Gulf Of Maine Distinct Population Segment Management Guidance for Recovery

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Appendix A

Goal:

The goal of this paper is to fulfill the requirement of defining objective, measurable criteria for determining when Atlantic salmon may be considered for removal from protection by Endangered Species Act.

1. Introduction

Atlantic salmon have a complex life history strategy well adapted to survival in diverse habitats in both the freshwater and marine environment throughout much of the North Atlantic generally above the 42 parallel (Klemetsen et al. 2003).

As juveniles, parr are territorial and feed on aquatic invertebrate drift in fluvial habitats; this has largely thought to be the preferred habitat for juvenile rearing of anadromous salmon (Gibson 1993, Marschall *et al.* 1998). However, anadromous parr also use lacustrine habitats for feeding and growth (Pepper 1976, Pepper *et al.* 1984, Hutchings 1986, Erkinaro *et al.* 1998, Halvorsen and Svenning 2000). In many instances, lacustrine rearing confers substantial benefits in terms of growth and survival (Hutchings 1986; O'Connell & Ash 1993; Erkinaro *et al.* 1998; Dempson *et al.* 1996; Halvorsen & Svenning 2000). The length of time that parr spend rearing is highly dependent upon temperature with populations in colder climates generally growing slower. Parr spend between two and eight years in freshwater before migrating to the marine environment as smolts (Klemetsen *et al.* 2003).

Atlantic salmon smolts most often migrate out of freshwater environments between late April and early June (McCormick 1999, USASAC 2007), though smolt migrations in the fall have also been documented (Klemetsen *et al.* 2003). Extreme variability in pre-smolt migration timing is not uncommon, and occurs not only at a broader geographic scale but within watersheds as well (Riddell and Leggett, 1981). Smolts that have successfully migrated from freshwater to the marine environment typically spend one to three years, and at times even longer, as post-smolts feeding in the North Atlantic off the coasts of Greenland or Iceland before migrating back to their natal rivers to spawn as mature adults (Klemetsen *et al.* 2003). Though most Atlantic salmon are believed to undertake fairly extensive migrations, salmon in the Koksoak River in Ungava, Quebec, are capable of reaching sexual maturity in the estuary as well as the marine environment (Robitaille *et al.* 1986). Female Atlantic salmon originating from the GOM DPS typically reach sexual maturity after spending two years at sea whereas male salmon originating from the GOM DPS are known to reach sexual maturity as parr, one sea winter grilse, or as two or more sea winter adults; this may be an adaptive trait that maximizes the potential of a female finding a mate for spawning as well as enhancing a populations genetic diversity (Ellner and Hairston, 1994). Atlantic salmon are also iteroparous, meaning that they are capable of spawning more than once, a strategy that may be particularly valuable in maximizing spawning escapement in small rivers and streams that have relatively low productivity. Furthermore, throughout their range, naturally reproducing populations of Atlantic salmon exist as both freshwater resident (landlocked) and anadromous (sea-run) forms.

Section 2: Defining criteria for geographic distribution of Atlantic salmon within the GOM DPS

2.1 Population Structure:

Over time, geographically widespread species[1] can become divided and isolated into a collection of smaller breeding units (i.e. Distinct Population Segments, sub-populations, or independent populations). The extent of these divisions (e.g. the extent in which the population exhibits unique genetic and/or morphological characteristics) depends upon the extent of isolation from other breeding units. Geographic isolation or habitat fragmentation of breeding units can occur both naturally or can be anthropogenically influenced. Isolation of breeding units can create reproductive and therefore genetic isolation within and/or between breeding units (Mayr 1954). If an isolated breeding unit is able to sustain itself over evolutionary time scales, the isolation often results in genetic differentiation, which, if strong enough, can result in breeding units which have lost their ability to interbreed with each other (Mayr 1954).

If isolation occurs, yet the ability to interbreed is still possible between breeding units, geographic and climatic differences can sometimes limit the success of their offspring. Over relatively shorter time periods, isolated breeding units can become highly adapted to the specific habitats in which they reside (Mayr 1954). As a result breeding units often exhibit noticeable genetic, morphological and behavioral differences, yet they are still capable of interbreeding and hence not distinct enough to be considered separate species (NRC 1995).

The breeding success or failure of individuals moving between two units is respectively referred to as either effective or ineffective straying. Most often, individuals straying between breeding units that are geographically close together have a greater chance of effective straying than individuals straying into breeding units that are geographically distant from each other (e.g. Ford 1998). In many cases, effective straying is essential in maintaining the genetic integrity of a population. The benefit of effective straying reduces the potential of the negative effects associated with increases in homozygosity that typically occur within a small breeding unit (e.g. the Founder Effect), thereby reducing the breeding units' vulnerability to extinction (Franklin 1980). For any population, the probability that the population will remain extant into the future is largely dependent upon its initial size and its ability to withstand demographic, environmental, and genetic stochasticity as well as natural catastrophes (Shaffer 1987). In essence, small populations are more vulnerable to extinction than large populations as they are often more vulnerable to stochastic events as well as natural catastrophic events (Shaffer 1981; Hanski & Gaggiotti, 2004).

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[1] A species is the fundamental unit of biological classification (http://plato.stanford.edu/entries/species/). Section 3 of the Endangered Species Act (ESA; as amended in 1978) defines species to include *any subspecies of fish or wildlife or plant, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature.*

Atlantic salmon as a species:

As a species, Atlantic salmon populations are geographically widespread and are made up of numerous breeding units functioning at a multidimensional scale (Vähä *et al.* 2007). The development of the Atlantic salmon's complex population structure is largely a result of the Atlantic salmon's strong homing tendencies. When adult salmon return to freshwater to spawn, they most frequently migrate back to their river of origin (Baum 1997) and may in fact return to their specific reach of origin within the river system. These strong homing instincts have required salmon populations to evolve into genetically distinct populations which have become highly specialized to particular environments. Conversely, limited straying has helped to maintain genetic diversity among neighboring populations and has provided the opportunity for Atlantic salmon to expand and/or sustain their distribution by colonizing or re-occupying nearby habitats that may have become vacant during occasional extirpations due to natural demographic, genetic, and/or environmental stochasticity and occasional catastrophic events. Within the U.S., the Atlantic salmon population is comprised of several breeding units represented as distinct population segments described by Fay et al (2006). Each of these DPS's most likely contains, or historically contained, numerous smaller breeding units which can be characterized as independent populations, management units or recovery units; depending upon the amount of straying that occurs between these smaller breeding units and the breeding units inherent biological value towards the DPS's sustainability.

