey beyond the immediate area of the action. Salmon and sturgeon habitats can become limited due to impaired passage. Sturgeon prefer highly productive foraging habitat including tidal/mud flats, SAV, and areas containing shellfish. They spawn in upstream habitat of large tidal rivers just below the fall line in areas with cobble habitat. Temporary or permanent removal of foraging or spawning habitat may adversely affect ESA-listed fish. Dredging, in-water construction, and fill may temporarily or permanently alter habitat for ESA-listed species, including critical habitat. Dredging can affect salmon and sturgeon by reducing prey species through the alteration of the existing biotic assemblages and habitat.

4.5.1.2 Sea turtles

Sea turtles may forage in a variety of habitat types including SAV, areas containing shellfish, in areas where crustaceans and gastropods are prevalent, and in pelagic zones on jellyfish. Dredging, in-water construction, and fill for staging areas may temporarily or permanently alter habitat for ESA-listed species. Dredging can affect sea turtles by reducing prey species through the alteration of the existing biotic assemblages and habitat.

4.5.1.3 Whales

Temporary or permanent destruction of pelagic or benthic forage resources (including a variety of small fish) by transportation activities could potentially affect whales. However, most transportation projects are located inshore, where whales are not expected to feed.

4.5.1.4 EFH and other NOAA-trust resources

Shallow water habitats may be impacted through burial of resources and/or alteration of habitats from fill placement, such as through shoreline armoring or dredge disposal. Transportation projects may include temporary fill in EFH which results in a temporal loss of ecological functions. Temporary fill associated with the construction of causeways can create hydraulic barriers. If not properly restored, ecological functions may be permanently lost. Potential foraging habitat may be permanently covered by riprap or compacted. Shoreline armoring can reduce the complexity and amount of intertidal habitats and negatively affect nearshore processes and the ecology of coastal species (Williams and Thom 2001; Johnson *et al.* 2008). During construction, managed species may be temporarily unable to use an area for forage or refuge habitat due to avoidance of construction activities and physical obstruction by temporary or permanent structures. Structures can also cause beach erosion and accretion in adjacent areas.

Placing fill material onto intertidal habitats can dramatically alter tidal flow. These effects can change the geomorphology and current patterns of rivers and estuaries and adversely affect habitat suitability for certain species. Counter current flows set up by freshwater discharges into estuaries are important for larvae and juvenile fish entering those estuaries. Behavioral adaptations of marine and estuarine species allow larvae and early juveniles to concentrate in estuaries (Deegan and Buchsbaum 2005). Alterations in bottom sediments, bottom topography, and altered circulation and sedimentation patterns related to dredging and other transportation activities can also lead to shoaling and sediment deposition on benthic habitats such as spawning grounds, SAV, and areas containing shellfish (Wilber *et al*. 2005; MacKenzie 2007).

Dredging may directly affect SAV through the physical removal of plants and indirectly affect SAV by the reduction in light penetration and burial, or smothering by turbidity plumes and sedimentation (Deegan and Buchsbaum 2005). While SAV may regrow in a dredged area if the exposure to excessive suspended sediments is not protracted and accumulated sediments are removed by currents and tides after dredging ceases (Wilber *et al*. 2005), SAV recolonization may be limited if the bottom sediments are destabilized or its composition is altered (Thayer *et al*. 1997). Even when bottom sediments are stabilized and conducive to SAV growth, deepening may result in the area not having enough light for SAV recolonization (Barr 1987). Dredging and excavation in intertidal habitats can also alter tidal flow, currents, and tidal mixing regimes of the dredged area and surrounding habitats, leading to changes in the environmental parameters necessary for successful nursery habitats (Barr 1987).

Overwater structures can cause shading that can lead to reductions in juvenile fish populations and reduced growth and survival of fish, compared to open habitats (Able *et al*. 1998; Duffy-Anderson and Able 1999). Fish use visual cues for spatial orientation, prey capture, schooling, predator avoidance, and migration. Reduced-light conditions under overwater structures limit the ability of fish, especially juveniles and larvae, to perform these essential activities (Hanson *et al*.

2003). In addition, the use of artificial lighting on bridges creates unnatural nighttime conditions that can increase the susceptibility of some fish to predation and interfere with predator/prey interactions (Nightingale and Simenstad 2001a; Johnson *et al.* 2008).

Overwater structures may also damage SAV and cause substrate scour (Kennish 2002). Shading can reduce prey organism abundance and the complexity of the habitat by reducing SAV and phytoplankton abundance (Haas *et al*. 2002). SAV provides food and shelter for many commercially and recreationally important species, attenuates wave and current energy, and plays an important role in the chemical and physical cycles of coastal habitats (Thayer *et al*. 1997). The loss of SAV results in a reduction in rearing and use of refuge by migrating and resident species. SAV beds are more difficult to map than some other subtidal habitats because of their spatial and temporal dynamic nature, making these habitats more vulnerable to inadvertent dredging (Thayer *et al*. 1997; Deegan and Buchsbaum 2005). The disturbance of sediments and rooted vegetation decreases habitat suitability for fish and shellfish resources and can affect the spatial distribution and abundance of fauna (Nightingale and Simenstad 2001a; Uhrin and Holmquist 2003; Eriksson *et al*. 2004; Johnson *et al.* 2008).

Waterway crossings can reduce or eliminate upstream and downstream fish passage through improperly placed or slip-lined culverts at road crossings (Evans and Johnston 1980; Belford and Gould 1989; Clancy and Reichmuth 1990; Furniss *et al*. 1991). Improperly designed stream crossings can adversely affect aquatic organisms by blocking access to spawning, rearing, and nursery habitat from perched culverts constructed with the bottom of the structure above the level of the stream, and hydraulic barriers to passage are created by undersized culverts which constrict flow and create excessive water velocities (Evans and Johnston 1980; Belford and Gould 1989; Furniss *et al*. 1991; Jackson 2003). Smooth-bore liners made from high density plastic can greatly increase flow velocities through the passage. Culverts and bridges can be plugged by debris or overtopped by high flows. The geometry of a stream is affected by the amount of water and sediment that the stream carries. These factors may be altered by roads and stream crossings. This can be exacerbated by climate change. Road damage, channel alteration, and extreme sedimentation from roads can cause stream flow to become too shallow for upstream fish movement through culverts. This can also lead to increased predation on fish. Alteration of stream morphology is usually detrimental to fish habitat and can change stream velocity and increase sedimentation of the streambed, adversely affecting spawning and migration of diadromous fish (Furniss *et al*. 1991; Johnson *et al.* 2008).

Tidal restrictions typically reduce upstream salinity and the maximum elevations of tidal flooding, which can transform the plant community and alter the entire upstream salt marsh. Invasive species which are more tolerant of brackish conditions, such as the common reed, often displace native salt marsh vegetation and reduce plant diversity and vegetative structure. Changes in vegetation can cause major shifts in wildlife use, from diverse native salt marsh fauna to fewer, more generalist species (Cape Cod Commission 2001). Improperly designed bridges and culverts may have such tidal restrictions. Data collected on the degree of restriction before the design process can be used to reduce or eliminate the restriction.

In addition, the loss and fragmentation of coastal wetlands by transportation infrastructure, tide gates, and other engineering structures, can reduce a wetland system's capacity to store floodwaters and to protect inland ecosystems and properties from storm damage. Consequently, the damages from major coastal storms are exacerbated as the structures impound storm water and increase the severity of flood events (Cape Cod Commission 2001). This can also be exacerbated by climate change. Wetland losses can interrupt the life history processes of managed species. Wetland impacts and hydrological modifications from transportation activities can increase the amount of run-off entering the aquatic environment and contribute to the reduced productivity of fishery resources. Wetlands serve as habitat for early life history stages of many species of fish, shellfish, crabs, and shrimp, which use the physical structure of marsh grasses as refuge from predators (Tyrrell 2005). Smaller fish, such as mummichog, Atlantic silverside, sticklebacks, and sheepshead minnow, rely on salt marshes for parts of their life cycles. These species form the prey base of many larger, commercially important species such as flounder species, black sea bass, and bluefish (Collette and Klein-MacPhee 2002).

4.6 Vessel Interaction

Construction and maintenance of transportation projects may result in increased vessel traffic. Vessels such as barge mounted cranes may be used to conduct general construction activities associated with transportation projects. An increase in vessel traffic may result from new vessels accessing the water at a project site, where there was previously no access, or through a temporary increase during construction. The use of dredges or other work vessels cause a small, localized, temporary increase in vessel traffic. Increases in the speed, size, and density of vessel traffic may require increased frequency of maintenance dredging and produce secondary impacts, such as shoreline erosion, sedimentation, and turbidity as noted in other stressors and effects categories. Improvement dredging may occur in areas that have not previously been subjected to heavy vessel traffic and dredging activities.

4.6.1 Effects

Vessel operation can result in harassment and/or injury and can physically impact ESA-listed species and managed species in the action area. Vessel interactions may contribute to serious injury and mortality events through direct hits or collisions. The physical presence of vessels can interrupt migrating, foraging, overwintering/sheltering, or spawning by ESA-listed species, managed species, and/or forage species such as diadromous fish.

