Biological valuation of Atlantic salmon habitat within the Gulf of Maine Distinct Population Segment

Biological assessment of specific areas currently occupied by the species; and determination of whether critical habitat in specific areas outside the currently occupied range is deemed essential to the conservation of the species

NOAA's National Marine Fisheries Service
Northeast Regional Office
1 Blackburn Drive
Gloucester, MA. 01930

2009

Foreword: Atlantic salmon life history 3
Chapter 1: Methods and Procedures for Biological Valuation of Atlantic Salmon Habitat in the Gulf of Maine Distinct Population Segment (GOM DPS) 6
1.1 Introduction 6
1.2 Identifying the Geographical Area Occupied by the Species and Specific Areas within the Geographical Area 7
1.3 Specific areas outside the geographical area occupied by the species essential to the conservation of the species 11
1.4 Identify those "Physical and Biological Features" in freshwater and estuary specific areas that are essential to the conservation of the species 16
1.4.1 Conservation defined 17
1.4.2 Physical and biological features needed by Atlantic salmon 17
(A). Physical and Biological Features of the Spawning and Rearing PCE 18
(B). Physical and Biological Features of the Migration PCE 22
(C). Physical and biological features of marine sites and "Specific Areas" within the geographic range occupied by the species 25
1.5 Identify special management considerations and protections 25
1.5.1 Specific activities that may effect physical and biological features 27
Agriculture 27
Forestry 28
Changing land-use and development 29
Hatcheries and stocking 31
Roads and road crossings 31
Mining 32
Dams 33
Dredging 33
Aquaculture 34
1.6 Procedure used to determine biological value of habitat within specific areas 37
1.6.1 Methods and procedures used to determine the biological value of HUC 10 watersheds 37
Habitat units 37
Habitat quantity 37
Habitat quality 38
Final habitat value 40
Final Migration Value 40
Final Biological Value 40
Chapter 2: Downeast Coastal SHRU Biological Report 41
2.1 Landscape and hydrologic features that shape the physical and Biological features within the Downeast Coastal SHRU 41
2.1.1 Geography 41
2.1.2 Geology and climate 41
2.1.3 Hydrology 42
2.1.4 Natural barriers 43
2.2 Human influence on Downeast Coastal SHRU 44
2.2.1 Current population structure and land-use 44
2.2.2 Dams and barriers to fish passage 44
2.2.3 Water Quality 45
2.2.4 Fisheries and fish introductions in the Downeast Coastal SHRU 47
2.3 Atlantic salmon habitat 49
Chapter 3: Penobscot Bay SHRU Biological Report 54
3.1 Landscape and hydrologic features that shape the physical and biological features within the Penobscot SHRU 54
3.1.1 Geography 54
3.1.2 Geology and climate 54
3.1.3 Hydrology 54
3.1.4 Natural barriers 56
3.2 Human Influence on the Penobscot SHRU 57

3.2.1 Current population structure and land use 57
3.2.2 Dams and diversions 57
Penobscot River restoration effort through dam removal 58
3.2.3 Fisheries and fish introductions in the Penobscot SHRU 60
3.3 Atlantic salmon habitat 63
Chapter 4: Merrymeeting Bay SHRU Biological Report 70
4.1 Landscape and hydrological features that shape the physical and biological features within the Merrymeeting Bay SHRU 70
4.1.1 Geography 70
4.1.2 Geology and climate 70
4.1.3 Hydrology 72
4.2 Human influence on Merrymeeting Bay SHRU 74
4.2.1 Current population structure and land use 74
4.2.2 Dams 75
The Kennebec River diadromous fish restoration project 75
Fish passage restoration efforts on the Androscoggin River 76
4.2.3 Water quality 77
4.2.4 Fisheries and fish introductions in the Merrymeeting Bay SHRU 77
4.3 Atlantic salmon habitat 78
References: 85

Foreword: Atlantic salmon life history

Atlantic salmon have a complex life history that ranges from territorial rearing in rivers to extensive feeding migrations on the high seas. During their life cycle, Atlantic salmon go through several distinct phases that are identified by specific changes in behavior, physiology, morphology, and habitat requirements.

Adult Atlantic salmon return to rivers from the sea with the objective of migrating to their natal stream and spawning. Adults ascend the rivers of New England beginning in the spring and will continue their ascent into the fall with the peak influx of adults occurring in June. Although spawning does not occur until late fall, the majority of Atlantic salmon in Maine enter freshwater between May and mid July (Meister, 1958; Baum, 1997; Dill personal communication). Early migration is an adaptive trait that ensures adults have sufficient time to effectively reach spawning areas despite the occurrence of temporarily unfavorable conditions that occur naturally (Bjornn and Reiser, 1991). Salmon that return in early spring spend nearly five months in the river before spawning; often seeking cool water refuge (e.g., deep pools, springs, and mouths of smaller tributaries) during the summer months.

In the fall, the female Atlantic salmon selects a site for spawning. Spawning sites are positioned within flowing water allowing for percolation of water through the gravel where up-wellings of groundwater occur (Danie *et al.,* 1984). These sites are most often positioned at the head of a riffle (Beland *et al.,* 1982b), the tail of a pool, or on the upstream edge of a gravel bar where water depth is decreasing and water velocity is increasing (McLaughlin and Knight, 1987; White, 1942) and where a hydraulic head of water allows for permeation of water through the redd. A spawning female Atlantic salmon uses her tail to scour or dig a depression in the gravel, called a redd, where the eggs are deposited. One or more males fertilize the eggs as they are deposited in the redd (Jordan and Beland, 1981). The female then continues digging upstream of the last deposition site, burying the fertilized eggs with clean gravel. A single female may create several redds before depositing all of her eggs. The digging behavior also serves to clean the substrate of fine sediments that can embed substrate and reduce egg survival (Gibson, 1993). Female anadromous Atlantic salmon produce a total of 1,500 to 1,800 eggs per kilogram of body weight yielding an average of 7,500 eggs per 2SW female (Baum and Meister, 1971). After spawning, Atlantic salmon may either return to sea immediately or remain in freshwater until the following spring before returning to the sea (Fay *et al.*, 2006). From 1967 to 2003, approximately 3% of the wild and naturally reared adult returns in rivers where adult returns are monitored were repeat spawners (USASAC 2004).

The embryos develop in the redd for a period of 175 to 195 days (Danie *et al.,* 1983). After eggs hatch in late March or April the newly hatched salmon are referred to as larval fry, alevin or sac fry. Alevins remain in the redd for approximately six weeks after hatching and are nourished by their yolk sac (Gustafson-Greenwood and Moring, 1991). Alevins emerge from the gravel and begin active feeding in mid-May. At this stage they are termed fry. The majority of fry (>95%) emerge from redds at night (Gustafson-

Marjanen and Dowse 1983). Survival from the egg to fry stage in Maine is estimated to range from 15 to 35% (Jordan and Beland, 1981). Survival rates of eggs and larvae is a function of stream gradient, overwinter temperatures, interstitial flow, predation, disease, and competition (Bley and Moring, 1988).

When fry reach approximately 4 cm in length, the young salmon are termed parr (Danie *et al.*, 1984). Parr have eight to eleven pigmented vertical bands on their sides that are believed to serve as camouflage (Baum, 1997). A territorial instinct, first apparent during the fry stage, grows more pronounced during the parr stage as the parr actively defend territories (Allen, 1940; Kalleberg, 1958; Danie *et al.,* 1984). Most parr remain in the river for two to three years before undergoing smoltification; the process in which parr go through physiological changes in order to transition from a freshwater environment to a saltwater marine environment. Some male parr may not go through smoltification and will become sexually mature and participate in spawning with sea-run adult females. These males are referred to as "precocious parr."

First year parr are often characterized as being small parr or 0+ parr (4 to 7 cm long), where as second and third year parr are characterized as large parr (greater than 7 cm. long) (Haines, 1992). Parr growth is a function of water temperature (Elliott, 1991), parr density (Randall, 1982), photoperiod (Lundqvist, 1980), interaction with other fish, birds and mammals (Bjornn and Resier, 1991), and food supply (Swansburg *et al.,* 2002). Parr movement may be quite limited in the winter (Cunjak 1988; Heggenes 1990); however, movement in the winter does occur (Hiscock *et al.,* 2002) and is often necessary as ice formation reduces total habitat availability (Whalen *et al.,* 1999a). Parr have been documented utilizing riverine, lake, and estuarine habitats; incorporating opportunistic and active feeding strategies; defending territories from competitors including other parr; and working together in small schools to actively pursue prey (Gibson, 1993; Marschall *et al.,* 1998; Pepper, 1976; Pepper *et al.,* 1984; Hutchings, 1986; Erkinaro *et al.,* 1998, Halvorsen and Svenning, 2000; Hutchings, 1986; Dempson *et al.,* 1996; Klemetsen *et al.,* 2003).

In a parr's second or third spring (age 1 or age 2 respectively), when it has grown to 12.5 to 15 cm in length, a series of physiological, morphological, and behavioral changes occur (Schaffer and Elson, 1975). This process, called smoltification, prepares the parr for migration to the ocean and life in salt water. In Maine, the vast majority of wild/naturally reared parr remain in freshwater for two years (90% or more) with the balance remaining for either one or three years (USASAC, 2005). In order for parr to smoltify they must reach a critical size of 10 cm total length at the end of the previous growing season (Hoar 1988). During the smoltification process, parr markings fade and the body becomes streamlined and silvery with a pronounced fork in the tail. The physiological changes that occur during smoltification prepare the fish for the dramatic change in osmoregulatory needs that come with the transition from a fresh to a salt water habitat (Ruggles, 1980; Bley, 1987; McCormick and Saunders, 1987; McCormick *et al.,* 1998). Smolt transition into seawater is usually gradual as they pass through a zone of mixing from freshwater to the marine environment that occurs most frequently in the estuary. Given that smolts undergo smoltification while they are still in the river, they are pre-adapted to make a direct entry into seawater with minimal acclimation (McCormick *et al.,* 1998). This is necessary under some circumstances where there is very little transition zone between some coastal rivers and streams and the marine environment. Naturally reared smolts in Maine range in size from 13 to 17 cm and most smolts enter the sea during May to begin their ocean migration (USASAC, 2004). During this migration, smolts must contend with changes in salinity, water temperature, pH, dissolved oxygen, pollution levels, and predator assemblages.

The early migration of post-smolts out of the coastal environment is generally rapid, within several tidal cycles, and follows a direct route (Hyvarinen *et al.,* 2006, Lacroix and McCurdy 1996, Lacroix *et al.,* 2004, Lacroix *et al.,* 2005). Post-smolts generally travel out of coastal systems on the ebb tide, and may be delayed by flood tides (Hyvarinen *et al.,* 2006, Lacroix and McCurdy, 1996, Lacroix *et al.,* 2004, Lacroix and Knox, 2005) although, Lacroix and McCurdy (1996) found that post-smolts exhibit active, directed swimming, in areas with strong tidal currents. Studies in the Bay of Fundy and Passamaquoddy Bay suggest that post-smolts aggregate together and move near the coast in "common corridors", and that post-smolt movement is closely related to surface currents in the bay (Hyvarinen *et al.,* 2006, Lacroix and McCurdy, 1996, Lacroix *et al.,* 2004). European post-smolts tend to use the open ocean for a nursery zone, while North American post-smolts appear to have a more near-shore distribution (Friedland *et al.,* 2003). Post-smolt distribution may reflect water temperatures (Reddin and Shearer, 1987) and/or the major surface-current vectors (Lacroix and Knox, 2005). Post-smolts live mainly on the surface of the water column and form shoals, possibly of fish from the same river (Shelton *et al.,* 1997).

During the late summer/autumn of the first year, North American post-smolts are concentrated in the Labrador Sea and off of the west coast of Greenland, with the highest concentrations between 56 and 58^{o}N (Reddin, 1985; Reddin and Short, 1991; Reddin and Friedland, 1992). The salmon located off of Greenland are composed of both 1SW and MSW immature salmon from both North American and European stocks (Reddin, 1988; Reddin *et al.,* 1988). The first winter at sea regulates annual recruitment, and the distribution of winter habitat in the Labrador Sea and Denmark Strait may be critical for North American populations (Friedland *et al.,* 1993). In the spring, North American post-smolts are generally located in the Gulf of St. Lawrence, off the coast of Newfoundland, and on the east coast of the Grand Banks (Reddin, 1985; Dutil and Coutu, 1988; Ritter, 1989; Reddin and Friedland, 1992; and Friedland *et al.,* 1999).

Some salmon may remain at sea for another year or more before maturing. After their second winter at sea, the salmon over-winter in the area of the Grand Banks before returning to spawn (Reddin and Shearer, 1987). Reddin and Friedland (1992) found non-maturing adults located along the coasts of Newfoundland, Labrador and Greenland, and in the Labrador and Irminger Sea in the later summer/autumn.

Chapter 1: Methods and Procedures for Biological Valuation of Atlantic Salmon Habitat in the Gulf of Maine Distinct Population Segment (GOM DPS)

1.1 Introduction

The Endangered Species Act (ESA) requires that critical habitat be designated concurrently with making the determination that a species is endangered or threatened. Critical habitat designations provide additional protections beyond classifying a species as either endangered or threatened, by avoiding the destruction or adverse modification of the physical and biological features essential for the conservation of the species. The ESA requires that any proposed Federal actions not adversely modify or destroy designated critical habitat.

When designating critical habitat, Section 4(b)(2) of the ESA requires NMFS to consider the economic, national security, and other impacts of designating a particular area as critical habitat. NMFS may exclude a particular area from critical habitat if we determine that the benefits of exclusion outweigh the benefits of specifying the area as part of the critical habitat, unless we also determine that the failure to designate the area as critical habitat will result in the extinction of the species concerned.

Section 3(5)(A) of the ESA (16 U.S.C. 1532(5)) defines critical habitat as:

(i) <u>the specific areas within the geographical area occupied by the species</u>, at the time it is listed in accordance with the provisions of section 4 of the Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and

(ii) <u>specific areas outside of the geographical area occupied by the species</u> at the time it is listed in accordance with the provisions of section 4 of the Act, upon a determination by the Secretary that such areas are essential for the conservation of the species.

Based on the best available scientific data, this report evaluates critical habitat throughout the GOM DPS and assigns a biological value to specific areas on which are found those physical and biological features essential to the conservation of the species and which may require special management consideration or protections. In doing so, chapter 1 of this report will identify: 1) the geographical area occupied by the species and specific areas within that geographical area; 2) specific areas outside the geographical occupied by the species essential to the conservation of the species; 3) identify those specific areas within the geographical area occupied by the DPS on which are found those physical and biological features (I) essential to the conservation of the species and (II) which may require special management considerations; and 4) review the methods and procedures used to assign biological value to specific areas essential to the conservation of the species.

Chapters 2, 3 and 4 of this report: 1) provide an overview of the physical and biological features and land use activities specific to three recovery units as described in sections 1.3; 2) assess the quantity of habitat within the currently occupied range relative to the quantity of habitat needed to achieve conservation of the species to determine if any unoccupied areas are essential to the conservation of the DPS; and 3) assign a biological value to each specific area within each recovery unit that will be used in the 4(b)(2) exclusion analysis in order to assess the benefits of exclusion of any particular areas compared the benefits of inclusion of those same areas.

1.2 Identifying the Geographical Area Occupied by the Species and Specific Areas within the Geographical Area

To designate critical habitat for Atlantic salmon, as defined under Section 3(5)(A) of the ESA, we must identify specific areas within the geographical area occupied by the species at the time it is listed.

The geographic range occupied by the GOM DPS of Atlantic salmon includes historically accessible freshwater habitat ranging from the Androscoggin River watershed in the south to the Dennys River watershed in the north, as well as the adjacent estuaries and bays that smolts and adults migrate through. This critical habitat analysis includes a comprehensive review of the entire Androscoggin, Kennebec, Penobscot and Downeast Coastal Basins, which make up the Gulf of Maine Distinct Population Segment as described in the Atlantic salmon proposed listing rule (50 CFR 51415). Throughout these basins, there are specific areas that are currently occupied by the species; specific areas historical occupied by the species, but currently unoccupied largely due to dams; and specific areas that were historically unoccupied by the species due to natural barriers. As part of the critical habitat assessment and through comments received during the public comment period, the natural barriers that define the upper limit of Atlantic salmon migration were identified and, therefore, the GOM DPS has been re-defined in the final listing rule (74 FR 29344) to accommodate these barriers. The GOM DPS in the final rule is specifically described as: 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 marine range of the GOM DPS extends from the Gulf of Maine, throughout the Northwest Atlantic Ocean, to the coast of Greenland. Included are all associated conservation hatchery populations used to supplement these natural populations; currently, such conservation hatchery populations are maintained at Green Lake National Fish Hatchery (GLNFH) and Craig Brook National Fish Hatchery (CBNFH). Excluded are landlocked salmon and those salmon raised in commercial hatcheries for aquaculture (74 FR 29344).

The geographic range occupied by the species extends out to the waters off Canada and Greenland, where post smolts complete their marine migration. However, critical habitat may not be designated within foreign countries or in other areas outside of the jurisdiction of the United States (CFR 424.12(h)). Therefore, for the purposes of critical habitat designation, the geographic area occupied by the species will be restricted to areas within the jurisdiction of the United States. This does not diminish the importance of habitat outside of the jurisdiction of the United States for the GOM DPS. In fact, a very significant factor limiting recovery for the species is marine survival. Marine migration routes and feeding habitat off Canada and Greenland is critical to the survival and recovery of Atlantic salmon, but the regulations prohibit designation of these areas as critical habitat. In designating critical habitat for Atlantic salmon, the emphasis is two fold: 1) Assuring that critical habitat essential for a recovered population is protected so that when marine conditions improve, sufficient habitat is available to support recovery; and 2) Enacting appropriate management measures to enhance and improve critical habitat areas that are not fully functional because the features have been degraded from anthropogenic causes.

Atlantic salmon are anadromous and spend a portion of life in freshwater and the remaining portion in the marine environment, therefore, it is conceivable that some freshwater habitat may be vacant for up to 3 years under circumstances where populations are extremely low. While there may be no documented spawning in these areas for that period of time, they would still be considered occupied because salmon at sea would return to these areas to spawn.

Current stock management and assessment efforts also need to be considered in deciding which areas are occupied including the stocking program managed by USFWS and the Maine Department of Marine Resources (MDMR). Furthermore, in addition to stocking programs, straying from natural populations can result in the occupation of habitat.

Hydrologic Unit Code (HUC) 10 (Level 5 watersheds) described by Seaber *et al.* (1994) are considered the appropriate "specific areas" within the geographic area occupied by Atlantic salmon to be examined for the presence of physical or biological features and for the potential need for special management considerations or protections for these features.

The HUC system was developed by the United States Geological Survey (USGS) Office of Water Data Coordination in conjunction with the Water Resources Council (Seaber *et al.,* 1994) and provides (1) a nationally accessible, coherent system of water-use data exchange; (2) a means of grouping hydrographical data; and (3) a standardized, scientifically grounded reference system (Laitta *et al.,* 2004). The HUC system currently includes six nationally consistent, hierarchical levels of divisions, with HUC 2 (Level 1) "Regions" being the largest (avg. 459,878 sq. km.), and HUC 12 (Level 6) "sub-watersheds" being the smallest (avg. 41-163 sq. km.).

The HUC 10 (level 5) watersheds were used to identify "specific areas" because this scale accommodates the local adaptation and homing tendencies of Atlantic salmon, and provides a framework in which we can reasonably aggregate occupied river, stream, lake, and estuary habitats that contain the physical and biological features essential to the conservation of the species. Furthermore, many Atlantic salmon populations within the GOM DPS are currently managed at the HUC 10 watershed scale. Therefore, we have a better understanding of the population status and the biology of salmon at the HUC 10 level, whereas less is known at the smaller HUC 12 sub-watershed scale.