2.2 The Gulf of Maine Distinct Population Segment (GOM DPS):

The GOM DPS of Atlantic salmon is comprised of all anadromous Atlantic salmon whose freshwater range occurs in the watersheds from the Androscoggin River northward along the Maine coast to the Dennys River, and wherever these fish occur in the estuarine and marine environment. The following impassable falls delimit the upstream extent of the freshwater range: Rumford Falls in the town of Rumford on the Androscoggin River; Snow Falls in the town of West Paris on the Little Androscoggin River; Grand Falls in Township 3 Range 4 BKP WKR, on the Dead River in the Kennebec Basin; the un-named falls (impounded by Indian Pond Dam) immediately above the Kennebec River Gorge in the town of Indian Stream Township on the Kennebec River; Big Niagara Falls on Nesowadnehunk Stream in Township 3 Range 10 WELS in the Penobscot Basin; Grand Pitch on Webster Brook in Trout Brook Township in the Penobscot Basin; and Grand Falls on the Passadumkeag River in Grand Falls Township in the Penobscot Basin. The GOM DPS was delineated based upon physiographic and biological information from extant stocks and incorporates both life history and genetic information (Fay *et al.* 2006). Physiographic information used includes climate, groundwater temperatures, geography, hydrography, and zoogeographic differences between geographic regions (Fay *et al.* 2006). Biological information included observed similarities in life history and genetic structure among populations within the range of the GOM DPS (Fay *et al.* 2006). Differences in life history strategies and genetic structure between salmon stocks in the GOM DPS and salmon stocks to the north of the GOM DPS were also considered (Fay *et al.* 2006) (*Refer to Appendix A for more information on the original 2000 GOM DPS and factors leading up to the expanded GOM DPS*).

Genetic differences between Atlantic salmon populations from North America and Europe are substantial enough that genetic material from Atlantic salmon of unknown geographic origin can be correctly assigned to the continent of origin with 100% accuracy (King *et al.* 2001). Genetic similarities within the GOM DPS as well as differences among the GOM DPS and populations to the North have also been observed by Spidle *et al.* (2003), Cordes *et al.* (2005), and Verspoor (2005), and are summarized in detail in Fay *et al.* (2006).

2.3 Population structure within the GOM DPS:

Promoting and maintaining genetic diversity is essential for preventing the deleterious effects of inbreeding, which can include effects on survival, reproduction, growth rate, and size at maturity (Franklin 1980). Small populations are more vulnerable to genetic drift given that by chance, specific genes have more or less frequent representation within the population regardless of whether they are detrimental or beneficial to the species. Continued genetic drift in the absence of selection, migration, or mutations can result in gradual increases in homozygosity in which gene sequences become fixed and phenotypic variability is lost (Franklin 1980). Many small populations can persist with some level of inbreeding because natural selection can counter the deleterious effects of genetic drift, and immigration from unrelated individuals can significantly reduce the effects of inbreeding depression; assuming that nearby populations are substantial enough that effective straying is likely to occur (Franklin 1980).

The population structure of the GOM DPS likely does not represent the historical architecture of the population given the amount of known manipulation of stocks through the hatchery program; the history of dams that have precluded fish passage from extensive portions of the DPS over varying time periods; and recent significant population declines which have resulted in a significant decline of genetic variability (Lage & Kornfield 2006). Yet remnant populations do still exist that indicate a wide range of diversity across the GOM DPS (King et al. 2000). Regardless of its history, the population structure within the GOM DPS may be best described as a collection of breeding units that are interconnected by some exchange of individuals between them - properly known as a metapopulation structure (NRC 2003 and Gilpin 1987). The natural exchange of individuals between breeding units is mediated by the physical distance between breeding units, and the characteristics of the habitat among them (Gilpin 1987). Throughout the DPS, spawning Atlantic salmon present within individual stream reaches, tributaries, and in some cases entire watersheds represent individual breeding units. Watershed specificity is supported by strong evidence of genetic differentiation found in Atlantic salmon among salmon rivers within the Gulf of Maine DPS (King *et al.* 2000). Due to the small population sizes within watersheds, it is likely that, for many of these breeding units to persist, they rely on some level of effective straying of salmon from nearby tributaries or adjacent watersheds with similar hydrologic and geomorphic characteristics. Effective straying between breeding units may help maintain and/or reinforce genetic diversity within breeding units as well as re-establish populations that have been substantially depleted or extirpated by demographic variability and/or catastrophic events. When effective straying between breeding units occurs in relative spatial isolation (limited straying), within specific geographic regions, the collection of breeding units has been characterized as an independent population as described by McElhany *et al.* (2000) or a management unit described by Moritz *et al.* (1995). While each breeding unit, functioning independently, has a negligible chance of population persistence over a significant time period (e.g., 100 yrs), a collection of breeding units (i.e. an independent population or a management unit) has a significantly higher probability of population persistence over this same time period as they experience reduced risk of extirpation resulting from demographic variability and catastrophic events (McElhany *et al.* 2000; Allendorf and Luikart 2007).

Role of large and small rivers within the DPS:

In general, large areas that support large populations face less extinction risks then small populations because of greater environmental heterogeneity (Shaffer1987; Hanski & Gaggiotti, 2004). As such, large complex river systems within the DPS such as the Penobscot, Androscoggin and Kennebec, that are capable of supporting large populations are generally less vulnerable to extinction risks than small coastal drainages that support smaller populations because of depensatory effects, demographic and environmental stochasticity and genetic variation.

In addition to being less diverse and more vulnerable to genetic deficiencies, small populations can also be vulnerable to what as known as the “allee effect” in which there is a positive relationship between any component of individual fitness and the number or density of conspecifics (Stephens *et al.* 1999). One area where this may be especially true for Atlantic salmon is in relation to the density of salmon and co-evolutionary prey items such as alewives and shad to the number predators in which the species co-exist. Darwin (1859:70) noted that “in many cases, a large stock of individuals of the same species, relatively to the number of its enemies, is absolutely necessary for its preservation”. This concept is likely especially important for Atlantic salmon smolts and adults that encounter a host of piscine, mammalian and avian predators in the estuary (See Saunders *et al.* 2006). Atlantic salmon in the estuaries of small coastal watersheds may be particularly vulnerable to decreases in population size as the proportion of salmon and other diadromous prey species relative to the number of predators that they encounter would be expected to be an order of magnitude smaller then what it would be for larger rivers. Large river basins, where one migratory corridor serves multiple watersheds, have much greater capacity to produce significantly greater numbers of salmon and other diadromous prey species which would potentially saturate the estuary likely serving as an effective buffer to predation, even during reduced run sizes. In fact, small population decreases in a high density population may actually result in increases in productivity known as compensation (McElhany *et al.* 2000), such that a reduction in densities would translate into a decrease in competition for food and space.