4.6.1.1 ESA-listed species

Salmon, sturgeon, sea turtles, and whales may be injured or killed if struck by boat hulls or propellers. The factors relevant to determining the risk to these species from vessel strikes vary, but may be related to the size and speed of the vessels, navigational clearance (i.e., depth of water and draft of the vessel) in the area where the vessel is operating, and the behavior of individuals in the area (e.g., foraging, migrating, or overwintering).

4.6.1.1.1 ESA-listed fish

Vessel strikes may be detrimental to the long-term viability of Atlantic sturgeon DPSs (Brown and Murphy 2010). The exact number of Atlantic sturgeon killed as a result of being struck by boat hulls or propellers is unknown. While there is some information on the number of mortalities in the Delaware and James rivers thought to be due to vessel strikes, GARFO is not able to use those numbers to extrapolate effects throughout one or more DPS. This is because of the small number of data points and lack of information on the percent of incidences that the observed mortalities represent. Given the time of year in which the fish were observed (predominantly May through July, with two in August), it is likely that many of the adults were migrating through the river to the spawning grounds. GARFO does not have information suggesting that Atlantic sturgeon are struck by vessels in the open marine environment, but vessel strikes are still believed to be a threat. No data is currently available on vessel strikes and Atlantic salmon.

4.6.1.1.2 Sea turtles

Interactions between vessels and sea turtles can take many forms, from the most severe (death or bisection of an animal or penetration to the viscera), to severed limbs or cracks to the carapace, which can also lead to mortality directly or indirectly. Sea turtle stranding data for the U.S. Gulf of Mexico and Atlantic coasts, Puerto Rico, and the U.S. Virgin Islands show that between 1986 and 1993, about 9% of living and dead stranded sea turtles had propeller or other vessel strike injuries (Lutcavage *et al*. 1997). According to 2001 Sea Turtle Stranding and Salvage Network stranding data, at least 33 sea turtles (loggerhead, green, Kemp's ridley, and leatherbacks) that stranded on beaches from Maine through North Carolina were struck by a vessel. This number underestimates the actual number of vessel strikes that occur since not every vessel-struck turtle will strand, not every stranded turtle will be found, and many stranded turtles are too decomposed to determine whether it was struck by a vessel. It should be noted, however, that it is not known whether all vessel strikes were the cause of death or whether they occurred post-mortem (NOAA Fisheries SEFSC 2001).

Information is lacking on the type or speed of vessels involved in turtle-vessel strikes; however, there appears to be a correlation between the number of vessel-struck turtles and the level of recreational vessel traffic (NRC 1990). Although little is known about a sea turtle's reaction to vessel traffic, it is generally assumed that turtles are more likely to avoid injury from slower moving vessels since the turtle has more time to maneuver and avoid the vessel. In addition, the risk of vessel strike is influenced by the amount of time the animal remains near the water surface.

4.6.1.1.3 Whales

Large whales, particularly right whales, are vulnerable to injury and mortality from vessel strikes. Although right whales are not the species reported struck most often overall, the low abundance of right whales suggests that right whales are struck proportionally more often than any other species of large whale (Jensen and Silber 2003). Vessel strike injuries to whales may be in the form of propeller wounds characterized by external gashes or severed tail stocks, or blunt trauma injuries indicated by fractured skulls, jaws, and vertebrae, and massive bruises that sometimes lack external expression (Laist *et al*. 2001). Collisions with smaller vessels may result in propeller wounds or no apparent injury, depending on the severity of the incident. Laist *et al*. (2001) reports that of 41 vessel strike accounts that reported vessel speed, no lethal or severe injuries occurred at speeds below ten knots, and no collisions were reported for vessels traveling less than six knots. All whales are potentially subject to collisions with vessels; however, vessel collisions pose the greatest threat to right whales due to their critical population status, slow speed, and behavioral characteristics that cause them to remain at the surface. Although the threat of vessel collision exists anywhere ESA-listed species and vessel activity overlap, vessel strike is more likely to occur in areas where high vessel traffic coincides with high species density. In addition, vessel strikes are more likely to occur and more likely to result in serious injury or mortality when large vessels are traveling at speeds greater than ten knots (Laist *et al.* 2001).

4.6.1.2 EFH and other NOAA-trust resources

Vessel operation and maintenance can affect benthic habitat, through shading of SAV, vessel groundings, and fuel spills. Grounded vessels may physically damage and smother benthic habitats, change wave energy and sedimentation patterns, and scatter debris across sensitive habitats (Precht *et al*. 2001; Zelo and Helton 2005). Benthic, shoreline, and pelagic habitats may be disturbed or altered by vessel use, resulting in cumulative impacts in heavy traffic areas (Barr 1993). Direct disturbances to bottom habitat include propeller scouring and vessel wake impacts on sensitive benthic habitats and direct contact by grounding out. Propeller scouring can result in a loss of benthic habitat, decrease productivity, fragment SAV beds, and lead to further erosion and habitat degradation (Uhrin and Holmquist 2003). Vessels can directly and indirectly impact SAV, by dragging and tearing plant tissues from increased wave-action or hydraulic pumping, reducing light availability by elevated turbidity and resuspension of bottom sediments, and altering habitat and substrate causing plants to be uprooted and inhibiting recruitment (Eriksson *et al.* 2004; Johnson *et al.* 2008). Wave energy caused by vessels can substantially impact aquatic shoreline and backwater areas, eventually causing the loss and disturbance of shoreline habitats (Karaki and vanHoften 1975; Barr 1993; Klein 1997). The degree of shoreline erosion caused by vessels generally depends on the wave energy and surge produced by the vessel and the slope of the shoreline, sediment type, type and amount of shoreline vegetation, characteristics of the water body (e.g., water depth and bottom topography), and distance between the vessel and shoreline (Karaki and vanHoften 1975; Barr 1993). Vessels could also temporarily exclude an area from being used by managed species if suitable clearances are not maintained from the bottom of the vessel to the substrate.

5.0 Transportation Activities and Sub-Activities

This section describes transportation activities and sub-activities that may impact ESA-listed species and their critical habitat, EFH, and other NOAA-trust resources. This information can be used in by transportation agencies to prepare biological evaluations/assessments and EFH assessments. Transportation actions that affect aquatic habitats can be broken out into four main activities with a variety of sub-activities. These are further described below. Transportation actions may fall under more than one applicable activity and may include one or more sub-activities.

The potential stressors produced by transportation activities generally fall within the following categories: underwater noise/hydroacoustic energy, impingement/entrainment and entanglement, turbidity and sedimentation, reduced water quality (dissolved oxygen [DO], temperature, and pollutants), habitat alteration, and vessel interaction. Section 4.0 of this guidance provides details on which activities produce specific stressors and their associated effects to ESA-listed species, EFH, and NOAA-trust resources. Each transportation activity has the potential to produce the all of these stressors, depending on the equipment or construction techniques used.

5.1 Transportation Activity Descriptions

5.1.1 Bridge Repair, Demolition, and Replacement

Bridges may cross rivers, streams, or other water bodies as well as other transportation infrastructure. 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. Bridge construction may be a component of larger roadway construction or a standalone project. Bridge replacements tend to be long-term projects requiring one or more years to complete. Installation of replacement bridges may require construction of a temporary or detour bridge.

Work under this activity can be deconstructed into the following sub-activities: cofferdams/ dewatering, demolition, pile driving/removal, dredging/excavation, fill/ stabilization, vessel activities, habitat restoration, scientific measurement devices/survey activities, and staging area establishment.

5.1.2 Culvert Repair and Replacement

Culverts are used to convey rivers, streams, and other water bodies under roadways or other fill. For the purposes of this BMP Manual, any culvert-like structure is considered a culvert and not a bridge, regardless of the length or size of the structure; this is due to the installation methods and expected stressors. Conventional culverts may be made of concrete, corrugated metal, timber, and PVC piping. Culvert installation may occur independently or as part of a larger transportation improvement project. Work on culverts may involve vegetation and sediment removal, pavement and roadbed 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. Culvert replacements are typically short term projects that require less than one month to complete.

Work under this activity can be deconstructed into the following sub-activities: cofferdams/ dewatering, demolition, excavation, fill/stabilization, habitat restoration, scientific measurement devices/survey activities, and staging area establishment.

5.1.3 Docks, Piers, and Waterway Access Projects

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. Decking may be made of plastic, timber, or steel. Docks, piers, and waterway access projects may be associated with other transportation projects or be independently created. They can be standalone structures or incorporated into existing or replacement crossings.

Work under this activity can be deconstructed into the following sub-activities: cofferdams/ dewatering, demolition, pile driving/removal, excavation, fill/stabilization, vessel activities, habitat restoration, scientific measurement devices/survey activities, and staging area establishment.

5.1.4 Slope Stabilization

Slope stabilization is the protection of embankments at bridges, culverts, and roadways from erosive forces of flowing water. 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.

Work under this activity can be deconstructed into the following sub-activities: cofferdams/ dewatering, pile driving/removal, excavation, fill/stabilization, vessel activities, habitat restoration, scientific measurement devices/survey activities, and staging area establishment.

5.2 Transportation Sub-Activity Descriptions

5.2.1 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.

5.2.2 Demolition

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.

5.2.3 Pile Driving/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, or mechanical demolition.

5.2.4 Dredging/Excavation

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.

5.2.5 Fill/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.

5.2.6 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.

5.2.7 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 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.

5.2.8 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.

