Atlantic Salmon Recovery Plan Companion Document

May 23, 2018

Atlantic Salmon Recovery Plan

The USFWS and the National Marine Fisheries Service approved the initial recovery plan for the Gulf of Maine (GOM) Distinct Population Segment (DPS) of Atlantic salmon in November, 2005. The 2005 plan was developed based on populations and threats identified in the initial listing rule (65 FR 69459; December 17, 2000). After approval of the 2005 recovery plan, significant new information led to expansion of the GOM DPS to include additional populations and a larger geographic area (June 19, 2009: 74 FR 29344). The 2009 listing rule for the expanded DPS identified a number of new threats, but called attention to two significant threats: the threat of dams and regulatory mechanisms related to dams, and the threat of marine survival. This recovery plan for the GOM DPS of Atlantic salmon addresses these threats as well as a number of lesser threats that together, constitute a significant threat. In addition to the threats identified at the time of listing, this Recovery Plan calls attention to the threat of road stream crossings an the intercept fishery in the North Atlantic, as there is growing concern about the magnitude of the effects of these actions on Atlantic salmon in the GOM DPS. This plan also identifies the threat of climate change is an emerging threat to Atlantic salmon in light of new information that has been brought forward since the time of listing.

The purpose of this plan is to help identify and guide recovery needs for the endangered Gulf of Maine Distinct Population Segment of Atlantic salmon. This plan includes (1) a description of site-specific management actions necessary to conserve the species; (2) objective, measurable criteria that, when met, will allow the species to be removed from the endangered and threatened species list; and (3) estimates of the time and funding required to achieve the plan's goals.

Background

Contents

The following information has been partially excerpted from the 2009 expanded Atlantic salmon listing rule (74 FR 29344), critical habitat rule (74 FR 29300), 2005 Recovery Plan (NOAA and USFWS 2005), 2006 Status Review (Fay et al. 2006), and additional more recent sources. For additional information, see Fay et al. (2006).

Table of Contents

CHAPTER 1: TAXONOMY AND SPECIES DESCRIPTION

Atlantic salmon are classified as a bony fish in the order Salmoniformes, family Salmonidae, genus *Salmo*, and species salar. There are many members of the Salmonidae family, commonly called salmonids, in North America (coho, chinook, steelhead, pink, chum, cutthroat), but there are only two members of the genus *Salmo* in North America: the native Atlantic salmon (*Salmo salar*) and the brown trout (*Salmo trutta*), which was introduced from Europe. The Atlantic salmon is anadromous, spending its first 2 to 3 years in fresh water, then migrating to the ocean, where it spends typically 2 years, and returning to its natal river to spawn. Atlantic salmon are iteroparous, meaning they can spawn multiple times, unlike Pacific salmon that spawn once and die (semelparous). A non-anadromous (resident) variety of Atlantic salmon is found in some lakes and rivers, but for purposes of this plan, the term "Atlantic salmon" refers to the anadromous form, while "landlocked salmon" refers to members of the non-anadromous populations.

Atlantic salmon have a fusiform body shape (i.e., like a spindle, broadest in the middle and tapering at each end). The shape is somewhat flattened towards the sides, the head is relatively small, and the ventral fins are paired. Juvenile salmon, called parr, have 8 to 11 vertical dark bars ("parr marks") on silvery sides. As parr reach the age when they migrate to the ocean, most undergo a physiological process called smoltification, typically turning silvery; they are then called smolts. In some instances, male parr can reach maturity while in freshwater and can participate in spawning activities. These parr are referred to as precocious parr. When adults return to freshwater to spawn they darken to a bronze color; after spawning, adults darken further and are often called "black salmon" or kelts. Upon returning to the ocean, adults return to the silvery color.

Out-migrating smolts in Maine average 14 to 18 centimeters (cm) in length. The size of returning adults depends upon the amount of time spent at sea. Grilse are young salmon returning to fresh water after one winter or 1 year at sea (called a one sea-winter or 1SW fish); they average 50 to 60 cm and 1 to 2 kilograms (kg). Adult salmon returning after 2 years at sea (2SW fish) range from 70 to 80 cm and 3.5 to 4.5 kg. Adult salmon returning after 3 years at sea (3SW fish) are 80 to 90 cm long and often weigh more than 7 kg (Baum, 1997).

CHAPTER 2: LIFE HISTORY AND ECOLOGY

Anadromous Atlantic salmon are a wide-ranging species with a complex life history. The historic range of Atlantic salmon occurred on both sides of the North Atlantic, from Connecticut to Ungava Bay, Canada, in the western Atlantic, and from Portugal to Russia's White Sea in the eastern Atlantic, including the Baltic Sea. The generalized Atlantic salmon life cycle is illustrated in Figure 1. Freshwater ecosystems provide spawning habitat and thermal refuge for adult Atlantic salmon, overwintering and rearing areas for eggs, fry, and parr, and migration corridors for smolts and adults (Bardonnet & Bagliniere, 2000).

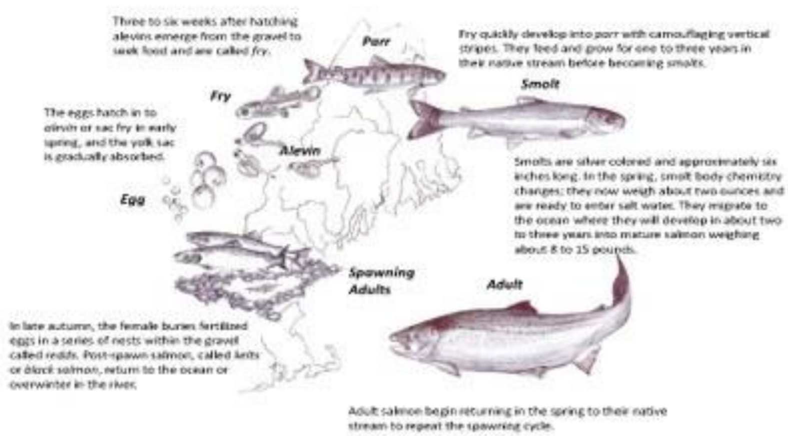

Figure 1. Life cycle of Atlantic salmon (salmo salar). (Katrina Mueller, USFWS)

Adult Atlantic salmon typically spawn in October and November. During spawning, the female uses its tail to scour or dig a series of nests in the gravel where the eggs are deposited; this series of nests is called a redd. The eggs remain in the gravel until they hatch in late March or April. At this stage, they are referred to as alevin or sac fry. The alevin remain in the redd for about six weeks and are nourished by their yolk sac until they emerge from the gravel in mid-May. At this time, they begin active feeding and are termed fry. Within days, the fry enters the parr stage, indicated by vertical bars (parr marks) on their sides that act as camouflage. Atlantic salmon parr are territorial and disperse upstream and downstream to suitable habitat to decrease densities. If suitable habitat is not available, dispersing juveniles may experience high mortality (Gee et al., 1978; Legault, 2005). In particular, suitable overwintering habitat may limit the abundance of large parr prior to smoltification (Cunjak et al., 1998).

Smoltification usually occurs at age two for most Atlantic salmon in Maine. Each individual smolt has a brief emigration period lasting only 2 to 3 weeks. During this brief emigration window, smolts must contend with rapidly changing environmental conditions (freshwater to marine) and predator assemblages (McCormick et al., 1998; Mather, 1998). Smolts migrate downstream, through the estuary, and into the ocean from late April through May.

Upon entering the estuary and bay, smolts select areas of high tidal movements to aid in their migration (Kocik et al., 2009). Atlantic salmon smolts experience comparatively higher mortality rates through the estuary and inner bay than they do anywhere else along their migration journey between the river and the open ocean (Kocik et al., 2009). Increased mortality may be associated with the transition to salt water, zonal ecological differences, or a combination of the two (Tytler et al., 1978; Lacroix & McCurdy, 1996; Stefansson et al., 2003). Developing adults generally spend from one to 3 years in the ocean. Upon entering the sea, Atlantic salmon smolts travel through the top 3 meters of the water column (Reddin, 1985) and begin a migration northward into the Gulf of St. Lawrence and Grand Bank, and into the Labrador Sea (Figure 2). Here, Atlantic salmon from the GOM DPS mix with other Atlantic salmon from Europe (see Fay, et al., 2006). In the ocean, adult Atlantic salmon prefer cooler waters, 4° to 8°C (40° to 46°F).

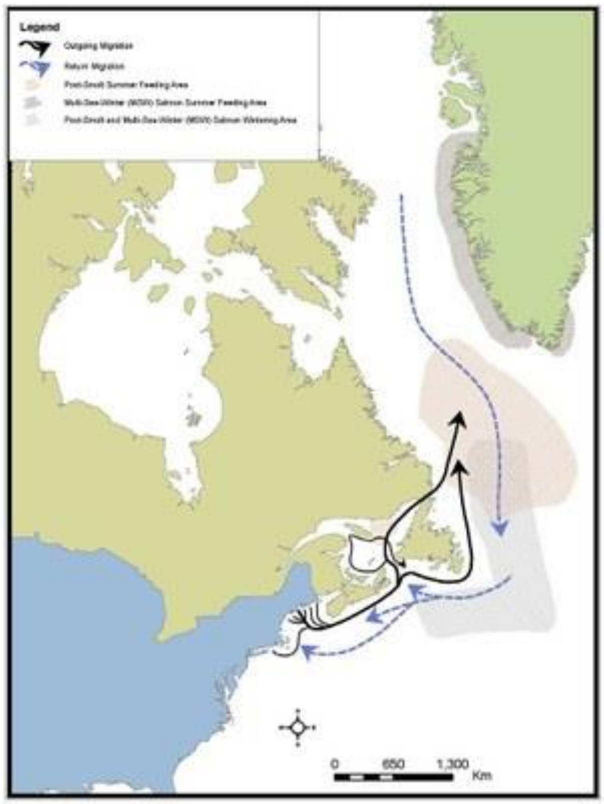

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Figure 2. Generalized marine migration routes of U.S. origin Atlantic salmon

In addition to anadromous Atlantic salmon, landlocked Atlantic salmon are native to four watersheds in Maine: The Union, including Green Lake in Hancock County; the St. Croix, including West Grand Lake in Washington County; the Presumpscot, including Sebago Lake in Cumberland County; and the Penobscot, including Sebec Lake in Piscataquis County (Warner & Harvey, 1985). Beginning in 1868, landlocked salmon were stocked extensively throughout the State to create or improve recreational fisheries. More than 51 million landlocked Atlantic salmon have been stocked in over 300 water bodies throughout Maine between 1937 and 1999 (Warner & Harvey, 1985; Fay, et al., 2006). Four state hatcheries continue to raise landlocked salmon that supports a landlocked salmon fishery in approximately 176 lakes in Maine. There are several lakes and rivers in Maine where landlocked salmon and anadromous salmon coexist (e.g., East Branch Penobscot River). Genetic studies have confirmed that little genetic exchange occurs between these two life-history types (King, Schill, Spidle, & Lubinski, 2001; Spidle, et al., 2003*; summarized in* Fay et al. 2006).

CHAPTER 3: ABUNDANCE AND DISTRIBUTION

Abundance and distribution of Atlantic salmon within the range of the GOM DPS have drastically declined from the historical levels of the 1800s (Fay, et al., 2006). NOAA and USFWS (2009) described the historical distribution of Atlantic salmon in the DPS. Their range included most of the Androscoggin River except above Rumford Falls and Snow Falls on the Little Androscoggin River; the Kennebec River except above Grand Falls on the Dead River; the Penobscot River except above Big Niagara Falls, Grand Pitch on Webster Brook, and Grand Falls on the Passadumkeag River; and all portions of the Downeast Rivers. Historical distribution is estimated to have covered 45,980 square kilometers (km^2), or 50 percent of the State of Maine (91,652 km^2). Approximately 19,311 km^2 (42 percent) of this historical habitat is thought to be occupied now (NOAA 2009).

Data sets tracking adult abundance back to the 1800's are not available throughout this historical time, but observations and catch data provide important reference points to compare to current population estimates. For example, Foster and Atkins (1869) estimated that roughly 100,000 adult salmon returned to the Penobscot River prior to the 1860s before dams reduced adult returns. Based on U.S. Fish Commission Reports, Baum (1997) reports commercial catches of 10,016 fish in the Penobscot in 1880 and approximately 20,000 fish per year from 1870 to 1890. He also assembles a comprehensive time series of adult sport catch data from Maine dating back to 1936 that includes rivers outside the current GOM DPS. This time series of sport catch data in Maine rivers shows a few hundred fish (maximum 480) per year were caught from 1936 to 1976, with more in the 1980s (maximum: 1,396). Contemporary abundance estimates (USASAC 2016) are informative in considering the current recovery status of the GOM DPS. After a period of population growth in the 1970s, adult returns of salmon in the GOM DPS steadily declined through the 1990s, leveling at around 1,000 adult returns since 2000 **Error! Reference source not found.** (Figure 3).