The vulnerability of small populations to extinction can be easily offset by nearby large populations through what is known as the rescue effect, where straying from nearby large populations not only increases the population size of small populations, but also offsets the deleterious effects of inbreeding depression (Hanski and Gaggiotti 2004). Both the Penobscot and Kennebec Basins historically supported very large populations of Atlantic salmon. Atkins & Foster (1867) estimated that approximately 216,000 adult Atlantic salmon were harvested in the Kennebec River in 1867; and Atkins & Foster (1868) “confidently” estimated that before the obstruction of dams on the Penobscot, the average yield of adult salmon could not have been less than 150,000. For the GOM DPS, the estimated stray rate for Atlantic salmon is 1% (Baum 1997). If we apply a 1% stray rate to the estimated populations for the Kennebec and Penobscot described by Atkins & Foster (1867) and Atkins & Foster (1868), we could predict that during that period of time, approximately 1500 and 2100 Atlantic salmon strayed annually from each of these two rivers into other rivers, of which nearby rivers and streams likely received the majority of the effective straying population. The strays from these two basins were likely very important in maintaining the population size and genetic variability of nearby small coastal drainages.

Though small populations are more vulnerable to extinction risk than large populations in a natural environment, the large populations in large rivers have suffered most from the effects of industrialization, particularly the construction of dams with limited to no fish passage. Today, these small coastal rivers are very important in the recovery of the large rivers, particularly the Kennebec, whose population has been at trivial levels for several decades because of dams without fish passage facilities. Nearby coastal rivers, such as the Sheepscot River, and lower Kennebec tributaries, such as Bond Brook, may retain some of the legacy genetic material that originated from the Kennebec River, and may serve as an effective donor stock in rebuilding the Kennebec’s population.

2.4 Establishing a geographic framework for recovery:

As described above, metapopulation theory suggests that the observed variability among anadromous salmonids is a solution to the variable environment with which they must cope (Bisbal and McConnaha 1998). Life history plasticity is one feature that enables Atlantic salmon to use a wide array of resources in both freshwater and saltwater environments (Klemetsen *et al.* 2003). Variable life history traits are often heritable (Hansen and Jonsson 1991) and appear to be an important “bet-hedging” strategy that allows some segments of a population to persist through times of unfavorable environmental conditions (Ellner and Hairston 1994, Hilborn *et al.* 2003).

These concepts must be explicitly considered in developing a geographic framework for recovery for the GOM DPS in order to minimize the risk of extirpation resulting from demographic variability and catastrophic events. In short, Atlantic salmon must have the ability to use a diverse array of habitat types and diverse life history forms should be maintained. In order to do this, we considered numerous approaches such as establishing management units, independent populations, and recovery units to define a geographic framework within the DPS.

An independent population as defined by McElhany *et al.* (2000) is any collection of one or more local breeding units whose population dynamics or extinction risk over 100 years is not substantially altered by exchanges of individuals with other populations. An independent viable population is different from that of an ESU as such that an ESU has the added criterion that the population must represent an important component of the evolutionary legacy of the species (Waples 1991) which in essence makes the ESU even more reproductively isolated over a longer period of time then the viable populations within them (McElhany *et al.* 2000).

A management unit and/or recovery unit, like an independent population, represents a subset of a larger population (e.g. a DPS or an ESU). Moritz *et al.* (1995) suggests establishing management units (MU's) to aid in the short-term management of the demographically independent sets of populations within the larger entity (being an ESU or DPS). Allendorf and Luikart (2007) recognize management units (MU's) as populations that are important for the long-term persistence of an entire ESU (and/or species) yet do not show long-term independent evolution or strong adaptive differentiation. Furthermore, Allendorf and Luikart (2007) state that MU's are generally smaller than ESU's or DPS's as such that MU often represents a subpopulation within a major metapopulation that represents the ESU or DPS. Hence an ESU or DPS might contain several MU's. (*Appendix B describes how McElhany et al. (2003) partitioned ESU's in the Willamette and Lower Columbia basin for Pacific salmonids to determine the number of independent populations within an ESU that are needed to reduce the extinction risk to the entire ESU*).

In the context of the ESA, as defined in the Endangered Species Consultation Handbook, a Recovery Unit is a "management subset of the listed species that is created to establish recovery goals or carry out management actions" – a definition very similar to the management unit described by Moritz *et al.* (1995). The handbook further states in section 4-38 that a Jeopardy Analysis may be based on an assessment of impacts to distinct population segments (DPS) of a species or to *recovery units* when those units are documented as *necessary to both the survival and recovery* of the species in a final recovery plan. The NMFS Interim Recovery Plan Guidance goes on to state that recovery units are frequently managed as management units, though makes the distinction that recovery units are deemed necessary to both the survival and recovery of the species, whereas MU's are defined as not always being "necessary" to both the survival and recovery.

Geographic delineation for the GOM DPS:

For the GOM DPS, we established a geographic framework represented by three Salmon Habitat Recovery Units, or SHRU's, within the DPS. The three SHRU's were selected to ensure that Atlantic salmon were widely distributed across the DPS such that recovery of the GOM DPS is not limited to one river or one geographic location, because widely distributed species are less likely to become threatened or endangered by limited genetic variability and tend to be more stable over space and time. The three SHRU's closely (though not entirely) resemble the HUC 8 basin divisions for the GOM DPS, and include: 1) the Merrymeeting Bay SHRU which incorporates two large basins: the Androscoggin and Kennebec, and extends east as far as, and including the St. George watershed; 2) the Penobscot Bay SHRU which includes the entire Penobscot basin and extends west as far as, and including the Ducktrap watershed, and east as far as, and including the Bagaduce watershed; and 3) the Downeast Coastal SHRU which includes all the small to medium size coastal watersheds extending east of the Penobscot SHRU as far as, and including the Dennys River watershed (Figure 1).