5.2.9 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.

6.0 Best Management Practices (BMPs)

The recommended BMPs provided here are based on the review of recommendations provided in past consultations with transportation agencies on similar in-water construction activities in the GAR and are adapted from Johnson *et al.* 2008. The BMPs are crafted to avoid and minimize impacts to ESA-listed species and their critical habitat, EFH, and other NOAA-trust resources, if present, at a particular site. The recommended BMPs are provided by stressor and will vary for a given activity based on site-specific and project-specific information, including the presence of ESA-listed species and their critical habitat, EFH and/or NOAA-trust resources. Not all BMPs or stressors may apply for all actions in a given stressor category. Likewise, additional or innovative BMPs not listed may be identified during coordination with NOAA Fisheries. The stressor-specific BMPs below should be incorporated into all transportation actions, to the maximum extent practicable, as site conditions allow.

6.1 Underwater Noise/Hydroacoustic Energy

These BMPs should be incorporated into all transportation activities that produce underwater noise/hydroacoustic energy, where possible and as site conditions allow.

- Use mechanical demolition methods, instead of blasting, when possible.
- Develop a detailed blast plan with minimization measures, and submit to GARFO for review, in advance of any detonation activity. The plan may include measures to:
  - Stem (cap/fill) each detonation bore hole;
  - Fire all charges in a single firing circuit with a delayed detonation between each charge;
  - Focus blast energy towards a solid substrate rather than towards the water column;
  - Install noise attenuating devices such as bubble curtains;
  - Conduct the blasting during periods of low water or low tide;
  - Use rubber blasting mats to reduce debris and acoustic signature;
  - Use low weight/energy repellant charges that startle fish from the area prior to blasting; and
  - Install appropriate monitoring devices to adaptively manage the blasting plan;
  - ESA-listed species: Detonate charges using explosive weights that result in pressure levels less than species injury/mortality and behavioral thresholds. The production of injury/mortality thresholds[14] should remain within 100 feet of the blasting source.
  - ESA-listed species: Place a weighted turbidity curtain around blast areas to act as a barrier. Ensure the area is clear of all ESA-listed species prior to closing the curtain. If injury/mortality thresholds are expected, the turbidity curtain should be placed at a distance from the source beyond where injury thresholds would occur.
- Conduct noise-generating work in a way that minimizes acoustic effects and avoids injury (single strike and cumulative exposure) to ESA-listed and managed species and NOAA-trust resources.

[14] Refer to Table 1 for species-specific thresholds.

- Use noise attenuation and minimization measures during piles driving, such as:
  - Surrounding piles with an air bubble curtain system, isolation casing, or dewatered cofferdam.
  - Driving piles in the dry or during low water conditions for intertidal areas.
  - Using vibratory hammers and construction phasing to minimize acoustic impacts.
  - Minimizing the number and size of temporary and permanent piles.
  - Limiting pile driving activities to no more than 12 hours per day.
  - Providing a 12 hour quiet (recovery) period between pile driving days.
  - Using a "soft start" or "ramping up" pile driving (e.g., driving does not begin at 100% energy).
  - Driving piles as deep as possible with a vibratory hammer prior to using an impact hammer.
  - Using cushion blocks when using an impact hammer.
  - Using drilled shafts instead of hammered piles where appropriate.
- Develop a project schedule and plan prior to construction, which avoids or minimizes noise during sensitive life stages (migration and spawning) of ESA-listed species, federally-managed species, and other NOAA-trust resources such as anadromous fish. This may include isolating in-water work or implementing time of year (TOY) restrictions.

6.2 Impingement/Entrainment and Entanglement

These BMPs should be incorporated into all transportation activities that may result in impingement/entrainment and entanglement, where possible and as site conditions allow.

- Ensure any in-water lines, ropes, or chains are 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.
- Attach any cables or utility lines to structures above the water, instead of locating them in water or within the substrate. Bury and prevent cables or utility lines from coming through the substrate if they are necessary to be in the water.
- Screen water diversions[15] on fish-bearing streams. Design intakes with minimal flows to prevent impingement/entrainment. See Anadromous Salmonid Passage Facility Design for the appropriate velocity (generally ≤ 0.5 ft/s).
- Allow all fish to exit an enclosed area prior to any dewatering.
- Properly secure turbidity control measures and design them in a manner that does not block entry to or exit from critical habitat.
- Monitor turbidity control measures to ensure aquatic species are not entangled or trapped within them.

[15] It is recommended that 2 mm wedge wire screens be used; the configuration of the wedge wire creates turbulence that reduces impingement/entrainment.

6.3 Turbidity and Sedimentation

These BMPs should be incorporated into all transportation activities that produce turbidity and sedimentation, where possible and as site conditions allow.

- Position new structures to avoid altering natural sediment accretion rates and patterns.
- Maintain or stabilize upstream and downstream channel and bank conditions if an existing stream crossing structure causes erosion or accretion problems.
- Limit the amount and extent of turbidity and sedimentation by using appropriate sedimentation and turbidity controls such as silt curtains, settling basins, cofferdams, and operational modifications such as conducting the work at low tide. Specify the measures to be used in the construction plans.
    - Install erosion control measures prior to ground-disturbance;
    - Survey erosion and sediment control measures daily for deficiencies: repair or replace deficiencies immediately;
    - Prevent sediment and debris from entering the water using geo-textile fabric, hay bales, or other methods. Use nets, tarps, and pans when demolishing bridge superstructures; remove demolition debris that falls into the water; and
    - Upon project completion, remove and stabilize all temporary construction materials with sediment and erosion control measures to prevent reentry into waterways.
- Minimize the suspension of sediments and disturbance of the substrate when removing piles by implementing the applicable techniques:
    - Remove piles with a vibratory hammer, rather than by direct pull or clamshell;
    - Remove piles slowly to reduce sediment sloughing off in the water column;
    - Strike or vibrate the pile to break the bond between the sediment and pile to minimize the pile breakage, and reduce the amount of sediment sloughing off the pile during removal;
    - Cut or drive the pile below the mudline and leave the stub in place;
    - Surround the pile with a silt curtain from the surface of the water to the substrate; and
    - Place piles on a barge equipped with a basin to contain all attached sediment and runoff water after removal.
- Dewater fine-grained sediments removed from inside culverts in an upland location and stabilize to prevent reentry into a waterway.
- Install a riprap bedding layer (such as a gravel filter blanket or geotextile) to prevent underlying sediments from washing through riprap during high water.
- Use operational modifications to minimize turbidity and sedimentation during dredging. This may include using an environmental bucket on mechanical dredges, reducing lift speeds, using small diameter cutterhead dredges, and/or limiting the use of large hopper dredges.
- Design the dredge footprint to avoid sensitive habitats and provide appropriate buffers to protect these areas from accretion of sediment resuspended during dredging.
- Prohibit side-casting or temporary storage of dredged material in the waterway.

- Prohibit unfiltered or unprocessed overflows from barges into the water, and ensure that any barge transfer is accomplished without generating sediment plumes.
- Develop a project schedule and plan prior to construction, which avoids or minimizes sediment disturbance, during sensitive life stages (migration and spawning) of ESA-listed species, federally-managed species, and other NOAA-trust resources such as anadromous fish and shellfish. This may include isolating in-water work or implementing TOY restrictions.

6.4 Reduced Water Quality

These BMPs should be incorporated into all transportation activities that may result in reduced water quality, where possible and as site conditions allow.

- Only use clean fill. Place fill so that it is not likely to be eroded by high water flows.
- Minimize the amount of new impervious surfaces, and maintain a vegetated buffer between the water and upland activities.
- Incorporate stormwater controls to minimize pollutants in aquatic habitats.
- Ensure temperature and DO levels remain within the appropriate ranges to reduce any effects to ESA-listed and managed species.[16]
- Control roadway sanding and the use of deicing chemicals and avoid side casting of road materials to reduce their entry into streams and wetlands.
- Disturbance of contaminated sediments should only occur behind weighted, full-depth silt curtains.
- Ensure that raw concrete or grout does not contact the water.
- Avoid the use of creosote or pressure treated (CCA, ACQ, etc.) piles and do not locate any treated piles in areas containing shellfish or in sensitive habitats.
- Cut removed creosote-treated timber piles into short lengths to prevent reuse and dispose of all debris from creosote-treated piles including attached, contaminated sediments, in an approved upland facility.
- Remove cofferdams or other diversion structures only after water quality is consistent with ambient levels outside the structure.
- Remove contaminants and sediments from water discharge prior to entering aquatic habitats.
- Treat bridge runoff before discharging into a water body to avoid and minimize the direct input of contaminants and pollutants into aquatic areas.
- Evaluate dredge material to determine the appropriate disposal method and location.

6.5 Habitat Alteration

These BMPs should be incorporated into all transportation activities that may result in habitat alteration, where possible and as site conditions allow.

- Site all transportation projects to minimize aquatic impacts.
- Ensure planting media is free of all non-native or invasive species.

[16] Refer to the ESA-listed species tables and EFH designations for these water quality parameters.