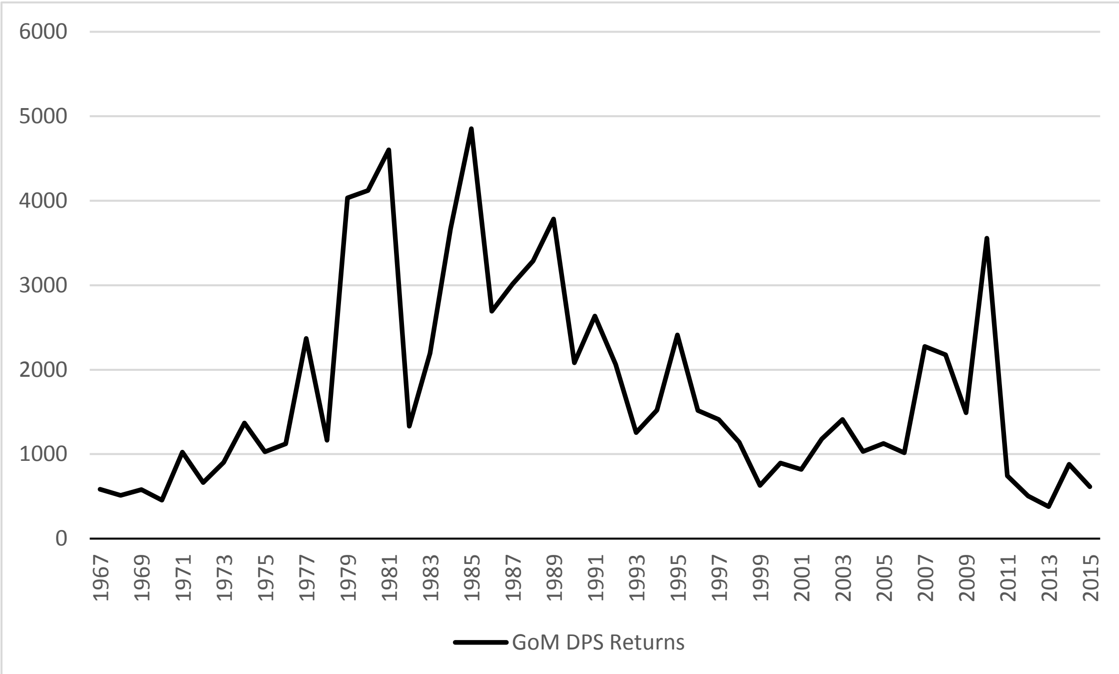

Figure 3. Atlantic salmon adult returns for the Gulf of Maine DPS, 1966 – 2016 (Data Source, USASAC 2017).

Wild vs. Hatchery Returns

A recovered GOM DPS will ultimately require wild adult spawners because they represent the self-sustaining portion of the population that will require minimal ongoing management and investment of resources. Until that time, naturally reared offspring are central to the recovery goal. The term ‘‘naturally reared’’ includes fish originating from wild spawners and hatchery egg or fry (USASAC 2013). Hatchery fry are included because they are not marked and cannot be visually distinguished from fish produced from natural spawning (termed “wild”). The term “hatchery-reared” includes fish that are stocked as either parr or smolts from CBNFH or GLNFH. For the purposes of down listing, naturally reared fish and hatchery reared parr can count towards the abundance and population growth criterion because all of these fish will have experienced the significant threats identified at the time of listing: Dams and Marine Survival. The assumption is that any increases in abundance and population growth rate by these life stages, whether from wild or hatchery origin fish, will be a clear indication of progress in addressing these significant threats. and although stocking these life stages is important in preventing extinction and increasing adult escapement, they cannot be counted towards recovery goals. **Figure 4** illustrates naturally reared adult returns relative to the total adult returns to the Gulf of Maine DPS from 1967 to 2016.

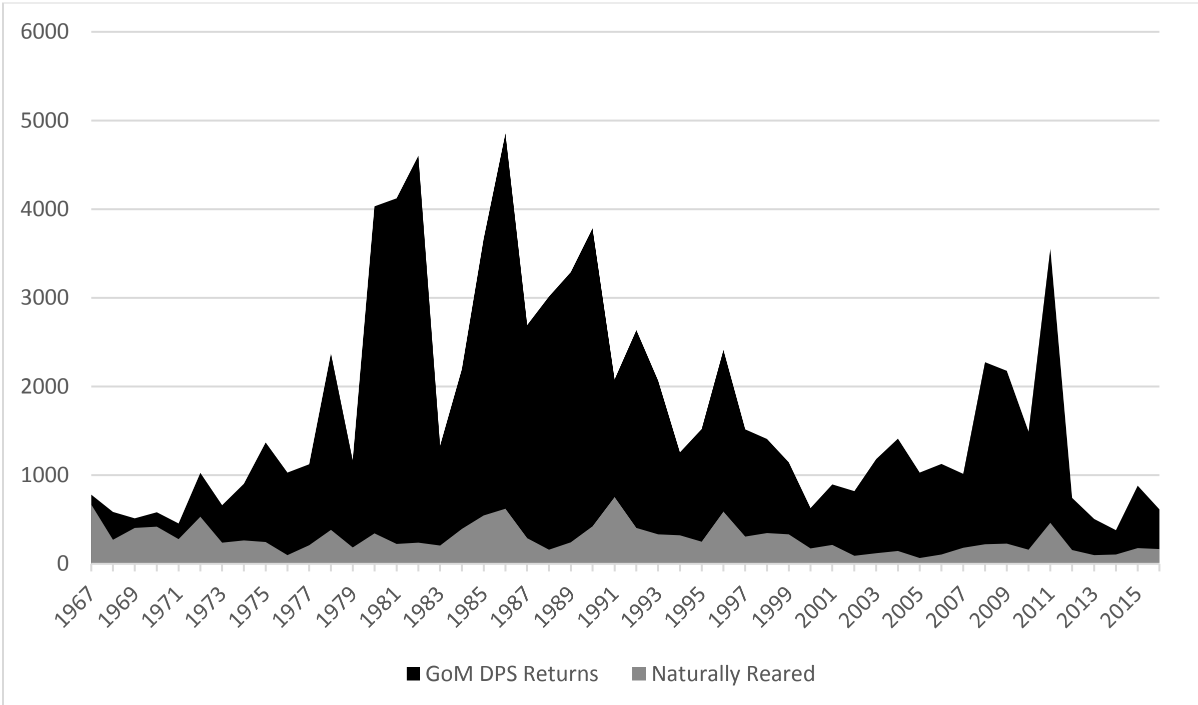

Figure 4. Total Atlantic salmon adult returns and the proportion of naturally reared returns to the Gulf of Maine DPS, 1966-2016 (Data Source, USASAC 2017).

The Purpose of the Stocking program:

The Federal hatcheries, Craig Brook NFH and Green Lake NFH, are the life-support systems that reduce short-term extinction risks to the GOM DPS. The goal of the conservation hatchery program is to maintain abundance and diversity of the GOM DPS. The three strategies used are:

1. Stocking large numbers of smolts aimed at increasing adult returns, thus reducing demographic risks (i.e., extinction risks) to populations that would otherwise be smaller.

2. Stocking large numbers of multiple life stages to reduce the risks of catastrophic loss. The assumption is that at least one cohort is always at sea and could be collected as broodstock in the case of a catastrophic event in fresh water (e.g., a large contaminant spill) or in a hatchery (e.g., disease outbreak).

3. Stocking large numbers of hatchery fish at the fry stage to maximize exposure to natural environmental factors throughout a majority of the life history. Increasing exposure to natural selection pressures provides some assurance of maintaining genetic fitness.

As adult populations of Atlantic salmon in the GOM DPS continue to be at critically low abundances, the conservation hatchery program has assisted by slowing the decline in abundance and maintaining the population's genetic diversity. The hatcheries have not contributed to an increase in the overall abundance of salmon as hatcheries do not address the threats that are responsible for the species decline (i.e. dams and marine survival). Furthermore, the hatcheries have not been able to halt the decline of the naturally reared component of the GOM DPS for the same reasons (Figure 5). The current percentage of fish that are naturally reared continues to be small (approximately 5 percent in recent years).

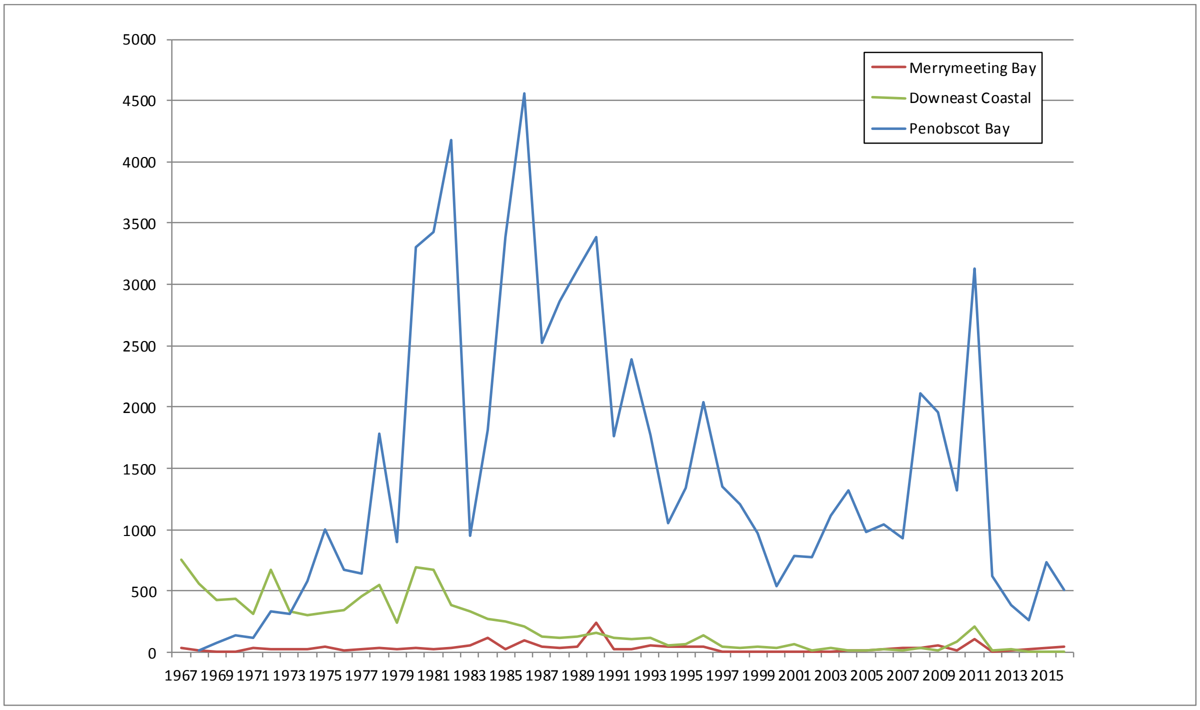

Figure 5. Atlantic salmon adult returns by SHRU 1966-2016 (Data Source, USASAC 2017).

Chapter 4: Habitat Requirements

General habitat characteristics for Atlantic salmon can be divided into those areas used for spawning, rearing, and migrating in fresh water and those marine areas used during migration and feeding.

Adult salmon can arrive at spawning grounds several months prior to actual spawning and seek holding areas that provide shade, protection from predators, and protection from environmental variables such as high flows, high temperatures, and sedimentation. Adults most frequently spawn from October through mid-November (Baum, 1997) in areas with coarse gravel or rubble substrate and adequate cool water to keep eggs buried and well oxygenated (Peterson, 1978). Spawning is usually initiated as water temperatures drop to 10.5°C (51°F) and ceases below 7°C (45°F). The depth of the water at spawning areas averages 36 cm and water velocities average 49 cm/second (Jordan and Beland 1981).

About 80 percent of the parr in Maine streams remain in fresh water for 2 years, while the rest remain for a third year (Baum 1997). Thus, stream habitat must provide extensive nursery areas for young salmon to find sufficient food and protection during this stage of life (Baum 1997). Parr can disperse upstream or downstream from the spawning area to find additional rearing habitat and preferred water temperatures (Beland, 1984). Upper lethal limits for Atlantic salmon are 33°C (Elliott 1991).
In terms of habitat availability, the table below shows current estimates.

Table 1. Estimates of total, suitable, and accessible spawning and nursery habitats for each SHRU (does not account for habitats blocked or impeded by road culverts).

SHRU	**Total Estimated Habitat Units By SHRU**	**Estimated Habitats that are Suitable and Accessible**
Penobscot Bay	397,092	18,600
Merrymeeting Bay	356,066	9,800
Downeast	60,363	28,500
Total	**813,520**	**56,900**

Less is known about the marine habitat characteristics of Atlantic salmon. Smolt movement in the predominantly freshwater portions of the estuary are thought to be passive, moving outward (seaward) or inward (shoreward) with the tide, and becoming more outward-moving as they transition into more saline water (Lacroix & McCurdy, 1996). After completing the physiological transition to salt water, the post smolts grow rapidly and move in schools and loose aggregations close to the surface (Dutil & Coutu, 1988, Kocik et al., 2009). Decreasing nearshore temperatures in autumn appear to trigger offshore movements (Dutil & Coutu, 1988). The 1SW and multi-sea-winter Atlantic salmon are thought to behave similarly to post smolts, moving through the top 3 meters (m) of the water column (Reddin, 1985).

CHAPTER 5: CRITICAL HABITAT

Under section 3 of the ESA (16 U.S.C. 1533(b)(2)), critical habitat is defined as the specific areas supporting those physical and biological features that are essential for the conservation of the species and that may require special management considerations or protection. Section four of the ESA and regulations at 50 CFR 424.12(a) require the designation of critical habitat based on the best scientific data available.

The necessary physical and biological features constituting critical habitat were identified and critical habitat was designated (*see* Figure 6) for the GOM DPS of Atlantic salmon by NOAA on June 19, 2009, (74 FR 29300) and later revised (74 FR 39903, 2009).

The essential physical and biological features for critical habitat are

A. Spawning and rearing

1. Deep, oxygenated pools and cover (e.g., boulders, woody debris, vegetation) near freshwater spawning sites necessary to support adult migrants during the summer while they await spawning in the fall.

2. Freshwater spawning sites that contain clean, permeable gravel and cobble substrate with oxygenated water and cool water temperatures to support spawning activity, egg incubation, and larval development.

3. Freshwater spawning and rearing sites with clean, permeable gravel and cobble substrate with oxygenated water and cool water temperatures to support emergence, territorial development, and feeding activities of Atlantic salmon fry.

4. Freshwater rearing sites with space to accommodate growth and survival of Atlantic salmon parr.

5. Freshwater rearing sites with a combination of river, stream, and lake habitats that accommodate Atlantic salmon parrs' ability to occupy many niches and maximize parr production.