Figure 1: GOM DPS representing three SHRU's

Dividing the GOM DPS into subsets represented as SHRU's provides the best management tool for establishing recovery goals in which the species is well represented over its entire range. The SHRU delineation fits well as either management units or recovery units as described above. However, Recovery Units are more appropriate given that maintaining a population in all three SHRU's is necessary in order to preserve the genetic variability of the DPS, which in turn is necessary in ensuring that the population is capable of adapting to and surviving natural environmental and demographic variation that all populations are subjected to over time. The independent population concept does not apply to the DPS as described by McElhany *et al.* (2000). Even though the recovery unit delineation may represent the historic independent populations at one time, we do not have substantial data to make this determination or to predict what the independent population structure may be in a recovered population such that an independent population has a negligible extinction risk from an exchange of individuals over a one hundred year period.

Our decision to select recovery units at a basin scale or larger was based on the fact that small populations are more vulnerable to catastrophic events, loss of genetic diversity, and environmental variation; all of which increase the risk of extinction to the species (McElhany *et al.* 2000; Hanski & Gaggiotti 2004). With this understanding recovery units were selected that combined large river basins, such as the Kennebec, Androscoggin and Penobscot, that are known to have supported large populations of salmon as well as other diadromous fish, with smaller coastal watersheds that were likely recipients of significant straying from these nearby large populations. The Downeast Coastal Basin was selected as a single recovery unit based upon the basins demonstrated resilience through the 1980's to both natural and anthropogenic factors that had resulted in the extirpation of the species south of the GOM DPS. Today, the Downeast Coastal Basin represent 5 of only 7 viable genetic groups retained at Craig Brook and Green Lake National Fish Hatchery representing a majority of the genetic diversity available for DPS recovery efforts (*Refer to appendix C for an alternate SHRU delineation that was considered; and Appendix D for a number of other factors that we considered in determining the recovery unit delineations for the DPS*).

Three SHRU's contribution towards recovery:

In order to define the geographic boundaries of the SHRU's within the GOM DPS, a number of factors were considered including climatic variations, hydrology, current and historic distribution and abundance, and genetics (Appendix C). Ultimately, three principle factors were used in determining the SHRU delineation:

1) Selecting areas that have demonstrated population persistence and currently retain populations used as a source of broodstock at Craig Brook and Green Lake National Fish Hatchery used for DPS recovery purposes

2) Selecting large rivers known to historically produce large populations of salmon in which significant straying occurred likely supporting nearby small coastal watersheds that are inherently more vulnerable to extinction risks because of their small size

3) Selecting small coastal watersheds nearby large producing rivers that were likely recipients of significant straying from historic runs and may contain legacy genetic material important in the recovery of the DPS

As described above, three SHRU's provide a way of ensuring that the species is reasonably distributed across the DPS diminishing the DPSs' vulnerability to natural demographic, environmental stochasticity and catastrophic risk. This is achieved by dividing the GOM DPS into three units that represent significant population groupings that we believe are necessary to minimize the risk that the population will become threatened or endangered after it is recovered.

One Recovery Unit, the Downeast Coastal SHRU, is populated by a series of small to medium size rivers that are all independently connected to the marine environment and have very short transition zones from the freshwater to the marine environment. This particular recovery unit has demonstrated remarkable resilience to both natural and anthropogenic threats up through the late 1980's, and represent 5 of only 7 viable genetic groups retained at Craig Brook and Green Lake National Fish Hatchery available for recovery purposes in the U.S

The other two recovery units, the Penobscot and Merrymeeting bay SHRU's are dominated by large, complex river systems (Kennebec, Androscoggin and Penobscot Rivers) that have one primary migration corridor that serves as the central conduit to numerous watersheds representing diverse habitats. Proportionally, the small coastal watersheds of eastern Maine drain between 1.5 percent (Dennys River (Beland *et al.* 1982) to 5.5 percent (Machias River (Fletcher *et al.* 1982) of what the Penobscot, Kennebec and Androscoggin basins drain (Baum 1983). The large river systems within these two SHRU's have enormous capacity to support large populations of diadromous fish (Atkins (1867) and Atkins (1868)) which we believe are essential in sustaining the small coastal populations of central and eastern Maine. Dividing the GOM DPS into three recovery units assures that neither the small coastal rivers nor the large rivers represent the entire recovered population, which would inherently increase the risk the population would become threatened or endangered again in the future.

3. Defining criteria for population abundance within the DPS:

This section establishes population level criteria to help assure that a recovered population is likely to be sufficiently robust to withstand natural demographic variability (eg. periods of low marine survival) and not likely to become an endangered species in the foreseeable future.

ESA protection requires that the threats occurring at the time of listing have been removed or sufficiently reduced so that the Atlantic salmon population present within the GOM DPS is no longer "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range". The ESA also requires that recovery plans, to the maximum extent practical, incorporate objective, measurable criteria which, when met, would result in a determination that the species be removed from the endangered species list (ESA Section 4, §16 U.S.C. 15.33(f)(1)).

3.1 Measurable criteria for delisting:

The minimum viable population (MVP) is defined by Shaffer (1981) as the smallest isolated population that has a 99% probability of remaining extant for 1000 years despite natural demographic, environmental, genetic stochasticity, and natural catastrophes. The number of organisms present within a population does not necessarily denote the actual number of viable organism within that population. Therefore, while determining delisting criteria, it is important to acknowledge the potential for variations between the actual (census) population and the viable (effective; N_e) component of that population. As a result, we not only recognize the importance of the MVP while defining delisting criteria, but also recognize the importance of defining criteria for effective population (N_e) size. 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 a inbreeding rate of less than one percent. Higher rates of inbreeding that can occur in populations less than 50 can fix deleterious genes too rapidly for natural selection to eliminate them. Soulé (1980) states that even at a one 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 loose about one fourth of its genetic variation along with much of its capacity to adapt to changing conditions. Franklin (1980) states that in random populations, when considering the consequences of inbreeding, the number of individuals should not fall below 50. Franklin (1980) also states that in the long term, genetic variability will only be maintained 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 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. Therefore applying a single abundance criterion may not be appropriate for all Pacific salmon stocks.