- Remove all obsolete and temporary structures and fills including monitoring devices in their entirety. Return aquatic habitats impacted by temporary activities, fills, or structures to pre-construction or better condition, including contours, elevations, substrate, and vegetation.
- Place a geotextile barrier under any temporary platforms and/or access fills to ensure that any fill will be removed completely at the end of construction.
- Develop a project schedule and plan prior to construction, which avoids or minimizes sediment disturbance, noise, and physical obstruction during sensitive life stages (migration and spawning) of ESA-listed species, federally-managed species, and other NOAA-trust resources such as anadromous fish and shellfish. This may include isolating in-water work or implementing TOY restrictions.
- Complete pre- and post-construction monitoring to determine the project was completed as intended to determine fishery resources present, habitat impacts, and mitigation needs.
- Use multiple-season biological sampling data (pre- and post-construction) to assess the potential and resultant impacts on habitat and aquatic organisms.
- Conduct benthic biological surveys to determine benthic communities present. Conduct post-dredge surveys to ensure targeted depths are reached and to determine benthic recovery.
- Fill all holes left by the piles with clean substrate appropriate for the site.
- Incorporate large woody material or other habitat features to promote habitat complexity, in a manner that does not obstruct aquatic organism passage.
- Orient artificial lighting on crossings to avoid illumination of the surrounding waters at night.
- Design crossings to serve multiple modes of transportation to reduce the number of structures.
- Prepare a culvert maintenance plan to ensure compliance with minimization measures.
- Construct bridges that span waterways instead of culverts.
- Design bridge abutments to minimize disturbances to banks and locate them outside of the floodplain.
- Orient bridges perpendicular to the waterbody/stream.
- Incorporate measures that increase the ambient light transmission under the bridge including:
    - maximizing the height of the structure;
    - minimizing the width of the structure; and
    - minimizing the number of instream pilings/piers.
- Use open-bottom culverts which maintain a natural stream bottom and natural stream characteristics.
- Repair and replace existing stabilization structures in the existing alignment.
- Use natural channel design and natural shorelines instead of hard erosion control structures. Incorporate vegetative plantings where possible.
- Ensure that bankward slopes of the dredged area are slanted to acceptable side slopes to prevent sloughing of the channel side slopes.
- Consider beneficial use of suitable sediments and give priority to beneficial uses of material that contributes to habitat restoration and enhancement.

- Ensure that any proposed dredging is necessary to maintain target depths. Evaluate recent bathymetric surveys to determine the existing depths of the proposed dredge area.
- Discuss the need for an observer plan[17] with GARFO PRD in areas where ESA-listed species may be present near proposed project areas.
- Coordinate with GARFO on specific recommended TOY restriction dates, based on the proposed activities and location.

Sensitive Habitats (tidal SAS, natural rocky habitats, intertidal areas, and areas containing shellfish)

- Avoid and minimize all activities (including work footprint, structures, shading, temporary and permanent fill, excavation, etc.) in shallow water habitats and sensitive habitats such as critical habitat, SAV, mudflats, salt marsh, areas containing shellfish, and intertidal areas.
- Use low ground pressure vehicles when working in wetlands and beach matting for work in intertidal areas.
- For bridges less than 30 feet high, do not construct weep holes or outlets that result in free fall over sensitive habitats, to minimize turbidity and scouring.
- Consult historic SAV surveys and conduct new pre-construction SAV surveys in the growing season due to the spatial and temporal dynamic nature of SAV beds. Have a qualified, professional biologist delineate any SAV in the field prior to the start of any work.
- Provide compensatory mitigation for all unavoidable impacts to EFH and sensitive habitats. Coordinate with GARFO HCD to determine the appropriate mitigation ratios. The amount of compensatory mitigation for a proposed project should focus on the type of mitigation, functional equivalency of the habitats lost and replaced, and factors such as habitat rarity, temporal loss of functions, time to reach full function, and difficulty in achieving success. Develop a compensatory mitigation plan that includes:
    - annual monitoring, performance measures to evaluate success, contingency plans, and protection mechanisms; and
    - provisions for relocating and maintaining any live shellfish during construction.

Fish Passage/Migration Habitat

- Ensure temporary structures or barriers do not block ESA-listed or managed species' access to an area, preventing movement in or out of a river or channel.
- Include a sufficiently large zone of passage that allows ESA-listed and managed species to safely navigate around undesirable noise and/or turbidity levels.
- Design projects to maintain adequate flow conditions for fish passage, maintain water quality, and to maintain properly functioning channel, floodplain, riparian, and estuarine conditions.
- Incorporate juvenile and adult fish passage facilities on all water diversion projects.

[17] Such plan should indicate methods for observing whether a particular species is present on site at time prior to/during construction and measures to avoid or protect such species. For example, if a particular species is observed, work may be ceased until the species has transited through.

- Design, construct, and maintain structures to provide sufficient water depth and maintain suitable water velocities for anadromous and resident fish. Consider seasonal headwater and tailwater levels and how variations could affect passage of all aquatic life stages. Design considerations include:
    - constructing a low flow channel and/or setting culvert invert elevations to maintain low flow conditions;
    - constructing grade control structures;
    - constructing energy dissipation pools;
    - adjusting culvert slope or alignment;
    - designing structures to pass peak flows; and
    - designing culverts/bridges for long-term, effective aquatic organism passage (generally ≥ 1.2 bank full width).
- For work on crossings with known or potential tidal restrictions, collect tide gauge data to quantify the restriction and develop alternatives that can be evaluated prior to and during the design of the project.
- Ensure the location and overall design of the fish passage structure and the stream crossing are compatible with local stream conditions and stream geomorphology.
- For projects that may affect fish passage, describe how the proposed project will meet the stream simulation or hydraulic design criteria. Fish passage criteria are described in Chapter 7 of the NOAA Fisheries Anadromous Salmonid Passage Facility Design. Analyze and evaluate the existing and proposed channel conditions within the action area and vicinity.
- Do not slip line existing culverts.

Climate Change Considerations

- Incorporate climate change considerations into the project design:[18]
    - For climate change projections, use the IPCC Representative Concentration Pathways (RCP) 8.5/high greenhouse gas (GHG) emission scenario and RCP 4.5/intermediate GHG emission scenario (IPCC 2014).
    - For design calculations for new or replaced structures, use the global mean and regional sea level rise projections for intermediate-high and extreme scenarios referenced in Sweet *et al.* (2017) in design calculations for new or replaced structures.
- Use early screening tools to determine the appropriate planning and design steps given the potential consequences; this can include vulnerability assessments.
- Ensure the level of effort undertaken to assess climate change and SLR impacts and to plan and engineer adaptation measures is commensurate with the scale of the project and its potential consequences.
- Design transportation projects to be resilient to the impacts of climate change and SLR; implement accommodation strategies (e.g., HEC- FHWA 2014).

[18] GARFO HCD is currently working on a Climate Change Guidance Document. Once available, the recommendations of this document should be incorporated into transportation projects where possible.

6.6 Vessel Interaction

These BMPs should be incorporated into all transportation activities that may result in vessel interaction, where possible and as site conditions allow.

- Reduce vessel speeds in inshore areas, or otherwise minimize wake damage to shorelines, and consider no-wake zones in highly sensitive areas, such as spawning habitat and SAV beds. Identify appropriate vessel routes in the design process to minimize impacts to shorelines and shallow water habitats.
- Consider the effects of increased vessel traffic when conducting in-water actions.
- Ensure that vessels are operated in adequate water depths to avoid propeller scour and grounding at all tides. Use shallow draft vessels that maximize the navigational clearance between the vessel and the bottom in shallow areas.
- Use posted lookouts and use measures to slow down and avoid any observed ESA-listed species when operating in areas where ESA-listed species may be present.
- Keep vessel speeds below 10 knots during transit activities to avoid sturgeon interactions, and avoid certain times of year (spawning run) or areas where sturgeon may congregate for spawning or foraging.
- Implement appropriate precautions to ensure an ESA-listed species' protection (e.g., parallel course and speed, do not attempt head-on approach, approach and leave stationary whales at no wake speed, etc.), if seen within 100 yards of vessel movement.
- Ensure vessels maintain at least a 500-yard minimum distance from whales.
- Do not moor vessels in SAV or in such a way that could shade SAV.

Literature Cited

Able KW, Manderson JP, Studholme AL. 1998. The distribution of shallow water juvenile fishes in an urban estuary: The effects of manmade structures in the lower Hudson River. Estuaries 21(4B):731-44.

Allen KO, Hardy JW. 1980. Impacts of navigational dredging on fish and wildlife a literature review. Washington (DC): Biological Services Program, U.S. FWS.

Anchor Environmental. 2003. Literature review of effects of resuspended sediments due to dredging. June. 140 pp.

Auld AH, Schubel JR. 1978. Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. Estuarine and Coastal Marine Science 6(2):153-64.

Auster PJ. 1998. A conceptual model of the impacts of fishing gear on the integrity of fish habitats. Conservation Biology 12:1198-1203.

Auster PJ, Langton R. 1999. The effects of fishing on fish habitat. American Fisheries Society Symposium 22:150-187.

Baker K. 2008. DRAFT. Assessment and Mitigation of Marine Explosives: Guidance for Protected Species in the Southeast U.S. National Marine Fisheries Service Southeast Regional Office St. Petersburg, FL v1: Feb 2008.

Barker SL, Townsend DW, Hacunda JS. 1981. Mortalities of Atlantic herring, *Clupea h. harengus*, smooth flounder, *Liopsetta putnami*, and rainbow smelt, *Osmerus mordax*, larvae exposed to acute thermal shock. Fisheries Bulletin 79(1):1981.