6. Freshwater rearing sites with cool, oxygenated water to support growth and survival of Atlantic salmon parr.

7. Freshwater rearing sites with diverse food resources to support growth and survival of Atlantic salmon parr.

B. Migration

1. Freshwater and estuary migratory sites free of physical and biological barriers that delay or prevent access for adult salmon seeking spawning grounds needed to support recovered populations.

2. Freshwater and estuary migration sites with pool, lake, and instream habitat that provide cool, oxygenated water, and cover items (e.g., boulders, woody debris, vegetation) to serve as temporary holding and resting areas during upstream migration of adult salmon.

3. Freshwater and estuary migration sites with abundant, diverse native fish communities to serve as a protective buffer against predation.

4. Freshwater and estuary migration sites free of physical and biological barriers that delay or prevent emigration of smolts to the marine environment.

5. Freshwater and estuary migration sites with sufficiently cool water temperatures and water flows that coincide with diurnal cues to stimulate smolt migration.

6. Freshwater migration sites with water chemistry needed to support seawater adaptation of smolts.

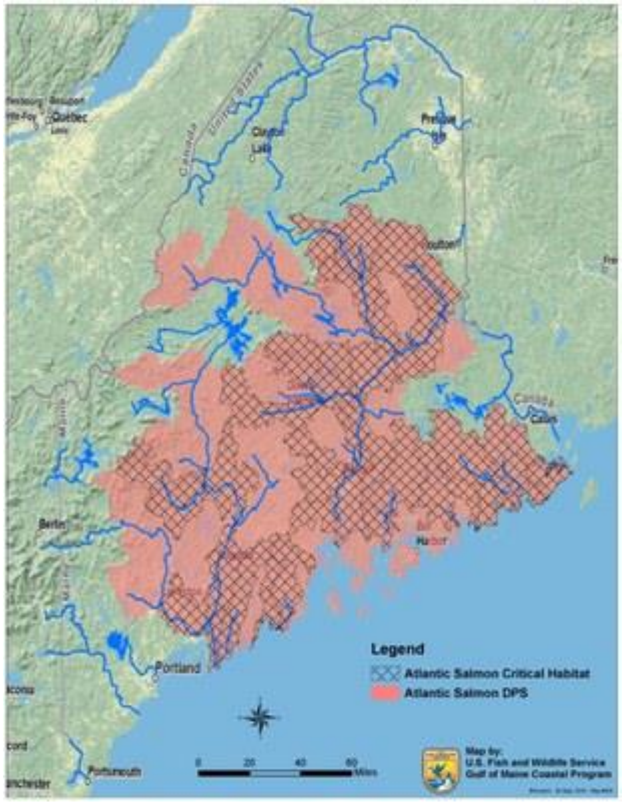

Figure 6. Critical habitat watershed boundaries in the Gulf of Maine DPS as defined in the 2009 critical habitat rule.

These freshwater features provide habitat requirements for the growth and survival of all freshwater stages of Atlantic salmon and illustrate the complexity of habitat required by Atlantic salmon. Determining the exact amounts and interspersion of each feature at the macro scale necessary for self-sustaining populations is currently not possible.

The location and features of physical and biological features of marine habitat essential for the conservation of the GOM DPS have not been fully identified. Unlike some species of Pacific salmonids that use nearshore marine environments for juvenile feeding and growth, Atlantic salmon migrate through the nearshore marine areas quickly during May and early June. Therefore, marine critical habitat was not identified, and the types of management considerations or protections necessary to protect the physical and biological features during the migration period were not identified (74 FR 29300, 2009). Although critical habitat cannot be accurately identified in marine areas, feeding areas in the North Atlantic and the migration corridors between these feeding areas and salmon's natal rivers are critically important to the species' continued survival and recovery.

Chapter 6: Reasons for Listing

In determining whether to list, delist, or reclassify a taxon under the ESA, five threat factors are evaluated, including:

- Factor A. the present or threatened destruction, modification, or curtailment of its habitat or range;
- Factor B. overutilization for commercial, recreational, scientific, or educational purposes;
- Factor C. disease or predation;
- Factor D. the inadequacy of existing regulatory mechanisms; and
- Factor E. Other natural or manmade factors affecting its continued existence.

Threats, categorized into the above factors, and the subsequent reasons for listing Atlantic salmon in Maine have been identified and extensively analyzed (National Research Council, 2004; Fay, et al., 2006). The 2009 listing rule (74 FR 29344, 2009) highlighted the threat of Dams (Factor A), Regulatory Mechanisms Related to Dams (Factor D), and Marine Survival (Factor E) as being significant factors affecting the continued survival and recovery of the species:

1) Threats Associated with Factor A:

Significant Threats

Dams

Salmon smolts and post spawning adults travel downstream to the ocean from spawning and rearing habitat and encounter the same dams their parents experienced on upstream migration to spawning habitats. Atlantic salmon face routes that pass through, over, or around the dam and facilities. For electricity-generating dams, salmon can travel over the spillway of the dam, through a downstream fish passage facility if the dam has one, or through power-generating turbines. Mortality can occur no matter which path Atlantic salmon take, but higher mortality rates occur if fish pass through the turbines.

Direct, indirect, or delayed mortality from entrainment into dam turbines, passage via spillways, or fish bypass has been shown to be an important factor affecting Atlantic salmon. Dams can also cause indirect mortality. Smolts injured or disoriented by dams may become more vulnerable to predators after passage (Mesa 1994). Descaling can also impair osmoregulation, possibly leading to estuarine mortality (Zydlewski et al. 2010). Lack of flow cues at dam reservoirs can increase the time in the impoundment and thus delay migration and increase predation (Holbrook et al. 2011).

Measuring indirect mortality from dams is difficult, but recent studies are approaching the problem. Holbrook et al. (2011) estimated the survival of out-migrating Atlantic salmon smolts through a large reach of the Penobscot River (up to Weldon dam) in 2005 and 2006. This study provides a snapshot of total survival through the river, including all causes of mortality (e.g., direct and indirect mortality from dams, predation, disease, fishing, and stress from handling during the research and assessment). An extensive acoustic array in the river, coupled with release of smolts with sonic transmitters, allowed researchers to separate out survival in specific reaches, including those with dams and those without dams. High rates of mortality were observed in three other reaches: Howland dam reach, West Enfield dam reach, and Milford dam reach. The estimated survival of tagged hatchery smolts through these three reaches with dams was as low as 52 percent, whereas survival in reaches without dams exceeded 95 percent. Although these data do not definitively reveal sources of mortality, these losses are likely attributable to the direct and indirect effects of the dams (e.g., physical injury, predation). Shepard (1991) found that for the three lower Penobscot River dams (Milford, Great Works, Veazie) and the intervening habitat, net smolt survival varied between 44 and 94 percent. For the lower four dams (West Enfield, Milford, Great Works, and Veazie, or for those fish choosing the Stillwater Branch route, (i.e., West Enfield, Stillwater, Orono, and Veazie) the survival rate was between 38 percent and 92 percent. Given that many Penobscot salmon must pass through at least three dams and sometimes as many as seven, mortality from dams in any single year is likely to be significant.

In addition to the complete or partial blockage to upstream and downstream passage and direct, indirect or delayed mortality associated with passage through dams, dams have a number of additional negative ecological effects on Atlantic salmon. Dams create impoundments that inundate the natural stream and river habitat and cause sediment deposition that can cover important rearing and spawning habitat. Impoundments create large pools of water in which water temperatures can increase above preferred Atlantic salmon temperature levels. These impoundments and associated habitat changes can become preferred habitat for warm water exotic species that prey on juvenile Atlantic salmon. Impoundments can cause migratory delays, which, in turn, can cause poor synchrony of physiological tolerance to salinity (McCormick et al. 2009), thereby increasing estuarine mortality (Ferguson et al. 2006). These effects may be exacerbated by climate change that may also alter predator/prey assemblages by decreasing qualitative habitat features that benefit salmon while concurrently increasing habitat features that benefit predators and competitors. For additional information, see Fay et al. (2006), and appendix 8 in Fay et al. (2006), and the 2009 GOM DPS Atlantic salmon listing rule (74 FR 29344).

In conclusion, the direct, indirect, and delayed downstream mortality associated with dams and the ecological effects of dams are a significant threat to the recovery of the GOM DPS of Atlantic salmon.

Secondary stressors

Habitat Complexity

Some forest, agricultural, and other land use practices have reduced habitat complexity in the range of GOM DPS Atlantic salmon. Historic timber harvest practices have reduced the abundance and diversity of large wood (LW) and large boulders from many rivers. Large wood is important for Atlantic salmon during several life history stages. Nislow et al. (1999) found that survival of salmon fry in small streams in Vermont was strongly correlated with the availability of low-velocity microhabitats, and that the addition of LW (length of LW greater than bank full width) increases the availability of these microhabitats. Large wood may be even more important for older juveniles, because they use stream cover, including LW, particularly during winter (Cunjak et al. 1998). In winter, salmon may require habitat that provides adequate shelter from adverse physical conditions and protection from predators. Thus, availability of high quality winter habitat may influence salmon survival during this critical life stage, LW may increase overwinter survival in Pacific salmon by increasing habitat complexity (Quinn and Peterson 1996, Solazzi et al. 2000), and the same mechanism may apply for Atlantic salmon.

Water Quantity

Direct water withdrawals and groundwater withdrawals for crop irrigation and commercial, and public use can directly impact Atlantic salmon habitat by depleting streamflow (Dudley & Stewart, 2006) (MASTF 1997, Dudley and Stewart 2006, Fay et al. 2006). Subsequently, reduced stream flow can reduce the quantity of habitat, increase water temperature and reduce dissolved oxygen. The cumulative effects of individual water withdrawal impacts on Maine rivers is poorly understood; however, it is known that adequate water supply and quality is essential to all life stages and life history behaviors of Atlantic salmon, including adult migration, spawning, fry emergence, and smolt emigration (Fay et al. 2006).

Water Quality

Atlantic salmon likely are impacted by degraded water quality caused by point and non-point source discharges. The MDEP administers the National Pollutant Discharge Elimination System (NPDES) program under the CWA and issues permits for point source discharges from freshwater hatcheries, municipal facilities, and other industrial facilities. Maine's water classification system provides for different water quality standards for different classes of waters (e.g., there are four classes for freshwater rivers, all of which are found within the GOM DPS range); however, these standards were not developed specifically for Atlantic salmon. Some portions of the GOM DPS are in areas with the highest water quality classification where water quality standards are the most stringent. These standards become progressively less stringent with each lower water classification. Additionally, permits allow an area of initial dilution or mixing zone where water quality requirements are reduced. Salmon in or passing through such zones would be exposed to discharges below water quality standards. The impacts to salmon passing through these zones are unknown. We are concerned that water quality standards for Class A, B, and C waters and mixing zones may not be sufficiently protective of all life stages of Atlantic salmon, particularly the more sensitive salmon life stages (e.g., smolts). Even where water quality standards are believed to be sufficiently protective, there are circumstances and conditions where discharges do not meet water quality standards. For example, there are documented cases in class C waters where dissolved oxygen standards (the lower bound of which is 5.0 ppm) were not met. This occurred in portions of the mainstem Androscoggin River, and in the East Branch of the Sebasticook River and Sabattus River (MDEP, 2008). When dissolved oxygen concentrations are less than 5.0 ppm, adult salmon breathing functions become impaired, embryonic development is delayed, and parr growth and health are impacted; conditions become lethal for salmon at dissolved oxygen concentrations less than 2.0 ppm (Decola, 1970).

When water quality reaches levels that are harmful to salmon, it is a stressor to the GOM DPS. Non-point source discharges such as elevated sedimentation from forestry, agriculture, urbanization, and roads can reduce survival at several life stages, especially the egg stage. Sedimentation can alter in-stream habitat and habitat use patterns by filling interstitial spaces in spawning gravels, and adversely affect aquatic invertebrate populations that are an important food source for salmon. Acid rain reduces pH in surface waters with low buffering capacity, and reduced pH impairs osmoregulatory abilities and seawater tolerance of Atlantic salmon smolts. A variety of pesticides, herbicides, trace elements such as mercury, and other contaminants are found at varying levels throughout the range of the GOM DPS. The effects of chronic exposure of Atlantic salmon, particularly during sensitive life stages such as fry emergence and smoltification, to many contaminants is not well understood. Fay et al. (2006) provide a discussion of water quality concerns in section 8.1.3. For these reasons, non-point source pollution, particularly sedimentation and acid rain, is a stressor to the GOM DPS. In summary, we have determined that degraded water quality is a stressor on the GOM DPS because of the known situations when water quality did not meet standards and was at levels that negatively affect salmon and because of the impacts of non-point source pollution, particularly sedimentation and acid rain.

2) Threats Associated with Factor B:

Significant threats

No significant threats associated with Factor B were identified at the time of listing.

Secondary Stressors

Fish Harvest

As summarized in the 2009 listing rule, overutilization for recreational and commercial purposes was a lesser stressor that contributed to the historical declines of the GOM DPS. Intercept fisheries in West Greenland and St. Pierre et Miquelon, by-catch in recreational fisheries, and poaching result in direct mortality or cause stress, thus reducing reproductive success and survival. Due to the continued involvement of the International Council for the Exploration of the Sea (ICES) and NASCO, the scientific advice from ICES to NASCO has been that there is no harvestable surplus of the mixed stock off West Greenland available for commercial harvest. As a result, since 2002 within the West Greenland Commission of NASCO there has been agreement for no commercial export and to restrict the fishery at Greenland to an internal-use-only fishery.