Specific areas delineated at the HUC 10 watershed level correspond well to the biology and life history characteristics of Atlantic salmon. Atlantic salmon, like many other anadromous salmonids, exhibit strong homing tendencies (Stabell, 1984). Strong homing tendencies enhance a given individual's chance of spawning with individuals having similar life history characteristics (Dittman and Quinn, 1996) that lead to the evolution and maintenance of local adaptations, and may also enhance their progeny's ability to exploit a given set of resources (Gharrett and Smoker, 1993). Local adaptations allow local populations to survive and reproduce at higher rates than exogenous populations (Reisenbichler, 1988; Tallman and Healey, 1994). Strong homing tendencies have been observed in many Atlantic salmon populations. Stabell (1984) reported that fewer than 3 of every 100 salmon in North America and Europe stray from their natal river. In Maine, Baum and Spencer (1990) reported that 98 percent of hatchery-reared smolts returned to the watershed where they were stocked. Given the strong homing tendencies and life history characteristics of Atlantic salmon (Riddell and Leggett, 1981), we believe that the HUC 10 watershed level accommodates these local adaptations and the biological needs of the species and, therefore, is the most appropriate unit of habitat to delineate "specific areas" for consideration as part of the critical habitat designation process.

Within the United States, the freshwater geographic range that the GOM DPS of Atlantic salmon occupy includes perennial river, lake, stream and estuary habitat connected to the marine environment ranging from the Androscoggin River watershed to the Dennys River watershed. Within this range, HUC 10 watersheds were considered occupied if they contained either of the primary constituent elements (PCEs) (e.g., sites for spawning and rearing or sites for migration, described in more detail below) along with the features necessary to support spawning, rearing and/or migration. Additionally, the HUC 10 watershed must meet either of the following criteria. The area is occupied if:

(a) redds or any life-stage of salmon have been documented in the HUC 10 in the last six years, or the HUC 10 is believed to be occupied and contain the PCEs based on the best scientific information available and the best professional judgment of state and Federal biologists;

(b) the HUC is currently managed by the MDMR and the USFWS through an active stocking program in an effort to enhance or restore Atlantic salmon populations, or the area has been stocked within the last 6 years and juvenile salmon could reasonably be expected to migrate to the marine environment and return to that area as an adult and spawn.

One hundred and five HUC 10 watersheds within the Penobscot, Kennebec, Androscoggin and Downeast Coastal basins were examined for occupancy based on the above criteria (Figure 1.2.1). We concluded that 87 HUCs are within the historic range of the species and therefore constitute the GOM DPS as defined above, and 48 of the HUC 10 watersheds within the geographic range are occupied by the species at the time of listing (Figure 1.2.1). Estuaries and bays within the occupied HUC 10 watersheds in the GOM DPS are also included in the geographic range occupied by the species.

Occupied areas also extend outside the estuary and bays of the GOM DPS as adults return from the marine environment to spawn and smolts migrate towards Greenland for feeding. We are not able at this time to identify the specific features characteristic of marine migration and feeding habitat within U.S. jurisdictional waters essential to the conservation of Atlantic salmon and are therefore unable to identify the specific areas where such features exist. Therefore, specific areas of marine habitat are not proposed as critical habitat.

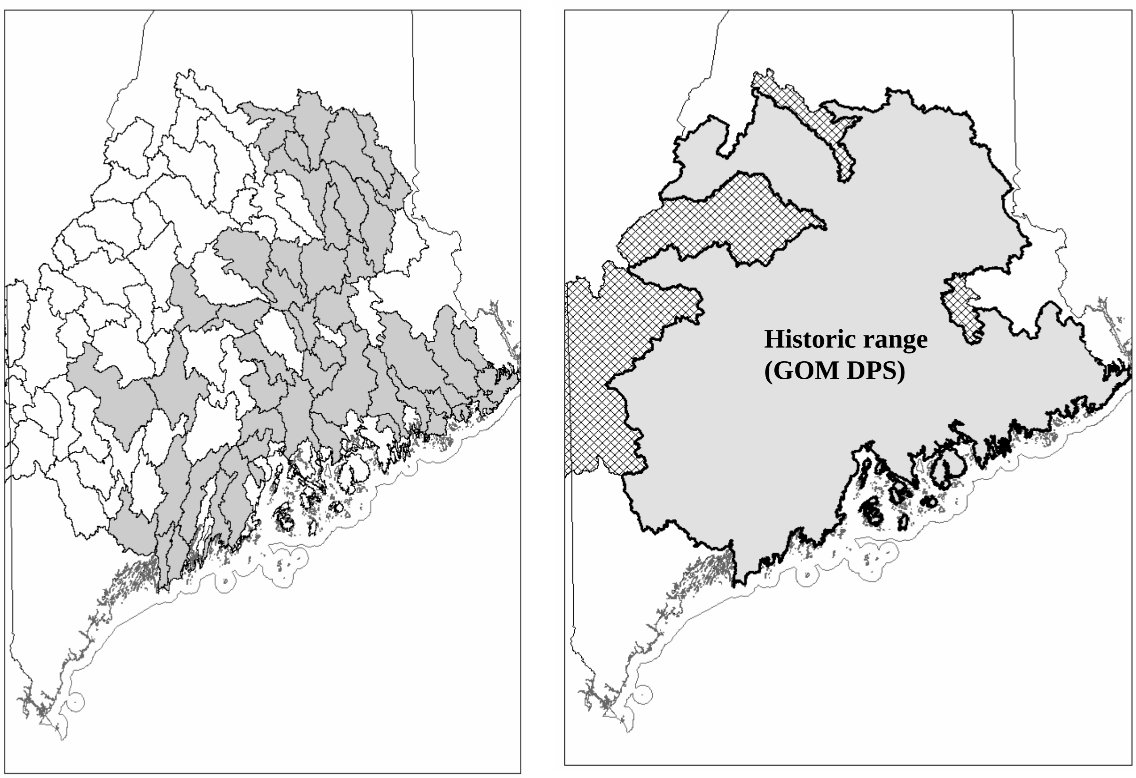

Figure 1.2.1: (LEFT) HUC 10 watersheds examined for occupancy with shaded areas denoting those areas identified as occupied; (RIGHT) study area (checkered) compared to historic range (gray) identified through occupancy evaluation and public comments. The historic range now denotes the Gulf of Maine Distinct Population Segment of Atlantic salmon.

1.3 Specific areas outside the geographical area occupied by the species essential to the conservation of the species

The ESA 3(5)(A)(ii) further defines "critical habitat" as "specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of [section 4 of this Act], upon a determination by the Secretary that such areas are essential for the conservation of the species". For the reasons stated above in the discussion of specific occupied areas, we delineated the specific areas outside the geographic area occupied by the species using HUC 10 (level 5) watersheds. To determine whether these unoccupied areas are essential for the conservation of the species, we: 1) established recovery criteria to determine when the species no longer warrants the protections of the ESA (*See Appendix A*) and the amount of habitat needed to support the recovered population; and 2) determined the amount of habitat currently occupied by the species relative to the amount of habitat necessary to achieve recovery.

In developing recovery criteria, we employed a strategy of identifying both geographic and population level criteria, that, if met would protect the DPS from demographic and environmental variation to the extent in which the population would no longer require protection under the ESA. Geographic criteria were established to assure that Atlantic salmon are well distributed across the DPS to accommodate the metapopulation characteristics of species; Atlantic salmon. Atlantic salmon have strong homing characteristics that allow local breeding populations to become well adapted to a particular environment, while at the same time, limited straying does occur as a means to assure population diversity and also allow for population expansion and recolonization of extirpated populations. To accommodate these life history characteristics, we established a geographic framework represented by three Salmon Habitat Recovery Units, or SHRUs, within the DPS (see appendix A) that would we believe to be reasonably protective of these life history characteristics and to ensure that Atlantic salmon are widely distributed across the DPS to provide protection from demographic and environmental variation. As explained in more detail in the Recovery Criteria (Appendix A), we determined that all three SHRUs must fulfill the criteria described below for the overall species, the GOM DPS, to be considered recovered.

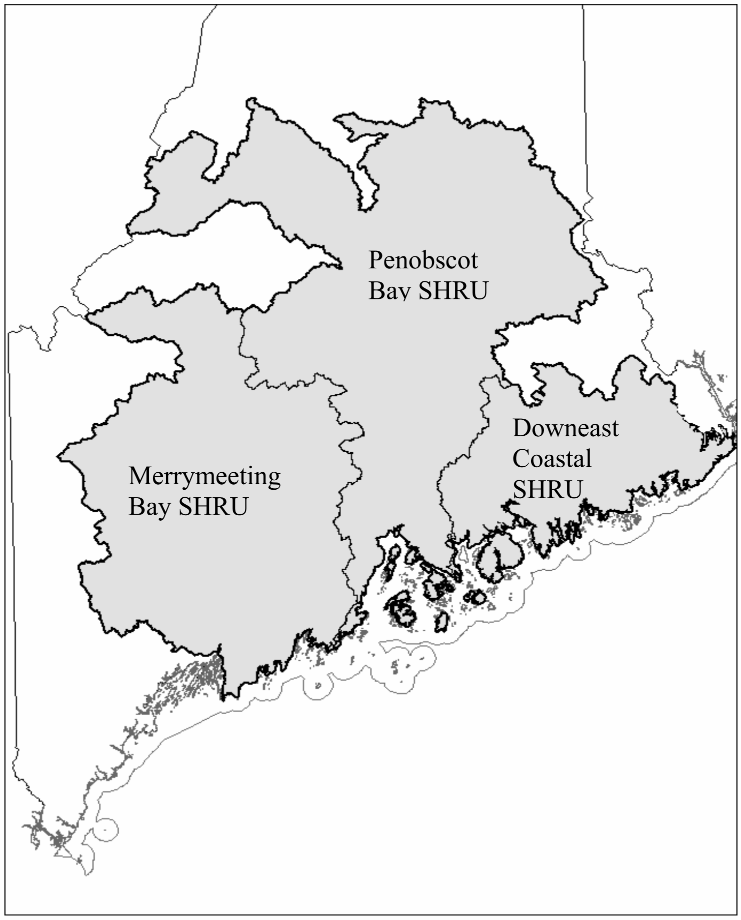

Figure1.3.1: GOM DPS displaying the three SHRUs

Criteria

Population level criteria were established to assure that a recovered population is likely to be sufficiently robust to withstand natural demographic variability (e.g., periods of low marine survival) and not likely to become an endangered species in the foreseeable future. We concluded that a census population of 500 adult spawners (assuming a 1:1 sex ratio) in each SHRU is to be used as a benchmark to evaluate the population as either recovered or one that requires protection under the ESA. Franklin (1980) introduced 500 as the approximate effective population size necessary to retain sufficient genetic variation and long term persistence of a population.

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. At this time there are not sufficient resources or time to fully assess the effective population size of the entire Gulf of Maine DPS on annual basis, whereas sufficient resources are already in place to reasonably assess the census population; 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 the following paragraph; 3) Atlantic salmon have tremendously complex life histories allowing for great opportunity for extensive cross generational breeding. This is because of 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 and 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).

To evaluate the GOM DPS for recovery, we have determined that five criteria must be met: 1) The adult spawner population of each SHRU must be 500 or greater 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 we have determined that we can make reasonable projections based on 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 delist 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 delist 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 Status Review (Fay *et al.*, 2006). Methods to address these threats will be addressed in a final recovery plan for the expanded GOM DPS.

After determining criteria for delisting, we applied these criteria to assess the number of adult spawners that would be needed to whether a downturn in survival as experienced between the years of 1991 and 2006; a period of exceptionally low survival. Using demographic data for this time period we applied the criteria described above in conjunction with a Population Viability Analysis (PVA) to determine how many adults would be required in each SHRU to weather a similar downturn in survival while having a greater than 50 percent chance of remaining above 500 adults (see Appendix B). This analysis projected that a census population of 2,000 spawners (1000 male and 1000 female) would be needed in each of the three SHRUs for the GOM DPS to weather a downturn in survival such as experienced over the time period from 1991 – 2006. Based on this analysis, we conclude that enough habitat is needed in each of the three SHRUs to support the offspring of these 2,000 adult spawners. Using an average fecundity per female of 7,200 eggs (Legault, 2004), and male to female ratio of 1:1, or 1000 females, and a target number of eggs per one unit of habitat ($100m^2$) of 240 (Baum, 1997) we determined that 30,000 units of habitat is needed across each SHRU (7,200 eggs X 1000 females/240 eggs = 30,000) to support the offspring of 2,000 spawners, which represents the quantity of habitat in each SHRU essential to the conservation of the species (Appendix B).

To calculate the existing quantity of habitat across the DPS both within the currently occupied range and outside the occupied range, we recognized that both habitat quantity and quality should be taken into consideration. As a result, we describe the existing quantity of habitat in terms of functional habitat units. To generate this estimate of functional habitat units, we considered the measured quantity of habitat within each HUC 10 as well as the habitat's quality. The functional habitat units values are a measure of the quantity of habitat (expressed in units where 1 unit of habitat is equivalent to $100m^2$ of habitat) within a HUC 10 based on qualitative factors that limit survivorship of juvenile salmon utilizing the habitat for spawning, rearing and migration. The functional habitat units also account for dams within or below the HUC 10 that would further reduce survivorship of juvenile salmon as they migrate towards the marine environment. In HUC 10s that are not believed to be limited by qualitative factors or dams, the functional habitat units would be identical to the measured quantity of habitat within the HUC 10. In HUC 10s where quality and dams are believed to be limiting, the functional habitat units would be less than the measured habitat within the HUC 10. The functional habitat unit value is used in the critical habitat evaluation process to describe the quantity of functioning habitat within each HUC 10. It is also used to describe the quantity of functioning habitat within the currently occupied range relative to the amount needed to support the offspring of 2000 adult spawners.

Functional habitat unit scores were generated by multiplying the quantity of spawning and rearing habitat units within each HUC 10 by the habitat quality score (e.g. 1 = 0.33, 2 = 0.66, and 3 = 1; discussed below under application of ESA section 4(b)(2)) divided by 3 to represent the relative values in terms of percentages such that a "1" habitat quality score has a qualitative value roughly equivalent to 33 percent of fully functioning habitat, accordingly, a "2" habitat quality score is roughly 66 percent the value of fully functioning habitat, and a "3" score equals 100 percent habitat quality. The sum of this value was then multiplied by 0.85 raised to the power of the number of dams both within and downstream of the HUC 10. We consider 0.85 to represent a coarse estimate of passage efficiency of smolts for FERC dams with turbines based on the findings of several studies (GNP, 1995; GNP, 1997; Holbrook, 2007; Shepard, 1991; Spicer *et al.*, 1995) and therefore roughly equivalent to a 15 percent reduction in functional habitat. Mainstem dams without turbines are not expected to affect smolts the same as dams with turbines, but can result in direct or indirect mortality from delays in migration and by increased predation from predators that congregate around dams. Therefore dams without turbines were estimated to reduce the functional capacity of habitat units by 7.5 percent (one half of 15 percent). Dams located at roughly the midpoint of habitat within a HUC 10 watershed were estimated to affect passage of roughly half the fish in the HUC 10 watershed (e.g. located half way up the HUC 10 watershed) and therefore were discounted accordingly (e.g. 7.5 percent for dams with turbines). A dam without turbine located at the midpoint of habitat within a HUC 10 was estimated to reduce the functional capacity of habitat units by 3.75 percent. The numbers of dams present both within and downstream of individual HUC 10s was used as an exponent to account for cumulative effects of dams. A formulaic representation of our method is written as:

Q_{SRH} x $(B_{SS}/3)$ x $(E_{DE}\wedge{}^{N})$ = Functional Habitat Units

Q_{SRH} = quantity of spawning and rearing habitat

B_{SS} = biological suitability score

E_{DE} = estimated downstream passage efficiency of a typical FERC licensed dam

N = number of dams within and downstream of HUC 10

Given that computing the functional habitat units was conducted to estimate the quantity of habitat necessary to support the offspring of 2000 adult spawners, only downstream passage efficiency was figured into the equation to calculate functional habitat units. We based our projected habitat needs on the amount of habitat needed to support the offspring of 2,000 adult spawners, so our analysis of functional habitat units was based on those factors that would diminish the survival of the offspring of the spawners. The freshwater component for Atlantic salmon only requires that there is sufficient spawning habitat and sufficient rearing habitat to support a recovered population. This rule is not designed to serve as a recovery plan but rather to ensure that there is sufficient habitat available to meet recovery goals.

Table 1.3.1. Total habitat and functional habitat for occupied areas among the three SHRUs in the GOM DPS

SHRU	Total Habitat Units	Functional Equivalent	Additional habitat needed to support the offspring of 2,000 adult spawners (i.e. 30,000 units)
Merrymeeting Bay	372,639	40,001	0
Penobscot Bay	323,740	66,263	0

Downeast Coastal	61,395	29,111	889

In both the Penobscot and Merrymeeting Bay SHRUs there are more than 30,000 units of functional habitat within the currently occupied area to support the offspring of 2000 adult spawners. In the Downeast SHRU, the amount of functional habitat available to the species is estimated to be 889 units short of what is needed to support 2000 adult spawners. Nonetheless, we determined that no areas outside the occupied geographical area within the Downeast SHRU are essential to the conservation of the species. This is because of the 61,395 total habitat units in Downeast Maine, the habitat is predicted to be functioning at the equivalent of only 29,111 units because of the presence of dams or because of degraded habitat features that reduce the habitats functional value. Through restoration efforts, including enhanced fish passage and habitat improvement of anthropogenically degraded features, a substantial portion of the approximate 32,000 units of non-functioning habitat may be restored to functioning. The Union River, for instance, has over 12,000 units of habitat, though its functional potential is estimated to be equivalent to approximately 4,000 units of habitat. This is largely because of dams without fish passage that preclude Atlantic salmon access to portions of the Union River watershed. Dam removal or improved fish passage has the potential to restore a significant amount of the 8,000 units within the Union River declared to be non-functioning habitat. Throughout Maine, there has been substantial effort on behalf of state and federal agencies and non-profit organizations in partnership with landowners and dam owners to restore habitat through a combination of land and riparian protection efforts, and fish passage enhancement projects. For example, Project SHARE, the Downeast Salmon Federation, watershed councils, Trout Unlimited, and the Atlantic Salmon Federation have collectively conducted a number of projects designed to protect, restore and enhance habitat for Atlantic salmon ranging from the Kennebec River in south central Maine to the Dennys River in Eastern Maine. Projects include (though are not limited to) dam removals along the Kennebec, St. George, Penobscot, and East Machias Rivers, land protection of riparian corridors along the Machias, Narraguagus, Dennys, Pleasant, East Machias, Sheepscot, Ducktrap rivers and Cove Brook; surveying and repair of culverts that impair fish passage; and outreach and education efforts on the benefits of such projects. The Penobscot River Restoration Project is another example of cooperative efforts on behalf of federal and state agencies, non profit organizations and dam owners. The PRRP goal is to enhance runs of diadromous fish through the planned removal of two mainstem dams and enhanced fish passage around several other dams along the Penobscot River. These cooperative efforts can increase the functional potential of Atlantic salmon habitat by both increasing habitat availability as well as increasing habitat quality. Therefore, we do not believe that it is essential to designate critical habitat outside of the currently occupied range.

1.4 Identify those "Physical and Biological Features" in freshwater and estuary specific areas that are essential to the conservation of the species

Section 3(5)(A)(i) of the ESA defines critical habitat as "the specific areas within the geographical area occupied by the species at the time it is listed…on which are found those physical and biological features essential to the conservation of the species". The

Departments of the Interior and of Commerce provide further regulatory guidance under 50 C.F.R. 424.12(b) stating that the Secretary shall "focus on the principle biological or physical constituent elements within the defined area that are essential to the conservation of the species"… "Primary Constituent Elements (PCE's) may include, but are not limited to, the following: roost sites, nesting grounds, spawning sites, feeding sites, seasonal wetland or dryland, water quality or quantity, host species or plant pollinators, geological formation, vegetation type, tide, and specific soil types".