An example of the 500 rule being applied is the *Draft Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs* (Cooney *et al*. 2007). 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 on the basis that populations with fewer than 500 individuals are at higher risk for inbreeding depression and a variety of other genetic concerns. They maintain that a minimum abundance of 500 spawners appears to be adequate for compensatory processes to operate and to maintain within-population spatial structure for smaller Interior Columbia Basin salmon populations.

We have chosen to use a census population (N) of 500 adult spawners (assuming a 1:1 sex ratio) in each SHRU to represent the effective population size and to serve as a benchmark to evaluate the population as either recovered or one that requires protection under the ESA. We used the census number rather than an effective population size for four reasons: 1) The adult census through redd counts or trap catches have 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 1800's; 2) a census population of 500 spawners per SHRU provides a starting point only for establishing criteria for delisting and does not represent the actual number in which the population warrants delisting. Other pre-decision criteria must also be met for delisting as described in Section 3.3; 3) Atlantic salmon have tremendously complex life histories allowing for great opportunity for extensive cross generational breeding. This is so given salmon's iteroparity and because precocious parr, one-sea winter 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 furthermore, makes determining the actual N_e/N ratios extremely difficult and highly debatable for the natural population. 4) Though there has been much debate in the literature regarding the application of assigning a general number to represent when populations are sufficiently large enough to maintain genetic variation (Allendorf and Luikart, 2007, Waples & Yokota 2007; Reiman & Allendorf 2001), the 500 rule introduced by Franklin (1980) has not been superseded by any other rule and does serve as useful guidance for indicating when a population may be at risk of losing genetic variability (Allendorf and Luikart, 2007).

3.2 The definition of the terms "threatened", "Endangered", "foreseeable" and "conservation" and applying these terms in the context of recovery:

The ESA states that an endangered species is a species which is in danger of becoming extinct throughout all or a significant portion of its range (ESA§3(6)). The ESA defines a threatened species as any species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (ESA§3(20)). The term recovered, while not defined in the ESA, is implicit in the definitions of endangered or threatened as such that a species is recovered when it no longer warrants the protection of the ESA, or otherwise is no longer "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range".

The term "Conservation" is a term defined in the ESA as using all methods and procedures which are necessary to bring any endangered or threatened species to the point at which the measures provided by the ESA are no longer necessary. Conservation, therefore, is intended to broadly describe those activities and efforts undertaken to achieve recovery. For the GOM DPS, we have determined that conservation includes ensuring successful return of salmon to spawning habitat, successful spawning, incubation and hatching of eggs, survival of juveniles during their rearing time in freshwater, and migration of smolts out of the rivers to the ocean. In applying conservation relative to recovery, the use of hatchery product in the decision to de-list is precluded. Though hatcheries are an essential tool in recovery of the species by serving as a gene bank to preserve genetic diversity, hatchery product cannot be counted towards a recovered population as these fish are not representative of a self-sustaining population that is capable of carrying out all the major life history functions as described in our interpretation of the term conservation.

The term "foreseeable" is not clearly defined in the criteria to de-list, and therefore relies on the best professional judgment of scientists and managers based on the historic demographic data that is available and the life history characteristics of the species. The term "foreseeable" is defined by the American Heritage Dictionary as: *To see or know beforehand.* Merriam-Webster's Dictionary of Law further defines foreseeable as: *such as reasonably can or should be anticipated**:** such that a person of ordinary prudence would expect to occur or exist under the circumstances*.

Predicting salmon populations into the future with absolute certainty is not possible. However, population modeling exercises can predict population trends based on demographic data. The probability that population projections will not be attained is based on the amount of risk that managers are willing to except. The amount of risk that accompanies population modeling is a largely a function of time and the amount of available information that can be applied to the model. Legault (2004) developed the Atlantic salmon PVA to predict likelihood of extinction based on demographic data for the Gulf of Maine DPS (as defined under the 1999 status review for Atlantic salmon). Given past demographic data available to us, we believe that using a PVA model similar to the one produced by Legault (2004), provides a reasonable projection forward - roughly three generations or fifteen years (accounts for population variability) on how the population will behave.

3.3 Benchmarks for a delisting determination

As stated previously, 500 adult spawners in each of the three SHRUs is being used as a benchmark for evaluating the entire GOM DPS for recovery. Though 500 adult spawners serves as an important benchmark for evaluating recovery, 500 adult spawners in each SHRU does not represent the absolute value that separates a recovered population from a population that requires the protections of the ESA.

Before a decision can be made to de-list the GOM DPS must meet the following five criteria:

1) The adult spawner population of each SHRU must be some number greater than 500 in an effort to maintain sufficient genetic variability within the population for long term persistence. This is to be determined or estimated through adults observed at trapping facilities or redd counts.

2) The GOM DPS must demonstrate self-sustaining persistence where each SHRU has less than a 50% probability of falling below 500 adult spawners in the next fifteen years based on PVA projections described above. The 50% assurance threshold satisfies the criterion that the population is “not likely” to become an endangered species; while 15 years represents the “foreseeable future” for which reasonable projections can be made given past demographic data available to us.

3) The entire GOM DPS must demonstrate consistent positive population growth for at least two generations (10 years) before the decision to de-list is made. Ten years of pre-decision data that reflects positive population trends provides some assurance that recent population increases are not happenstance but more likely a reflection of sustainable positive population growth.

4) A recovered GOM DPS must represent the natural population. Hatchery product cannot be counted towards recovery because a population reliant upon hatchery product for sustainability is indicative of a population that continues to be at risk.

5) In order to de-list the GOM DPS, the threats identified at the time of listing must be addressed through any regulatory or other means. These threats are identified in the five listing factors specified in the ESA as described in the 2006

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Appendix A:

Atlantic salmon ESA listing background, the GOM DPS expansion and DPS policy

In November of 2000, the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) (collectively referred to as the "services") issued a final rule listing of Atlantic salmon in the Gulf of Maine Distinct Population Segment (GoM DPS) as endangered (65 FR 69459). The listing was based on recommendations from a biological review team (BRT) that defined the GoM DPS as all naturally reproducing wild populations of Atlantic salmon, having historical river-specific characteristics found north of and including tributaries of the lower Kennebec River to, but not including the mouth of the St. Croix River at the United States-Canada border, and the Penobscot River above the site of the former Bangor Dam. Populations which met these criteria were those found in the Dennys, East Machias, Machias, Pleasant, Narraguagus, Cove Brook, Ducktrap, and Sheepscot rivers. The listing also incorporated "river-specific hatchery populations of Atlantic salmon having historical river-specific characteristics which include populations found at Craig Brook National Fish Hatchery and Green Lake National Fish Hatchery". Deferred from the 2000 GoM DPS designation were the Androscoggin River, Kennebec River above the site of the old Edwards Dam, and the Penobscot River above the site of the former Bangor Dam.