Recreational angling of many freshwater species occurs throughout the range of the GOM DPS, and the potential exists for the incidental capture and misidentification of both juvenile and adult Atlantic salmon (Fay et al. 2006). Juvenile Atlantic salmon may be easily misidentified as brook trout, brown trout, or landlocked Atlantic salmon, while adult salmon may be confused with adult landlocked Atlantic salmon or brown trout (Fay et al. 2006). Direct or indirect mortality may result even in fish that are released because of injury or stress.

3) Threats Associated with Factor C:

Significant Threats

No significant threats associated with Factor C were identified at the time of listing.

Secondary Stressors

Disease

Disease outbreaks, whether occurring in the natural or hatchery environment, have the potential to cause negative population-wide effects. Atlantic salmon are susceptible to numerous bacterial, viral, and fungal diseases. Bacterial diseases common to New England waters include bacterial kidney disease (BKD), enteric redmouth disease (ERD), cold-water disease (CWD), and vibriosis (Mills, 1971; Gaston, 1988; Olafsen & Roberts, 1993; Egusa, 1992). Fungal diseases such as furunculosis can affect all life stages of salmon in both fresh and salt water, and the causative agent (*Saprolignia* spp.) is ubiquitous to most water bodies. The risk of an epizootic event occurring during fish culture operations is greater because of the increased numbers of host animals reared at much higher densities than would be found in the wild. A number of viral diseases that could affect wild populations have occurred during the culture of Atlantic salmon, such as infectious pancreatic necrosis, salmon swimbladder sarcoma virus, infectious salmon anemia (ISA), and salmon papilloma (Olafsen & Roberts, 1993). ISA is of particular concern for the GOM DPS because of the nature of the pathogen and the high mortality rates associated with the disease. Most notably, a 2001 outbreak of ISA in Cobscook Bay led to an emergency depopulation of all commercially cultured salmon in the bay.

Parasites can also affect salmon. There are more than 30 parasites of Atlantic salmon, of which the sea louse is one of the more common (Fay et al. 2006). Sea lice are common and infestations can occur on wild fish in some areas where Atlantic salmon farming is concentrated (Fay et al. 2006). A severe infestation can result in scale loss and flesh exposure. Furthermore, sea lice may be vectors for diseases, particularly ISA (Nylund et al., 1994) as lice move from fish to fish (Fay et al. 2006).

Federally managed conservation hatcheries adhere to rigorous disease prevention protocols and management regulations; these must be continued. These protocols and regulations are designed to prevent the introduction of pathogens into the natural and hatchery environments; prevent and control, as necessary, disease outbreaks in hatchery populations; and prevent the inadvertent spread of pathogens between facilities and river systems.

Predation

As summarized in the 2009 listing rule, the impact of predation on the GOM DPS is important because of the imbalance between the very low numbers of adults returning to spawn and the increase in population levels of double-crested cormorants, striped bass, seals, and nonnative predators, such as smallmouth bass. Increasing levels of predators combined with decreasing abundance of alternative prey sources has likely increased predation mortality on juvenile Atlantic salmon, especially at the smolt life stage.

Threats Associated with Factor D:

Significant threats

Regulatory mechanisms related to dams

Atlantic salmon require access to suitable habitat to complete their life history. As described under Factor A, dams within the range of the GOM DPS impede access to much of the suitable habitat that was historically available.

As explained in the 2009 rule (74 FR 29344, 2009), hydroelectric dams in the GOM DPS are licensed by FERC under the Federal Power Act (FPA). At the time of listing there were 19 FERC-licensed dams in the Androscoggin watershed (16 impassable), 18 in the Kennebec watershed (15 impassable), and 23 in the Penobscot (12 impassable). It should be noted that the numbers of impassible dams may include dams with fish ladders that are ineffective at passing Atlantic salmon that would allow for their survival and recovery.

Current licenses for many dams, though not all, contain a reservation provision under FPA section 18 (16 U.S.C. 797) that could allow fishways to be prescribed by the Services (16 U.S.C. 811). However, exercise of that authority requires administrative proceedings before the FERC and the Services. The FERC maintains that, for the remainder of the projects whose licenses do not contain reserved authority, reopening these licenses may be dependent upon the success of a petition to the FERC to exercise its own reserved authority. The Services maintain that the listing of a species, designation of critical habitat, or the availability of any new information should trigger a re-initiation. Regardless, if “take” is occurring at these facilities, such incidental take needs to be authorized under section 7 or 10 of the ESA. The habitat degradation and ecological impacts caused by these dams cannot be addressed by the Services’ prescriptive authority under section 18 of the FPA, but may be under FPA section 10(j) (16 U.S.C. 803) recommendations.

The majority of dams within the GOM DPS do not generate electricity, and therefore do not require either a FERC exemption or a Maine Department of Environmental Protection (MDEP) water quality certification. These dams are typically small and historically were used for a variety of purposes, including flood control, log drives, mill working, storage, recreation, and processing water. Most of these facilities do not have fish passage. Before salmon were listed, lack of fish passage and other impacts to salmon could be addressed only through State law, as noted previously. Further, although the USFWS worked in Maine on salmon passage for decades before the DPS was listed, to a large extent the fishways the services approved were either not effective or were not maintained properly. Overall, the inadequacy of existing regulatory mechanisms relating to dams is a significant threat to the GOM DPS

Regulatory mechanisms for non-FERC dams are also insufficient to provide for fish passage. Because most non-FERC dams predate the Clean Water Act (CWA), section 404 of which regulates the discharge of dredged or fill material into waters of the United States, State law 12 M.R.S.A section 12760 is the only statute other than the ESA dealing with fish passage at these structures. However, this law requires an administrative process and hearing only if requested by the dam owner. For the State to require fish passage under this statute, a finding that fish can be restored “in substantial numbers” and the habitat above the dam “is sufficient or suitable to support a substantial, commercial or recreational fishery” must occur. This statute has been used to require fish passage at only one dam in Maine and remains untested in the courts and at the administrative level (74 FR 29344). It should be noted that construction of any new barriers would be subject to CWA section 404 guidelines regarding water degradation if they significantly impair aquatic life movement.

Secondary Stressors

No significant threats associated with Factor D were identified at the time of listing.

Threats Associated with Factor E:

Significant threats

Marine survival

Given a broad geographic range, extensive life history variation, and diverse management regimes, factors that influence survival in the ocean are considered the primary driver of variability in Atlantic salmon abundance trends across the North Atlantic. Upon entering nearshore waters, post-smolts move rapidly to common marine feeding and wintering areas for 1 to 2 years before returning to natal river to spawn, all while being subjected to natural and anthropic mortality sources including environmental stresses, predation, starvation, disease, and direct and indirect harvest.

Generally, Atlantic salmon populations in Europe are more productive than in North America and northern populations are more productive than southern populations. However, salmon populations have been declining throughout the North Atlantic range, particularly since the early 1990's when a significant decline (e.g. phase shift) in marine productivity occurred. Population declines of other species in the North Atlantic also occurred at this time. The hypothesized cause of the change in productivity is large-scale climate forcing factors that altered thermal, salinity, and oceanographic regimes, which altered the flow of energy through the ecosystem. The resulting increased mortality due to these processes have been particularly acute for the two sea winter components of populations whereas the abundance of one sea winter adults (i.e. 1SW returns) have remained relatively stable over time. Thus, the second year at sea is a hypothesized survival bottleneck for many populations, particularly for southern populations given their demographic reliance on a high proportion of two-sea-winter females (i.e. 2SW returns). Approximately 100% of U.S. origin females return after two winters at sea and increased mortality for this life history strategy can have major consequences for the population dynamics of the US stock complex

Although decreased marine survival resulting from the regime shift is considered a major driver of population abundance, many additional factors may influence marine survival on regional scales. For example, thermal and osmotic stress in the early marine phase, especially during the freshwater to marine transition, is known to influence survival through direct and indirect effects associated with decreased predator avoidance or foraging success. Fish health (disease, infections, and parasites) may also influences marine survival and may be naturally occurring or of increased prevalence due to anthropogenic activities such as salmonid aquaculture. Additionally, indirect latent and cumulative impacts from hydroelectric facilities are also known to decrease marine survival directly and indirectly through the absence of ecosystem processes provided by co-occurring healthy diadromous species complexes. However, the exactly mechanisms of these interactions are not fully understood.

Additional anthropic activities are also potential sources of mortality during the marine phase. Although direct fisheries for Atlantic salmon have been greatly reduced or eliminated, mixed stock fisheries targeting Atlantic salmon off the coast of St. Pierre et Miquelon, Labrador, and West Greenland remain. These fisheries have the potential to harvest post-smolt, 1SW maturing and 1SW non-maturing Atlantic salmon in route to marine wintering areas, feeding areas, and natal rivers prior to spawning. The potential for indirect harvest of Atlantic salmon as bycatch in other fisheries is thought to be low given the lack of overlap with major commercial pelagic fisheries. However, it remains a potential mortality source, especially as new fisheries develop or if existing fishery dynamics change in time and space. Other possible sources of mortality at sea include energy development projects, dredging or dumping of dredge spoils, and offshore development projects although the potential impacts of these threats have yet to be quantified.

Impacts from dams in freshwater and poor survival in the ocean are considered the primary impediments to U.S. Atlantic salmon recovery. Despite this, a comprehensive understanding of all the impact these factors have on Atlantic salmon populations is limited and the marine phase has historically been considered a 'black-box'. Although significant advances have been made in our understanding of the marine phase of Atlantic salmon and in identifying the magnitude of spatiotemporal-specific survival bottlenecks, our understanding is imperfect and clear management actions to increase marine survival have yet to be identified. Further work is needed by scientists and managers to identify actions that can increase the marine survival of this endangered species.

Secondary stressors

Depleted Diadromous Communities

Dam building played an important role in reducing Atlantic salmon and other co-evolved diadromous species. The Atlantic salmon is one of 12 native diadromous species in Maine: Atlantic shad, alewife, blueback herring, sea-run brook trout, rainbow smelt, shortnose sturgeon, Atlantic sturgeon, striped bass, sea lamprey, and Atlantic tomcod are anadromous. The American eel is the only catadromous species.

Conservative estimates of the historical numbers of the diadromous fishes that co-evolved with Atlantic salmon are in the millions. 1,000,000 alewives in the Penobscot in 1867; 1,200,000 alewives per year in 1 tributary of the Kennebec in the early 1800s; 2,472,000 alewives in the Damariscotta in 1896; 400,000 blueback herring in the Kennebec in 1880; 2,000,000 American shad in the Penobscot prior to the 1830s; and 3,500,000 rainbow smelt in the Penobscot in 1887 (Saunders et al. 2006).

Damming rivers, thus preventing migration to former spawning grounds, was a major factor in the decline of Atlantic salmon, sturgeon, river herring (blueback herring and alewife), and shad (Moring, 2005; Limburg & Waldman, 2009). Many co-evolved diadromous species have experienced dramatic declines throughout their ranges, and current abundance indices are fractions of historical levels.

Range wide population declines are dramatic: American shad, 97 percent; alewife, 99 percent; blueback herring, 99 percent; rainbow smelt, 99 percent; Atlantic sturgeon, 91 percent; Atlantic salmon, 96 percent; and American eel, 72 percent (Limburg & Waldman, 2009). Similarly, in Maine current population levels are orders of magnitude smaller than historical population levels (Saunders et al., 2006).

This dramatic decline in diadromous species has negative impacts on Atlantic salmon populations. At historical levels, the alewife, blueback herring, American shad, rainbow smelt, and sea lamprey likely provided several important benefits for Atlantic salmon, such as providing alternative prey for predators of salmon (i.e., prey buffering) (Saunders et al. 2006); serving as food for juvenile and adult salmon (Cunjak et al. 1998), nutrient cycling (Durbin et al., 1979; Nislow & Kynard, 2009); and habitat conditioning

(Saunders et al. 2006). Habitat conditioning refers to sea lamprey, whose spawning movements remove sediment and algae from stream rocks, which may improve habitats for Atlantic salmon spawning (Guyette et al., 2014, Hogg et al, 2013, Gardner et al., 2012).

Because diadromous fish populations have been significantly reduced, ecological benefits from marine derived nutrients (MDN), habitat conditioning, prey buffering, and alternative sources of food for Atlantic salmon are significantly lower today compared to historical conditions. These impacts may be contributing to decreased survival through (1) reduction of prey for reconditioning kelts, (2) increased predation risks for smolts in lower-river and estuarine areas, and (3) increased predation risks to adults in estuarine and lower river areas. Although these impacts do not occur in the open ocean, the demographic impact to the species occurs after smolt emigration, and is thus a component of the marine survival regime.

Removing dams and providing access to spawning habitat will significantly help restoration of all diadromous species in the GOM DPS, which should aid in the recovery of Atlantic salmon. The ecological interplay and interdependence of Atlantic salmon and other diadromous species is still being investigated, but at present, the lack of a robust diadromous community is a lesser stressor on the GOM DPS.

Artificial Propagation

The conservation hatchery programs at Craig Brook and Green Lake National Fish Hatcheries (NFH) are vital to preserving individual and composite genetic stocks until freshwater and marine conditions improve for wild adults to reach stable recovery numbers. Currently, progeny produced from wild and captive broodstock are released into their rivers of origin as eggs, fry, parr, and smolts. In addition, surplus adult broodstock are returned to their river of origin. Information on the numbers and life stages of Atlantic salmon stocked in the Gulf of Maine DPS can be found in the annual Atlantic salmon assessment committee report (*e.g.* USASAC, 2016).