Barr BW. 1987. The Dredging Handbook: A primer for dredging in the coastal zone of Massachusetts. Publication No. 14,870-181-500-6-87-CR. Massachusetts Coastal Zone Management Program.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth symposium on coastal and ocean management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Bejda AJ, Phelan BA, Studholme AL. 1992. The effects of dissolved oxygen on growth of young of-the-year winter flounder. Environmental Biology of Fishes 34:321-7.

Belford DA, Gould WR. 1989. An evaluation of trout passage through six highway culverts in Montana. North American Journal of Fisheries Management 9(4):437-45.

Berry WJ, Hinchey EK, Rubinstein NI, Klein-MacPhee G. 2004. Winter flounder, *Pseudopleuronectes americanus*, hatching success as a function of burial depth in the laboratory. Ninth flatfish biology conference- poster presentation; 2004 Dec 1-2; Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Berry WJ, Rubinstein NI, Hinchey EK, Klein-MacPhee G, Clarke DG. 2011. Assessment of dredging-induced sedimentation effects on winter flounder (*Pseudopleuronectes americanus*) hatching success: results of laboratory investigations. Proceedings of the WEDA XXXI Technical Conference and TAMU 42 Dredging Seminar.

Beschta RL, Bilby RE, Brown GW, Holtby LB, Hofstra TD. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Salo EO, Cundy TW, editors. Streamside management: forestry and fishery interactions. Seattle (WA): University of Washington, College of Forest Resources. p 191-232.

Bilby RE, Ward JW. 1991. Characteristics and function of large woody debris in streams draining old-growth, clearcut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 48:2499-508.

Boesch DF, Anderson DM, Horner RA, Shumway SE, Tester PA, Whitledge TE. 1997. Harmful algal blooms in coastal waters: options for prevention, control and mitigation. Silver Spring (MD): NOAA Coastal Ocean Office. NOAA Coastal Ocean Program Decision Analysis Series No. 10. 46 p + appendix.

Blaxter JHS. 1969. Development: eggs and larvae. In: Hoar WS, Randall DJ, editors. Fish physiology: Vol. 3, reproduction and growth, bioluminescence, pigments, and poisons. New York (NY): Academic Press. p 177-252.

Brawn VM. 1960. Temperature tolerance of unacclimated herring (*Clupea harengus* L.). Journal of the Fisheries Research Board of Canada 17(5):721-3.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

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

Burton WH. 1993. Effects of bucket dredging on water quality in the Delaware River and the potential for effects on fisheries resources. Versar, Inc., 9200 Rumsey Road, Columbia, Maryland 21045.

Cape Cod Commission. 2001. Cape Cod atlas of tidally restricted salt marshes. Cape Cod, Massachusetts.

Cargnelli LM, Griesbach SJ, Packer DB, Berrien PL, Johnson DL, Morse WW. 1999. Essential Fish Habitat Source Document: Pollock *Pollachius virens*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-131.

Chang S, Berrien PL, Johnson DL, Morse WW. 1999. Essential Fish Habitat Source Document: Windowpane, *Schophthalmus aquosus*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-137.

Christie RW, Allen DE, Jobsis GJ. 1993. Diversions. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 181-6.

Clancy CG, Reichmuth DR. 1990. A detachable fishway for steep culverts. North American Journal of Fisheries Management 10(2):244-6.

Clarke D. 2011. Sturgeon Protection. Dredged Material Assessment and Management Seminar. 24-26 May, 2011. Jacksonville, FL. Presentation. http://el.erdc.usace.army.mil/workshops/11May-dmams/21_Sturgeon-Issues_Clarke.pdf

Collette BB, Klein-MacPhee G, editors. 2002. Bigelow and Schroeder's fishes of the Gulf of Maine. 3rd ed. Washington (DC): Smithsonian Institution Press. 748 p.

Costello CT, Kenworthy WJ. 2011. Twelve-year mapping and change analysis of eelgrass (*Zostera marina*) areal abundance in Massachusetts (USA) identifies statewide declines. Estuaries and Coasts 34:232–242.

Danie DS, Trial JG, Stanley JG. 1984. Species profiles: life histories and environmental requirements of coastal fish and invertebrates (North Atlantic)-Atlantic salmon. Washington (DC): U.S. Fish and Wildlife Service, FWS/OBS-82/11.22 and the U.S. Army Corps of Engineers, TR EL-82-4. 19 p.

De Laney TA. 1995. Benefits to downstream flood attenuation and water quality as a result of constructed wetlands in agricultural landscapes. Journal of Soil and Water Conservation 50:620-6.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

DeRuiter SL, Doukara LK. 2012. Loggerhead turtles dive in response to airgun array sounds. Endangered Species Research 16:55-63. Available from: http://www.int-res.com/abstracts/esr/v16/n1/p55-63/.

Dolat SW. 1997. Acoustic measurements during the Baldwin Bridge demolition. Waterford (CT): Prepared for White Oak Construction by Sonalysts. 34 p + appendices.

Doll C, Chu J, Ramjerdi F, and Kuhn K. 2012. Special issues on infrastructures in a changing environment. *Journal of Infrastructure Systems* 18: 229-231.

Duffy-Anderson JT, Able KW. 1999. Effects of municipal piers on the growth of juvenile fishes in the Hudson River estuary: a study across a pier edge. Marine Biology 133(3):409-18.

Enright JT. 1977. Power plants and plankton. Marine Pollution Bulletin 8(7):158-61.

Eriksson BK, Sandstrom A, Iscus M, Schreiber H, Karas P. 2004. Effects of boating activities on aquatic vegetation in the Stockholm archipelago, Baltic Sea. Estuarine, Coastal and Shelf Science 61(2):339-49.

Evans WA, Johnston B. 1980. Fish migration and fish passage: a practical guide to solving fish passage problems. Washington (DC): U.S. Department of Agriculture, Forest Service. 163 p.

Fajen OF, Layzer JB. 1993. Agricultural practices. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 257-67.

Fay C, Bartron M, Craig S, Hecht A, Pruden J, Saunders R, Sheehan T, Trial J. 2006. Status review for anadromous Atlantic salmon (*Salmo salar*) in the United States. Report to the National Marine Fisheries Service and U.S. Fish and Wildlife Service. 294 p.

Feist BE, Anderson JJ, Miyamoto R. 1996. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. Seattle (WA): Fisheries Research Institute-University of Washington. FRI-UW-9603. 58 p.

Federal Highway Administration (FHWA). 2010. Culvert design for aquatic organism passage. Publication No. FHWA-HIF-11-008. Hydraulic Engineering Circular No. 26, First Edition. FHWA. Washington DC.

Federal Highway Administration (FHWA). 2014. Highway in the coastal environment – assessing extreme events. Publication No. FHWA-NHI-14-006. Hydraulic Engineering Circular No. 25.

Fitzsimons JD, Brown SB, Honeyfield DC, Hnath JG. 1999. A review of early mortality syndrome in Great Lakes salmonids and its relationship with thiamine. *Ambio*, 28: 9- 15.

Fletcher R. 2003. Loss of wetlands: how are bird communities affected? American Institute of Biological Sciences, c2000-2007.

Fonseca MA, KenworthyWJ, Thayer GW. 1992. Seagrass beds: nursery for coastal species. Pages 141-147 *in* R.H. Stroud, editor. Stemming the tide of coastal fish habitat loss: proceedings of a symposium on conservation of coastal fish habitat, Baltimore, Maryland, March 7- 9, 1991. Marine Recreational Fisheries 14. National Coalition for Marine Conservation, Inc., Savannah, Georgia.

Fonseca MS, Kenworthy WJ, Thaywer GW. 1998. Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters. NOAA Coastal Ocean Program Decision Analysis Series No. 12. NOAA Coastal Ocean Office, Silver Spring, MD. 222 pp.

Fraser S, Gotceitas V, Brown JA. 1996. Interactions between age-classes of Atlantic cod and their distribution among bottom substrates. Canadian Journal of Fisheries and Aquatic Sciences 53(2):305-314.

Furniss MJ, Roelofs TD, Yee CS. 1991. Road construction and maintenance. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19th ed. Bethesda (MD): American Fisheries Society. p 297-323.

Goldsborough WJ. 1997. Human impacts on SAV-a Chesapeake Bay case study. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington (DC): ASMFC Habitat Management Series #1. 68 p + appendices.

Goertner JF. 1978. Fish killing potential of a cylindrical charge exploded above the water surface. Naval Surface Weapons Center, White Oak Lab., Silver Spring, MD. Technical Report NCSWC/WOL/TR 77-90.

Gotceitas V, Fraser S, Brown JA. 1997. Use of eelgrass beds (*Zostera marina*) by juvenile Atlantic cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Sciences 54(6):13606-1319.

Govoni JJ, West MA, Settle LR, Lynch RT, Greene MD. 2008. Effects of underwater explosions on larval fish: implications for a coastal engineering project. Journal of Coastal Research 24(2): 228-233.

Greene K. 2002. Beach Nourishment: A Review of the Biological and Physical Impacts. ASMFC Habitat Management Series #7. Washington DC. 118 pp.