1.4.1 Conservation defined

As stated previously, critical habitat is defined as specific areas which contain physical and biological features essential to the conservation of the species. In order to determine which features are essential to the conservation of the GOM DPS, we first define what conservation means for this species. Conservation is 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, 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. We have further identified specific physical and biological features essential to creating conditions for successful spawning, egg incubation, juvenile rearing, and migration of adults and smolts.

1.4.2 Physical and biological features needed by Atlantic salmon

Within the occupied range of the Gulf of Maine DPS, Atlantic salmon PCEs include sites for spawning and incubation, sites for juvenile rearing, and sites for migration. The physical and biological features of the PCEs that allow these sites to be used successfully for spawning, incubation, rearing and migration are the features of habitat within the GOM DPS that are essential to the conservation of the species. A detailed review of the physical and biological features required by Atlantic salmon is provided in Kircheis and Liebich (2007). As stated above, Atlantic salmon also use marine sites for growth and migration; however, we did not identify critical habitat within the marine environment because the specific physical and biological features of marine habitat that are essential for the conservation of the GOM DPS (and the specific areas on which these features might be found) cannot be identified. Unlike Pacific salmonids, some of which use near-shore marine environments for juvenile feeding and growth, Atlantic salmon migrate through the near-shore marine areas quickly during the month of May and early June. We have limited knowledge of the physical and biological features that the species uses in the marine environment, however, we have very little information on the specifics of these physical and biological features and how they may require special management considerations or protection. Therefore, we cannot accurately identify the specific areas where these features exist or what types of management considerations or protections may be necessary to protect these physical and biological features during the migration period.

Detailed habitat surveys have been conducted in some areas within the range of the GOM DPS of Atlantic salmon, providing clear estimates of and distinctions between those sites most suited for spawning and incubation and those sites most used for juvenile rearing. These surveys are most complete for seven coastal watersheds: Dennys, East Machias, Machias, Pleasant, Narraguagus, Ducktrap, and Sheepscot watersheds; and portions of the Penobscot Basin, including portions of the East Branch Penobscot, portions of the Piscataquis and Mattawamkeag, Kenduskeag Stream, Marsh Stream and Cove Brook; and portions of the Kennebec Basin, including a portion of the lower mainstem around the site of the old Edwards Dam and portions of the Sandy River. Throughout most of the range of the GOM DPS, however, this level of survey has not been conducted, and, therefore, this level of detail is not available.

In order to determine habitat quantity for each HUC 10 we relied on a GIS based habitat prediction model (*See appendix C*). The model was developed using data from existing habitat surveys conducted in the Machias, Sheepscot, Dennys, Sandy, Piscataquis, Mattawamkeag, and Souadabscook Rivers. A combination of reach slope derived from contour and digital elevation model (DEM) datasets, cumulative drainage area, and physiographic province were used to predict the total amount of rearing habitat within a reach. These features help to reveal stream segments with gradients that would likely represent areas of riffles or fast moving water, habitat most frequently used for spawning and rearing of Atlantic salmon. The variables included in the model accurately predict the presence of rearing habitat approximately 75 percent of the time. We relied on the model to generate the habitat quantity present within each HUC 10 to provide consistent data across the entire DPS and on existing habitat surveys to validate the output of the model.

Although we have found the model to be nearly 75 percent accurate in predicting the presence of sites for spawning and rearing within specific areas, and we have an abundance of institutional knowledge on the physical and biological features that distinguish sites for spawning and sites for rearing, the model cannot be used to distinguish between sites for spawning and sites for rearing across the entire geographic range. This is because: (1) sites used for spawning are also used for rearing; and (2) the model is unable to identify substrate features most frequently used for spawning activity, but rather uses landscape features to identify where stream gradient conducive to both spawning and rearing activity exists. As such, we have chosen to group sites for spawning and sites for rearing into one PCE. Therefore, sites for spawning and sites for rearing are discussed together throughout this analysis as sites for spawning and rearing. In the section below, we identify the essential physical and biological features of spawning and rearing sites and migration sites found in the occupied areas described in the previous section.

(A). Physical and Biological Features of the Spawning and Rearing PCE

1. Deep, oxygenated pools and cover (e.g. boulders, woody debris, vegetation, etc.), near freshwater spawning sites, necessary to support adult migrants during the summer while they await spawning in the fall. Adult salmon can arrive at spawning grounds several months in advance of spawning activity. Adults that arrive early require holding

areas in freshwater and estuarine areas that provide shade, protection from predators, and protection from other environmental variables such as high flows, high temperatures, and sedimentation. Early migration is an adaptive trait that ensures adults sufficient time to reach spawning areas despite the occurrence of temporarily unfavorable conditions that occur naturally (Bjornn and Reiser, 1991). Salmon that return in early spring spend nearly 5 months in the river before spawning; often seeking cool water refuge (e.g., deep pools, springs, and mouths of smaller tributaries) during the summer months. Large boulders or rocks, over-hanging trees, logs, woody debris, submerged vegetation and undercut banks provide shade, reduce velocities needed for resting, and offer protection from predators (Giger, 1973). These features are essential to the conservation of the species to help ensure the survival and successful spawning of adult salmon.

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. Spawning activity in the Gulf of Maine DPS of Atlantic salmon typically occurs between mid-October and mid-November (Baum, 1997) and is believed to be triggered by a combination of water temperature and photoperiod (Bjornn and Reiser, 1991). Water quantity and quality, as well as substrate type, are important for successful Atlantic salmon spawning. Water quantity can determine habitat availability, and water quality may influence spawning success. Substrate often determines where spawning occurs, and cover can influence survival rates of both adults and newly hatched salmon.

Preferred spawning habitat contains gravel substrate with adequate water circulation to keep buried eggs well oxygenated (Peterson, 1978). Eggs in a redd are entirely dependent upon sub-surface movement of water to provide adequate oxygen for survival and growth (Decola, 1970). Water velocity and permeability of substrate allow for adequate transport of well-oxygenated water for egg respiration (Wickett, 1954) and removal of metabolic waste that may accumulate in the redd during egg development (Decola, 1970; Jordan and Beland, 1981). Substrate permeability as deep as the egg pit throughout the incubation period is important because eggs are typically deposited at the bottom of the egg pit.

Dissolved oxygen (DO) content is important for proper embryonic development and hatching. Embryos can survive when DO concentrations are below saturation levels, but their development is often subnormal due to delayed growth and maturation, performance, or delayed hatching (Doudoroff and Warren, 1965). In addition, embryos consume more oxygen (i.e., the metabolism of the embryo increases) when temperature increases (Decola, 1970). An increase in water temperature, however, decreases the amount of oxygen that the water can hold. During the embryonic stage when tissue and organs are developing and the demand for oxygen is quite high, embryos can only tolerate a narrow range of temperatures. These sites are essential for the conservation of the species because without them embryo development would not be successful.

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. The period of

emergence and the establishment of feeding territories is a critical period in the salmon life cycle since at this time mortality can be very high. When fry leave the redd, they emerge through the interstitial spaces in the gravel to reach the surface. When the interstitial spaces become embedded with fine organic material or fine sand, emergence can be significantly impeded or prevented. Newly emerged fry prefer shallow, low velocity, riffle habitat with a clean gravel substrate. Territories are quickly established by seeking out areas of low velocities that occur in eddies in front of or behind larger particles that are embedded in areas of higher velocities to maximize drift of prey sources (Armstrong *et al.*, 2002). Once a territory has been established, fry use a sit-and-wait strategy, feeding opportunistically on invertebrate drift. This strategy enables the fish to minimize energy expenditure while maximizing energy intake (Bachman, 1984). These sites are essential for the conservation of the species because without them fry emergence would not be successful.

4. Freshwater rearing sites with space to accommodate growth and survival of Atlantic salmon parr. When fry reach approximately 4 cm in length, the young salmon are termed parr (Danie *et al.*, 1984). The habitat in Maine rivers currently supports on average between five and ten large parr (age one or older) per 100 square meters of habitat, or one habitat unit (Elson, 1975; Baum, 1997). The amount of space available for juvenile salmon occupancy is a function of biotic and abiotic habitat features, including stream morphology, substrate, gradient, and cover; the availability and abundance of food; and the makeup of predators and competitors (Bjornn and Reiser, 1991). Further limiting the amount of space available to parr is their strong territorial instinct. Parr actively defend territories against other fish, including other parr, to maximize their opportunity to capture prey items. The size of the territory that a parr will defend is a function of the size and density of parr, food availability, the size and roughness of the substrate, and current velocity (Kalleberg, 1958; Grant *et al.*, 1998). The amount of space needed by an individual increases with age and size (Bjornn and Reiser, 1991). Cover, including undercut banks, overhanging trees and vegetation, diverse substrates and depths, and some types of aquatic vegetation, can make habitat suitable for occupancy (Bjornn and Reiser, 1991). Cover can provide a buffer against extreme temperatures; protection from predators; increased food abundance; and protection from environmental variables such as high flow events and sedimentation. These features are essential to the conservation of the species because without them, juvenile salmon would have limited areas for foraging and protection from predators.

5. Freshwater rearing sites with a combination of river, stream, and lake habitats that accommodate parr's ability to occupy many niches and maximize parr production. Parr prefer, but are not limited to, riffle habitat associated with diverse rough gravel substrate. The preference for these habitats by parr that use river and stream habitats supports a sit-and-wait feeding strategy intended to minimize energy expenditure while maximizing growth. Overall, large Atlantic salmon parr using river and stream habitats select for diverse substrates that predominately consist of boulder and cobble (Symons and Heland, 1978; Heggenes, 1990; Heggenes *et al.*, 1999).

Parr can also move great distances into or out of tributaries and mainstems to seek out habitat that is more conducive to growth and survival (McCormick *et al.*, 1998). This occurs most frequently as parr grow and they move from their natal spawning grounds to areas that have much rougher substrate, providing more suitable over-wintering habitat and more food organisms (McCormick *et al.*, 1998). In the fall, large parr that are likely to become smolts the following spring have been documented leaving summer rearing areas in some head-water tributaries and migrating downstream, though not necessarily entering the estuary or marine environment (McCormick *et al.*, 1998).

Though parr are typically stream dwellers, they also use pools within rivers and streams, dead-waters (sections of river or stream with very little to no gradient), and lakes within a river system as a secondary nursery area after emergence (Cunjak, 1996; Morantz *et al.*, 1987; Erkinaro *et al.*, 1998). It is known that parr will use pool habitats during periods of low water, most likely as refuge from high temperatures (McCormick *et al.*, 1998) and during the winter months to minimize energy expenditure and avoid areas that are prone to freezing or de-watering (Rimmer *et al.*, 1984). Salmon parr may also spend weeks or months in the estuary during the summer (Cunjak *et al.*, 1989, 1990; Power and Shooner, 1966). These areas are essential to the conservation of the species to ensure survival and species persistence when particular habitats become less suitable or unsuitable for survival during periods of extreme conditions such as extreme high temperatures, extreme low temperatures, and droughts.

6. <u>Freshwater rearing sites with cool, oxygenated water to support growth and survival of Atlantic salmon parr.</u> Atlantic salmon are cold water fish and have a thermal tolerance zone where activity and growth is optimal (Decola, 1970). Small parr and large parr have similar temperature tolerances (Elliott, 1991). Water temperature influences growth, survival, and behavior of juvenile Atlantic salmon. Juvenile salmon can be exposed to very warm temperatures (> 20^{o}C) in the summer and near freezing temperatures in the winter, and have evolved with a series of physiological and behavioral strategies that enables them to adapt to the wide range of thermal conditions that they may encounter. Parr's optimal temperature for feeding and growth ranges from 15^{o} to 19^{o}C (Decola, 1970). When water temperatures surpass 19^{o}C, feeding and behavioral activities are directed towards maintenance and survival. During the winter when temperatures approach freezing, parr reduce energy expenditures by spending less time defending territories, feeding less, and moving into slower velocity microhabitats (Cunjak, 1996). Oxygen consumption by parr is a function of temperature. As temperature increases, the demand for oxygen increases (Decola, 1970). Parr require highly oxygenated waters to support their active feeding strategy. Though salmon parr can tolerate oxygen levels below 6mg/l, both swimming activity and growth rates are restricted. These features are essential to the conservation of the species because high and low water temperatures and low oxygen concentrations can result in the cessation of feeding activities necessary for juvenile growth and survival and can result in direct mortality.

7. <u>Freshwater rearing sites with diverse food resources to support growth and survival of Atlantic salmon parr.</u> Atlantic salmon require sufficient energy to meet their basic metabolic needs for growth and reproduction (Spence *et al.*, 1996). Parr largely depend on invertebrate drift for foraging, and actively defend territories to assure adequate food resources needed for growth. Parr feed on larvae of mayflies, stoneflies, chironomids, caddisflies, blackflies, aquatic annelids, and mollusks, as well as numerous terrestrial

invertebrates that fall into the river (Scott and Crossman, 1973; Nislow *et al.*, 1999). As parr grow, they will occasionally eat small fishes, such as alewives, dace, or minnows (Baum, 1997).

Atlantic salmon attain energy from food sources that originate from both allochthonous (outside the stream) and autochthonous (within the stream) sources. What food is available to parr and how food is obtained is a function of a river's hydrology, geomorphology, biology, water quality, and connectivity (Annear *et al.*, 2004). The riparian zone is a fundamental component to both watershed and ecosystem function, as it provides critical physical and biological linkages between terrestrial and aquatic environments (Gregory *et al.*, 1991). Flooding of the riparian zone is an important mechanism needed to support the lateral transport of nutrients from the floodplain back to the river (Annear *et al.*, 2004). Lateral transport of nutrients and organic matter from the riparian zone to the river supports the growth of plant, plankton, and invertebrate communities. Stream invertebrates are the principle linkage between the primary producers and higher trophic levels, including salmon parr. These features are essential to the conservation of the species, as parr require these food items for growth and survival.

(B). Physical and Biological Features of the Migration PCE

1. Freshwater and estuary migratory sites free from physical and biological barriers that delay or prevent access of adult salmon seeking spawning grounds needed to support recovered populations. Adult Atlantic salmon returning to their natal rivers or streams require migration sites free from barriers that obstruct or delay passage to reach their spawning grounds at the proper time for effective spawning (Bjornn and Reiser, 1991). Physical and biological barriers within migration sites can prevent adult salmon from effectively spawning either by preventing access to spawning habitat or impairing a fish's ability to spawn effectively by delaying migration or impairing the health of the fish. Migration sites free from physical and biological barriers are essential to the conservation of the species because without them, adult Atlantic salmon would not be able to access spawning grounds needed for egg deposition and embryo development.

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, and vegetation) to serve as temporary holding and resting areas during upstream migration of adult salmon. Atlantic salmon may travel as far as 965 km upstream to spawn (New England Fisheries Management Council, 1998). During migration, adult salmon require holding and resting areas that provide the necessary cover, temperature, flow, and water quality conditions needed to survive. Holding areas can include areas in rivers and streams, lakes, ponds, and even the ocean (Bjornn and Reiser, 1991). Holding areas are necessary below temporary seasonal migration barriers such as those created by flow, temperature, turbidity, and temporary obstructions such as debris jams and beaver dams, and adjacent to spawning areas. Adult salmon can become fatigued when ascending high velocity riffles or falls and require resting areas within and around high velocity waters where they can recover until they are able to continue their migration. Holding areas near spawning areas are necessary when upstream migration is not delayed and adults reach

spawning areas before they are ready to spawn. These features are essential to the conservation of the species because without them, adult Atlantic salmon would be subject to fatigue, predation, and mortality from exposure to unfavorable conditions, significantly reducing spawning success.

3. Freshwater and estuary migration sites with abundant, diverse native fish communities to serve as a protective buffer against predation. Adult Atlantic salmon and Atlantic salmon smolts interact with other diadromous species indirectly. Adult and smolt migration through the estuary often coincides with the presence of alewives (*Alosa* spp.), American shad (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*), and striped bass (*Morone saxatilis*). The abundance of diadromous species present during adult migration may serve as an alternative prey source for seals, porpoises and otters (Saunders *et al.*, 2006). As an example, pre-spawned adult enter rivers and begin their upstream spawning migration at approximately the same time as early migrating adult salmon (Fay *et al.*, 2006). Historically, shad runs were considerably larger than salmon runs (Atkins and Foster, 1869; Stevenson, 1898). Thus, native predators of medium to large size fish in the estuarine and lower river zones could have preyed on these 1.5 to 2.5 kg size fish readily (Fay *et al.*, 2006; Saunders *et al.*, 2006). In the absence or reduced abundance of these diadromous fish communities, it would be expected that Atlantic salmon will likely become increasingly targeted as forage by large predators (Saunders *et al.*, 2006).
As Atlantic salmon smolts pass through the estuary during migration from their freshwater rearing sites to the marine environment, they experience high levels of predation. Predation rates through the estuary often result in up to 50 percent mortality during this transition period between freshwater to the marine environment (Larsson, 1985). There is, however, large annual variation in estuarine mortality, which is believed to be dependent upon the abundance and availability of other prey items including alewives, blueback herring, and American shad, as well as the spatial and temporal distribution and abundance of predators (Anthony, 1994).

The presence and absence of co-evolutionary diadromous species such as alewives, blueback herring, and American shad likely play an important role in mitigating the magnitude of predation on smolts from predators such as striped bass, double-crested cormorants (*Phalacrocorax auritus*), and osprey (*Pandion haliaetus*). The migration time of pre-spawned adult alewives overlaps in time and space with the migration of Atlantic salmon smolts (Saunders *et al.*, 2006). Given that when alewife populations were robust, alewife numbers not only likely greatly exceed densities of Atlantic salmon smolts, making them more available to predators, but the caloric content per individual alewife is greater than that of an Atlantic salmon smolt (Schulze, 1996), likely making the alewife a more desirable prey species (Saunders *et al.*, 2006). These features are essential to the conservation of the species because without highly prolific abundant alternate prey species such as alewives and shad, the less prolific Atlantic salmon will likely become a preferred prey species.

4. Freshwater and estuary migration sites free from physical and biological barriers that delay or prevent emigration of smolts to the marine environment. Atlantic salmon smolts require an open migration corridor from their juvenile rearing habitat to the marine environment. Seaward migration of smolts is initiated by increases in river flow and

temperature in the early spring (McCleave, 1978; Thorpe and Morgan, 1978). Migration through the estuary is believed to be the most challenging period for smolts (Lacroix and McCurdy, 1996). Although it is difficult to generalize migration trends because of the variety of estuaries, Atlantic salmon post-smolts tend to move quickly through the estuary and enter the ocean within a few days or less (Lacroix *et al.*, 2004; Hyvarinen *et al.*, 2006; McCleave, 1978). In the upper estuary, where river flow is strong, Atlantic salmon smolts use passive drift to travel (Moore *et al.*, 1995; Fried *et al.*, 1978; LaBar *et al.*, 1978). In the lower estuary smolts display active swimming, although their movement is influenced by currents and tides (Lacroix and McCurdy 1996; Moore *et al.*, 1995; Holm *et al.*, 1982; Fried *et al.*, 1978). In addition, although some individuals seem to utilize a period of saltwater acclimation, some fish have no apparent period of acclimation (Lacroix *et al.*, 2004). Stefansson *et al.*, (2003) found that post-smolts adapt to seawater without any long-term physiological impairment. Several studies also suggest that there is a "survival window" which is open for several weeks in the spring, and gradually closes through the summer, during which time salmon can migrate more successfully (Larsson, 1977; Hansen and Jonsson, 1989; Hansen and Quinn, 1998). These features are essential to the conservation of the species because a delay in migration of smolts can result in the loss of the smolts' ability to osmoregulate in the marine environment which is necessary for smolt survival.