As reviewed in Fay et al., (2006), captive propagation and maintenance of broodstocks can be used to sustain or supplement threatened or endangered fish populations (Flagg & Nash, 1999)0. Though potentially effective at maintaining or increasing the population size, there is potential for altering unique genetic characteristics of the natural population (Berejikian & Ford, 2004). Mating strategies used in hatchery propagation can reduce genetic variability inherent in populations through artificial reductions in the number of spawning adults through reproductive variation (Withler, 1988). Artificial selection may alter population specific life history or genetic traits that may both alter the genetic characteristics of the captive population in relation to the wild source population, or result in decreased ability of the population to survive in the natural environment (Berejikian & Ford, 2004). Therefore, implementing hatchery practices that minimize artificial selection are important to maintain population-specific genetic characteristics and within-population genetic diversity. In an effort to minimize the genetic risks associated with maintenance of captive broodstocks, a broodstock management plan (Bartron M. L., et al., 2006) was developed with the goal of maintaining genetic diversity throughout the hatchery management process, including estimating genetic diversity for each captive broodstock.

Aquaculture

As reviewed in Fay et al. (2006), Atlantic salmon that escape from farms and hatcheries pose a threat to native Atlantic salmon populations (Naylor, et al., 2005). Because captive reared fish are selectively bred to promote behavioral and physiological attributes desirable in captivity (Hindar, Ryman, & Utter, 1991; Utter, Seeb, & Seeb, 1993; Hard, et al., 2000). Experimental tests of genetic divergence between farmed and wild salmon indicate that farming generates rapid genetic change because of both intentional and unintentional selection in culture and that those changes alter important fitness-related traits (McGinnity, et al., 1997; Gross, 1998). Consequently, aquaculture fish are often less fit in the wild than naturally produced salmon (Fleming, et al., 2000). Annual invasions of adult aquaculture salmon have the potential to disrupt local adaptations and reduce genetic diversity of wild populations (Fleming, et al., 2000). Bursts of immigration also disrupt genetic differentiation among wild Atlantic salmon stocks, especially when wild populations are small (Mork, 1991). Natural selection may be able to purge wild populations of maladaptive traits but may be less able to if the intrusions occur year-after-year. Under this scenario, population fitness is likely to decrease as the selection from the artificial culture operation overrides wild selection (Hindar, Ryman, & Utter, 1991; Fleming & Einum, 1998), a process called outbreeding depression. The threat of outbreeding depression is likely to be greater in North America where aquaculture salmon have been based, in part, on European Land catch strain.

In addition to genetic effects, escaped farmed salmon can disrupt redds of wild salmon, compete with wild salmon for food and habitat, transfer disease or parasites to wild salmon, and degrade benthic habitat (Windsor & Hutchinson, 1990; Saunders R. L., 1991; Youngson et al., 1993; Webb, et al., 1993; Clifford et al., 1997). Farmed salmon in have been documented to spawn successfully, but not always at the same time as wild salmon (Lura & Saegrov, 1991; Jonsson et al., 1991; Webb et al., 1991; Fleming et al., 1996). Late spawning aquaculture fish could limit wild spawning success through red superimposition. There has also been recent concern over potential interactions when wild adult salmon migrate past closely spaced cages, creating the potential for behavioral interactions, disease transfer, or interactions with predators (Lura & Saegrov, 1991; Crozier, 1993; Skaala & Hindar, 1997; Carr et al., 1997; DFO, 1999). In Canada, the survival of wild posts molts moving from Passamaquoddy Bay to the Bay of Fundy was inversely related to the density of aquaculture cages (DFO, 1999)

Concerns about aquaculture continue in the GOM DPS, but recent advances in containment and marking of aquaculture fish offer more control over these threats and reduce the risk of negative impacts of aquaculture fish on the GOM DPS. Permits issued by the Army Corps of Engineers (ACOE) and MDEP require genetic screening to ensure that only North American-strain salmon are used in commercial aquaculture; marking to facilitate tracing fish back to the source and cause of the escape; containment management plans and audits; and rigorous disease screening. Aquaculture is a lesser stressor on the GOM DPS; however, these measures do not eliminate the risk aquaculture fish pose to wild Atlantic salmon but serve to reduce the potential for negative impacts. It is important to note that at this time equally protective requirements regarding salmon aquaculture do not exist on the Canadian side of the border. Fish held in Canadian cages, or those that may escape from Canadian cages, can still pose disease, genetic, and ecological risks to U.S. Atlantic salmon.

Competition

As reviewed in Fay et al. (2006), prior to 1800, the resident riverine fish communities in Maine were relatively simple consisting of brook trout, cusk, white sucker, and a number of minnow species. Today, Atlantic salmon co-exist with a diverse array of non-native resident fishes including landlocked salmon, brown trout, largemouth bass, smallmouth bass, chain pickerel, and northern pike (MDIFW 2002). The range expansion of non-native fishes is important given evidence that niche shifts may follow the addition or removal of other competing species (Fausch, 1998). For example, in Newfoundland, Canada, where fish communities are simple, Atlantic salmon inhabit pools and lakes, which are generally considered atypical habitats in systems where there are more complex fish communities (Gibson, 1993). Use of lacustrine habitat in particular, can increase smolt production (Matthews et al., 1997). Conversely, if salmon are excluded from these habitats through competitive interactions, smolt production may suffer (Ryan, 1993). Even if salmon are not completely excluded from a given habitat type, they may select different, presumably sub-optimal, habitats in the presence of certain competitors (Fausch, 1998). Thus, competitive interactions may limit Atlantic salmon production through niche constriction (Hearn, 1987). Competition is a lesser stressor to the GOM DPS because it can exclude salmon from preferred habitats, reduce food availability, and increase predation.

CHAPTER 7: NEW AND EMERGING THREATS

Current threats to Atlantic salmon include both the primary and secondary factors identified in the final rule (74 FR 29344, 2009). In addition, this recovery plan identifies undersized or poorly designed and installed road stream crossings, climate change and the Greenland intercept fishery as emerging significant threats.

Emerging Threats Associated with Factor A:

Road stream crossings

Road stream crossings were identified at the time of listing as a lesser stressor, which in conjunction with other lesser stressors constituted a significant threat to the species. In the draft recovery plan, the threat of road crossings is identified as constituting a significant threat to the species. Road stream crossings are found throughout the GOM DPS. In the Gulf of Maine DPS, 10,169 road crossings have been assessed for fish passage effectiveness. Of these, there are 3,259 impassible culverts, 3,677 culverts that are a partial barrier to fish passage, and another 1,803 where passage effectiveness is unknown (A. Abbott, personal communications, 8-2017). Most of those road-crossing barriers are found on the smaller first and second order streams within a watershed. Corrugated metal, plastic or cement culverts, rather than bridges or bottomless arch culverts, are frequently installed at road crossings to reduce costs. Undersized culverts create hydraulic barriers that sever habitat connectivity within the range of the GOM DPS. Improperly placed and undersized culverts create fish passage barriers through perched outlets, increased water velocities, or insufficient water flow and depth within the culvert. Poorly placed or designed road stream crossings reduce access to habitat necessary for Atlantic salmon spawning and rearing and alter stream processes including transport of sediment and materials.

Road stream crossings that restrict movements within and among suitable habitats on first and second order tributary streams have a significant impact on parr production. In a study on the Sheepscot River, Sweka et al. (2007), found that smaller tributary streams contributed more individuals to the total out-migrating smolt population than larger mainstem habitats. Sweka and Mackey (2010) found a similar relationship throughout Maine Atlantic Salmon Rivers in which parr density decreased with increasing cumulative drainage area. They modeled this relationship using quantile regression to illustrate an upper bound (90th percentile) of parr density that could be expected in a stream reach of a given cumulative drainage area. They estimated that approximately 83 percent of predicted parr production in the GOM DPS occurs in the small drainage areas reaches with drainage areas less than 100 km^2 (90 percent from habitat with drainage areas less than 209 km^2, and 95 percent from habitat with drainage areas less than 411 km^2). Many of these smaller drainage areas constitute 1st and 2nd order streams where road-crossing barriers are most often found.

Emerging Threats Associated with Factor B:

Mixed-stock fisheries

Commercial fisheries for Atlantic salmon within the United States have been closed since 1947; however, small but significant fisheries continue within the species' migratory corridor off the coast of Canada and Greenland. To effectively engage in issues requiring international collaboration such as these distant water fisheries, the United States maintains a presence at the North Atlantic Conservation Organization (NASCO) and International Conference for the Exploration of the Seas (ICES). The United States is a signatory to the "Convention for the Conservation of Salmon in the North Atlantic Ocean" which entered into force in October 1983, creating NASCO to ensure that the burden of Atlantic salmon conservation was shared by both States of Origin and Distant Water Countries. NASCO promotes the conservation, restoration, enhancement, and rational management of salmon stocks in the North Atlantic Ocean through international cooperation. NASCO has six members, which include Norway, the United States, European Union (EU), Canada, the Russia Federation, and Denmark (in respect of the Faroe Islands and Greenland). The United States is represented at NASCO by scientists and managers from NOAA Fisheries as well as staff from the Department of State, other Federal and non-federal agencies, and private sector advisors. NMFS' role is to work to reduce impacts to U.S. stocks from distant water fisheries, and seek to hold ourselves and other countries accountable for the protection and conservation of Atlantic salmon. NMFS scientists compile and analyze data on the status of the GOM DPS and take this information to the International Council for the ICES Working Group on North Atlantic Salmon. This group takes and analyzes data from throughout the North Atlantic to provide scientific advice to NASCO. NMFS scientists coordinate and participate in the international sampling effort for the Greenland fishery.

Intercept fisheries (adult fish captured in nets while in transit to or from their feeding grounds in the North Atlantic or on their feeding grounds in the North Atlantic) have posed a significant challenge to recovery of the GOM DPS. For instance, the reported catch estimate for the West Greenland fishery in 2014 was 57.8 tons; given the potential for under-reporting for the 2014 fishery at West Greenland, total catch in Greenland that year may have been higher.

In response, a new regulatory measure for the intercept mixed stock salmon fishery at West Greenland was adopted at the 2015 annual meeting NASCO, effective through 2017. Although this measure does not include a stated catch limit for the fishery, Greenland unilaterally set a 45-ton quota for the 2015 to 2017-time period. The new regulations maintain the prohibition on exports of Atlantic salmon from Greenland and will require Greenland to implement stronger monitoring, control, and reporting requirements. The new measures include enhanced licensing requirements for fishermen, such as annual catch reporting to maintain a license and in-season catch reporting, that will allow Greenland to close the fishery if and when the catch limit is reached. They also ensure that if any overharvest of the unilateral catch cap occurs in a particular year, it will result in an equal reduction in the catch limit for the following year and will preclude any under-harvest from carrying forward to a future year. It should be noted that these regulations are subject to periodic review and revision.

Populations of United States origin salmon are also harvested by St. Pierre and Miquelon (an offshore territory of France located off the coast of Newfoundland). Although smaller in scale than the West Greenland fishery, this fishery operates outside any international management regime, as France (with respect to St. Pierre and Miquelon) has refused to join NASCO as a party. Moreover, the domestic management regime in place does not effectively limit what can be caught.

U.S. origin salmon are also harvested in Labrador, Canada. There are two types of subsistence net fisheries in Labrador that authorize the harvest of Atlantic salmon: resident subsistence trout fisheries that permit some by-catch of salmon; and aboriginal food, social and ceremonial (FSC) fisheries that allow direct harvest of Atlantic salmon. In recent years, the fishing season and mesh sizes in the various fisheries have been modified in an effort to reduce the capture of large salmon (NAC(16)3, 2016). Carcass tags are required for all harvested salmon in these fisheries. Carcass tag allocations are set by DFO for each group, which limits the total harvest of salmon that can be taken. All sales of salmon are prohibited. The majority (roughly 80%) of the subsistence food fishery harvest occurs in estuaries with roughly 20% of that harvest occurring in coastal areas (NAC(16)3, 2016). Recent genetic information presented by Bradbury et al. (2014; 2015), and ICES (2015) suggests that salmon of U.S. origin accounted for a very low level of the harvest in that fishery (approximately 0.6% from 2006 to 2011 and <0.1% from 2012 to 2014). Even though the relative proportion of U.S.-origin salmon in that fishery is low, the effect to U.S. returns is still an important consideration. For example, Bradbury et al. (2015) reported exploitation rates of U.S.-origin salmon to range from 1.04 to 4.20% from 2006 to 2011.

Emerging Threats Associated with Factor E:

Climate Change

Fay et al. (2006) and NRC (2004) summarize the potential impacts of climate change on Atlantic salmon. At the time of listing in 2009, although there was reasonable certainty that climate change was affecting Atlantic salmon in the GOM DPS, there was uncertainty surrounding specifically how and to what extent. Since listing, new and emerging science has helped us gain a better understanding of these effects and just what the ramifications are for salmon. Recent information indicates that climate change is having significant impacts on the ecosystems that Atlantic salmon depend on and subsequently having significant impacts on the overall survival and recovery of Atlantic salmon (Mills et al., 2013). Following is a synopsis of the effects of climate change, and the new and emerging science that has elevated its concern for Atlantic salmon.

Since the 1970s, there has been a historically significant change in climate (Greene et al., 2008). Climate warming has resulted in increased precipitation, river discharge, and glacial and sea-ice melting (Greene et al., 2008). The past 3 decades have witnessed major changes in ocean circulation patterns in the Arctic, and these were accompanied by climate associated changes as well (Greene et al., 2008). Shifts in atmospheric conditions have altered Arctic Ocean circulation patterns and the export of freshwater to the North Atlantic (Greene et al. 2008, IPCC 2006). With respect specifically to the North Atlantic Oscillation (NAO), changes in salinity and temperature are thought to be the result of changes in the earth's atmosphere caused by anthropogenic forces (IPCC, 2006).

Global climate change can affect all aspects of the salmon's life history. Entire ecosystems can shift rapidly (compared to evolutionary timescales) from one state to another. Furthermore, increases in sea surface temperatures (IPCC, 2001); changes in frequency of seasonal cycles of phytoplankton, zooplankton and fish populations in the marine environment (Greene & Pershing, 2007) and changes in freshwater hydrologic regimes can alter the habitat features that salmon depend. All of these factors can significantly alter the ecosystem in which salmon have become adapted by effecting environmental cues that stimulate migration, spawning and feeding activities.