Grunwald C, Stabile J, Waldman JR, Wirgin II. 2002. Population genetics of shortnose sturgeon *Acipenser brevirostrum* based on mitochondrial DNA control region sequences. Molecular Ecology 11:1885–1898. doi:10.1046/j.1365-294X.2002.01575. x.

Haas MA, Simenstad CA Jr, Cordell JR, Beauchamp DA, Miller BS. 2002. Effects of large overwater structures on epibenthic juvenile salmon prey assemblages in Puget Sound, WA. Seattle (WA): Washington State Transportation Center (TRAC), University of Washington, and Washington State Department of Transportation. Final Research Report WA-RD 550.1. 114 p.

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

Haro A, Castro-Santos T, Noreika J, Odeh M. 2004. Swimming performance of upstream migrant fishes in open-channel flow: a new approach to predicting passage through velocity barriers. Canadian Journal of Fisheries and Aquatic Sciences 61(9):1590-601.

Hastings R. 1983. A study of the shortnose sturgeon (*Acipenser brevirostrum*) population in the upper tidal Delaware River: assessment of impacts of maintenance dredging. In: Final report to the United States Army Corps of Engineers, Philadelphia District.

Hawkins AD. 1986. Underwater sound and fish behaviour. In: Pitcher TJ, editor. The behavior of teleost fishes. Baltimore (MD): The Johns Hopkins University Press. p 114-51.

Hedger RD, Dodson NE, Bergeron NE. 2005. Habitat selection by juvenile Atlantic salmon: the interaction between physical habitat and abundance. Journal of Fish Biology 67:1054-1071.

Helfman G, Collette BB, Facey DE, Bowen BW. 2009. The diversity of fishes: biology, evolution, and ecology. John Wiley & Sons.

Helton D, Zelo I. 2003. Developing information and support necessary to prioritize and support removal of abandoned vessels impacting coral resources. In: Proceedings of the 13th 156 Biennial Coastal Zone Conference; 2003 Jul 13-17; Baltimore, MD. Charleston (SC): NOAA Coastal Services Center.

Hempen GL, Keevin TM, Jordan TL. 2007. Underwater blast pressures from a confined rock removal during the Miami Harbor dredging project. International Society of Explosives Engineers, 2007G Volume 1, 12 pp.

Howard-Williams C. 1985. Cycling and retention of nitrogen and phosphorus in wetlands: theoretical and applied perspective. Freshwater Biology 15(4):391-431.

Illingworth and Rodkin, Inc. and Jones and Stokes. 2009. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish. Prepared for California Department of Transportation.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report (AR5) of the

Intergovernmental Panel on Climate Change (IPCC). Core Writing Team, Pachauri RK and Meyer LA. IPCC, Geneva, Switzerland, 151 pp.

Jackson SD. 2003. Design and construction of aquatic organism passage at road-stream crossings: ecological considerations in the design of river and stream crossings. In: Irwin CL, Garrett P, McDermott KP, editors. 2003 Proceedings of the International Conference on Ecology and Transportation; 2003 Aug 24-29; Lake Placid, NY. Raleigh (NC): Center for Transportation and the Environment, NC State University. p 20-9.

Jensen AS, Silber GK. 2003. Large Whale Ship Strike Database. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-OPR, 37 pp.

Johnson MR, Boelke C, Chiarella LA, Colosi PD, Greene K, Lellis K, Ludemann H, Ludwig M, McDermott S, Ortiz J, Rusanowsky D, Scott M, Smith J. 2008. Impacts to marine fisheries habitat from nonfishing activities in the Northeastern United States. NOAA Tech. Memo. NMFS-NE-209.

Kalmijn AJ. 1988. Hydrodynamic and acoustic field detection. In: Atema J, Fay RR, Popper AN, Tavolga WN, editors. Sensory biology of aquatic animals. New York (NY): SpringerVerlag. p 83-130.

Karaki S, vanHoften J. 1975. Resuspension of bed material and wave effects on the Illinois and upper Mississippi Rivers caused by boat traffic. St. Louis (MO): U.S. Army Engineer District. Cont. No. LMSSD 75-881.

Keevin TM, Hempen GL. 1997. The environmental effects of underwater explosions with methods to mitigate impacts. U.S. Army Corps of Engineers, St. Louis District. August 1997.

Keevin TM, Gaspin JB, Gitschlag GR, Hempen GL, Linton TL, Smith M, Wright DG. 1999. Underwater explosions: natural resource concerns, uncertainty of effects, and data needs. In: Proceedings of the twenty-fifth annual conference on explosives and blasting technique; 1999 Feb 7-10; Nashville, TN. Cleveland (OH): International Society of Explosive Engineers. p 105-16.

Kennedy VS, Twilley RR, Kleypas JA, Cowan JH, Hare SR. 2002. Coastal and marine ecosystems and global climate change: potential effects on U.S. resources. Arlington (VA): Pew Center on Global Climate Change. 51 p.

Kennish MJ. 2002. Impacts of motorized watercraft on shallow estuarine and coastal marine environments. Journal of Coastal Research Special Issue 37:1-202.

Kircheis D and Liebich T. 2007. Habitat requirements and management considerations for Atlantic salmon (*Salmo salar*) in the Gulf of Maine Distinct Population Segment (GOM DPS). National Marine Fisheries Service, Gloucester, Massachusetts, USA.

Klein R. 1997. The effects of marinas and boating activities upon tidal waters. Owing Mills (MD): Community and Environmental Defense Services. 23 p.

Klein-MacPhee G, Macy WK, Berry W. 2004. In situ effects of suspended particulate loads produced by dredging on eggs of winter flounder (*Pseudopleuronectes americanus*). In: Ninth flatfish biology conference- oral presentation; 2004 Dec 1-2; Water's Edge Resort, Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Knudsen FR, Schreck CB, Knapp SM, Enger PS, Sand O. 1997. Infrasound produces flight and avoidance responses in Pacific juvenile salmonids. Journal of Fish Biology 51:824-9.

Kritzer JP, Delucia, MB, Greene E, Shumway C, Topolski MF, Thomas-Blate J, Chiarella LA, Davy KB, Smith K. 2016. The Importance of Benthic Habitats for Coastal Fisheries. BioScience 66(4):274-284.

Kynard B, Pugh D, Parker T. 2005. Experimental studies to develop guidance and a bypass for shortnose sturgeon at Holyoke Dam. Prepared for the City of Holyoke, Massachusetts.

Laist DW, Knowlton AR, Mead JG, Collet AS, Podesta M. 2001. Collisions between ships and whales. Marine Mammal Science 17(1):35-75.

Larson K, Moehl CE. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): Washington Sea Grant, University of Washington. p 102-12.

Lindholm J, Auster PJ, Kaufman L. 1999. Habitat-mediated survivorship of juvenile (0-year) Atlantic cod (*Gadus morhua*) Marine Ecology Progress Series 180:247-255.

Lindholm J, Auster PJ, Ruth M, Kaufman L. 2001. Modeling the effects of fishing and implications for the design of marine protected areas: juvenile fish responses to variations in seafloor habitat. Conservation Biology 15: 424-437.

Lutcavage, ME, Plotkin P, Witherington B, Lutz PL. 1997. Human impacts on sea turtle survival. Pages 387-409. In: P.L. Lutz and J.A. Musick (eds). The Biology of Sea Turtles. Boca Raton, Florida: CRC Press.

MacKenzie CL Jr. 2007. Causes underlying the historical decline in eastern oyster (*Crassostrea virginica* Gmelin, 1791) landings. Journal of Shellfish Research 26(4):927-38.

Marten K, Herzing D, Poole M, Newman-Allman K. 2001. The acoustic predation hypothesis: Linking underwater observations and recordings during Odontocete predation and observing the effects of loud impulsive sounds on fish. Aquatic Mammals 27(1):56-66.

McCauley RD, Fewtrell J, Duncan AJ, Jenner C, Jenner MN, Penrose JD, Prince RIT, Adhitya A, Murdoch J, McCabe K. 2000a. Marine seismic surveys- a study of environmental implications. *APPEA Journal*. 40:692-708.

McCauley RD, Fewtrell J, Duncan AJ, Jenner C, Jenner MN, Penrose JD, Prince RIT, Adhitya A, Murdoch J, McCabe K. 2000b. Marine seismic surveys: analysis of airgun signals, and effects of airgun exposure on humpback whales, sea turtles, fishes and squid. Report to APPEA by the Centre for Marine Science and Technology, Curtin University of Technology, Australia.

McGraw K, Armstrong D. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): University of Washington Sea Grant. p 113-31.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Milliken AS, Lee V. 1990. Pollution impacts from recreational boating: a bibliography and summary review. Narragansett (RI): Rhode Island Sea Grant. National Sea Grant Depository Publication # RIU-G-002.

Mitsch WJ, Gosselink JG. 1993. Wetlands. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 p.

Moazzam M, Rizvi SHN. 1980. Fish entrapment in the seawater intake of a power plant at Karachi coast. Environmental Biology of Fishes 5:49-57.

Morgan RP II, Rasin VJ Jr, Noe LA, Gray GB. 1973. Effects of the water quality in the C and D Canal region on the survival of eggs and larvae of the striped bass and white perch. Appendix XIII to Hydrographic and Ecological Effects of Enlargement of the Chesapeake and Delaware Canal. Contract No. DACW-61-71-CC-0062, Army Corps of Engineers, Philadelphia District. NRI Ref. No. 73-112: 17 pp.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

Moser M. 1999. Wilmington Harbor Blast Effect Mitigation Tests: Results of Sturgeon Monitoring and Fish Caging Experiments. CZR, Inc.