In November, 2005, the Services published the Final Recovery Plan for the GoM DPS of Atlantic Salmon (*Salmo salar*). In creating the Final Recovery Plan, the Services adhered to guidance provided in the Endangered Species Act (ESA; 16 U.S.C. Chapter 35, §1533 (1)(B)) which stated that each plan should incorporate three items: 1) a description of site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species; 2) objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of the section, that the species be removed from the list (e.g. recovery criteria); 3) estimates of the time required and the cost to carry out those measures needed to achieve the plans goal and to achieve intermediate steps toward that goal.

The 2005 Recovery Plan for Atlantic salmon identified recovery as being: "when conditions have been attained that allow self sustaining populations to persist under minimal ongoing management and investment of resources". In order to achieve this, the plan lays out an approach in which a list of site-specific management actions were identified and prioritized as actions that must be taken in order to:

1) Priority 1 actions: Prevent extinction or to prevent the species from declining irreversibly

2) Priority 2 actions: Prevent a significant decline in population/habitat quality or other significant negative impacts short of extinction

3) Priority 3 actions: Provide full recovery of the species

The 2005 Final Recovery Plan did not include demographic criteria for reclassification and delisting of the GoM DPS. The services and the Maine Department of Marine Resources (DMR) (formally the Maine Atlantic Salmon Commission) concluded that all available methods to develop delisting criteria at the time were insufficient for purposes of the plan and therefore concluded that it was not practical to include demographic criteria for reclassification and delisting of the GoM DPS. However the services did incorporate preliminary reclassification and delisting guidance. As preliminary guidance, the services recommended that in order to reclassify the GoM DPS of Atlantic salmon from endangered to threatened, the Services must determine that the species' abundance, survival and distribution, taken together with the ESA listing factors, no longer render the species "in danger of extinction throughout all or a significant portion of its range". In order to remove the protections of the ESA for Atlantic salmon, the DPS would have to found to no longer be "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range". The Services went on to recommend that in the development of final delisting criteria, that the salmon Population Viability Analysis (Legault, 2005) be used in conjunction with guidance from the Viable Salmonid Population (VSP) approach (McElhany et al. 2000) to determine appropriate final reclassification and delisting criteria.

In 2003, before the publication of the Final Recovery Plan, a new biological review team (referred to as the "2005 BRT") was assembled with the charge to review and evaluate all relevant scientific information necessary to evaluate the current DPS delineations. In addition, the 2005 BRT was charged with the task of determining the conservation status of the U.S. Atlantic salmon populations that were deferred in 2000 as well as their relationship to the currently listed GoM DPS. The 2005 BRT published the Status Review for Anadromous Atlantic Salmon (*Salmo salar*) in the United States in 2006 (Fay et al. 2006). While creating the 2005 Status Review, the BRT relied upon genetic, life history, and zoogeographic information to determine that the GoM DPS is comprised of all anadromous Atlantic salmon whose freshwater range occurs in the watersheds from the Androscoggin northward along the Maine coast to the Dennys, including all associated conservation hatchery populations used to supplement natural populations, currently such populations are maintained at Craig Brook and Green Lake National Fish Hatcheries. The major difference between the determination of the 2005 Status Review and the earlier Status Review are the inclusion of the three large river systems: Androscoggin, Kennebec, and Penobscot Rivers.

.2 Distinct Population Segments (DPS):

In section 3 of the ESA (as amended in 1978), a "species" is defined as any "subspecies of fish, wildlife, or plant and any Distinct Population Segment (DPS) of any species of vertebrate fish or wildlife which interbreeds when mature." The U.S. Fish and Wildlife Service and the National Marine Fisheries Service published a DPS policy in February 1996 that further clarifies the interpretation of "Distinct Population Segment" for the purposes of listing, de-listing, and re-classifying species under the ESA (61 FR 4722). When making a threatened or endangered determination under the ESA, the DPS policy requires consideration of three elements:

1) The discreteness of the population segment in relation to the remainder of the species or subspecies to which it belongs
2) The significance of the population segment to the species or subspecies to which it belongs
3) The conservation status of the population segment in relation to ESA listing standards

For example, a population segment of a vertebrate species may be considered discrete (i.e. a DPS) if it is markedly separate from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors, which may include measures of genetic or morphological discontinuity; or, if it is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act (e.g. inadequate regulatory mechanisms).

If a population segment is found to be discrete based upon the criteria described above, a determination of the species biological and ecological significance to the taxon is then examined based upon four factors:

1) Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon

2) Evidence that the loss of the discrete population segment would result in a significant gap in the range of the taxon

3) Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range

4) Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics

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Appendix B:

Method used by McElhany et al. (2003) to determine number of independent populations within an ESU

In the Willamette/Lower Columbia Salmonid Viability Criteria (McElhany et al. 2003), the TRT partitioned salmonid populations within an ESU into different strata. Strata are defined based on two factors: 1) major life-history differences and 2) ecological zones. So for example; Lower Columbia steelhead populations were divided into two ecological zones (cascade and Columbia Gorge) and then were further partitioned into major life history types for each ecological zone (summer and winter runs). But in three other ESU's, three species were not partitioned based by run timing. Further more two of these populations were not partitioned based on ecological zones. Rather these populations were lumped into a single major life-history type within a single ecological zone.

In order to determine the number of viable populations within each strata, the W/CR TRT considered the following factors:

1) They were not striving for a zero extinction risk in each strata
2) ESU viability is more likely if each stratum has a relatively low probability of extinction

Furthermore, they estimated the probability that there would be no populations remaining in a stratum after a period of time, given an initial number of populations and an independent, identical, per-population extinction rate. Under these assumptions, the stratum extinction risk declines exponentially with the intial number of populations as

$$\varnothing = \theta^{\eta}$$

Where

$\varnothing$ *= the probability that all the populations in a stratum will be extinct within y years*
Θ*= the probability that a single population will go extinct in y years, and*
$\eta =$ *the number of initial populations in the stratum.*

Though the calculation makes broad assumptions, in general, it indicated that 2 to 3 populations within a stratum with low extinction risk provides a relatively significant reduction in risk compared to a single population. With this the TRT concluded that at least two populations per strata within the ESU should be viable. The VSP guidance document also provides guidance by stating that a population that more closely represents its historic structure has a lower risk of extinction then one that does not. The Willamette VSP provided a "stratum evaluation system" that provides some guidance on the probability that a stratum will reach extinction based on the number of independent populations within the stratum (Figure 1).