Friedland et al. (2005) summarized numerous studies that suggest that climate mediates marine survival for Atlantic salmon as well as other fish species. Recent analyses of bottom water temperatures found that negative NAO years are warmer in the north and cooler in the Gulf of Maine (Petrie, 2007). Positive NAO years are warmer in Gulf of Maine and colder in the north (north of 45° N) (Petrie 2007). Strength of NAO is related to annual changes in diversity of potential predators: at southern latitudes, there are more species during positive NAO years (Fisher et al., 2008). The effect is system-wide where 133 species showed at least a 20 percent difference in frequency of occurrence in years with opposing NAO states (Fisher et al. 2008).

In a recent study, Mills et al. (2013) was able to associate a major decline in Atlantic salmon abundance to a series of oceanic changes across multiple levels of a salmon's ecosystem because of changing climate conditions. Her results suggest that climate driven environmental factors and warmer ocean temperatures resulted in poor trophic conditions constraining the productivity and recovery of Atlantic salmon populations in the North Atlantic. Though all Atlantic salmon in the North Atlantic are affected by the changes in trophic conditions, the effects on populations dominated by two sea-winter fish (such as the GOM DPS) appears greater than populations dominated by 1 sea-winter fish. This suggests that there is a greater cumulative effect of poor trophic conditions on 2 sea-winter fish because of longer residence times at sea. Mills' study goes on to suggest that the impacts to Atlantic salmon are most associated with salmon's ecosystem response to warming rather than the direct impacts of warming itself. These effects include changes to phytoplankton and zooplankton communities that salmon's principle prey species, capelin, feed on. Subsequent to these changes, the size, distribution and behavior patterns of capelin has shifted making them less available for salmon to prey on, subsequently reducing the overall fitness and survival of Atlantic salmon.

Within the freshwater range of Atlantic salmon, water temperature is one of the most important environmental factors affecting all forms of aquatic life in rivers and streams (Annear, et al., 2004). In addition to climate change, water temperature can be influenced by changes in riparian cover, dams, alterations in stream channel morphology (Annear, et al., 2004), wastewater discharge, and urban development. Among rivers within the GOM DPS, records extending back to the early 1900's indicate that spring runoff has become earlier, fall ice-on is later, and there are fewer days of total winter ice on Maine rivers (Dudley & Hodgkins, 2002). In support of these observations, a combination of land-surface and sea-surface air temperature data shows an overall increasing trend in annual air temperatures for New England between the period of 1901 to 2000. The greatest seasonal warming rates occur in the winter months between December and February as indicated by a period of record extending from 1976 to 2000 (IPCC 2001). Several studies indicate that small thermal changes may substantially alter reproductive performance, species distribution limits, and community structure of fish populations (Pankhurst & Van Der Kraak, 1997; McCormick et al., 1999; Rahel et al., 1996; McCarthy & Houlihan, 1997; Welch et al., 1998; Schindler, 2001). Changes in fish community structure can alter predator/prey assemblages by decreasing qualitative habitat features that benefit salmon while concurrently increasing habitat features that benefit predators and competitors.

Temperature is especially important for Atlantic salmon given that they are poikilothermic (*i.e.* their body temperatures and metabolic processes are determined by temperature). Temperature can be a stimulant for salmon migration, spawning, and feeding (Elson, 1969). Thermal changes of just a few degrees Celsius can critically affect biological functions of salmon including metabolism (McCarthy & Houlihan, 1997; Somero & Hofmann, 1997; Reid et al., 1998), reproductive performance (Pankhurst & Van Der Kraak, 1997), response to contaminants (Reid et al., 1997) and smolt development (McCormick et al., 1998). Unnatural changes in water temperatures may also affect growth, survival and migration timing of Atlantic salmon in freshwater, the survival and timing of migrating smolts in the estuarine environment, and the survival of juveniles soon after entering the marine environment (National Research Council, 2004). Juanes et al*.,* (2004) examined migration timing data from the Connecticut River drainage and from drainages in Maine and Canada and found a shift towards earlier peak migration dates across systems, correlating with long term changes in temperature and flow that may represent a response to global climate change. For migrating smolts, the interrelatedness of water temperature and photoperiod may be extremely important to consider. One of the concerns with climate change is the rate at which water temperatures increase could conceivably regulate the window of opportunity in which smolts can successfully transition from freshwater to saltwater. McCormick *et al.* (1998) suggested that smolts experiencing delays in migration, such as those that occur at dams, may have lower survival rates if they are unable to reach saltwater within the migration window. One possible explanation for this reduced survivorship is that a shortened migration window due to increased temperatures could conceivably result in increased predation pressure as more smolts are forced to migrate over a shorter period of time.

CHAPTER 8: CONSERVATION EFFORTS

Stakeholder Recovery Efforts

History

Atlantic salmon conservation and restoration efforts have been underway for more than 150 years. By the mid-1850s, Atlantic salmon had been virtually extirpated from many rivers outside Maine. The earliest restoration efforts began in 1862 and were motivated by depleted fish stocks resulting from non-sustainable commercial fisheries, coupled with habitat loss due to dams. The Civil War delayed much work on restoring Atlantic salmon stocks until peacetime, and in 1866 Maine joined the first U.S. Federal Interstate Commission in restoring and improving anadromous fish runs in New England Rivers (Baum, 1997). Charles Atkins and Nathan Foster were appointed the first two Commissioners of Fisheries for Maine. Their first report, (Atkins & Foster, 1867), attributed the depletion of Atlantic salmon to impassable dams, overfishing, and pollution, with dams and overfishing as the principal causes. When Atkins became the sole Commissioner in 1869, he advanced the idea of artificial propagation and in 1871 established the Craig Brook Hatchery. The hatchery became a Federal facility in 1889.

Although the Atlantic salmon has not been fully restored since then, the listing has brought about large-scale, multi-million-dollar conservation efforts, such as the removal of dams in the Penobscot and removal of impassable culverts in the Machias, restoring accessibility to miles of rearing and spawning habitat.

Recovery Efforts

A long list of partners in salmon recovery exists. This list includes: American Rivers, Appalachian Mountain Club, Atlantic Salmon Federation, Downeast Land Trust, Downeast Salmon Federation, Ducks Unlimited, Environmental Protection Agency, Fisheries Improvement Network, Forest Products Council, Forest Society of Maine, Huber, Inc., Keeping Maine’s Forests, Maine Audubon, Maine Department of Environmental Protection, Maine Department of Inland Fisheries and Wildlife, Maine Department of Marine Resources, Maine Department of Inland Fisheries and Wildlife, Maine Department of Transportation, Maine Forest Service, Maine Rivers, Maine Tree Foundation, Natural Resources Conservation Service, Natural Resources Council of Maine, Penobscot Indian Nation, Penobscot River Restoration Trust, Project SHARE, Sewell, Inc., The Nature Conservancy , Trout Unlimited, University of Maine Cooperative Extension Service, U.S. Geological Survey, University of Maine; U.S. Army Corps of Engineers, among many others.

Penobscot River Restoration Project

The Penobscot River Restoration project opened up approximately 10 miles of the mainstem Penobscot River through the removal of the Veazie and Great Works Dam – the lower most dams on the Penobscot River. Fish passage improvements at the Milford dam and the construction of a bypass channel around the Howland dam significantly improved access to nearly 1,000 miles of the river and its tributaries. Since the project’s completion there has already been significant increases in the numbers of river herring, American shad along with other sea run fish observed passing through the fishway at the Milford dam. Successful implementation of the project is expected to improve not only native fisheries but also social, cultural, and economic traditions of New England's second largest river, the Penobscot.

Table 2

Penobscot Documented Returns (Orono and Milford)				
Year	River Herring	American Shad	Atlantic salmon	Mainstem Passage Improvements
2017 (as of Dec. 4, 17)	1,357,037	3,868	849	
2016	1,259,384	7,861	506	
2015	589,503	1,806	731	Howland Bypass
2014	187,438	812	261	
2013	12,708	0	381	Veazie Removed/Milford Completed
2012	54	7	624	Greatworks removed
2011	2,039	1	3125	
2010	222	0	1315	
2009	2,336	0	1958	

(pink)	Post Veazie Removal
(green)	Pre-Veazie Removal

Lower Kennebec River Comprehensive Hydropower Settlement Accord (KHDG Accord, 1998)

The KHDG Accord was put in place to address fish passage issues at eight hydroelectric facilities: Edwards (removed), Lockwood, Hydro Kennebec, Shawmut, and Weston projects on the Kennebec River and Fort Halifax (removed), Benton Falls, and Burnham on the Sebasticook River. In 2002, the Anson and Abenaki Offer of Settlement (Settlement) added the Anson and Abenaki projects, also on the Kennebec. The KHDG Accord and Anson-Abenaki Settlement contain biological triggers for implementing upstream passage on the Kennebec and Sebasticook rivers. Both are legally binding. The biological triggers were based upon adults' returns of American shad to the Kennebec River; these triggers have not been met and in all likelihood will never be met given poor returns of shad to the river. Given this, it is unlikely that new upstream fishways will be installed on the Kennebec River under the KHDG Accord.

Road-Stream Barrier Prioritization Efforts of the Maine Interagency Stream Connectivity Work Group

For the past several years, the USFWS GOM Coastal Program has collaborated with other organizations to inventory road-stream crossings in an effort to identify barriers to stream connectivity (Abbott 2008). Aside from characterizing the geographic scope, magnitude, and nature of road-stream barriers in Maine, these inventories have considerable value in providing the basic information necessary to prioritize corrective action among the many severe barriers to the functioning of streams and recovery of key species of management interest. To that end, the Maine Interagency Stream Connectivity Work Group, a statewide effort to address connectivity issues in Maine, is working to develop a prioritization approach. The work group has drafted a provisional list of parameters (e.g., miles of accessible habitat upstream of the site) that would inform the relative ecological value of a given corrective action at any single road-stream crossing. It is anticipated that these parameters will be integrated into adaptations of one or more GIS prioritization tools being developed by The Nature Conservancy, with the ultimate goal of developing a publicly accessible, Web-based application that should allow users to gather information at will (Laser and Moore 2010).

In addition, the Work Group has developed an on-line Stream Habitat Viewer: (*http://mapserver.maine.gov/streamviewer/streamdocHome.html*) to enhance statewide stream restoration and conservation efforts. The Viewer provides a starting point for towns, private landowners, and others to learn more about stream habitats across the State.

Penobscot Indian Nation Water Quality Monitoring Program

The PIN implements a rigorous water quality-testing program throughout the Penobscot Watershed, though predominately in the mainstem Penobscot and major tributaries between Old Town and Millinocket, Maine. The program aims to ensure water quality standards are being met and licensed discharges comply with permit conditions, to upgrade river and tributary classifications, to identify and remediate sources of nonpoint source pollution, and to gather data needed to support the role of the Tribe in hydroelectric re-licensing. The PIN has extended its monitoring to include the mainstem Penobscot downstream to the Veazie Dam tailwater as part of the monitoring program for the Penobscot River Restoration Project. The PIN also has a cooperative agreement with the MDEP to share water quality data and technical assistance. This agreement has led to improved water quality and the revision of water classifications for more than 500 rivers and streams.

Project SHARE (Salmon Habitat and River Enhancement)

Project SHARE (SHARE) was created as a cooperative forum between stakeholders and industry to contribute to Atlantic salmon recovery via habitat restoration in the five Downeast Rivers: Narraguagus, Pleasant, Machias, East Machias, and Dennys. Project SHARE is a cooperative partnership of landowners, State and Federal agencies, universities and other stakeholders that seeks to actively restore fish passage and natural stream function at a landscape scale to benefit Atlantic salmon and other native sea-run and resident fishes. Project SHARE's primary restoration activity in recent years has been the removal or replacement of traditional round culverts with bottomless structures designed to accommodate natural stream processes and fish passage. The first pilot project was completed in 2005, and SHARE has now completed hundreds of connectivity projects throughout the Downeast Salmon Habitat Recovery unit restoring and improving access to critical Atlantic salmon habitat as well as restoring the ecological processes that create habitats most suited for Atlantic salmon survival. Project SHARE has also conducted other restoration activities, including placing large wood in streams to increase habitat complexity, removing remnant log-drive dams, and planting native trees to increase shade along restored stream reaches.

CHAPTER 9: PLANNING AND MANAGEMENT EFFORTS

Recovery of the GOM DPS requires coordinating conservation planning and management efforts across the DPS. This recovery plan provides guidelines to achieve recovery and is based on the agencies' year-to-year actions combined with important ongoing stakeholder actions. In addition, this plan identifies other priority actions that are not currently funded. In the section below, we provide brief overviews of ongoing conservation planning and management efforts across the DPS.

Statement of Cooperation

Upon listing Atlantic salmon as endangered in 2000, both the USFWS and NOAA shared jurisdiction in fulfilling the agencies' obligations under the ESA. This shared jurisdiction allowed the agencies to share existing resources and expertise in implementing recovery efforts for Atlantic salmon. Over time, the Services recognized that many aspects of the joint authority that resulted in confusion, inefficiencies, and delays. To address these issues, the Services developed a statement of cooperation in 2006 with amendments made in 2009. These amendments more clearly delineated roles and responsibilities, with the USFWS focusing efforts within freshwater and NOAA focusing efforts on the estuary and marine environment. In addition, NOAA is responsible for actions that relate to dams.