5. <u>Freshwater and estuary migration sites with sufficiently cool water temperatures and water flows that coincide with diurnal cues to stimulate smolt migration.</u> The process of smoltification is triggered in response to environmental cues. Photoperiod and temperature have the greatest influence on regulating the smolting process. Increase in day length is necessary for smolting to occur (Duston and Saunders, 1990). McCormick *et al.*, (1999) noted that in spite of wide temperature variations among rivers throughout New England, almost all smolt migrations begin around the first of May and are nearly complete by the first week in June. However, the time that it takes for the smoltification process to be completed appears to be closely related to water temperature. When water temperatures increase, the smolting process is advanced, evident by increases in Na+, K+ -ATPase activity - the rate of exchange of sodium (Na+) and potassium (K+) ions across the gill membrane or the regulation of salts that allow smolts to survive in the marine environment (Johnston and Saunders, 1981; McCormick *et al.*, 1998; McCormick *et al.*, 2002). In addition to playing a role in regulating the smoltification process, high temperatures also are responsible for the cessation of Na+, K+-ATPase activity of smolts limiting their ability to excrete excess salts when they enter the marine environment. McCormick *et al.*, (1999) found significant decreases in Na+, K+-ATPase activity in smolts at the end of the migration period, but also found that smolts in warmer rivers had reductions in Na+, K+-ATPase activity earlier then smolts found in colder rivers. Hence any delay of migration has the potential to reduce survival of out-migrating smolts because as water temperatures rise over the spring migration period, smolts experience a reduction in Na+, K+-ATPase reducing their ability to regulate salts as they enter the marine environment. Though flow does not appear to play a role in the smoltification process, flow does appear to play an important role in stimulating a migration response (Whalen *et al.*, 1999b). These features are essential to the conservation of the species because elevated water temperatures that occur in advance of a smolts diurnal cues to migrate can result in a decreased migration window in which smolts are capable of

transitioning into the marine environment. A decrease in the migration window has the potential to reduce survival of smolts especially for fish with greater migration distances.

6. Freshwater migration sites with water chemistry needed to support sea water adaptation of smolts. The effects of acidity on Atlantic salmon have been well documented. The effects of acidity cause ionoregulatory failure in Atlantic salmon smolts while in freshwater (Rosseland and Skogheim, 1984; Farmer *et al.*, 1989; Staurnes *et al.*, 1996; Staurnes *et al.*, 1993). This inhibition of gill Na+, K+-ATPase activity can cause the loss of plasma ions and may result in reduced seawater tolerance (Rosseland and Skogheim, 1984; Farmer *et al.*, 1989; Staurnes *et al.*, 1996; Staurnes *et al.*, 1993) and increased cardiovascular disturbances (Milligan and Wood, 1982; Brodeur *et al.*, 1999). Parr undergoing parr/smolt transformation become more sensitive to acidic water, hence water chemistry that is not normally regarded as toxic to other salmonids may be toxic to smolts (Staurnes *et al.*, 1993, 1995). This is true even in rivers that are not chronically acidic and not normally considered as being in danger of acidification (Staurnes *et al.*, 1993, 1995). Atlantic salmon smolts are most vulnerable to low pH in combination with elevated levels of monomeric labile species of aluminum (aluminum capable of being absorbed across the gill membrane) and low calcium (Rosseland and Skogheim, 1984; Rosseland *et al.*, 1990; Kroglund and Staurnes, 1999). These features are essential to the conservation of the species because Atlantic salmon smolts exposed to acidic waters can lose sea water tolerance, which can result in direct mortality or indirect mortality from altered behavior and fitness.

(C). Physical and biological features of marine sites and "Specific Areas" within the geographic range occupied by the species

The specific physical and biological features of marine habitat that are essential for the conservation of the GOM DPS cannot be identified and the specific areas in the marine environment containing physical and biological features likewise cannot be identified. Unlike Pacific salmonids, of which some species utilize nearshore marine environments for juvenile feeding and growth, Atlantic salmon migrate through the nearshore marine areas quickly during the month of May and early June. Though we have some limited knowledge of the physical and biological features that the species utilize in the marine environment, we have very little information on the specifics of these physical and biological features. Therefore, we cannot accurately identify the specific areas where these features exist or what types of management considerations or protections may be necessary to protect these physical and biological features during the migration period.

1.5 Identify special management considerations and protections

Specific areas within the geographic area occupied by a species may be designated as critical habitat only if they contain physical or biological features that "may require special management considerations or protections." It is the features and not the specific areas that are the focus of the "may require" provision. Use of the disjunctive "or" also suggests the need to give distinct meaning to the terms "special management considerations" and "protection". "Protection" suggests actions to address a negative impact. "Management" seems broader than protection, and could include active manipulation of the feature or aspects of the environment. The ESA regulations at 50

CFR 424.02(j) further define special management considerations as "any methods or procedures useful in protecting physical and biological features of the environment for the conservation of listed species". The term "may" was the focus of two Federal district courts that ruled that features can meet this provision on either present requirement for special management considerations or protections or on possible future requirements. *See Center for Biol. Diversity v. Norton,* 240 F. Supp. 2d 1090 (D. Ariz. 2003); *Cape Hatteras Access Preservation Alliance v. DOI*, 344 F. Supp. 108 (D.D.C. 2004). The Arizona district court ruled that the provision cannot be interpreted to mean that features already covered by an existing management plan must be determined to require additional special management, because the term additional is not in the statute. Rather, the court ruled that the existence of management plans may be evidence that the features in fact require special management. *Center for Biol. Diversity v. Norton*, 1096 – 1100.

The primary impacts of critical habitat designation result from the consultation requirements of ESA section 7(a)(2). Federal agencies must consult with NMFS to ensure that their actions are not likely to result in the destruction or adverse modification of critical habitat (or jeopardize the species' continued existence). These impacts are attributed only to the designation (i.e., are incremental impacts of the designation) if Federal agencies modify their proposed actions to ensure they are not likely to destroy or adversely modify the critical habitat beyond any modifications they would make because of listing and the jeopardy requirement. Incremental impacts of designation include state and local protections that may be triggered as a result of designation, and education of the public about to the importance of an area for species conservation. When a modification is required due to impacts both to the species and critical habitat, the impact of the designation is considered to be co-extensive with ESA listing of the species.

The ESA 4(b)(2) Report (NMFS, 2009) and Economic Analysis (IEc, 2009) describe the impacts in detail. These reports identify and describe potential future Federal activities that would trigger section 7 consultation requirements because they may affect the physical and biological features.

We identified a number of activities and associated threats that may affect the PCEs and associated physical and biological features essential to the conservation of Atlantic salmon within the occupied range of the GOM DPS. These activities, which include agriculture, forestry, changing land-use and development, hatcheries and stocking, roads and road crossings, mining, dams, dredging and aquaculture have the potential to reduce the quality and quantity of the PCEs and their associated physical and biological features. There are other threats to Atlantic salmon habitat including acidification and global climate change. However, we are not able to clearly separate out the specific activities responsible for acidification or global climate change, and therefore are unable to specifically identify a federal nexus. The activities are evaluated below based on whether the spawning and rearing PCE and/or the migration PCE may require special management considerations or protection. Specific areas where these activities occur are represented in a table following the evaluation of activities. Further evaluation of the activities listed below is presented in detail in section 5 of Kircheis and Liebich (2007).

1.5.1 Specific activities that may effect physical and biological features

<u>*Agriculture*</u>

Agricultural practices influence all specific areas proposed for designation and negatively impact PCE sites for spawning and rearing and migration. Physical disturbances caused by livestock and equipment associated with agricultural practices can directly impact the habitat of aquatic species (USEPA, 2003). Traditional agricultural practices require repeated mechanical mixing, aeration and application of fertilizers and pesticides to soils. These activities alter physical soil characteristics and microorganisms. Tilling aerates the upper soil, but causes compaction of finely textured soils below the surface, which alters water infiltration. Use of heavy farm equipment and construction of roads also compact soils, decrease water infiltration, and increase surface runoff (Spence *et al.*, 1996). Agricultural grazing and clearing of riparian vegetation can expose soils and increase soil erosion and sediment inputs into rivers.

Agricultural practices may also reduce habitat complexity and channel stability through physical stream alterations such as: channelization, bank armoring, and removal of large woody debris (LWD) and riparian vegetation (Spence *et al.*, 1996). These effects often result in streams with higher width to depth ratios which exhibit more rapid temperature fluctuations and may also be subject to increased embeddedness as function of decreased water velocity affecting habitat use in sites for spawning, juvenile rearing and migration (Fay *et al.*, 2006).

Clearing of land for agricultural practices such as livestock grazing and crop cultivation typically loosens and smoothes land surfaces increasing soil mobility and vulnerability to surface erosion thereby increasing sedimentation rates in affected streams (Waters, 1995; Spence *et al.*, 1996). Increased sedimentation can have significant effects on Atlantic salmon habitat by embedding substrates and increasing turbidity in spawning and rearing sites. Increased turbidity can reduce light penetration and result in a reduction of aquatic plant communities used for cover and foraging in juvenile rearing sites. Sedimentation from agricultural practices can also increase the inputs of nutrients such as phosphorus and ammonia as well as contaminants such as pesticides and herbicides throughout a watershed. An increase in nutrients can lead to eutrophication and potential oxygen depletion in surface waters. Exposure of contaminated sediments to anaerobic environments (lacking oxygen) often results in the release of organically bound chemicals (USEPA, 2003), possibly creating a toxic environment for biotic communities downstream of these agricultural areas.

Agricultural practices can affect stream hydrology through removal of vegetative cover, soil compaction, and irrigation. Removal of vegetation and soil compaction can increase runoff which can increase the frequency and intensity of flooding (Hornbeck *et al.*, 1970). Increases in frequency and intensity of flood events can increase erosion, increase sedimentation and scour affecting sites for spawning and rearing. Direct water withdrawals and ground-water withdrawals for crop irrigation can directly impact Atlantic salmon habitat by depleting stream-flow (MASTF, 1997; Dudley and Stewart, 2006; Fay *et al.*, 2006). Currently, the cumulative effects of individual irrigation impacts on Maine rivers is poorly understood, however, it is known that adequate water supply and quality is essential to all life stages of Atlantic salmon and life history behaviors including adult migration, spawning, fry emergence and smolt emigration (Fay *et al.*, 2006).

Fertilizer runoff can increase nutrient loading in aquatic systems, thereby stimulating the growth of aquatic algae. If nutrient loading due to fertilizer run-off is significant, resulting algal blooms may have numerous detrimental impacts on multiple processes occurring within the affected aquatic ecosystem. Surface algal blooms that block sunlight can kill submerged aquatic vegetation important for juvenile rearing. Loss of submerged vegetation can lead to a loss of habitat for invertebrates and juveniles fishes and the decomposition of dead algae consumes large quantities of oxygen, an impact which, at times, can result in significant oxygen depletion (NMFS and FWS, 2005). A reduction in submerged aquatic vegetation and dissolved oxygen (DO) can cause both direct and indirect harm to salmon by affecting not only the physiological function of salmon (e.g., oxygen deprivation) but by impacting prey species and other necessary ecological functions sites for rearing. We conclude that the spawning and rearing and migration PCEs in each HUC 10 are, and will likely continue to be negatively affected by agricultural practices well into the future, and therefore may require special management or protections which may include increasing the riparian buffer between agriculture lands and aquatic ecosystems that contain salmon habitat to prevent erosion and the runoff or leaching of contaminants and nutrients.

<u>Forestry</u>

Forestry practices influence all specific areas proposed for designation and negatively impact PCE sites for spawning and rearing and migration. Timber harvest can significantly affect hydrologic processes. In general, timber removal increases the amount of water that infiltrates the soil and reaches the stream by reducing water losses from evapotranspiration (Spence *et al.*, 1996). Soil compaction can decrease infiltration and increase runoff, and roads created for logging can divert and alter water flow. Logging can also influence snow distribution on the ground, and consequently alter the melting rates of the snowpack (Chamberlin *et al.*, 1991). Through a combination of these effects, logging can change annual water yield and the magnitude and timing of peak and low flows (Spence *et al.*, 1996). Alteration of hydrologic regimes may impact sites for spawning, migration and rearing.

The increased erosion and runoff caused by forestry practices and road building can increase sedimentation affecting sites for spawning and rearing and may impact migration. Compared to other forestry activities, roads are the greatest contributor of sediment on a per area basis (Furniss *et al.*, 1991). Contribution of sediments by roads most frequently occurs from mass failure of road beds (Furniss *et al.*, 1991). Other forestry practices generally cause surface erosion, creating chronic sediment inputs. The combined effect of chronic and mass erosion can cause elevated sediment levels even when a small percentage of a watershed is developed by roads (Montgomery and Buffington, 1993), which can embed cobble, gravel substrates used for spawning and juvenile rearing.

The most direct effect of logging on stream temperature is the reduction in shade provided by riparian vegetation. Alterations in water temperature can affect egg development and alter foraging behaviors of juvenile salmon in both spawning and rearing sites. Removal of riparian vegetation also affects evaporation, convection and advection by altering wind speed and the temperature of surrounding land areas (Beschta *et al.*, 1987, 1995). In general, greater effects on stream temperatures are more apparent in smaller streams; however, the magnitude of these effects is dependent on stream size and channel morphology in relation to the quantity of riparian vegetation harvested (Beschta *et al.*, 1995). Removal of riparian vegetation can also lead to increased maximum temperatures and increased daily fluctuations in stream temperatures (Beschta *et al.*, 1987, 1995).

Timber harvest and preparation of soil for forestry practices can decrease LWD as well as increase erosion. Removal of LWD and increased erosion can have many harmful effects in sites for rearing, spawning and migration by reducing channel complexity, reducing in-stream cover and riffle/pool frequency, decreasing sediment retention and channel stability and reducing availability of microhabitats (Spence *et al.*, 1996). Loss of riparian vegetation can also reduce the presence of overhanging banks that are frequently used for cover by salmon (Spence *et al.*, 1996). A 30 meter buffer has been identified as what is generally required to maintain or restore optimal habitat in fish-bearing streams (Murphy, 1995) and necessary to protect invertebrate communities (Erman and Mahoney, 1983) that salmon require for forage. Murphy (1995) further states that narrower buffers or selective harvest within the buffers may not provide for maintenance of large woody debris contributions into the stream over the long term. We conclude that the spawning and rearing and migration PCEs in each specific area are, and will likely continue to be negatively effected by forestry practices, and therefore may require special management considerations or protections which may include the use of best management practices that reduce erosion, support contributions of LWD, and limit thermal impacts.

Changing land-use and development

Changing land-use and development affects all specific areas proposed for designation and negatively impact PCE sites for spawning and rearing and migration. Changing land-use patterns include a shift from forestry and agriculture to construction of housing, commercial shopping and business centers, and industrial facilities. Increased development and population growth can cause declines in water and habitat quality caused by increases in erosion, reduction of riparian vegetation, increases in sediment deposition, homogenizing of habitat features, and an overall reduction in water quality resulting from point and non-point source pollution.

Development can affect sites for spawning, rearing and migration by reducing soil infiltration rates and increasing erosion. Construction of impervious surfaces can indirectly influence habitat by increasing surface water runoff while concurrently reducing groundwater recharge. Surface runoff from developed areas can increase erosion rates, carry pollutants from developed areas, and increase flooding (Morse and Kahl, 2003), whereas a reduction in groundwater recharge can lead to reduced summer baseflows, potentially reducing available aquatic habitat (Morse and Kahl, 2003).

Development practices can redirect, channelize, and/or armor stream banks to accommodate and protect the development. Certain development practices can clear riparian areas decreasing shade and altering thermal regimes and nutrient inputs. These practices can also remove vegetation that would otherwise intercept rainfall and therefore reduce runoff. As more water is carried downstream during rain events or when stream channels are altered, the result can be an increase in streambed widening or scouring. Streambed widening or scouring can directly reduce the quality and quantity of habitat available to Atlantic salmon. Development can lead to alterations in physical habitat within sites for spawning, rearing and migration in rivers. Therefore, we conclude that the spawning and rearing and migration PCEs in each HUC 10 are, and will likely continue to be negatively effected by changing land-use and development into the future, and therefore may require special management considerations or protections which may include improvements in the handling of waste water discharge to limit inputs of contaminants and assuring sufficient riparian buffers between development sites and aquatic ecosystems that support salmon habitats.

Maine's population is expected to grow at a rate of approximately 0.5% per year over the 2004 to 2020 period, and this projected growth rate is consistent with the growth rate over the 1990 to 2004 period (Maine State Planning Office, 2005). Most population growth in the state of Maine is expected to be centered around southern and central coastal counties, while northern counties and counties that border Canada are expected to have slower growth rates (Kennebec, Franklin, Somerset, Androscoggin, and Penobscot) or even negative growth rates (Washington, Piscataquis, and Aroostook) (Table 1.5.1)

Table 1.5.1a: Population growth and growth projections by county for Maine

County	Growth 1990 – 2004	Forecast Growth 2004-2020
York	1.4%	1.2%
Waldo	1.1%	1.0%
Lincoln	1.0%	0.9%
Hancock	0.9%	0.7%
Knox	0.8%	0.6%
Cumberland	0.8%	0.6%
Sagadahoc	0.7%	0.9%
Oxford	0.5%	0.4%
Kennebec	0.3%	0.3%
Somerset	0.2%	0.2%
Franklin	0.1%	0.0%
Androscoggin	0.1%	0.2%
Penobscot	0.1%	0.2%
Washington	-0.4%	-0.5%
Piscataquis	-0.5%	-0.2%
Aroostook	-1.2%	-1.3%

Maine's younger population, as well as those that move to Maine, are now choosing to live in more urban environments that provide access to public resources, particularly access to higher education, and have greater opportunity for employment (Benson and

Sherwood, 2004). According to the Maine State Planning Office, the fastest growing towns in Maine are new suburbs that are within 16 to 40 km from four metropolitan areas in the State of Maine (*i.e.* Bangor, Waterville, Lewiston-Auburn, and Augusta) centered in Penobscot, Androscoggin, and Kennebec Counties (O'Hara and Benson, 1997; Benson and Sherwood, 2004) (*see* Figure 1.5.1).

Hatcheries and stocking

Hatcheries and stocking occurs in all specific areas proposed for designation and can negatively affect PCE sites for spawning and rearing. Use of hatcheries may be essential to rebuild Atlantic salmon populations; however, without proper adherence to genetic, evolutionary, and ecological principles, the use of hatcheries could have adverse consequences for naturally reproducing fish that may undermine other rehabilitation efforts. Stocking of Atlantic salmon that are river specific, non-river specific, or a combination of both, is taking place in many DPS rivers, and supportive breeding through adult stocking of captive-reared brood stock is also occurring in small numbers in most DPS rivers (NRC, 2004). Smallmouth bass and chain pickerel, important non-native predators to juvenile salmon, have also been introduced throughout a significant portion of the DPS and are important non-native predators of juvenile salmon (Fay *et al.,* 2006). These species, along with a host of other native and non-native fish, may compete for food and space with Atlantic salmon in freshwater, affecting sites for juvenile rearing and spawning. We conclude that the spawning and rearing PCEs in each specific area are, and will likely continue to be negatively affected by hatcheries and stocking, and therefore may require special management considerations or protections. Management considerations or protection may include efforts that employ genetic and stock management of Atlantic salmon such that stocked fish do not present a genetic or competitive risk to natural populations, and stocking of other species that do not introduce threats of predation, competition, genetics or disease.

Roads and road crossings

Roads and road crossings occur in all specific areas proposed for designation negatively affect sites for spawning and rearing, and sites for migration. Roads, which are typically built in association with logging, agriculture, and development, are often negatively correlated with the ecological health of an area (Trombulak and Frissell, 2000). Road networks modify the hydrologic and sediment transport regimes of watersheds by accelerating erosion and sediment loading, altering channel morphology and accelerating runoff (Furniss *et al.*, 1991) which can effect sites for spawning and rearing. The construction of roads near streams can prevent natural channel adjustments, and urban roads may increase runoff of pollutants (Spence *et al.*, 1996).