Munday DR, Ennis GL, Wright DG, Jefferies DC, McGreer ER, Mathers JS. 1986. Development and evaluation of a model to predict effects of buried underwater blasting charges on fish populations in shallow water areas. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1418.

Myrberg AA Jr. 1972. Using sound to influence the behavior of free-ranging marine mammals. In: Winn HE, Olla BL, editors. Behavior of marine animals. Vol. 2: Vertebrates. New York (NY): Plenum Press. p 435-68.

Myrberg AA Jr, Riggio RJ. 1985. Acoustically mediated individual recognition by a coral reef fish (*Pomacentrus partitus*). Animal Behaviour 33:411-6.

Naiman RJ, editor. 1992. Watershed management: balancing sustainability and environmental change. New York (NY): Springer-Verlag New York. 542 p.

Nedwell JR, Thandavamoorthy TS. 1992. The waterborne pressure wave from shallow underwater blasting: An experimental investigation. Applied Acoustics 37:1.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol 1.

Newell RC, Seiderer LJ, Hitchcock DR. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. In: Ansell AD, Gibson RN, Barnes M, editors. Oceanography and marine biology: an annual review. Vol. 36. Oban, Argyll (Scotland): UCL Press. p 127-78.

Nightingale BJ, Simenstad CA Jr. 2001a. Overwater structures: marine issues. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. 133 p + appendices.

Nightingale B, Simenstad CA Jr. 2001b. Dredging activities: marine issues. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. 119 p + appendices.

[NOAA Fisheries] National Marine Fisheries Service Southeast Fisheries Science Center (SEFSC). 2001. Stock assessments of loggerhead and leatherback sea turtles and an assessment of the impact 346 of the pelagic longline fishery on the loggerhead and leatherback sea turtles of the Western North Atlantic. NOAA Technical Memorandum NMFS-SEFSC-455. 343 pp.

[NOAA] National Oceanic and Atmospheric Administration. 1994. Experimental fish guidance devices. Position statement. Long Beach (CA): National Marine Fisheries Service, Southwest Region. 7 p.

Normann JM, Houghtalen RJ, Johnston WJ. 2005. “Hydraulic Design Series No. 5, 2nd Edition, rev.: Hydraulic Design of Highway Culverts.” Rep. No. FHWA-NHI-01-020, Federal Highway Administration.

[NRC] National Research Council. 1990. Decline of sea turtles: causes and prevention. National Academy Press, Washington DC. 259 pp.

[NRC] Natural Research Council. 2002. Effects of trawling and dredging on seafloor habitat. Washington, District of Columbia: National Academy Press. 136 p.

O’Keefe, DJ. 1984. Guidelines for predicting the effects of underwater explosions on swimbladder fish. Report No. NSWC TR 82-328. Naval Surface Weapons Center, White Oak Lab., Silver Spring, MD.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck Jr KL, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Williams SL. 2006. A global crisis for seagrass ecosystems. *BioScience* 56:987-996.

Penttila D, Doty D. 1990. Results of 1989 eelgrass shading studies in Puget Sound. Olympia (WA): Washington Department of Fisheries. Draft Progress Report. 41 p.

Pereira JJ, Goldberg R, Ziskowski JJ, Benien PL, Morse WW, Johnson DL. 1999. Essential Fish Habitat Source Document: Winter Flounder, *Pseudopleuronectes americans*, Life History and Characteristics. NOAA Technical Memorandum NMFS-NE-138. Northeast Fisheries Science Center, Woods Hole, MA.

Poston T. 2001. Treated wood issues associated with overwater structures in freshwater and marine environments. Olympia (WA): Washington State Departments of Transportation, Fish and Wildlife, and Ecology. White Paper. 85 p.

Precht WF, Aronson RB, Swanson DW. 2001. Improving scientific decision-making in the restoration of ship-grounding sites on coral reefs. Bulletin of Marine Science 69(2):1001-12.

Rago PJ. 1984. Production forgone: an alternative method for assessing the consequences of fish entrainment and impingement losses at power plants and other water intakes. Ecological Modelling 24(1-2):79-111.

Reine, K, Clarke D. 1998. Entrainment by hydraulic dredges- a review of potential impacts. Technical Note DOER-E1. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Richard JD. 1968. Fish attraction with pulsed low-frequency sound. Journal of the Fisheries Research Board of Canada 25(7):1441-52.

Richardson WJ, Greene CR, Malme CI, Thomas DH. 1995. Marine mammals and noise. San Diego (CA): Academic Press. 576 p.

Richkus WA, McLean R. 2000. Historical overview of the efficacy of two decades of power plant fisheries impact assessment activities in Chesapeake Bay. Environmental Science and Policy 3(Supplement 1):283-93.

Robinson WE, Pederson J. 2005. Contamination, habitat degradation, overfishing - An “either-or” debate? In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.

Sand O, Enger PS, Karlsen HE, Knudsen F, Kvernstuen T. 2000. Avoidance responses to infrasound in downstream migrating European silver eels, *Anguilla anguilla*. Environmental Biology of Fishes 57(3):327-36.

Sherman K, Jaworski NA, Smayda TJ, editors. 1996. The Northeast Shelf Ecosystem: assessment, sustainability, and management. Cambridge (MA): Blackwell Science. 564 p.

Spence BC, Lomnicky GA, Hughes RM, Novitzki RP. 1996. An ecosystem approach to salmonid conservation. Corvallis (OR): ManTech Environmental Research Services Corp. TR-4501-96-6057.

Stevenson D, Chiarella L, Stephan D, Reid R, Wilhelm K, McCarthy J, Pentony M. 2004. Characterization of the fishing practices and marine benthic ecosystems of the Northeast U.S. Shelf, and an evaluation of the potential effects of fishing on essential fish habitat. Woods Hole (MA): National Marine Fisheries Service, Northeast Fisheries Science Center, NOAA Technical Memorandum NMFS-NE-181. 179 p.

Stevenson D, Chiarella L, Stephan D, Reid R, Wilhelm K, McCarthy J, Pentony M. 2006. Characterization of the fishing practices and marine benthic ecosystems of the northeast U.S. shelf, and an evaluation of the potential effects of fishing on essential habitat. NOAA Tech Memo NMFS NE 181. 179 p.

Stevenson DK, Tuxbury S, Johnson MR, Boelke C. 2014. Shallow water benthic habitats in the Gulf of Maine: A summary of habitat use by common fish and shellfish species in the Gulf of Maine. Greater Atlantic Region Policy Series 14-01. NOAA Fisheries GARFO. 77 pp.

Stocker M. 2002. Fish, mollusks and other sea animals’ use of sound, and the impact of anthropogenic noise in the marine acoustic environment. Journal of Acoustical Society of America 112(5):2431.

Sweet WV, Kopp RE, Weaver CP, Obeysekera J, Horton RM, Thieler ER, Zervas C. 2017. Global and Regional Sea Level Rise Scenarios for the United States. NOAA Technical Report NOS CO-OPS 083. 56 pp.

Thayer WG, Fonseca MS, Kenworthy JW. 1997. Ecological value of seagrasses: a brief summary for the ASMFC habitat committee's SAV subcommittee. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington, DC: ASMFC Habitat Management Series #1. p 68 + appendices.

Transportation Research Board (TRB). 2008. Potential Impacts of Climate Change on U.S. Transportation. Special Report 290.

Travnichek VH, Zale AV, Fisher WL. 1993. Entrainment of ichthyoplankton by a warmwater hydroelectric facility. Transactions of the American Fisheries Society 122(5):709-16.

Trombulak SC, Frissell CA. 2000. "Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities." Conservation Biology, 14(1), 18-30.

Tyrrell MC. 2005. Gulf of Maine marine habitat primer. Gulf of Maine Council on the Marine Environment. vi + 54 p.

Uhrin AV, Holmquist JG. 2003. Effects of propeller scarring on macrofaunal use of the seagrass *Thalassia testudinum*. Marine Ecology Progress Series 250:61-70.

[U.S. ACOE] U.S. Army Corps of Engineers. 1983. Dredging and Dredged Material Disposal. U.S. Dept. Army Engineer Manual 111 0-2-5025.

[U.S. ACOE] U.S. Army Corps of Engineers. 2001. Monitoring of Boston Harbor confined aquatic disposal cells. Compiled by L.Z. Hales, ACOE Coastal and Hydraulics Laboratory. ERDC/CHL TR-01-27.

[U.S. ACOE] U.S. Army Corps of Engineers. 2014. 2014. Procedures to evaluate sea level change: impacts, responses and adaptation. 2014. Engineering Technical Letter. CECW-CE; CECW-P. Technical Letter No 1100-2-1.

[U.S. EPA] U.S. Environmental Protection Agency. 1986. Quality Criteria for Water. EPA 440/5-86-001.

[U.S. EPA] U.S. Environmental Protection Agency. 2000. Environmental screening checklist and workbook for the water transportation industry. Washington (DC): U.S. EPA Office of Water. EPA-305-B-00-004.