The Atlantic salmon Recovery Framework

The Atlantic salmon recovery framework was developed to establish a collective strategy to identify and implement the highest priority management actions and scientific studies that have the greatest potential to further our recovery objectives. The MDMR, USFWS and NMFS share responsibility for Atlantic salmon. The Passamaquoddy Tribe and the Penobscot Nation also have certain management and regulatory responsibilities regarding sustenance fishing within their respective tribal reservations. Differences in legal authorities, agency procedures and protocols, and expertise have led to confusion, delays in decision-making and disagreements. The governance structure articulates roles and responsibilities as well as a pre-agreed procedure and timeline for making decisions in order to avoid such problems in the future. The MDMR, USFWS and the NMFS agree that the fundamental objective of our efforts on behalf of Atlantic salmon is to achieve recovery of the species with the overall objectives of increased distribution and abundance.

The framework identifies a set of strategies and a wide range of alternative strategies that can be implemented to achieve the fundamental objectives of increasing abundance (productivity) and distribution. Five strategies were identified as necessary for achieving these objectives: Increase Marine and Estuarine Survival; Increase Connectivity; Maintain Genetic Diversity through the Conservation Hatchery; Increase Adult Spawners through the Conservation Hatchery; and Increase Adult Spawners through the Freshwater Production of Smolts.

Action Teams were formed for each of the five strategies. Each Action Team was charged with developing a list of actions that could be implemented to achieve the biological objectives and oversee, facilitate, and coordinate the implementation of those actions. A Management Board and a Policy Board were established to provide detailed direction, commit resources, reaffirm priorities and set broad policy direction for the program.

2008 Strategic Plan for the Restoration of the Diadromous Fishes to the Penobscot River (Strategic Plan)

The goal of the Strategic Plan (MDMR & MDIFW, 2008) is to guide the restoration and management of 12 diadromous fish to the Penobscot River as well as other aquatic resources, and the ecosystems on which they depend for their intrinsic, ecological, economic, recreational, scientific, and educational values. The strategic plan includes four goals:

1. Coordinate fisheries management and restoration activities among State and Federal fisheries agencies, Penobscot Indian Nation, and stakeholders and develop criteria to address management differences that strike an appropriate balance in fish community structure compatible with individual agency and stakeholder objectives.
2. Provide safe and effective upstream and downstream passage for diadromous fishes at barriers that restrict access between their historical habitat in the Penobscot basin and the ocean.
3. Restore and maintain a healthy aquatic ecosystem that conserves native biodiversity, manages or prevents the invasion of nonnative aquatic species, increases the natural recruitment of fish, and improves aquatic habitat.
4. Rebuild sustainable fish populations, manage populations of native and naturalized aquatic species, reduce populations of nonnative undesirable species, and maintain and enhance fishing opportunities using adaptive management principles.

An interagency technical committee also developed an operational plan (MDMR & MDIFW, 2009), that details specific actions to accomplish the strategic plan's objectives. The strategic plan has a 25-year time frame.

International Efforts

To be effective in engaging on issues requiring international collaboration, such as distant water fisheries, the United States maintains a presence at the North Atlantic Conservation Organization (NASCO) and International Conference for the Exploration of the Seas (ICES). The United States is a signatory to the "Convention for the Conservation of Salmon in the North Atlantic Ocean" which entered into force in October 1983, creating NASCO to ensure that the burden of Atlantic salmon conservation was shared by both States of Origin and Distant Water Countries. Intercept fisheries (adult fish captured in nets while in transit to or from their feeding grounds in the North Atlantic or on their feeding grounds in the North Atlantic) have posed a significant challenge to recovery of the GOM DPS. Among distance water fisheries, the West Greenland fishery intercepts the greatest number of U.S. origin fish. Other fisheries where U.S. origin fish are harvested include the St. Pierre and Miquelon fishery located off the coast of Newfoundland, and a subsistence fishery that occurs in Labrador, Canada. Through multiparty negotiations, this organization works to limit the number of adult GOM DPS Atlantic salmon taken in international waters.

In addition, NASCO serves an important role in international cooperation and collaboration to advance rational management of Atlantic salmon stocks within the Convention area. This involves developing agreements, such as the Williamsburg Resolution (NASCO, 2006), for aquaculture and related activities, and guidance documents related to management of fisheries and habitat. For NASCO, ICES provides scientific support to help inform NASCO's management decisions as they relate to Atlantic salmon. ICES is an international organization that coordinates marine research in the North Atlantic and provides scientific advice to government and international regulatory bodies that manage the north Atlantic Ocean and adjacent seas.

Hatchery Biosecurity Plan to Control Disease

Federal and State-managed hatcheries and programs have stringent biosecurity plans in place to prevent the spread of pathogens between river systems. Hatchery biosecurity plans outline disinfection and fish-handling procedures for preventing the introduction of pathogens from wild broodstock, process water sources, and other facilities. In addition to biosecurity plans, both Federal facilities are in the process of developing hazard analysis critical control point plans (HACCPs), which are designed to identify the activities and processes that pose the greatest risk of incoming or outgoing pathogens and strategies to mitigate risk (USFWS 1999).

Broodstock Management Plan

The Captive Broodstock Management Plan for Atlantic salmon at Craig Brook National Fish Hatchery (Bartron M. , et al., 2006) was developed to establish a set of protocols for the collection and spawning of Atlantic salmon broodstock at Craig Brook National Fish Hatchery. The goal of the broodstock management plan is to describe and explain current broodstock management practices at CBNFH. The plan details hatchery operations and describes the facilities and production practices, which aid in the evaluation of future management options at CBNFH. The second goal of the plan is to provide a framework with quantifiable values to evaluate the hatchery program in relation to the management objectives. The plan establishes both short and long-term guidance for spawning, monitoring, and evaluation of the captive broodstock program to achieve its restoration and recovery goals.

CHAPTER 10: POPULATION VIABILITY ANALYSIS

Rationale for population viability recovery criteria for the gulf of Maine DPS of Atlantic salmon

The 50/500 Rule

A minimum viable population (MVP) is defined by Shaffer (1981) as the smallest isolated population that has a 99 percent probability of remaining extant for 1000 years despite natural demographic, environmental, and genetic stochasticity and natural catastrophes. The number of organisms present within a population does not necessarily denote the actual number of viable organisms within that population. Therefore, when determining viability, it is important to acknowledge the potential for variations between the actual (census) population size (N) and the viable (effective) component of that population. As a result, we not only recognize the importance of the MVP but also the importance of defining criteria for effective population size (N_e) for setting robust recovery criteria. Franklin (1980) described an N_e size of 500 as necessary to retain sufficient genetic variation for long-term population persistence. Soulé (1980) identified an N_e of 50 or greater needed to assure that a population, over the short term, would have an inbreeding rate of less than 1 percent. Higher rates of inbreeding that can occur in populations of fewer than 50 can fix deleterious genes too rapidly for natural selection to eliminate them. Soulé (1980) states that even at a 1 percent rate of inbreeding, the loss of genetic variation after a few generations will be appreciable even in the presence of natural selection. Soulé (1980) also states that after 20 to 30 generations, a population held at 50 can expect to lose about one fourth of its genetic variation along with much of its capacity to adapt to changing conditions. Franklin (1980) also states that in random populations, when considering the consequences of inbreeding, the number of individuals should not fall below 50 and that, in the long term, genetic variability will be maintained only if population sizes are an order of magnitude higher than 50.

Allendorf et al. (1997) applied the 50/500 rules described by Franklin (1980) and Soulé (1980) to describe risk of extinction to Pacific salmon populations, where populations with an N_e below 500 per generation would be at high risk of losing potentially important genetic variability and populations with an N_e below 50 per generation would be at very high risk. Wainwright and Waples (1998) responded to Allendorf et al. (1997), stating that the inclusion of demographic and environmental stochasticities as well as depensatory effects would be significant and likely to vary with life history and habitat types. They concluded that applying a single abundance criterion may not be appropriate for all Pacific salmon stocks.

An example of the 500 rule being applied to salmon is the Draft Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs (Cooney, et al., 2007). (ESU is the acronym for “evolutionarily significant units,” a construct adopted by NOAA Fisheries that is analogous to distinct population segments.) Cooney et al. (2007) developed ESU-level viability criteria needed to maintain the Lower Columbia/Willamette ESU in the face of long-term ecological and evolutionary processes. They proposed a minimum abundance threshold of 500 spawners (census population) for some salmonid populations within the ESU based on the reasoning that populations with fewer than 500 individuals are at higher risk for inbreeding depression and a variety of other genetic concerns. They maintained that a minimum abundance of 500 spawners appears to be adequate for compensatory processes and to maintain within-population spatial structure for smaller Interior Columbia Basin salmon populations.

Using similar reasoning, we have chosen to use a census population of 500 adult spawners (assuming a 1:1 sex ratio) in each SHRU to represent the effective population size for recovery. We used the census number rather than an effective population size for four reasons: (1) The adult census through redd counts or trap catches has been used as the principle indicator of population health in the GOM DPS since Charles Atkins first started estimating returns in the mid- to late-1800s. (2) A census population of 500 spawners per SHRU is only one of several considerations related to reduce extinction risk. (3) Atlantic salmon have tremendously complex life histories, allowing great opportunity for extensive cross-generational breeding. This is so because of the salmon's iteroparity and because precocious parr, one-sea winter fish, and multi-sea winter fish can all participate in spawning activity. Having multi-generational participation in spawning activity significantly reduces the effective population to census population ratio, but it also makes determining the actual N_e /N ratios extremely difficult and highly debatable for the natural population. (4) Although there has been much debate in the literature about assigning a general number to represent when specific populations are sufficiently large enough to maintain genetic variation (Reiman & Allendorf, 2001; Allendorf & Luikart, 2007; Waples & Yokota, 2007), the 500 rule introduced by Franklin (1980) has not been superseded by any other rule and continues to serve as a useful indicator of when a population may be at risk of losing genetic variability (Allendorf and Luikart, 2007).

Demographic Modeling

The current low numbers of adult Atlantic salmon are a result of a regime shift in productivity of Atlantic salmon in the northwest Atlantic from 1991 to 2006 (Chaput et al. 2005). Applying estimates of spawner escapement from this period to a simplified PVA, NOAA (2009) projected that 2,000 wild spawners in each SHRU would support a population that is not likely to fall below 500 adult spawners 15 years into the future.

The input data used in the PVA were based on an adult return redd count linear regression model (described in USASAC 2013) for the watersheds included in the GOM DPS as delineated in 2000 (65 FR 69469). The 2000 DPS data are thought to be most appropriate because of the relative consistency in management practices among those watersheds (see NOAA 2009). The Penobscot River was excluded from the input data to the PVA, because the river has been dominated by smolt stocking, and the large variations in stocking practices there could bias the estimation of population growth rates.

The PVA used the mean population growth rate and standard deviation from the 2000 GOM DPS to simulate the number of spawners 15 years into the future. Populations were simulated with initial population sizes starting at 500, and 10,000 iterations of the model were run to determine the probability of falling below 500 spawners in 15 years. Additional simulations were conducted in which the initial population size was increased until an initial population was found that had a less than 50 percent probability of falling below 500 spawners in 15 years. This initial population equaled 2,000 spawners per year. We therefor assume this the minimum population necessary to withstand a downturn in marine survival similar to that seen starting in 1991 and stay above the threshold of 500 spawners (NOAA 2009).

Genetic Considerations

Effective population size (N_e) is defined as the size of an ideal population (N) that will result in the same amount of genetic drift as the actual population being considered. Many factors can influence N_e, such as sex ratios, generation time (Ryman et al., 1981), overlapping generations (Waples, 2002), reproductive variance (Ryman & Laikre, 1991), and gene flow (Waples R. S., 1998). Applied to conservation planning, the concept of N_e has been used to identify minimal targets necessary to maintain adequate genetic variance for adaptive evolution in quantitative traits (Franklin 1980), or as the lower limit for a wildlife population to be genetically viable (Soule M. E., 1987). Estimation of N_e in Atlantic salmon is complicated by a complex life history that includes overlapping generations, precocious male parr, and repeat spawning (Palstra et al., 2009). Effective population size is measured on a per generation basis, so counting the number of adults spawning annually is only a portion of the total N_e for a population. In Atlantic salmon, Palstra et al. (2009) identified a range of N_e to N ratios from 0.03 to 0.71, depending on life history and demographic characteristics of populations. Assuming an N_e to N ratio of 0.2 for recovery planning, the N_e for a GOM DPS of Atlantic salmon population should be approximately equal to the average annual spawner escapement, assuming a generation length of 5 years. Although precocious male parr can reproduce and therefore be included in estimates of the number of adult spawners, Palstra et al. (2009) determined that reproduction by male Atlantic salmon parr makes a limited contribution to the overall N_e for the population.

Although NOAA (2009) attempted to minimize bias in estimating the mean population growth rate used in the PVA by excluding the Penobscot River due to stocking of hatchery fish, it is likely that some bias remains. The numbers of returns used in the estimation of population growth rate are still the product of natural spawning and fry stocking. If returning adults resulting from stocked hatchery fry are reproducing and contributing to the next generation, then true population trends may be masked (McClure et al., 2003), and the true population growth rate may be lower than that estimated by NOAA (2009). In this case, the minimum population required to have a less than 50 percent chance of falling below 500 spawners under another period of low marine survival is 2,000 spawners per year in each SHRU. Estimates of population growth rate can be corrected for the input of hatchery fish, but this requires differentiating between returns of wild origin and fry-stocked salmon; this in turn requires genetic determination of parentage, but the ability to sample returning adults on all rivers is limited. The estimate of 2,000 spawners thus serves as a starting point for evaluating population status, but this benchmark and the methods by which it is calculated should be re-evaluated in the future, as more data and better methods for partitioning returning adults become available. The threshold of 2,000 wild spawners per SHRU, totaling 6,000 annual wild spawners for the GOM DPS is similar to other estimates of the population size needed for long-term persistence (Thomas, 1990; Traill et al., 2010).