The use of culverts and bridges can impair habitat connectivity limiting accessibility of habitat to juvenile and adult salmon, as well as other fish and aquatic organisms (Furniss *et al.*, 1991). Culverts, if not properly installed or maintained, can partition a watershed and make reaches inaccessible to migratory fish while simultaneously preventing upstream movement of resident fish and invertebrates. Conditions induced by culverts that block fish passage include high water velocities through the culvert over extended distances without adequate resting areas; water depth within the culvert that is too shallow for fish to swim; and culverts that are perched or hanging and exclude fish from entering the culvert (Furniss *et al.*, 1991). Bridges, while preferred to culverts (Furniss *et al.*, 1991), may also induce negative ecological impacts. Poorly designed bridges, like culverts, can alter sediment transport, natural alluvial adjustments, and downstream transport of organic material, particularly large woody debris. This alteration can affect sites for spawning, rearing and migration.

We conclude that the migration PCE and the spawning and rearing PCE in each specific area are, and will likely continue to be negatively affected by roads and road crossings into the future, and therefore may require special management considerations or protection that may include applying best management practices that reduce sedimentation and pollution, and allow for unobstructed passage of juvenile and adult Atlantic salmon at road crossings.

Mining

Sand, gravel, cement, and some varieties of stone (e.g., slate and granite) and clay are mined extensively throughout Maine and can negatively affect PCE sites predominately those for spawning and rearing. Mining is known to occur within 36 specific areas proposed for designation. Mining of these materials in Maine occurs to the extent that Maine is largely self-sufficient with respect to these commodities (Lepage *et al.,* 1991). Sand and gravel mining can occur in the form of gravel pits and in some cases can involve dredging of streambeds. Sand and gravel mining in or adjacent to streams can affect sites for spawning and rearing by increasing fine and course particle deposition and elevating turbidity from suspended sediments (Waters, 1995).

We conclude that the spawning and rearing PCE are, and will likely continue to be affected by sand and gravel mining into the future, and therefore may require special management or protections through increased riparian buffers that protect streams from sedimentation. Direct mining of gravel from streambeds does not currently occur in any of the specific areas, though such mining has been proposed in the past and may be proposed in the future. Therefore, spawning and rearing sites affected by streambed mining may require special management or protections, which may include preclusion of streambed mining operations.

Maine's crystalline rocks are potential hosts to an array of metals including copper, zinc, lead, nickel, molybdenum, tin, tungsten, cobalt, beryllium, uranium, manganese, iron, gold and silver (Lepage *et al.,* 1991) and mining of these metals can negatively affect sites for spawning and rearing and sites for migration. Many metals occur naturally in rivers and streams and in trace concentrations are considered essential for proper physiological development of fish (Nelson *et al.,* 1991). The process of mining for metals can introduce toxic metals into streams as acid stimulation mobilizes metal ions from metalliferous minerals (Nelson *et al.,* 1991) and therefore may alter water chemistry in sites for spawning, rearing and migration. The most frequent metals that are released into streams and may be toxic to salmon depending on their concentration include arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, and zinc (Nelson *et al.,* 1991). Dissolved copper is known to affect a variety of biological endpoints in fish (e.g., survival, growth, behavior, osmoregulation, sensory system, and others (reviewed in Eisler, 1998)). Laboratory exposure of 2.4 micrograms/L dissolved copper in water with hardness 20mg/L resulted in avoidance behavior by juvenile Atlantic salmon and 20 micrograms/L dissolved copper in water with a hardness of 20mg/L resulted in interrupted spawning migrations in the wild (Sprague *et al.,* 1965). A combined effect of copper-zinc may result in a complete block of migration at 0.8 toxic units (Sprague *et al.,* 1965). Currently metal mining does not occur within any of the specific areas, though recent mining exploration within the state suggests that metal mining may occur in the future. We conclude that spawning and rearing and migration PCEs in each specific area may, in the future, be negatively affected and therefore may require special management considerations or protections, possibly through implementation of best management practices (BMPs) that protect rivers and streams from pollutants.

There are only two active, though limited, peat mining operations in Maine, both of which are located in Washington County (USGS, 2006) located in the Narraguagus River HUC 10 (HUC code 105000209). Although there is currently no direct evidence that peat mining in other countries (i.e. Ireland, Norway) has affected Atlantic salmon, studies have shown that peat mining can affect water quality, wetlands, aquatic resources and sediment load (MASTF, 1997). One potential effect of peat mining on Atlantic salmon habitat is from runoff that may have historically exacerbated depressed pH in DPS rivers (NMFS and FWS, 1999). Low pH levels are known to impair smolt migrations as they transfer from the freshwater environment to the marine environment (Staurnes *et al.,* 1995; Brodeur *et al.,* 2001). We conclude that peat mining may negatively affect PCE sites in the Narraguagus River HUC 10, particularly for migration, as depressed pH levels are known to adversely affect migration smolts, and therefore may require special management considerations or protections through measures that protect rivers and streams from acid discharge of waste water or runoff.

Dams

Dams occur in 40 specific areas proposed for critical habitat designation and negatively affect sites for spawning and rearing and sites for migration PCEs. Dams obstruct migration of Atlantic salmon which can delay or preclude adult salmon access to spawning sites and smolts from access to the marine environment. Dams also preclude or diminish access of co-evolutionary diadromous fish communities that likely serve as buffers from predators of migrating salmon (Saunders *et al.,* 2006). Dams can also degrade spawning and rearing sites through alterations of natural hydrologic, geomorphic and thermal regimes (American Rivers *et al.,* 1999; Heinz Center, 2002; NRC, 2004; Fay, *et al.,* 2006). Dams are also the most significant contributing factor to the loss of salmon habitat connectivity within the range of the DPS (Fay *et al.,* 2006) and have been identified as the greatest impediment to self-sustaining Atlantic salmon populations in Maine (NRC, 2004). We conclude that the migration and spawning and rearing PCEs are, and will likely continue to be negatively effected by dams into the future, and therefore may require special management considerations or protection through dam removal or improved fish passage devices.

Dredging

Dredging frequently occurs within bays and estuaries along the coast of Maine and can negatively effect the migration PCEs. Dredging may occur within 25 specific areas proposed for designation in the GOM DPS and is often a temporary activity that occurs over a period of a few weeks to a few years depending on the size of the dredging project. Dredging is the practice of removing sediment from an aquatic system and commonly occurs in freshwater, estuarine, and marine environments. Nightingale and Simenstad (2001a) place dredging practices into one of two categories: the creation of new projects and waterway deepening, or maintenance dredging for the purpose of preserving already existing channels. New construction dredging is outlined by Nightingale and Simenstad (2001a) as "any modification that expands the character, scope, or size of an existing, authorized project". By contrast maintenance dredging is the periodic re-dredging of already existing sites and/or channels. Nightingale and Simenstad (2001a) list some examples of why dredging might be used and include activities such as maintaining water depths, creating or expanding marinas, mining gravel or sand for shoreline armoring, opening channels for passage of flood flows, retrieving cement mixture ingredients, and removing contaminated sediments.

Dredging can cause a range of negative impacts to water quality in the affected area, particularly in sites for migration where dredging is most likely to occur. Of greatest concern is the associated temporary increase in the water's turbidity (the measure of suspended solids in the water column). Increased turbidity can have adverse effects upon the impacted area's fish community that include a range of impacts from difficulty absorbing oxygen from the water, altered feeding behavior, and changes in predator-prey relationships (Nightingale and Simenstad, 2001a). In addition, increased turbidity causes reductions in the light's ability to penetrate the water column. Light penetration plays a central role in the level of productivity of aquatic environments, predator/prey relationships, schooling behavior, and fish migration (Nightingale and Simenstad, 2001a).

Juvenile salmonids migrating through and residing in estuaries are naturally capable of coping with high levels of turbidity; however, suspended solids introduced via dredging can produce material that is of the right size and shape to adversely affect the young salmon by inhibiting their ability to diffuse oxygen through their gills (Nightingale and Simenstad, 2001a). According to Nightingale and Simenstad (2001b), suspended solids in concentrations of ≥4000 mg/L, have been shown to cause erosion to the terminal ends of fish gills. In addition to impacting juvenile salmon, suspended solids at levels of 20 mg/L and 10 mg/L have been shown to result in avoidance behaviors from rainbow smelt, and Atlantic herring, respectively (Wildish and Power, 1985). We conclude that the migration PCE is, and will likely continue to be negatively affected by dredging into the future, and therefore may require special management considerations or protections which may include time of year restrictions and employment of sediment control measures.

Aquaculture

Aquaculture occurs in four specific areas proposed for designation within the GOM DPS and can negatively affect PCE sites for spawning and rearing, and migration. The influence of aquaculture on Atlantic salmon is most frequently related to the interactions between wild fish and fish that have escaped from aquaculture facilities. Most escapes of farm salmon occur in the marine environment and involve smolts, post-smolts and adults.

Escaped farmed salmon generally migrate up the nearest rivers. Large escapes of aquaculture fish have occurred in Maine and Canada and escaped farm salmon are known to return to Maine rivers. Escapes have been caused by storms, cage failure, anchor failure, human error, vandalism, and predator attacks (e.g., seals; NMFS/FWS, 2005). Although there is little direct information about the effects of net-pen salmon aquaculture on wild Maine salmon (NRC, 2004), potentially harmful interactions between wild and farmed salmon can be divided into ecological and genetic interactions. Ecological interactions can occur in sites for migration, resulting in alterations in disease transmission and changes to competition and predation pressures, whereas genetic interactions occur in spawning sites, which can modify the timing of important life history events and thereby alter selection pressures and fitness. These interactions are not mutually exclusive, and the effects of each may compound and influence the effects of the other. We conclude that the spawning and rearing PCE and the migration PCE in each effected HUC 10, will, and will likely continue to be negatively affected by aquaculture into the future, and therefore may require special management considerations or protections which may include better containment of aquaculture fish to prevent escapement and enhanced disease and parasite control procedures.

Table 1.5.1b: Specific areas within the geographic area occupied by a species and the associated special management considerations or protections that may be required

HUC Code	Watershed Name	Special Management Considerations*								
105000205	Machias River	A	F	C/L	H/S	R		Da	Dr	
105000204	East Machias River	A	F	C/L	H/S	R	M	Da	Dr	
105000208	Pleasant River	A	F	C/L	H/S	R	M	Da	Dr	
105000201	Dennys River	A	F	C/L	H/S	R	M	Da	Dr	
105000207	Chandler River	A	F	C/L	H/S	R	M	Da	Dr	
105000209	Narraguagus River	A	F	C/L	H/S	R	M	Da	Dr	
105000213	Union River Bay	A	F	C/L	H/S	R	M	Da	Dr	Q
105000203	Grand Manan Channel	A	F	C/L	H/S	R	M	Da	Dr	Q
105000206	Roque Bluffs Coastal	A	F	C/L	H/S	R	M	Da	Dr	
105000210	Tunk Stream	A	F	C/L	H/S	R		Da	Dr	
105000212	Graham Lake	A	F	C/L	H/S	R	M	Da		
102000202	Grand Lake Matagamon	A	F	C/L	H/S	R		Da		
102000203	East Branch Penobscot River	A	F	C/L	H/S	R				
102000204	Seboeis River	A	F	C/L	H/S	R		Da		
102000205	East Branch Penobscot River	A	F	C/L	H/S	R		Da		
102000301	West Branch Mattawamkeag River	A	F	C/L	H/S	R	M	Da		
102000302	East Branch Mattawamkeag River	A	F	C/L	H/S	R	M			

102000303	Mattawamkeag River	A	F	C/L	H/S	R	M			
102000305	Mattawamkeag River	A	F	C/L	H/S	R	M			
102000306	Molunkus Stream	A	F	C/L	H/S	R				
102000307	Mattawamkeag River	A	F	C/L	H/S	R	M	Da		
102000401	Piscataquis River	A	F	C/L	H/S	R		Da		
102000402	Piscataquis River	A	F	C/L	H/S	R	M	Da		
102000404	Pleasant River	A	F	C/L	H/S	R		Da		
102000405	Seboeis Stream	A	F	C/L	H/S	R		Da		
102000406	Piscataquis River	A	F	C/L	H/S	R	M	Da		
102000501	Penobscot River at Mattawamkeag	A	F	C/L	H/S		M	Da		
102000502	Penobscot River at West Enfield	A	F	C/L	H/S	R	M	Da		
102000503	Passadumkeag River	A	F	C/L	H/S	R	M	Da		
102000505	Sunkhaze Stream	A	F	C/L	H/S	R				
102000506	Penobscot River at Orson Island	A	F	C/L	H/S	R	M			
102000507	Birch Stream	A	F	C/L	H/S	R	M			
102000509	Penobscot River at Veazie Dam	A	F	C/L	H/S	R	M	Da		
102000510	Kenduskeag Stream	A	F	C/L	H/S	R	M	Da	Dr	
102000511	Souadabscook Stream	A	F	C/L	H/S	R	M	Da	Dr	
102000512	Marsh River	A	F	C/L	H/S		M	Da	Dr	
102000513	Penobscot River	A	F	C/L	H/S	R	M	Da	Dr	
105000218	Belfast Bay	A	F	C/L	H/S	R	M	Da	Dr	
105000219	Ducktrap River	A	F	C/L	H/S	R		Da	Dr	Q
105000301	St. George River	A	F	C/L	H/S	R	M	Da	Dr	
105000302	Medomak River	A	F	C/L	H/S	R	M	Da	Dr	
105000305	Sheepscot River	A	F	C/L	H/S	R	M	Da	Dr	
103000306	Kennebec River at Waterville Dam	A	F	C/L	H/S	R	M	Da	Dr	
103000305	Sandy River	A	F	C/L	H/S	R	M	Da	Dr	
103000312	Kennebec at Merrymeeting Bay	A	F	C/L	H/S	R	M	Da	Dr	Q
105000306	Sheepscot Bay	A	F	C/L	H/S	R	M	Da	Dr	
105000307	Kennebec River Estuary	A	F	C/L	H/S	R	M	Da	Dr	
104000210	Little Androscoggin River	A	F	C/L	H/S	R	M	Da	Dr	

* A = Agriculture; F = Forestry, C/L = Changing Land Use; H/S = Hatcheries and Stocking; R = Roads and Road Crossings; M = Mining; Da = Dams; Dr = Dredging; Q = Aquaculture

1.6 Procedure used to determine biological value of habitat within specific areas

NMFS is required under Section 4(b)(2) of the ESA to consider the economic, national security, and other impacts of designating a particular area as critical habitat. NMFS may exclude an area from critical habitat if we determine that the benefits of exclusion outweigh the benefits of specifying the area as part of the critical habitat, unless we determine that the failure to designate the area as critical habitat will result in the extinction of the species. In order to consider exclusions in the 4(b)(2) analysis, we assigned a biological value based on habitat quantity and habitat quality needed to support spawning, rearing and migration of Atlantic salmon. The Final Biological Value indicates the habitat's current value to Atlantic salmon spawning, rearing and migration activities and is applied in the 4(b)(2) exclusion analysis, where it is weighed against the economic, national security, and other relevant impacts to consider whether specific areas may be excluded from designation.

The variables used to develop the Final Biological Value include a combination of Habitat Units, Habitat Quantity, Habitat Quality, and the value of the HUC 10 to migration of smolts and adults and are presented in the tables at the end of Chapters 2, 3, and 4.

1.6.1 Methods and procedures used to determine the biological value of HUC 10 watersheds

<u>*Habitat units*</u>

A habitat unit represents 100 m^2 of spawning and rearing habitat. To determine habitat units for each HUC 10 we relied on a GIS based habitat prediction model (*see Appendix C*). The model was developed using data from existing habitat surveys conducted in the Machias, Sheepscot, Dennys, Sandy, Piscataquis, Mattawamkeag, and Souadabscook Rivers. A combination of reach slope, cumulative drainage area, and physiographic province, were used to predict the total amount of rearing habitat within a reach. The variables included in the model explain 73 percent of the variation in rearing habitat. Although habitat surveys exist for some areas of the GOM DPS, we relied on the model to generate the habitat values for this exercise to provide consistent data across the entire DPS. Existing habitat surveys were used to validate the output of the model.

<u>*Habitat quantity*</u>

Habitat quantity reflects the units of habitat generated by the model and were calculated for each HUC 10. The units of habitat were then binned into four categories for each of the three SHRUs. A HUC 10 with no habitat was assigned a score of "0" and was considered unoccupied. HUC 10's with the lowest 25 percent of total units of habitat across the entire SHRU received a "1" score, the middle 50 percent received a "2" score, and the upper 25 percent received a "3" score. A "3" score represents the highest relative habitat quantity score. This method resulted in the majority of the habitat receiving a score of “2” and therefore representing an average habitat quantity. Habitat scores outside the middle 50 percent were considered to have above average habitat quantity or below average habitat quantity.

Habitat quality

Habitat quality scores were assigned to HUC 10s based on information and input from fisheries biologists working with the State of Maine Department of Inland Fisheries and Wildlife, the MDMR, NMFS, and Kleinschmidt Energy and Water Resource Consultants, who retain specific knowledge and expertise about the geographic region. For each of the three SHRUs, a minimum of three biologists with knowledge and expertise of the geographic area were asked to independently assign habitat scores, using a set of scoring criteria developed by fisheries biologists from NMFS (Figure 1.6.1) to HUC 10s based on the presence of, and quality of physical and biological features essential to the conservation of the species. The scoring criteria ranked qualitative features including temperature, biological communities, water quality, and substrate and cover, as being highly suitable (“3”), suitable (“2”), marginally suitable (“1”) or not suitable (“0”) for supporting Atlantic salmon spawning, rearing and migration activities. A habitat value of “0” indicates that one or more factors is limiting to the point that Atlantic salmon could not reasonably be expected to survive in those areas; a score of “1”, “2” or “3” indicates the extent to which physical and biological features are limiting with a “1” being most limiting and a “3” being not limiting. In HUC 10s that are, and have always been inaccessible due to natural barriers, the entire HUC 10 was automatically scored as “0” and considered not occupied by the species. During the scoring process, biologists were given the option to consider all the HUC12 sub-watersheds present within each HUC 10 watershed to aid in reaching a final HUC 10 watershed score. Emphasis was placed on identifying whether or not the physical and biological features needed for Atlantic salmon spawning and rearing are present and at what level.