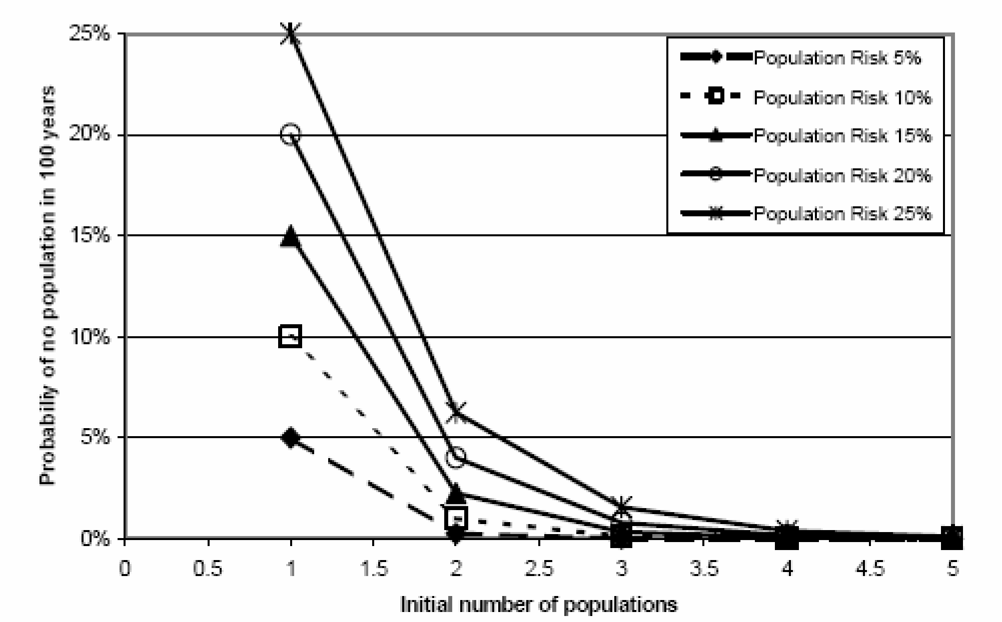


Figure 1: Probability of loosing all the populations in a stratum within 100 years as a function of the initial number of populations, assuming populations are independent. Each curve represents a different per-population probability of extinction in 100 years. *(Source: P. McElhany et al.. 2003)*

Reference:

McElhany, P., T., T. Backman, C. Busack, S. Heppell, S. Kolmes, A. Maule, J. Myers, D. Rawding, D. Shively, A. Steel, C. Steward, & T. Whitesel. 2003. Interim report on viable criteria for Willamette and Lower Columbia basin pacific salmonids. Willamette/Lower Columbia Technical Review Team.

Appendix C:

Alternate SHRU delineation

Option B:

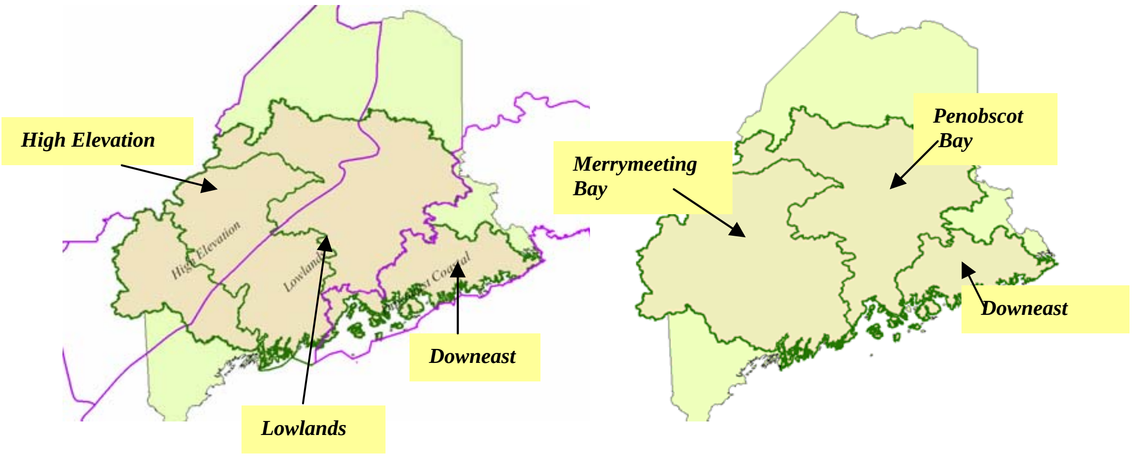
The alternate approach that we considered relied heavily on the ecological classification system proposed by Robert Bailey (1995) and the Ecological Drainage Units described by Olivero (2003) (see appendix C). Under this scenario the GoM DPS would be divided into three strata. Within each strata the basin delineations would represent the SHRU's, so that the mountainous strata and lowland strata would each have three SHRU's and the downeast coastal strata would have one SHRU. Proposed strata and SHRU delineations are presented in Table 1 and Figure 1 with Option A being the proposed SHRU delineation and Option B being the SHRU delineation that was considered but not selected:

Table 1: Options considered for population assemblages within the GOM DPS

Option A:		
	Strata	**SHRU's**
Gulf of Maine DPS	Gulf of Maine DPS	Downeast Coastal Rivers
		Mid Coast
		Penobscot

Option B:		
	Strata	**SHRU's**
Gulf of Maine DPS	High Elevation	Upper Androscoggin
		Upper Kennebec
		West Branch Penobscot
	Lowlands	Lower Androscoggin
		Lower Kennebec
		Penobscot River excluding the West Branch
	Downeast Coastal Rivers	Downeast Coastal Rivers

Figure 1: Option B (Left) and Option A (Right)



Final Decision for Establishment of Salmon Habitat Recovery Units (SHRU's) within the GoM DPS:

In effect, we chose to use Option A as our current delineation system for SHRU's within the GoM. Our decision to use Option A as opposed to Option B is based on the fact that large populations are less prone to extinction risks than small populations, and that there are currently no populations of salmon in the high elevation regions of the Penobscot, Androscoggin and Kennebec rivers as described in option B. To establish Recovery Units we need to demonstrate that each unit is necessary to the survival and recovery of the species. For recovery purposes, having populations that represent the geographic diversity across the entire range of the DPS is essential in ensuring the survival and recovery of the species as it ensures genetic variability and enhanced a species ability to adapt to changing environments. In option A, each SHRU has an existing population in which to build from. Whereas option B, we would need to rely on genetic material from outside the high elevation SHRU's to reestablish their populations. This would mean that in order to achieve recovery within the DPS, evolutionary adaptation to these SHRU's would need to occur to qualify them as necessary to the survival and recovery of the species.