As an intermediate target, naturally reared adult spawners (i.e., returning adults originating from egg and fry stocking) can be included in assessments of recovery progress; however, full recovery should include only adult spawners of wild origin. Hatchery-origin adult spawners (i.e., returns from parr and smolt stocking) will not be included when assessing recovery progress, because targets could be artificially met by simply increasing hatchery production of smolts. Further, naturally reared adult spawners are likely to be more fit than hatchery-origin adult spawners, as their fitness is less due to hatchery influence and the majority of their lifetime is spent under the influence of natural selection processes in the wild. In addition, carrying capacities in the freshwater environment elicit a density-dependent effect on survivorship above which additional fry stocking would not produce greater numbers of fish at later life stages (McMenemy, 1995; Armstrong et al., 2003). Finally, a population reliant upon hatchery fish for sustainability is indicative of a population that continues to be at risk.

Annual trap count and redd survey data is used to estimate the adult spawner populations within the GOM DPS. Given that we are unable to count all adult returns and survey all rivers to look for redds, a statistical model is used in conjunction with the redd survey data and adult return data to estimate the total returns of adult spawners to GOM DPS.

Recovery progress will also be assessed based on each SHRU demonstrating a sustained population growth rate indicative of an increasing population. Currently the mean life span of Atlantic salmon in the GOM DPS is 5 years and is what we use to estimate growth rate of the population. In parts of Canada and Europe, the mean life span of salmon is sometimes greater and sometimes less than five years based on environmental variables and anthropogenic factors that affect growth, maturity and survival. Likewise, it is conceivable that the mean life span of Atlantic salmon in the GOM DPS changes over time in response to environmental changes or changes in anthropogenic threats, in which case we would adjust our calculations to account for those changes. Under current conditions though, the average survival of salmon remains at approximately 5 years, and therefore we conclude that in order to show sustained improvement in the population that we must observe consistent population growth for at least two generations (currently 10 years). If the geometric mean population growth rate of the most recent 10-year period is greater than 1.0, this provides assurance that recent population increases are not random population fluctuations but more likely are a reflection of true positive population growth. The geometric mean population growth rate is calculated as:

$$GM_{\bar{R}} = \sqrt[10]{R_t \cdot R_{t-1} \cdot R_{t-2} \cdot \ldots R_{t-9}}$$

where $GM_{\bar{R}}$ is the geometric mean population growth rate of the most recent 10-year period and R_t is the 5-year replacement rate in year *t*. The 5-year replacement rate in year *t* is calculated as:

$$R_t = N_t / N_{t-5}$$

where N_t is the number of adult spawners in year *t* and N_{t-5} is the number of adult spawners 5 years prior.

Naturally reared adult spawners can count in this calculation of population growth rate in assessing progress toward achieving reclassification objectives, while only wild adult spawners can be used in assessing progress toward achieving delisting objectives. As described in the 2009 Critical Habitat rule, a recovered GOM DPS must represent the natural population where the adult returns must originate from natural reproduction that has occurred in the wild.

If and when the GOM DPS is considered to be no longer at risk of extinction and eligible for reclassification to threatened status, a hatchery management plan will be needed to detail how hatchery supplementation should be phased out to reach recovered status; this plan should include population benchmarks that trigger decreasing hatchery input. The benchmarks should be based upon improved PVA models that incorporate contemporary demographic rates and simulate various stocking scenarios to assess the probability of achieving long-term demographic viability.

Allowing for hatchery origin eggs, fry and parr in reclassification criteria:

Hatchery origin eggs, fry or parr in conjunction with wild origin fish will be considered in any decision to reclassify Atlantic salmon from endangered to threatened. Our rationale for allowing these hatchery-origin life stages in our decision to reclassify is our belief that all of these life stages across most of Atlantic salmon's designated critical habitat will experience the significant threats identified at the time of listing, including the threat of dams and the threat of marine survival. Furthermore, all of these life stages will also experience selective pressure of both freshwater and marine conditions. Likewise, any increases in survival and abundance of hatchery origin eggs, fry, parr or wild origin fish will be indicative of progress towards addressing the significant threats identified at the time of listing. We do not include hatchery origin smolts in the reclassification decision because they experience almost no freshwater selection pressures, and can be stocked to avoid the significant threats associated with dams. Therefor any changes in abundance and survival of smolts will only be indicative of improved conditions in the marine environment.

Chapter 11: Governance structure for communication and approval of proposed recovery actions

The USFWS, NMFS, MDMR and PIN share a common stewardship interest and responsibility for Atlantic salmon. This partnership-based approach, which includes many other nongovernment organizations, provides benefits for the additional expertise and resources brought to bear on recovery efforts. However, differences in legal authorities, agency procedures, agency protocols, and expertise can often lead to confusion, delays in decision-making, and disagreements. The following governance structure is intended to minimize the impacts of these differences among the government entities involved in efforts to recover Atlantic salmon and to maintain a high level of timely and effective communication among these government entities and non-government organizations, including industry and the public.

Purpose:

The purpose of this Governance Structure is to:

1) ensure that recovery of the Gulf of Maine DPS as defined in the final listing rule is achieved in a manner that is transparent and easily understood in terms of roles and responsibilities of the government entities;

2) ensure that the best available science is being integrated into recovery;

3) ensure that resources are made available to implement those actions or measures agreed to in any given cycle;

4) serve as dispute resolution and continuity of operations throughout the operational year;

5) ensure horizontal and vertical communication amongst the agencies and the various organization levels within the agencies; and

6) ensure that the trust responsibilities of the federal fisheries agencies to federally recognized tribes are appropriately exercised.

Description of the Governance Structure:

The Atlantic Salmon Recovery Program governance structure entails three basic levels; a policy level, management level, and the implementation or action level. These will be referred to as the Policy Board, the Management Board, and Action Teams respectively. Policy Board The purpose of the Policy Board is to: (1) Set broad policy direction; (2) Annually reaffirm priorities; (3) Commit resources for recovery implementation. The members of the Policy Board include the USFWS Regional Director; National Marine Fisheries Service Regional Administrator; Maine Department of Marine Resources Commissioner; Penobscot Indian Nation Representative.

Management Board

The purpose of the Management Board is to: (1) Provide annual updates of potential and real changes to resource commitments; and (2) Resolve disagreements among the Action Teams. The members of the Management Board include the USFWS Assistant Regional Director for Fisheries, the National Marine Fisheries Service Assistant Regional Administrator for Protected Resources, Maine Department of Marine Services Sea-run Fisheries and Habitat Division Director, and a Tribal Representative.

Action Teams

The purpose of the Action Teams are to:

1) Develop 5-year implementation plans;

2) Receive and review proposals for recovery actions;

3) Identify and resolve areas of policy or scientific disagreement;

4) Coordinate across teams to increase efficiency and maintain effective communication; and

5) Oversee, implement and monitor recovery actions.

The Action Teams are composed of individuals from the state, federal and tribal government agencies. Action Teams can bring in additional technical expertise or advice for review of recovery actions. Final approval or rejection of recovery action proposals are made by the Action Team Chairs (6) based on the recommendations of their team members. Proposals that do not secure consensus with regard to approval or rejection will be sent to the Management Board members (4) to determine final approval or rejection.

Under this Governance Structure, Action Teams focus on the areas of: maintaining and operating the Atlantic salmon conservation hatcheries, maintaining and increasing the genetic diversity of hatchery and wild stocks, enhancing habitats and maximizing the survival of hatchery stocks and increasing the abundance of wild salmon smolts in the freshwater environment, maximizing the connectivity of freshwater and marine habitats, and understanding and increasing survival of Atlantic salmon in the marine and estuarine environments.

The effectiveness of the governance structure will be reviewed annually and may be adapted as needed to assist in meeting the recovery goals for Atlantic salmon in the GOM DPS.

GLOSSARY

Note: To maintain consistency in terminology, most definitions are pulled directly from the 2005 Final Recovery Plan for the Gulf of Maine Distinct Population Segment and the 2010 Annual Report of the U.S. Atlantic Salmon Assessment Committee. Definitions of genetic terms are from Allendorf and Luikart (2007)

Accessibility:

> **Habitat with No Access (Does not meet recovery criteria standard):** Habitat above an artificial barrier (dam or road stream crossing) where the barrier is defined as severe.
>
> **Habitat with Impeded Access (Does not meet recovery criteria standard):** Habitat above an artificial barrier where the barrier impairs a salmon's natural ability to pass the barrier and therefore prevents some passage. This habitat is above Potential Barriers.
>
> **Habitat that is Accessible (Meets recovery criteria standard):** At a minimum, the accessible habitat must allow for upstream and downstream movements of parr that seek out suitable habitats for feeding and sheltering; downstream movements of smolts during the spring migration; and upstream and downstream movement of adults that seek out habitats for spawning and resting. To meet the recovery standard, habitat must fall under one of the following categories:
>
> 1) Accessible above a dam with upstream and downstream passage that does not preclude recovery: Any dam that has received an incident take statement (pursuant to section 10 or section 7 of the ESA) for continued operations of that dam has undergone an analysis that considers the ongoing effects of that dam. Thus, if the dam is covered under either section 7 or section 10 of the ESA, then the dam must attain sufficient performance standards to ensure that it does not jeopardize the continued existence of the GOM DPS both in terms of the immediate effects (effects on survival) and long term effects (effects on recovery potential).
>
> 2) Accessible above stream crossings (e.g., culverts) that are set at the correct elevation using stream simulation (http://stream.fs.fed.us/fishxing/aop_pdfs.html): This approach to designing crossing structures creates structures that are as similar as possible to the natural channel. When channel dimensions, slope, and streambed structure are similar, water velocities and depths also will be similar. Thus, the simulated channel should present no more of an obstacle to aquatic animals than the natural channel because they tend to have natural streambeds throughout, and span the channel at least 1.2 times the bankfull width.
>
> **Habitat that is Fully Accessible (Meets recovery criteria standard):** Habitat where there are no artificial barriers from that point to the ocean.

Alevins: The period after hatching when the salmon feeds only on the yolk sac. Alevins are buried within the substrate of the stream bottom. This is the same stage known as "sac fry."

Anadromous: A term to describe fish that are hatched and reared in freshwater, migrate to salt-water to feed, and then migrate back to freshwater to spawn.

Annual Spawning Escapement: Salmon that return to the river and successfully reproduce on the spawning grounds in a given year.

Barrier: Does not allow for upstream passage.

Barrier (Partial): May preclude upstream and/or downstream passage at certain stream flows or at certain times of the year.

Black salmon: A post-spawned adult salmon while in freshwater. Also known as kelt.

Captive broodstock: Adults produced from parr that were initially captured in rivers and reared to maturity in a hatchery.

Domestic broodstock: Salmon that are progeny of sea-run adults and have been reared entirely in captivity for the purpose of providing eggs for fish cultural activities.

Sea-run broodstock: Adult Atlantic salmon that return to the river, are captured alive, and held in confinement for the purpose of providing eggs for fish culture activities.

Conservation spawning escapement: Number of returning adults needed to fully use the spawning habitat.

Critical Habitat: From ESA section 3(5)(A), 16 U.S.C. 1532(5)(A): Specific areas within the geographical area occupied by the species at the time of listing, in which those physical or biological features are found that are essential to the conservation of the listed species and may require special management considerations or protection. Critical habitat may also refer to specific areas outside the geographical area occupied by the species at the time of listing that are essential for the conservation of a listed species.

Diadromous: Fish that regularly migrate between freshwater and seawater. This category includes anadromous, catadromous and amphidromous fishes such as sea-lampreys, sturgeons, salmons, etc[DK2] .

Effective Population Size: The size of an ideal population that would experience the same loss of genetic variation, through genetic drift, as the observed population.

Entrainment: Involuntary movement of fish into a turbine or other environment that causes high mortality.

Eyed egg: The egg stage from the appearance of faint eyes until hatching.

Fry (Sac, embryonic, or Alevin): (See Alevin)

Fry (Feeding): The period from the end of the primary dependence on the yolk sac (initiation of feeding) to June 30 of the same year.

Fry (Fed Fry): Hatchery Fry that have been fed prior to being stocked.

Fry (Unfed Fry): Hatchery Fry that have not been fed prior to being stocked.

Grilse: A salmon that has spent 1 winter at sea before returning to its natal river to spawn. These fish usually weigh less than 5 pounds.

Hatchery Reared: Atlantic salmon of hatchery-origin.

HUC 10: USGS Hydrologic Unit Code having 10 digits and delineating watersheds between 40,000 and 250,000 acres in size.

Kelts: (See Black Salmon)**.**

Landlocked salmon: Non-anadromous Atlantic salmon, i.e., fish that do not migrate away from rivers upon maturity.

Metapopulation: A collection of spatially divided subpopulations that experience a certain degree of gene flow among them.

Naturally Reared: Includes fish originating from wild spawners and hatchery origin eggs and fry.

Parr: Life history stage immediately following the fry stage until the commencement of migration to the sea as smolts; parr are characterized by 8 to 11 vertical, dark pigmented bars (known as "parr marks") on their sides.

Precocious parr: An Atlantic salmon that becomes sexually mature in fresh water without ever going to sea.

Redd: Nest where female salmon lay eggs.

Repeat Spawners: Salmon that return numerous times to the river to spawn.

Smolt: An actively migrating young salmon that has undergone the physiological changes to survive the transition from freshwater to saltwater.

Smoltification: The process by which parr change into smolt. This includes osmoregulatory changes that allow the fish to survive in saltwater.

Straying: Fish spawning in a stream other than the one in which they hatched.

Stakeholder: Any group that is interested in Atlantic salmon recovery that is not the USFWS, NOAA, MDMR, or PIN.

Stocked Salmon: Salmon that have been raised in the hatchery and then released into the wild.

Weir: A structure across a river channel that obstructs the free passage of fish and is often used to capture fish.

Wild Salmon: Salmon that have spent their entire life cycle in the wild and originate from parents that were also spawned in the wild.

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