Habitat Quality Scoring Criteria

<u>Temperature:</u>
Highly Suitable (3) = Stream temperatures are typically below *19C with no known fluctuations above **22.5C
Suitable (2) = Stream temperatures may exceed 22.5C but are <u>not</u> known to exceed ***29C at any time
Marginally Suitable (1) = Stream temperatures may <u>not</u> exceed 29C for periods greater than 16 Hours
Not Suitable (0) = Stream temperatures are known to exceed 29C for periods greater than 16 Hours
**Upper limit for optimal foraging (Decola 1970)*
***Upper incipient temperature limit for feeding (Elliott 1991)*
****Upper incipient lethal temperature based on a 20C acclimation (Elliott 1991)*

<u>Biological Communities:</u>
Highly Suitable (3) = Streams are highly productive and support abundant, diverse, populations of invertebrates and fishes. Streams do not contain *non-native species.
Suitable (2) = Streams contain abundant and/or diverse populations of invertebrates and fishes. Streams contain low abundances of non-native species.
Marginally Suitable (1) = Streams contain a limited abundance and diversity of invertebrates and fishes. Streams contain a high abundances of non-native species.
Not Suitable (0) = Atlantic salmon cannot survive with current fish community structure.
**Non-native species of concern are Smallmouth Bass, Northern Pike, Chain Pickerel, Brown Trout, Rainbow Trout, and Largemouth Bass*

<u>Water Quality:</u>
Highly Suitable (3) = pH does not fall below *6 and dissolved oxygen content consistently remains above **8mg/L.
Suitable (2) = pH sometimes falls below 6 but always remains above ***5.5 and dissolved oxygen sometimes falls below 8mg/L but always remains above ****6mg/L
Marginally Suitable (1) = pH often falls below 6 and at times below 5.5. Dissolved oxygen sometimes falls below 6mg/L.
Not Suitable (0) = pH is chronically below 5.5 and dissolved oxygen typically remains below 6mg/L.
** Point at which egg survival becomes significantly affected (Peterson et al. 1980)*
***Oxygen requirement for alevin survival (McLaughlin and Knight 1987)*
**** Point at which pH inhibits hatching of Atlantic salmon eggs (Peterson et al. 1980)*
*****General oxygen requirement for Atlantic salmon parr (Decola 1970)*

<u>Substrate and Cover:</u>
Cover items, including undercut banks, diverse substrates and depths, overhanging trees and vegetation, and some types of aquatic vegetation can increase habitat suitability (Bjornn and Reiser 1991). Cover items such as these can serve as a substitute for gravel and boulders and presence of these items should be taken into consideration when scoring a HUC12.
Highly Suitable (3) = Streams contain boulders roughly *20cm diameter at abundances greater than **0.2 per sq.meter and clean (silt-free) gravel ranging in diameters from ***1.6-6.4cm is also abundant.
Suitable (2) = Streams contain sufficiently sized boulders and clean (silt-free) gravel, but boulders are present at densities sometime less than 0.2/sq.meter.
Marginally Suitable (1) = Streams contain boulders and/or gravel but neither are available in optimal sizes and/or abundances
Not Suitable (0) = Streams do not contain substrate and cover suitable for juvenile Atlantic salmon rearing.
**Mean boulder diameter used in study by Dolinsek et al. (2007)*
***Boulder density used by Dolinsek et al. (2007)*
****Preferred gravel diameter of small parr (Symons and Heland 1978)*

Figure 1.6.1: Criteria used to score biological quality within HUC 10 watersheds

Final habitat value

Final Habitat Values were generated for each HUC 10 by combining habitat quantity and habitat quality scores within each HUC 10. Scores were combined by multiplying the two variables together giving scores of 0, 1, 2, 3, 4, 6, 9. HUC 10s with zero scores received a zero score for Final Habitat Value. Scores of 1 or 2 were valued as low or "1" final habitat value. Scores of 3 or 4 were valued as medium or "2" final habitat value, and scores of 6 or 9 were valued as high or "3" final habitat value.

Final Migration Value

A final migration value was generated based on the final habitat values and the migratory requirements of adults to reach spawning areas and smolts to reach the marine environment. We determined the final migration value of a HUC 10 to be equal to the highest final habitat value upstream from the HUC 10 as we concluded that access to spawning and rearing habitat was equally as important as the spawning and rearing habitat itself.

Final Biological Value

The final biological value for each HUC 10, which is the value used in weighing economic cost against the biological value of habitat to salmon, was determined by selecting the higher of the final habitat value and the final migration value of each HUC 10. This approach assures the preservation of spawning and rearing habitat as well as migration habitat. The method was used in order to accommodate for migration and the species need to access spawning and rearing habitat as well as the marine environment by treating access to spawning and rearing habitat as being equally important as the spawning and rearing habitat itself.

Chapter 2: Downeast Coastal SHRU Biological Report

2.1 Landscape and hydrologic features that shape the physical and Biological features within the Downeast Coastal SHRU

2.1.1 Geography

The Downeast Coastal SHRU encompasses fourteen HUC 10 watersheds covering approximately 1,852,549 acres within Washington and Hancock Counties in Eastern Maine. Within this SHRU there are several watersheds actively managed for Atlantic salmon including the Dennys, Machias, East Machias, Pleasant, Narraguagus, and Union rivers. As a complex, these rivers are typically small to moderate sized coastal drainages in the Laurentian Mixed Forest Province ecoregion (Bailey 1995). This commonality of zoogeographic classification makes coarse level descriptions of watersheds very similar between the rivers. The watersheds of the Downeast Coastal SHRU are best known for containing five watersheds with extant Atlantic salmon populations.

2.1.2 Geology and climate

The surficial geology of Maine largely consists of sand, gravel and unconsolidated sediments transported and deposited by glaciers (Marvinney and Thompson 2000). The geology within the Downeast Coastal SHRU and the geology to the north and west can be separated by a line running from the Penobscot River near Winterport, ME northeast towards Topsfield, ME (Norumbega Fault). North and west of this line the rocks are mostly derived from former marine sediments with some rocks containing a fraction of carbonate minerals. The rocks south and east of this line (the vast majority of the Downeast Coastal SHRU) are derived from volcanic and more recent intrusive igneous rocks. These rocks differ in their chemistry (especially calcium, magnesium, aluminum, and iron) and resistance to erosion or dissolution (Surficial Geologic Map of Maine 1985) when compared to rocks north and west of this line.

As a result of the geology within the Downeast Coastal SHRU, surface water chemistry may be affected in several ways. Rocks, such as those present south and east of the Norumbega fault weather slowly and produce relatively fewer ions per unit time (i.e., less calcium, magnesium) under similar conditions of hydrology than those present north and west of the fault. In addition, the mantle of marine clay or wetland within the Downeast Coast SHRU may hydrologically isolate bedrock or till from weathering. Therefore, surface waters within this basin have naturally low concentrations of major cations derived from chemical weathering, and experience a relatively high influence of vegetation on ion and nutrient chemistry.

Climate in the Downeast Coastal SHRU exhibits four seasons with mild summers and cold winters. Average annual air temperatures across Maine range from 4 – 7.3^{o}C and average precipitation ranges from 95 – 112 cm/year (NOAA - National Climate Data Center). As a result, the Downeast Coastal SHRU lies within the Laurentian Mixed Forest ecoregion, which is described as transitional zone between broadleaf deciduous and boreal forest (Bailey 1995). The basin is largely characterized by rolling hills with forested stream valleys and a number of barren areas with ground cover typically consisting of shrubs; including blueberries. The headwaters are composed mostly of hills and ridges, with forests of spruce, fir, and hardwoods (Dube and Jordan, 1982; Beland *et al.,* 1982a; Fletcher *et al.,* 1982; Baum and Jordan, 1982). Dissolved organic carbon originating from decomposing organic material on stream banks and within bogs discolor many of the rivers and streams within the basin (Fletcher *et al.,* 1982; Dube and Jordan, 1982; Johnson and Kahl, 2005).

2.1.3 Hydrology

The Downeast Coastal SHRU is composed of six major watersheds that have substantial potential for Atlantic salmon production (Table 3; Figure 1). The Downeast Coastal SHRU is heavily forested with low relief rolling topography. The relatively recent glacial activity of river systems along coastal Maine has resulted in stream beds that typically contain bedrock and large boulders (Dudley, 2004). Unlike alluvial systems in other regions of the U.S. that are largely unregulated with routinely adjusting meandering stream corridors and channel slopes according to the size of the drainage and the amount of water and sediment transported through the system, coastal Maine systems appear to be largely bedrock controlled limiting stream channel mobility and sediment transport (Dudley, 2004). Stream flows are typically largest in late winter (March – April) and spring (May – June) given the combination of melting snow, spring rains and saturated soils (Dudley, 2005; Johnson and Kahl, 2005). Stream flows recede throughout the summer as the snow pack melts and evapotranspiration increases, conveying flows that are dominated by surface runoff in the winter and spring to flows that are dominated by ground-water discharge (Dudley, 2005). During the fall, evapotranspiration decreases followed by an increase in precipitation and occasional hurricane related events that can result in high flows (Dudley, 2005). During the winter (December – February) stream flows are often low, as both precipitation and surface waters are frozen for extended periods (Dudley, 2005).

Table 2.1.3: Major HUC 10 watersheds of the Downeast Coastal SHRU

HUC 10 Watershed	Area (hectares)	Proportion of SHRU
Dennys	34,188	4%
East Machias	65,009	8%
Machias	119,140	16%
Pleasant	22,015	3%
Narraguagus	60,088	8%
Union	129,500	17%
Other small coastal streams	317,797	42%
Downeast SHRU	**747,737**	**Proportion of GOM DPS: 13%**

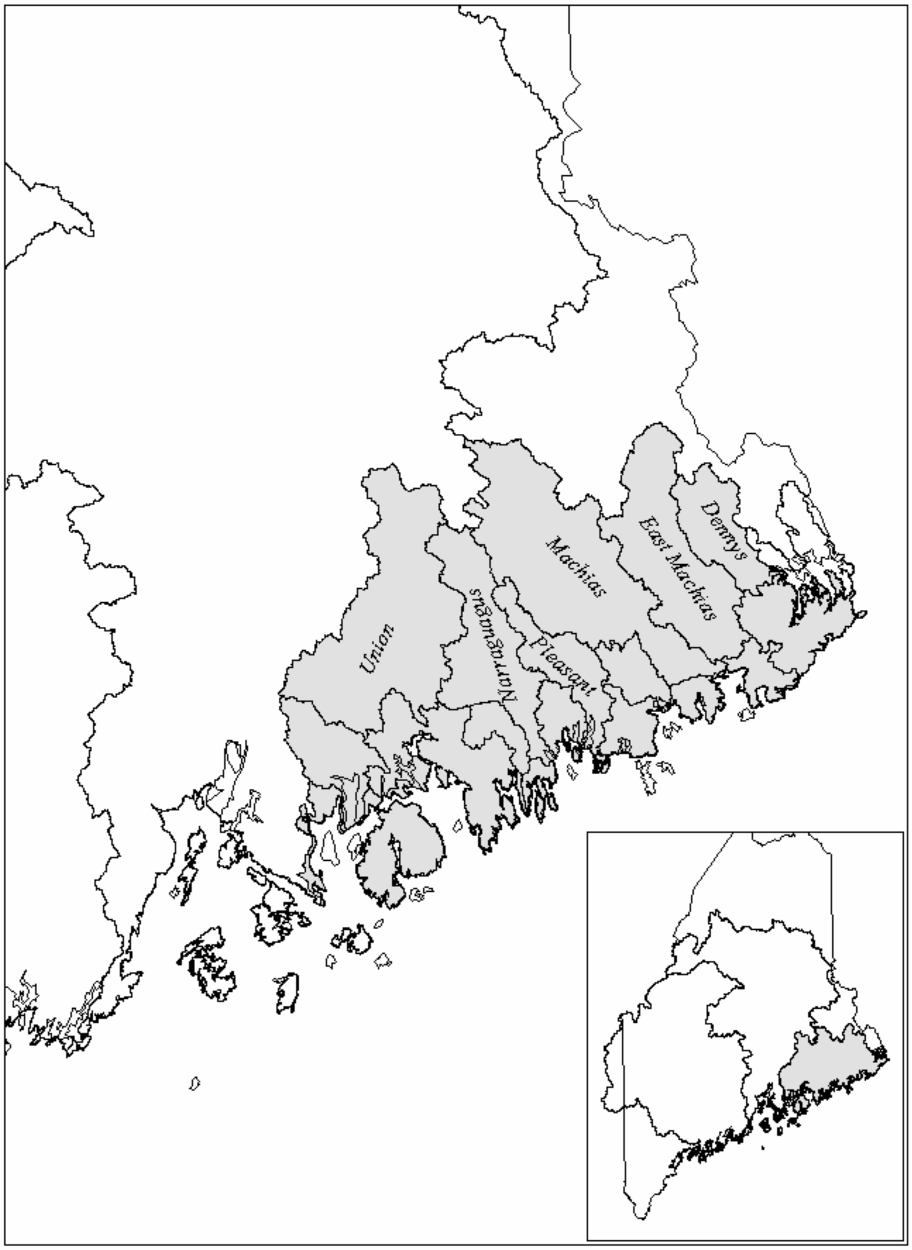

Figure 2.1.3: HUC 10 watersheds in the Downeast Coastal SHRU

2.1.4 Natural barriers

Natural geological falls occur in throughout the GOM DPS and sometimes act as temporary barriers or deterrents to fish passage during certain flow conditions and in some cases excluding some or all migratory fish from continued upstream migration. Fish ladders have been constructed at Bad Little Falls on the Machias River in Machias (Fletcher *et al.,* 1982), at Saco Falls on the Pleasant River (Dube and Jordan, 1982) and at Marion Falls on Cathance Stream (a tributary of the Dennys River). Bad Little Falls under most conditions is a partial or complete barrier to some anadromous fish including alewives and shad, though is not a barrier to Atlantic salmon but may delay passage under some conditions. The Bad Little Falls fishway once provided passage around the dam that was constructed at the head of the Machias Gorge. In order to facilitate upstream passage, concrete defectors were built to provide eddies and resting areas for salmon moving upstream through the gorge at Bad Little Falls. Today, the fish passage is no longer functional. In 1970, the dam was breached by the spring freshets and now fish most often use the west channel to pass above the falls rather than the fishway, which is in the center channel (Fletcher *et al.,* 1982).

On the Pleasant River a fish ladder was constructed at Saco Falls in 1955 to improve fish passage around this natural obstruction (Dube and Jordan, 1982). In 2005, the Downeast Salmon Federation and U.S. Fish and Wildlife Service did some repair work on the fishway including some cement work and updating the baffles. In 2006, the Dept. of Marine Resources observed many Atlantic salmon redds upstream of the fishway and it is still believed to pass alewives. Today, the Saco Falls fish ladder is functional though needs additional repairs.

On Cathance Stream, a tributary to the Dennys River, Marion Falls below the Marion road in Dennysville is believed to be a partial obstruction to some diadromous fish under some conditions. In 1962, a 48 foot Denil fishway was constructed by the Maine Atlantic Salmon Commission around the 9-foot ledge obstruction to enhance upstream migration (Beland *et al.,* 1982). In 2006, Maine Dept. of Transportation enhanced attraction flows to the fishway in conjunction with replacing the Marion Road bridge.

2.2 Human influence on Downeast Coastal SHRU

2.2.1 Current population structure and land-use

Washington and Hancock County has a population of approximately 55,000 people with a density of roughly 32.6 persons per square mile. Over 90 percent of the population living within Washington and Hancock Counties is located within five miles of the coast (Downeast RCD) with Machias (pop. 2,353) and Calais (pop. 3,447) being the two major population centers in Washington County; and Ellsworth (pop. 6,456), Bucksport (pop. 4,908) and Bar Harbor (pop. 4,820) being the three major population centers in Hancock County (U.S.Census of Population and Housing, 2000).

Today, approximately 89 percent of the Downeast Coastal SHRU is forested and supports a large wood, paper, and lumber industry. However, there are no paper mills located within the Doweast Coastal SHRU. Downeast Maine is also known for its wild blueberries with approximately 16,192 ha[1] of land in wild blueberries (USDA, 2002) supporting Maine as the world's largest producer of wild blueberries (Yarborough, 1998).

2.2.2 Dams and barriers to fish passage

Historically, dams were a major cause of the decline of Atlantic salmon runs in many Maine rivers and streams (Baum, 1997). At one time, dams existed at various times on all six of the major salmon rivers within the Downeast Coastal SHRU. Dams were constructed to produce electricity, operate mills, transport logs and as ice control

[1] 16,192 ha represent twice the harvested acres for 2002 provided by USDA (2002) given that wild blueberries are harvested on a two year crop cycle (Yarborough, 2002)

structures. Historic records indicate that many of the old, low-head timber crib dams had significant leakage and were not complete barriers to fish passage.

In the late 1940s, the presence of dams on the Narraguagus, Machias, East Machias and Pleasant rivers were identified as a threat to the continued existence of Atlantic salmon in those rivers (Rounsefell and Bond, 1949). According to Rounsefell and Bond (1949), the Atlantic salmon run in the Dennys River was almost always in peril during the 1880s because of dams. Today, most of the dams in the SHRU have either been removed or breached and no longer threaten salmon migration. The Stillwater Dam on the Narraguagus River and the Ellsworth and Graham Lake dams on the Union River are the only remaining dams in the six major salmon rivers located in the Downeast Coastal SHRU that obstruct a significant portion of their associated watershed from free migration of diadromous fish.

The U.S. Army Corps of Engineers (ACOE) constructed the Stillwater Dam in Cherryfield, Maine on the Narraguagus River in 1961 as a flood- ice-control structure (Baum and Jordan, 1982). The dam is equipped with a Denil fishway which most fish normally use though during high water, salmon are often observed swimming over the top of the spillway (Baum and Jordan, 1982).

Around 1763, Benjamin Milliken traveled to Ellsworth Maine to construct dams on the Union River to be used to support saw mills and the exploitation of the areas forest resources. The Ellsworth dam on the Union River was constructed at the site of one of the former Milliken dams in 1907 as a hydroelectric facility. In 1923, the Graham Lake dam was constructed creating the 3,642 ha reservoir known as 'Graham lake' as a flow control structure to support the Ellsworth dam. Today, fish passage around the two dams, currently owned and operated by Pennsylvania-based PPL Maine, is restricted to a trap and truck program where Atlantic salmon captured at the Ellsworth facility are trapped and transported around the Graham Lake facility and released.

Other obstructions to passage, including poorly designed road crossings and culverts, remain a potential hindrance to salmon recovery. Improperly placed or designed culverts can create barriers to fish passage through hanging outfalls, increased water velocities or insufficient water velocity and quantity within the culvert. Poorly placed or undersized culverts (usually from road building and maintenance) can also hinder fish passage, thus reducing access to potential habitat. The extent of impacts on salmon populations within the DPS from improperly installed or designed culverts, damaged riparian areas and associated fish passage problems is not well known.

2.2.3 Water Quality

In the Downeast Coastal SHRU pH has been identified by many scientists as one of the leading water quality concerns for Atlantic salmon (Beland *et al.,* 1995; Haines *et al.,* 1990; Kahl and Johnson, 2005; MEDEP unpublished data). Atlantic salmon smolts are particularly sensitive to low pH as it affects their ability to osmoregulate as smolts make the transition from the freshwater environment to the marine environment (McCormick *et al.,* 1998). In the Downeast Coastal SHRU, rivers are particularly vulnerable to episodic events of low pH from acidic precipitation because of the geography and geology which contributes to the large number of bogs in the region; reduces the flushing rate of rivers and streams; and reduces the weathering rate of the underlying bedrock (Johnson and Kahl, 2005).

The historical water chemistry available for Maine salmon rivers is not extensive. Of the non-winter months, discharge in the Downeast rivers are lowest during the summer. Fall flows can vary from as high as spring flows to as low as summer flows. Spring flows are typically derived from snowmelt and spring rains. During spring melt the conductivity and base cation concentration of receiving streams and rivers are generally diluted as flow increases (Heath *et al.,* 1993; Kahl *et al.,* 1992), and early spring flushes may be acidic or quite basic, depending on the hydrology and geology of the location. Periods of snowmelt can result in decreased pH from base cation dilution and/or influx of DOC from overland flow and bog drainage (Kahl *et al.,* 1992). Within the Downeast Coastal SHRU Kahl *et al.,* (1989) documented wetland ponds in salmon river watersheds with pH values as low as 3.5, with mean pH of less than 4.0, compared to the pH of precipitation of 4.6.