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Appendix D:

Factors considered in determining the geographic boundaries for SHRU's within the GOM DPS

Climatic regions

When referring to and/or attempting to define ecological regions, two primary classifications are commonly used. One classification system, developed by Robert Bailey (1995) distinguishes ecological divisions based on land forms, soils, vegetation and topography. Bailey's classification system divides the GoM DPS into two provinces: (1) The "Adirondack – New England Mixed Forest – Coniferous Forest – Alpine Meadow Province" which incorporates all of the high elevation mountainous areas of western Maine that extends from the White Mountains at the Maine/New Hampshire border north to Mt. Katahdin and upward to the roof top of Maine. This particular region encompasses the upper Androscoggin north and west of a line that extends from Norway to Dixfield; the upper Kennebec north of a line that extends from Farmington to Kingsberry Plantation; and the upper Piscatiquis above Katahdin Iron Works, and the West Branch of the Penobscot River; and (2) The "Laurentian Mixed Forest Province" which incorporates the New England low lands from the high elevation areas described above east to the Canadian Border in New Brunswick. This particular region would incorporate the lower Kennebec and Androscoggin basins, all of the downeast coastal basin, and the Penobscot basin with the exception of the West Branch and upper Piscatiquis.

The second method, developed by Olivero (2003) is a regional classification system that stratifies regions into ecological drainage units (EDU's). Olivero defined EDU's by aggregating watersheds with similar zoogeographic history that account for variations in freshwater ecosystems, physiographic conditions, climatic characteristics and basin geography. Olivero's classification divides the GoM DPS into two ecological drainage units. One drainage incorporates all of the small downeast coastal rivers east of the St. George River in Thomaston, Maine east into New Brunswick, Canada but does not include the Penobscot River. The other ecological drainage unit incorporates the rest of the GoM DPS which includes the basins of the Penobscot, Kennebec and Androscoggin Rivers along with the small coastal rivers from the Saint George River west to the Androscoggin.

Hydrology

When defining hydrologic regions, the Hydrologic Unit Code (HUC) system is commonly used. The HUC system was developed by the USGS Office of Water Data Coordination in conjunction with the Water Resource Council (Seaber et al, 1987). Units based on topography and surface flow divide the country into six nested levels where level 1 (HUC 2) represents a region; level 2 (HUC 4) represents a sub region; Level 3 (HUC 6) represents a basin; Level 4 (HUC 8) represents a sub basin; level 5 (HUC 10) represents a watershed; and level 6 (HUC 12) represents a sub watershed. The nation is divided into 21 major geographic areas or level 1 (HUC 2) regions based on the drainage area of a major river such as the Missouri region, or a combination of rivers such as the Texas-Gulf region (Seaber et al. 1987). The State of Maine falls within region 1 and includes all those rivers that ultimately drain into: (a) the Bay of Fundy; (b) the Atlantic Ocean within and between the state of Maine and Connecticut; (c) Long Island Sound north of the New York-Connecticut state line; and (4) the Riviere St. Francois – a tributary of the St. Lawrence River. Within Maine there are 6 level 3 (HUC 6) basins (MEGIS, 2004), of which 4 basins make up the boundaries for the GoM DPS. These include the Penobscot, Androscoggin, Kennebec, and Eastern Maine Coastal Basins.

Distribution and abundance across the DPS

Remnant populations of Atlantic salmon exist within all four basins present within the GOM DPS though the remnant populations remaining in the Androscoggin are believed to be Penobscot strays (Fay et al. 2006). Of the three remaining basins, the Penobscot basin has the largest population, followed by the Eastern Maine Coastal Basin. Occasional runs of naturally reproducing Atlantic salmon have been documented within the last ten years in the Kennebec Basin, specifically in Togus and Bond Brooks. In recent years a few adult salmon have been captured at Lockwood, the lower most dam on the Kennebec, following the installation of a new fish lift. The first season, fifteen salmon were captured and transported to the Sandy River (USASAC 2007). Of these salmon, five were determined to be wild, originating from either natural reproduction or fry stocked fish (USASAC 2007). Of the five wild fish, one was determined to have originated from a 2003 fry release in the Sandy River and the other four were undetermined (USASAC 2007). The remaining ten were determined to be of hatchery origin (USASAC 2007).

Genetics

By examining genetic data from Atlantic salmon populations throughout North America, Spidle et al. (2003) found that the Atlantic salmon populations in Maine represent a discrete independent gene pool within North America. A tree of genetic distance values presented by Spidle et al. (2003) indicates two primary population clusters within Maine's anadromous salmon populations. One population is centered around the Machias and Narraguagus Rivers, and includes the Penobscot River. This clustering of the Penobscot population with the Machias and Narraguagus populations is believed to be indicative of historic stocking practices in which a nearly extirpated Penobscot salmon population in the mid 1900's was subsequently restored using Machias and Narraguagus stocks between 1968 and 1971 (Baum 1997). A second cluster comprised of populations in the Kenduskeag, Ducktrap, Sheepscot, and Dennys Rivers as well as Bond Brook – a tributary to the Kennebec was also identified by Spidle et al. (2003). Populations within this cluster are more disjunct and not as closely related to each other as the Penobscot, Machias and Narraguagus are to each other.

Assuming that an independent population represents a "collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period are not substantially altered by exchanges of individuals with other populations" (McElhany et al. 2000), there does not appear to be a clear independent population structure within the GOM DPS at this time. The inability to clearly define independent population structures within the GoM DPS is likely a result of historic stocking and management practices as well as the construction of dams; both of which have significantly affected the population dynamics of the DPS.

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