[U.S. EPA] U.S. Environmental Protection Agency. 2003. National management measures for the control of non-point pollution from agriculture. Washington (DC): U.S. EPA Office of Water. EPA-841-B-03-004.

[U.S. EPA] U.S. Environmental Protection Agency. 2005. National management measures to control nonpoint source pollution from urban areas. Washington, DC: U.S. EPA Office of Water. EPA-841-B-05-004. 518 p.

[U.S. GAO] U.S. General Accounting Office. 2001. Restoring fish passage through culverts on Forest Service and BLM lands in Oregon and Washington could take decades. Washington, DC: U.S. GAO. GAO-02-136. 29 p.

[U.S. GCRP] U.S. Global Change Research Program. 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. Melillo JM, Richmond T, Yohe GW. Eds. 841 pp.

Waldman JR, Grunwald C, Stabile J, Wirgin I. 2002. Impacts of life history and biogeography on genetic stock structure in Atlantic Sturgeon, *Acipenser oxyrinchus oxyrinchus*, Gulf sturgeon *A. oxyrinchus desotoi*, and shortnose sturgeon, *A. brevirostrum*. Journal of Appl Ichthyology 18:509–518. doi:10.1046/j.1439-0426.2002. 00361.x.

Walsh MG, Bain MB, Squiers T Jr, Waldman JR, Wirgin I. 2001. Morphological and genetic variation among shortnose sturgeon *Acipenser brevirostrum* from adjacent and distant rivers. Estuaries 24:41–48. doi:10.2307/1352811.

[WDFW] Washington Department of Fish and Wildlife. 1998. White Paper submitted to Washington Department of Fish and Wildlife, Washington Dept. of Ecology, Washington Dept. of Transportation. Sequim (WA): Battelle Memorial Institute. 99 p.

Weis JS, Weis P. 2002. Contamination of saltmarsh sediments and biota by CCA treated wood walkways. Marine Pollution Bulletin 44:504-10.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Wilber D, Brostoff W, Clarke D, Ray G. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. DOER Technical Notes Collection. Vicksburg (MS): U.S. Army Engineer Research and Development Center. ERDC TN-DOER-E20. 14 p.

Wilbur AR, Pentony MW. 1999. Human-induced nonfishing threats to essential fish habitat in the New England region. American Fisheries Society Symposium 22:299-321.

Wiley ML, Gaspin JB, Goertner GF. 1981. Effects of underwater explosions on fish with a dynamic model to predict fishkill. Ocean Science and Engineering 6:223-284.

Williams GD, Thom RM. 2001. Marine and estuarine shoreline modification issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Dept. of Ecology, Washington Dept. of Transportation. Sequim (WA): Battelle Memorial Institute. 99 p.

Wirgin I, Grunwald C, Carlson E, Stabile J, Peterson DL, Waldman JR. 2005. Range-wide population structure of shortnose sturgeon *Acipenser brevirostrum* based on sequence analysis of the mitochondrial DNA control region. Estuaries 28:406–421. doi: 10.1007/BF02693923.

Wright DG. 1982. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories. Winnipeg (Manitoba): Western Region, Department of Fisheries and Oceans. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1052.

Yelverton JT, Richmond DR, Hicks W, Sanders K, Fletcher ER. 1975. The relationship between fish size and their response to underwater blast. Defense Nuclear Agency, topical report DNA 3677T.

Zelo I, Helton D. 2005. Removal of grounded, derelict or abandoned vessels as site restoration. In: Abandoned Vessel Program (AVP) Conference Proceedings-International Oil Spill Conference; 2005 May 15-19; Miami Beach, FL. Seattle (WA): NOAA Ocean Service Office of Response and Restoration. 15 p.

Ziegler AD, Sutherland RA, Gaimbelluca TW. 2001. Interstorm surface preparation and sediment detachment by vehicle traffic on unpaved mountain roads. Earth Surface Processes and Landforms 26(3):235-50.

List of Appendices

Appendix A. Recommended Time of Year Restrictions for Essential Fish Habitat

Time of year (TOY) restrictions are provided for each state in the GAR so that in-water work (i.e., turbidity and noise producing activities) may be avoided during sensitive life stages of managed species. These standard TOY restrictions take into account the breeding, nursery, and migration stages of species which are especially vulnerable to in-water silt-producing activities, noise impacts, or activities which may encroach greater than 25% into a waterway interfering with migration.

State/District	TOY Restrictions
Maine	Winter Flounder: March 15 to June 30 Diadromous Fish: April 1 to June 30 Shellfish: June 1 to October 31
New Hampshire	Winter Flounder/Diadromous Fish: March 16 to November 14
Massachusetts[1]	Winter Flounder: January 15 to June 30 Diadromous Fish: March 1 to June 30 Shellfish: June 1 to October 31
Rhode Island	Winter Flounder: February 1 to June 30 Diadromous Fish: March 15 to June 30 Shellfish: May 1 to October 14
Connecticut[2]	Winter Flounder: February 1 to May 31 Diadromous Fish: April 1 to June 30 Shellfish: May 1 to September 30
New York[3]	Winter Flounder: January 15 to May 31 Diadromous Fish: March 1 to June 30 Overwintering Blue Crab and Striped Bass: November 15 to April 15
New Jersey[3,4]	Winter Flounder: January 1 to May 31 Diadromous Fish: March 1 to June 30 SAV: April 15 to September 30 Overwintering Blue Crab and Striped Bass: November 15 to April 15
Pennsylvania[5]	Diadromous Fish: March 15 to June 30
Delaware	Diadromous Fish: March 15 to June 30 Sandbar Shark: April 15 to September 15 Horseshoe Crab: April 15 to September 15
Maryland	Diadromous Fish: February 15 to June 15 SAV: April 15 to October 15
District of Columbia (Washington, D.C.)	Diadromous Fish: February 15 to June 15 SAV: April 15 to October 15
Virginia	Diadromous Fish: February 15 to June 30 SAV: April 15 to October 15

All diadromous areas: September 1- November 30. Fall TOY restrictions are not always recommended, but should be used in cases where an action will substantially block the waterway in the fall.

[1] The Massachusetts Division of Marine Fisheries developed site-specific TOY restrictions by waterbody. The TOY document may be referenced for applicable locations.

[2] For work occurring in the Connecticut River, the TOY restriction north of Old Saybrook, is from April 1 through June 30 and from February 1 to May 31 for areas south of Old Saybrook. For dredging in Mumford Cove and connecting parts of Venetian Harbor, the water temperatures must be ≤ 42°F for 3 consecutive days.

[3] Diadromous runs may begin March 15 in upstream areas in the Delaware River.

[4] There is no winter flounder EFH designated south of the Absecon Inlet, New Jersey.

[5] Diadromous runs may begin closer to March 15 in upstream areas in the Delaware River.

Appendix B. Natural Resources and Habitat Links

Useful Links:

National Wetland Inventory Maps
EPA's National Estuaries Program
Northeast Regional Ocean Council (NROC) Data Portal
Mid-Atlantic Regional Council on the Ocean (MARCO) Data Portal

Resources by State:

Maine
Eelgrass Maps
Maine Office of GIS Data Catalog
State of Maine Shellfish Sanitation and Management
Casco Bay Estuary Partnership
Maine GIS Stream Habitat Viewer

New Hampshire
New Hampshire's Statewide GIS Clearinghouse, NH GRANIT
New Hampshire Coastal Viewer
State of NH Shellfish Program

Massachusetts
MassGIS Data – Data layer: Shellfish Suitability Areas
MA Shellfish Sanitation and Management Program
Eelgrass Maps
MADMF Recommended Time of Year Restrictions Document
Massachusetts Bays National Estuary Program
Buzzards Bay National Estuary Program
Massachusetts Division of Marine Fisheries
Massachusetts Office of Coastal Zone Management

Rhode Island
RI Shellfish and Aquaculture
RI Shellfish Management Plan
Eelgrass Maps
RI GIS Data – Habitat and coastal resources data layers
Narraganset Bay Estuary Program
Rhode Island Division of Marine Fisheries
Rhode Island Coastal Resources Management Council

Connecticut
CT Bureau of Aquaculture: Shellfish maps and town information
CT GIS Resources: Shellfish; Shellfish Classification Areas; CT managed shellfish beds
Natural Shellfish Beds in CT designated in 2014. Includes layers for all habitat types.
Eelgrass Maps
Long Island Sound Study

CT GIS Resources
CT DEEP Office of Long Island Sound Programs and Fisheries
CT Bureau of Aquaculture Shellfish Maps
CT River Watershed Council

New York
Eelgrass Report
Peconic Estuary Program
NY/NJ Harbor Estuary
New York GIS Clearinghouse

New Jersey
Submerged Aquatic Vegetation mapping
Barnegat Bay Partnership
NJ GeoWeb

Pennsylvania
Delaware River Management Plan
PA DEP Coastal Resources Management Program
PA DEP GIS Mapping Tools

Delaware
Partnership for the Delaware Estuary
Center for Delaware Inland Bays
Delaware FirstMap

Maryland
Submerged Aquatic Vegetation mapping
MERLIN
Maryland Coastal Bays Program

Virginia
Submerged Aquatic Vegetation mapping
Data VA

Appendix C. BMP Spreadsheet

Note that Appendix C. is provided as a separate downloadable Microsoft Excel spreadsheet.