Haines and Akielaszek (1984) reported that field pH in the Narraguagus and Machias rivers in Downeast Maine was typically between 6.0-7.0, but that seasonal depressions below 6.0 associated with high spring discharge were common. Studies conducted in the early 1990's, and again in the early 2000's, reported similar results for the Narraguagus River system (Beland *et al.,* 1995; MEDEP unpublished data; Kahl and Johnson, 2005). In the mainstem of the Pleasant River, episodic pH values from the low 5's to low 4's have been documented during high flows (Beland *et al.,* 1995; MEDEP unpublished data; Kahl and Johnson, 2005). Episodic field pH values below 5.0 have been observed in many smaller tributaries (Haines and Akielazsek, 1984; Haines *et al.,* 1990; Beland *et al.,* 1995; MEDEP unpublished data; Kahl and Johnson, 2005). The Senator George J. Mitchell Center for Environmental and Watershed Research at the University of Maine (GMC) and the Maine Atlantic Salmon Commission (MASC), conducted the most spatially extensive assessment of water chemistry in Maine salmon rivers in 2003 - 2004 to understand the spatial and seasonal patterns in water chemistry. The goal of the survey was to characterize the water quality of Maine salmon rivers by sampling water at multiple sites along the rivers on the same day. The surveys were repeated seasonally to determine the range of chemistry found in each river. All the samples were analyzed at the Watershed Research Laboratory of the Senator George J. Mitchell Center to eliminate differences in analytical techniques that arise among different workers and laboratories. The results from survey were: 1) all rivers experienced depressed pH and acid neutralizing capacity (ANC) values associated with rain events that occurred in the day(s) immediately prior to the sampling; 2) watersheds to the west of the Penobscot River (i.e. Ducktrap River, Sheepscot River, Cove Brook, Marsh Stream, Kenduskeag River, and Sandy River) have higher pH, acid neutralizing capacity (ANC), and Ca and lower DOC and Aluminum than sites to the east of the Penobscot River (i.e. Union River, Tunk Stream, Narraguagus River, Pleasant River, Machias River, East Machias River, and Dennys River); 3) tributaries tend to have lower pH than mainstem sites; 4) summer base-flow sampling showed that all of the rivers, except Tunk Stream, had pH values favorable for salmon health for that time of year. The lower ANC and higher DOC make the eastern sites more susceptible to event-driven pH depressions than sites to the west of the

Penobscot River. Spatial patterns that relate to surficial geology are recognizable within individual drainages.

2.2.4 Fisheries and fish introductions in the Downeast Coastal SHRU

Maine Atlantic salmon rivers historically supported abundant populations of native diadromous fish species including alewives (*Alosa aestivalis*), blueback herring (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), sea lamprey (*Petromyzon marinus*), anadromous rainbow smelt (*Osmerus mordax*), Atlantic sturgeon (*Acipenser oxyrhynchus*), shortnose sturgeon (*Acipenser* brevirostrum) and American eel (*Anguilla rostrata*), white perch (*Morone americana*), and striped bass (*Morone saxatilis*). Salmon co-evolved over time with these and other aquatic organisms native to Maine rivers. Large populations of clupeids, such as shad, alewife, and blueback herring, used rivers within the DPS as migratory corridors, spawning grounds and juvenile nursery habitat. As these fish completed their life cycles, they likely performed important ecological functions including but not limited to prey buffering, marine derived nutrient cycling and habitat modification and enhancement.

In addition to the diverse diadromous community, Maine waters also support diverse community of indigenous freshwater fish including brook trout (*Salvelinus fontinalis*), burbot (*Lota lota*), lake trout or togue (*Salvelinus namaycush*), chain pickerel (*Esox niger)*, landlocked salmon (*salmo salar*), arctic charr (*Salvelinus alpinus oquassa*), lake whitefish (*Coregonus clupeaformis*), brown bullhead (*Ameiurus nebulosus*); pumpkinseed sunfish (*Lepomis gibbosus*); redbreast sunfish (*Lepomis auritus*); yellow perch (*perca flavenscens*; Page and Burr, 1991); as well as numerous species of fish classified by Maine IF&W as "non-sportfish" which include numerous members of the family Cyprinidae (minnows), Catostomidae (suckers) and two species in the family Percidae (perch) – not including the yellow perch (Kramer, 2002).

Today, much of Maine's waters are host to a variety of introduced and invasive species of fish. Many species, including smallmouth bass (*Micropterus dolomieui*), largemouth bass (*Micropterus salmoides*), brown trout (*Salmo trutta*), splake (*Salvelinus namaycush* x *Salvelinus fontinalis*) and rainbow trout (*Oncorhynchus mykiss*) have been introduced as part of an effort to enhance recreational fishing opportunities. Carp (*Cyprinus carpio*) were introduced in ponds in the late 1800's for cultivation purposes and later likely escaped from these ponds into the tidal waters of the Scarborough and Kennebec Rivers (Lucas 2001). Other species, including northern pike (*Esox lucius*), muskellunge (*Esox masquinongy*), black crappie (*Pomoxis nigromaculatus*), green sunfish (*Lepomis cyanellus*), white catfish (*Ictalurus cattus*), and several species of cyprinids have been introduced illegally or through accidental introductions often associated with the transport and release of live bait used for recreational fishing. Species such as chain pickerel and landlock salmon are native to the state of Maine, however, their range has been vastly expanded to enhance angler opportunity.

In the downeast coastal basin, chain pickerel, smallmouth bass, largemouth bass, brown trout and splake are non – native species that compete with Atlantic salmon as either predators or competitors. Chain pickerel, though native to southwestern Maine (Brokaw, 2001), were introduced into the Penobscot river in 1819, where they rapidly dispersed throughout eastern Maine (Baum, 1997). Chain pickerel have been found to be aggressive predators of Atlantic salmon smolts in the Narraguagus River and Penobscot Rivers where, at times, between 20 and 30 percent of pickerel have been found to contain smolts (Barr, 1962; and Van de Ende, 1993).

Smallmouth bass were first introduced into Maine waters from New York in 1868 (Jordan, 2001) and are now found in all of the major watersheds in the downeast coastal basin (MASCP, 1997; Baum, 1997). Today bass are considered by Maine's Department of Inland Fisheries and Wildlife to be one of Maine's most important sport fishes, along with brook trout and landlocked salmon (Jordan, 2001). Smallmouth bass are likely aggressive competitors as well as predators to Atlantic salmon as juvenile bass are found consistently in the same habitats as juvenile salmon feeding and utilizing space that would otherwise be utilized by parr. Largemouth bass, not native to New England, are believed to have been incidentally introduced into Maine in the late 1800's along side a planned smallmouth introduction. Largemouth bass are currently found in the East Machias river and are also known to prey on Atlantic salmon (Warner, 1972; Anthony, 1994).

Brown Trout, native to Europe, northern Africa, and western Asia (Page and Burr, 1991), were first introduced into U.S. waters in 1883 when fish from Germany were stocked in the Pere Marquette River in Michigan (Mather, 1889; Courtenay *et al.,* 1984). Brown Trout were first introduced to Maine in 1885 when they were stocked in Branch Lake in Ellsworth, Maine (Boland, 2001); part of the Union River watershed. As of 2000, roughly 40 lakes in the downeast coastal basin had populations of brown trout, with the most number of lakes occurring in the Union River drainage (Boland, 2001). Brown Trout are believed to be responsible for reducing native fish populations, especially salmonids, through predation, displacement, and food competition (Taylor *et al.,* 1984).

Splake are the only salmonid cross capable of reproducing for an infinite number of generations, although they are not known to reproduce successfully in the wild (Obrey, 2001). Splake were first introduced into Maine in Long Pond, Washington County in 1958. In 2000, roughly 17 lakes in the Downeast Coastal SHRU contained populations of splake. In 1995, IFW stocked splake in seven lakes within the Narraguagus, Pleasant and Machias river watersheds.

In 2001, splake were stocked into Mopang Lake, Second Old Stream, Beddington Lake, Keeley Lake, Burntland Lake, Pleasant River Lake, and Peaked Mountain Pond. The potential exists for stocked splake to reach a size such that smolt predation becomes possible (Beland, 2001). ASC and IFW biologists sampled splake in Beddington Lake (Narraguagus drainage) in 2001 and found one splake that had consumed an Atlantic salmon smolt (Ken Beland, ASC, Personal Communication). As a result, stocking of splake in Beddington Lake was terminated. Beddington Lake was the only Downeast splake stocking program on a mid-drainage lake that Atlantic salmon smolts migrate through. In other Downeast lakes, splake are stocked upstream of Atlantic salmon rearing habitats.

Landlocked salmon (*Salmo salar sebago*) are native to only four river basins in Maine: the St. Croix at West Grand Lake in Washington County; the Union at Green Lake in Hancock County; the Penobscot at Sebec Lake in Piscataquis County; and the Presumpscot at Sebago Lake in Cumberland County. Today, landlock salmon have been introduced into lakes within the Narraguagus, Pleasant, Machias, East Machias and Dennys river watersheds. Because sea-run and landlocked Atlantic salmon are the same species (though differences in behavior and life history separate them from interbreeding), direct competition for food and space is inevitable when the fish are in the same area (Maine ASC and Maine IFW 2002).

2.3 Atlantic salmon habitat

The Downeast Coastal SHRU once contained high quality Atlantic salmon habitat in quantities sufficient to support robust Atlantic salmon populations. Degradation of habitat and the construction of dams have diminished both habitat quality and availability. In the Downeast Coastal SHRU, there are approximately 61,400 units of historical spawning and rearing habitat for Atlantic salmon among approximately 6,039 km of rivers, lakes and streams. Of the 61,400 units of historical spawning and rearing habitat, approximately 53,400 units of habitat are considered to be currently occupied. Based upon the biological valuation described in Chapter 1, the Machias, Narraguagus, and East Machias contain the highest quality habitat relative to other HUC 10's in the Downeast Coastal SHRU, and collectively account for approximately 40 percent of the spawning and rearing habitat in the Downeast Coastal SHRU (Table 2.3a).

Impacts to substrate and cover, water quality, water temperature, biological communities, and migratory corridors, among a host of other factors, have impacted the quality and quantity of habitat available to Atlantic salmon populations within the Downeast Coastal SHRU. Two hydropower dams on the Union river, and to a lesser extent the small ice dam on the lower Narraguagus River which limits access to roughly 18,500 units of spawning and rearing habitat. In the Union River, which contains over 12,000 units of spawning and rearing habitat, physical and biological features have been most notably limited by high water temperatures and abundant smallmouth bass populations. In the Pleasant River and Tunk Stream, which contain over 4,300 units of spawning and rearing habitat, pH has been identified as possibly being the predominate limiting factor.

Of the 53,400 occupied units within the Downeast Coastal SHRU we calculated these units to be the equivalent of roughly 29,111 functional units of habitat or approximately 47 percent of the estimated historical functional potential (Table 2.3a). This estimate is based on the configuration of dams within the SHRU that limit migration and degradation of physical and biological features from land use activities which reduce the productivity of habitat within each HUC 10. For each SHRU 30,000 fully functional units of habitat are needed in order to achieve recovery objectives. Though the downeast SHRU does not currently meet this objective, there is enough habitat within the occupied range that in a restored state (e.g. improved fish passage or improved habitat) would satisfy recovery objectives.

Throughout Maine, there has been substantial effort on behalf of state and federal agencies and non-profit organizations in partnership with landowners and dam owners to restore habitat through a combination of land and riparian protection efforts, and fish passage enhancement projects. Project SHARE, the Downeast Salmon Federation, watershed councils, Trout Unlimited, and the Atlantic Salmon Federation, for example, have conducted a number of projects designed to protect, restore and enhance habitat for Atlantic salmon ranging from the Kennebec River in south central Maine to the Dennys River in Eastern Maine. Projects include (though are not limited to) dam removals along the Kennebec, St. George, Penobscot, and East Machias Rivers, land protection of riparian corridors along the Machias, Narraguagus, Dennys, Pleasant, East Machias, Sheescot, Ducktrap rivers and Cove Brook; surveying and repair of culverts that impair fish passage; and outreach and education efforts on the benefits of such projects. The Penobscot River Restoration Project is another example of cooperative efforts on behalf of federal and state agencies, non profit organizations and dam owners. The PRRP goal is to enhance runs of diadromous fish through the planned removal of two mainstem dams and enhanced fish passage around several other dams along the Penobscot River. These cooperative efforts can increase the functional potential of Atlantic salmon habitat by both increasing habitat availability as well as increasing habitat quality. Therefore, we do not believe that any unoccupied areas are essential to the conservation of the species.

Table 2.3a: Total habitat units and functional equivalents by HUC 10 for the Downeast Coastal SHRU

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quality	Dams Encountered	Functional Equivalent	Management Activities**
0105000205	Machias River	Y	14,964	2	0	9,876	A, F, C/L, H/S, R, Da, Dr
0105000204	East Machias River	Y	6,129	2	0	4,086	A, F, C/L, H/S, R, M, Da, Dr
0105000208	Pleasant River	Y	3,025	2	0	2,017	A, F, C/L, H/S, R, M, Da, Dr
0105000201	Dennys River	Y	1,717	2	0	1,145	A, F, C/L, H/S, R, M, Da, Dr
0105000207	Chandler River	Y	1,520	2	0	1,013	A, F, C/L, H/S, R, M, Da, Dr
0105000209	Narraguagus River	Y	6,500	2	0.25	4,161	A, F, C/L, H/S, R, M, Da, Dr
0105000213	Union River Bay	Y	4,062	2	1	2,302	A, F, C/L, H/S, R, M, Da, Dr, Q
0105000203	Grand Manan Channel	Y	3,105	1	0	1,035	A, F, C/L, H/S, R, M, Da, Dr, Q
0105000206	Roque Bluffs Coastal	Y	3,031	1	0	1,010	A, F, C/L, H/S, R, M, Da, Dr
0105000210	Tunk Stream	Y	1,274	1	0	425	A, F, C/L, H/S, R, , Da, Dr
0105000212	Graham Lake	Y	8,063	1	2	1,942	A, F, C/L, H/S, R, M, Da
0105000214	Lamoine Coastal	N	4,442	1	0	1,481	
0105000215	Mt. Desert Coastal	N	2,058	1	0	686	
0105000211	Bois Bubert Coastal	N	1,505	1	0	502	

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

** A = Agriculture; F = Forestry, C/L = Changing Land Use; H/S = Hatcheries and Stocking; R = Roads and Road Crossings; M = Mining; Da = Dams; Dr = Dredging; Q = Aquaculture

Table 2.3b: Biological value of Atlantic salmon habitat in HUC 10 watersheds in the Downeast Coastal SHRU.

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quantity Score	Habitat Quality Score	Habitat Score (E x F)	Final Habitat Value	Final Migration Value	**Final Biological Value**
105000205	Machias River	Y	14,964	3	2	6	3	3	**3**
105000209	Narraguagus River	Y	6,500	3	2	6	3	3	**3**
105000204	East Machias River	Y	6,129	3	2	6	3	3	**3**
105000212	Graham Lake	Y	8,063	3	1	3	2	2	**2**
105000213	Union River Bay	Y	4,062	2	2	4	2	2	**2**
105000208	Pleasant River	Y	3,025	2	2	4	2	2	**2**
105000201	Dennys River	Y	1,717	2	2	4	2	2	**2**
105000203	Grand Manan Channel	Y	3,105	2	1	2	1	1	**1**
105000206	Roque Bluffs Coastal	Y	3,031	2	1	2	1	1	**1**
105000207	Chandler River	Y	1,520	1	2	2	1	1	**1**
105000210	Tunk Stream	Y	1,274	1	1	1	1	1	**1**
105000214	Lamoine Coastal	N	4,442	2	1	2	1	1	**1**
105000215	Mt. Desert Coastal	N	2,058	2	1	2	1	1	**1**
105000211	Bois Bubert Coastal	N	1,505	1	1	1	1	1	**1**

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

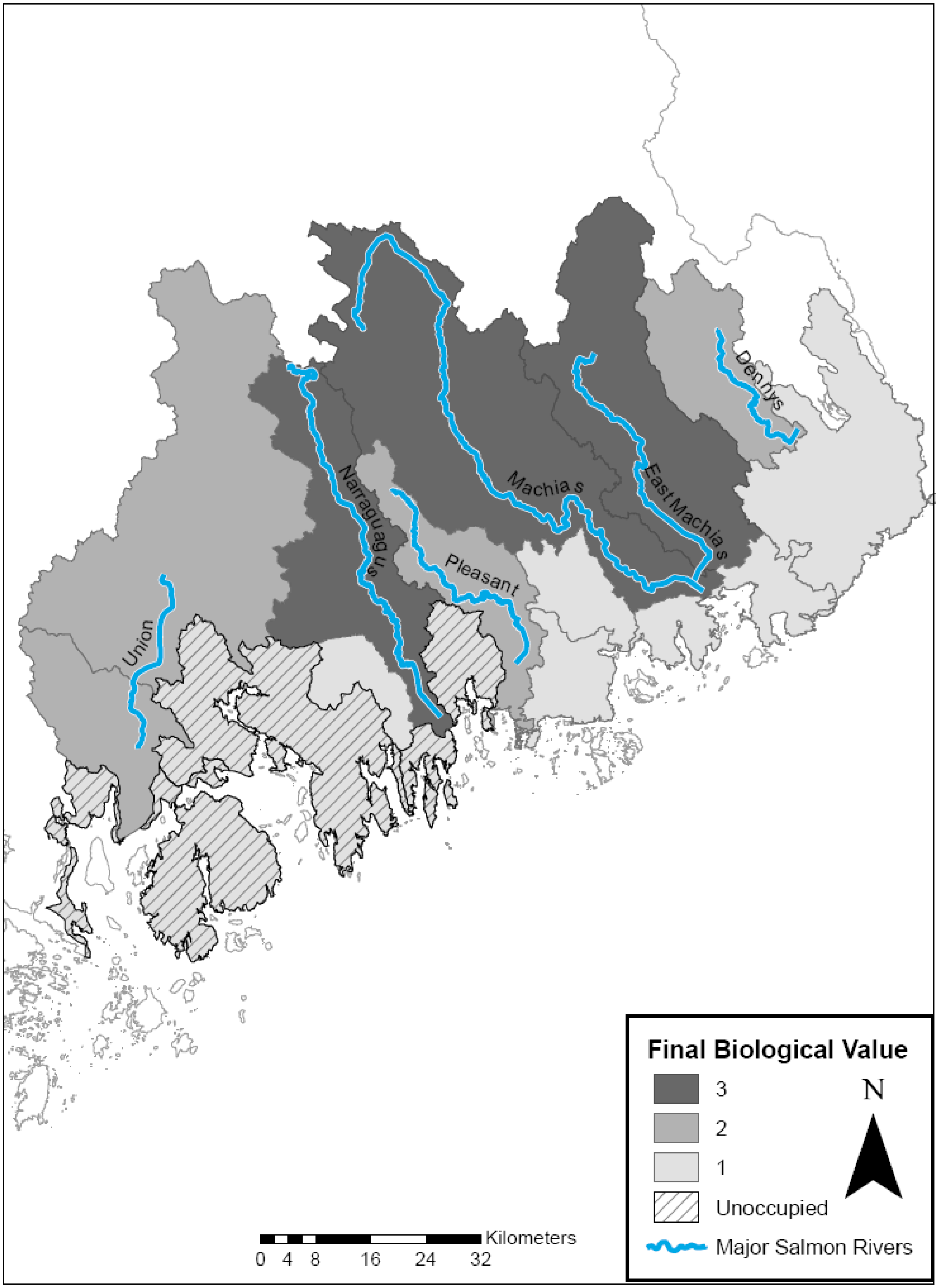

Figure 2.3: Final biological value of HUC 10 watershed in Downeast Coastal SHRU

Chapter 3: Penobscot Bay SHRU Biological Report

3.1 Landscape and hydrologic features that shape the physical and biological features within the Penobscot SHRU

3.1.1 Geography

The Penobscot Bay Salmon Habitat Recovery Unit (SHRU) includes the entire Penobscot basin and extends west as far as, and includes the Ducktrap River watershed, and east as far as, and includes the Bagaduce River watershed. The Penobscot basin is the largest river basin in Maine and the second largest in New England. The river drains a 22,225,200 ha (22,252 $km^{2)}$) watershed, roughly one-quarter of the state's land area, that occupies sections of Aroostook, Hancock, Penobscot, Piscataquis, Somerset, Waldo, and Washington counties (Baum 1983).

3.1.2 Geology and climate

The Penobscot lies mostly within the Laurentian Mixed Forest ecoregion, which is described as transitional zone between broadleaf deciduous and boreal forest (Bailey, 1995). Portions of the West Branch lie within the New England Mixed Forest ecoregion, which is primarily composed of a transitional forest between boreal spruce-fir to deciduous forest with vertical vegetation zonation (Bailey, 1995).

The geology of the Penobscot SHRU, like the rest of Maine, is a variable mixture of landforms resulting from numerous mountain-building and glacial events. The Penobscot SHRU ranges from non-erosive granite and rhyolite mountains in the headwaters to flat, expansive glacial moraines that are interspersed with some of the longest eskers in the world (Caldwell, 1998). Consequently, channels of the Penobscot SHRU range from high gradient channels in the headwaters to low gradient channels dominated by fine sediment in the forested lowlands. Along the main tributaries of the lower Penobscot are extensive, flat areas where the ocean invaded the land after the glaciers retreated, forming a layer of marine silt and clay that became the bottom layers of today's bogs and fens (Davis and Anderson, 2001). Sunkhaze Meadows, Alton Bog, and Caribou Bog are examples.

The West Branch originates on the Maine-Quebec border near Sandy Bay Township and Penobscot Lake, in mountainous terrain 520-550 meters above sea level (Baum, 1983). The East Branch begins at East Branch Pond, northwest of Baxter State Park, in a lake-filled region 300 meters above sea level. The mainstem of the river begins at the confluence of the East and West Branches at Medway and flows to Stockton Springs/Castine, where it opens up into Penobscot Bay.

3.1.3 Hydrology

The Penobscot watershed is comprised of several sub-basins (Table 3). Water flow in the Penobscot River basin varies seasonally, with high flows in early spring and late fall and low flows generally in the summer and early fall. The great extent of wetland in the Penobscot watershed (almost one-third of the watershed; Jackson *et al.*, 2005) soaks up water when it rains and slowly releases it to rivers and groundwater, with the ultimate effect of moderating fluctuations in the river's flow.

Flows are also regulated by numerous dams and impoundments, which have a combined capacity of about 1.5 billion m^3 (Stewart *et al.,* 2006). The U.S. Geological Survey (USGS) maintains monitoring stations on the lower Penobscot at Eddington and West Enfield. The 102-year average flow at West Enfield is 334 cubic meters per second (m^3/s); the highest flow on record was 4,333 m^3/s in May 1923. The lowest flow on record was 46.2 m^3/s in October 1905 (Stewart *et al.,* 2006). Average annual discharge of the Penobscot River near the point of tidal influence is 402 cubic meters per second (Jackson *et al.,* 2005).

Table 3.1.3: Major HUC 8 Sub-basins in the Penobscot SHRU

River	Watershed Area (ha)	Proportion of Penobscot SHRU:
East Branch	289,561	13%
West Branch (Penobscot Lake to Medway)	551,806	24%
Piscataquis River	377,853	16%
Mattawamkeag River	390,631	17%
Penobscot River	616,682	27%
Penobscot Bay area	132,918	0.6%
Penobscot SHRU	**2,359,451**	**Proportion of DPS: 41%**

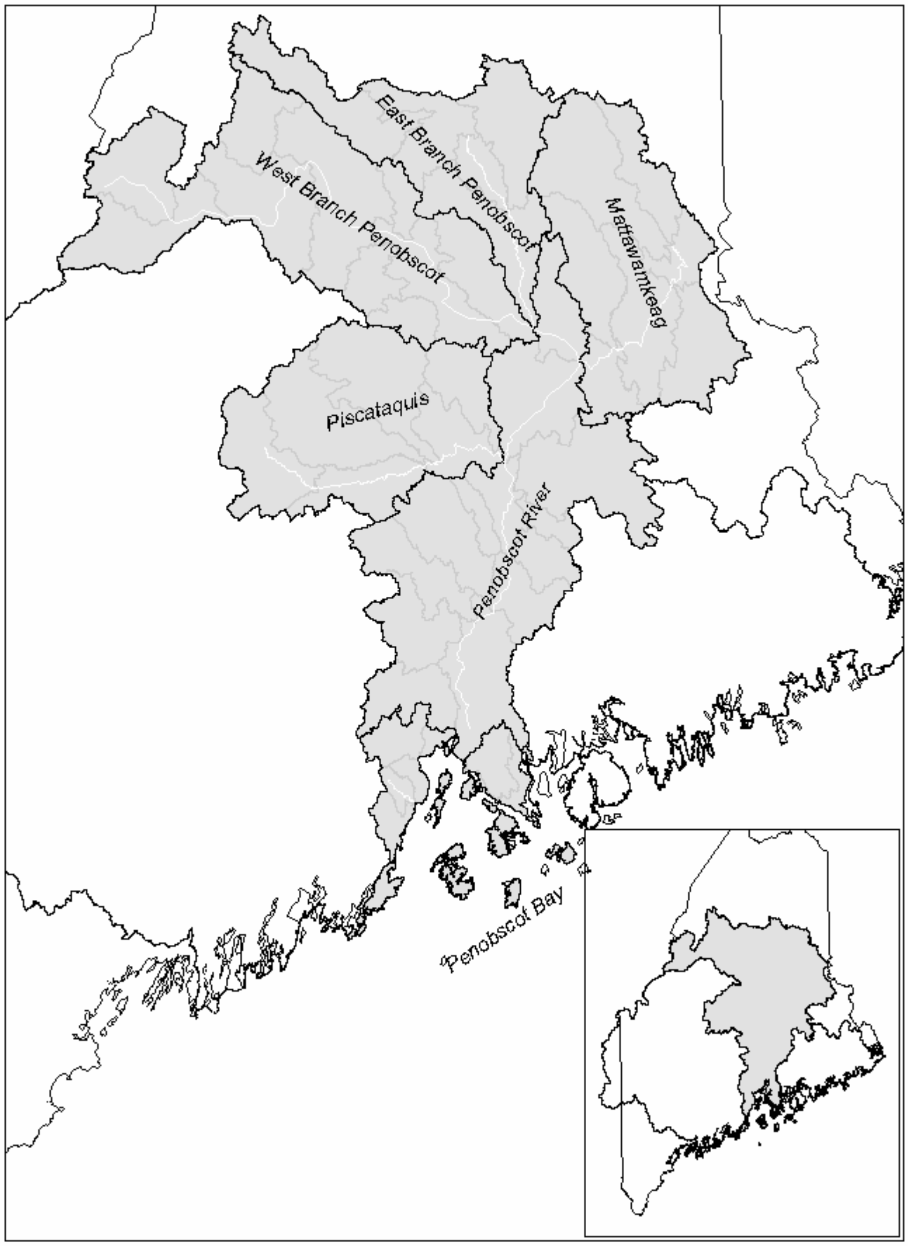

Figure 3.1.3: Sub-basins within the Penobscot River SHRU

3.1.4 Natural barriers

Few natural migration barriers exist in the Penobscot SHRU. Historical reports indicate that Atlantic salmon habitat extended to Penobscot headwaters in the West Branch over 350km inland at least as high as Ripogenus Falls (Atkins, 1870). Though there are some reports of anadromous salmon 35 miles above Chesuncook Lake (Commissioner of Fisheries, 1873).

3.2 Human Influence on the Penobscot SHRU

3.2.1 Current population structure and land use

Today, most of the Penobscot SHRU is sparsely populated, with the greatest proportion of the population being south of Old Town. Bangor, the largest urban center in the watershed, has a population of approximately 32,000 (U.S. Census of Population and Housing, 2000). Development issues are likely to grow in importance, as residential development is predicted to increase in over 121,400 ha of the Lower Penobscot watershed in the next few decades (Stein *et al.,* 2005).

Today, the Penobscot SHRU is over 90 percent forested, including forested wetlands which comprise approximately one third of the drainage (Jackson *et al.,* 2005). The upper Penobscot is predominantly spruce-fir forest and the lower is a mix of spruce-fir, pine, and maple-beech-birch stands (Bailey, 1995). The extensive private forests in northern portions of the drainage have experienced dramatic change in silvicultural harvest and ownership over the past two decades (Irland, 2000; McWilliams *et al.,* 2005). Silviculture techniques have shifted away from clear-cutting and land ownership has shifted from large industrial forest parcels to smaller fragmented ownership (e.g. Field *et al.,* 1994). Approximately five percent of the Penobscot is in agricultural use (Houtman, 1994). The 55,700 ha Kenduskeag Stream watershed is the most intensively farmed watershed in the Penobscot River basin. There are over 100 farms raising sheep, goats, dairy and beef cattle, and growing potatoes, beans, and other crops (PCSWCD 2005). Other agricultural land uses are along the eastern edge of the East Branch watershed in southern Aroostook County and the Piscataquis sub-basin.

3.2.2 Dams and diversions

There are at least 116 dams in the Penobscot River watershed (FERC, 1997). The five major dams on the mainstem of the Penobscot, Veazie, Great Works, Milford, West Enfield, and Weldon dams, are located at river kilometers 48, 60, 62, 101,149, respectively. All of the larger dams in the basin, with the exception of many of the licensed dams in the West Branch Penobscot and three unlicensed dams on the East Branch Penobscot, are licensed to operate solely in a "run-of the-river" mode (i.e. inflow typically equals outflow; Fay *et al.,* 2006).

Dams are a significant impediment to self-sustaining Atlantic salmon populations in Maine (NRC, 2003). FERC (1997) estimated that 27 percent of the 31 kilometers of the habitat in the mainstem Penobscot is impounded by the five dams between the head-of-tide and the confluence of the West and East Branches of the Penobscot in Medway. The U.S. Army Corp of Engineers (USACOE, 1990) estimates that on the West Branch Penobscot, approximately 57 percent of the 158 river kilometers is impounded; on the Piscataquis river mainstem, approximately 11 percent of the roughly 119 river kilometers is impounded; on the Sebec River tributary to the Piscataquis, approximately 28 percent of the roughly 69 kilometers is impounded; and on the Passadumkeag River roughly 8 percent of the roughly 40 kilometers of the river below Grand Falls is impounded.

The Telos Cut is a man-made canal that connects the Penobscot SHRU to the Allagash watershed. The Telos Cut was constructed to move logs from Telos lake into Webster lake where they were subsequently floated down the East Branch Penobscot, and down the Penobscot into Bangor where the logs were processed for commerce. The Telos dam in conjunction with the lock dam at the outlet of Chamberlain Lake controlled the flow of water through the canal. Today the dams continue to be maintained as flow control structures.

Penobscot River restoration effort through dam removal

A clear and thorough understanding of fish passage is requisite for effective management of migratory fishes. However, fish passage in the Penobscot River has been poorly documented throughout history. Several investigations of fish passage on the Penobscot River have occurred, but they are all limited spatially (e.g., Rizzo, 1983) or temporally (e.g., Cutting, 1959). Though many details of the fish passage story remain elusive, dams have clearly obstructed Atlantic salmon migration in the Penobscot River for nearly 200 years. The extent to which mainstem dams have hindered fish passage has varied markedly through time.

Though periods of poor fish passage did occur, most dams were passable at a range of flows prior to 1935 (Atkins and Foster, 1867; Everhart, 1957; Cutting, 1959; FERC, 1994). The majority of the mainstem dams were constructed prior to 1900. Between 1820 and 1853, four mainstem dams (Veazie, Ayer's Falls, Great Works, and Old Town) were built between Veazie and Milford. Ayer's Falls, Great Works, and Old Town Dams were relatively low head facilities. These dams allowed upstream passage through aprons used for passing logs and were passable at a range of flows (Atkins and Foster, 1867). However, Veazie Dam was a complete barrier to upstream migration from 1833, when it was built, to at least 1846. Fish passage was also substantially hindered at the Bangor Dam (1874-1876) and West Enfield Dam (1896-1900) after their construction until fishways were installed.

The incremental modification of the mainstem dams toward higher head (i.e. greater power generating capacity) made upstream passage very unlikely between 1935 and 1970 (Everhart and Cutting, 1967). However, passage was possible at specific flows via fishways that were often poorly located or in need of repair (Cutting, 1959). The addition of the final mainstem dam, Mattaceunk, in 1939 further hindered upstream passage. The trend toward higher dams, the low efficiency of most fishways, and the addition of the 39 foot high Mattaceunk Dam in 1939 made upstream migration to suitable spawning areas highly unlikely during this time period (Pratt, 1946).

Since 1970, passage in the Penobscot River has been possible at a range of flows. In fact, passage conditions have generally been improving due to the construction of several modern fishways at Bangor, Veazie, Great Works, Milford, and West Enfield. Several modifications to the Mattaceunk Dam have improved fish passage (Rizzo, 1983). Additionally, an 80-foot breach in the Bangor Dam in 1977 (with subsequent removal) has essentially eliminated the Bangor Dam as a hindrance to fish passage. However, a rigorous examination of the efficiency of current fish passage facilities is still necessary.

In addition to hindering passage of Atlantic salmon, hydropower development in the Penobscot has also prevented anadromous salmon from accessing at least 30 percent of their historical habitat (e.g., West Branch, Mattamiscontis Stream; Baum 1983; Moring *et al.,* 1995). The largest portion of historical habitat that remains inaccessible is the West Branch. Anadromous salmon are known to have spawned at least as high as Ripogenus Falls (Atkins, 1870).

Currently, of the 17 FERC licensed hydropower projects (20 dams) within the historical range of diadromous fishes in the Penobscot River basin, thirteen dams have upstream anadromous fish passage, and 10 have a structure or measures for downstream passage (DMR and DEP, 2008).

In 2004, a settlement agreement between PPL Corporation, state and federal resource agencies, and six conservation groups allows for the purchase of three out of the four lowermost large dams in the Penobscot SHRU. The agreement allows for the purchase and removal of the Veazie and Great Works dams and the purchase, decommissioning and construction of a natural bypass around the Howland dam, the lowermost dam on the Piscataquis sub-basin. At the Milford Dam located above Great Works, there will be installation of a state-of-the-art fish passage facility (fishlift), while both and upstream and downstream eel passage will be enhanced at Milford, Orono, Stillwater, and West Enfield (Figure 3.2.2). Purchase of the three dams is expected to occur in 2008 while removal is anticipated to start around 2010 (DMR and DEP, 2008).

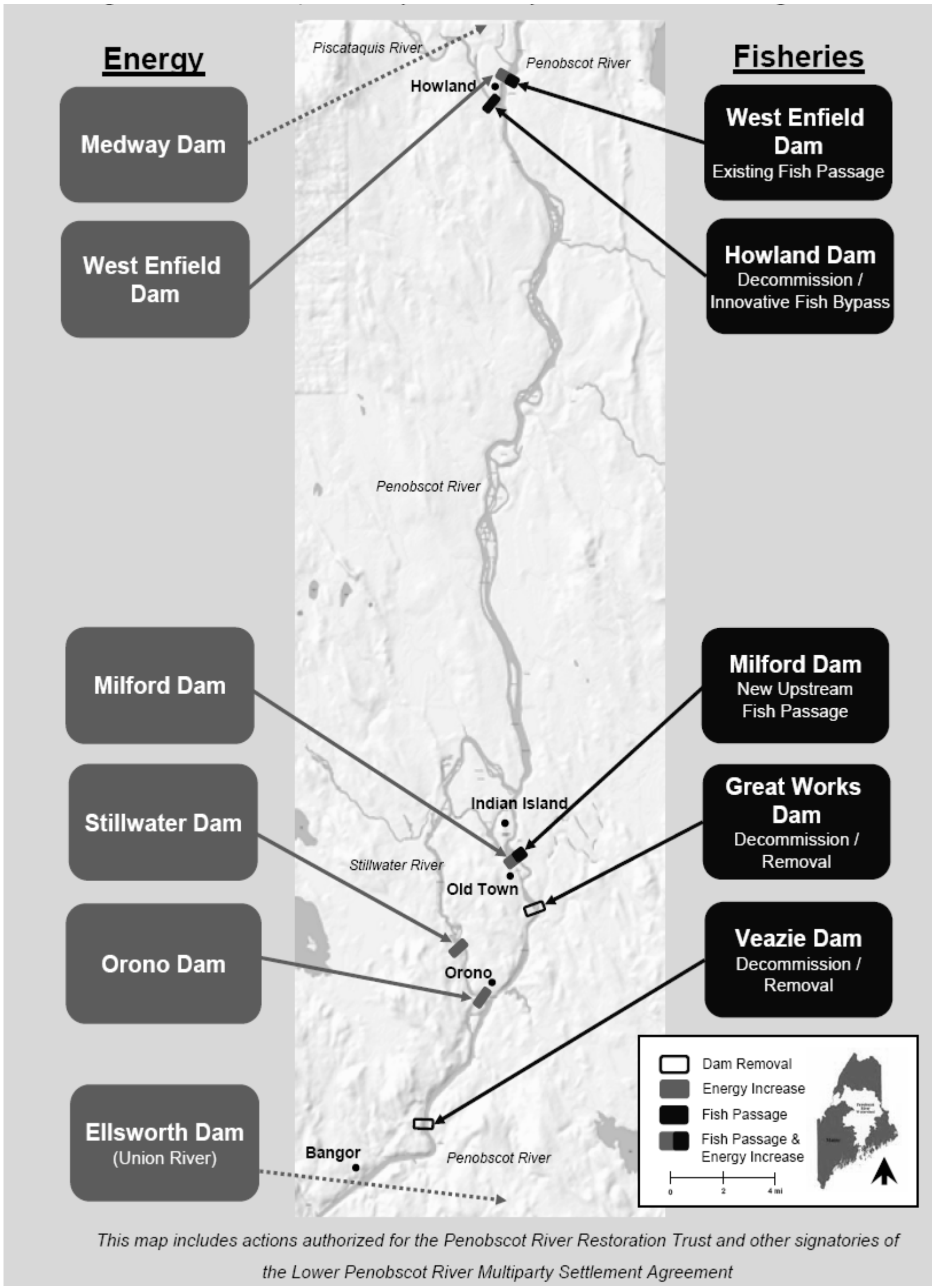

Figure 3.2.2 Penobscot River Restoration Project Dam Removal and Fish Passage Enhancement Map (*Source: Penobscot River Restoration Trust 2005-2008*)

3.2.3 Fisheries and fish introductions in the Penobscot SHRU

Historically, the Penobscot SHRU contained a substantially greater and more diverse diadromous fish community than is present today (Saunders *et al.*, 2006). Diadromous fish species historically present in the Penobscot include alewife, American eel, American shad, Atlantic sturgeon, Atlantic tomcod, blueback herring, brook trout, rainbow smelt, sea lamprey, shortnose sturgeon, and striped bass (Saunders *et al.*, 2006).

Prior to European occupation, millions of alewives migrated as far as 320km upriver each year (Baum, 1983). The annual run of alewives was estimated at 1,000,000 fish in the Penobscot (Foster and Atkins, 1869). American shad were abundant in the Penobscot, with catch estimates up to 2,000,000 before construction of dams in the 1830s (Foster and Atkins, 1869). Pre-settlement abundance estimates of anadromous Atlantic Salmon spawners range from 40,000 (Baum, 1983) to 200,000 (Baum, 2002). In addition to these populations of anadromous salmon, potamodromous (i.e. 'landlocked') salmon also existed in the drainage (Warner and Havey, 1985). These fish had similar life history patterns to anadromous salmon except that the post-smolts and adults fed and grew in Sebec Lake and did not migrate to the ocean (Warner and Havey, 1985). Today, there are still substantial numbers of 'landlocks' in the drainage that may have ancestral linkages to anadromous salmon. These populations include Sebec Lake, the West Branch Penobscot, and the East Branch Penobscot.

Today, much of Maine's waters are host to a variety of introduced and invasive species of fish. Many species, including smallmouth bass, largemouth bass, brown trout, splake and rainbow trout have been introduced as part of an effort to enhance recreational fishing opportunities. Carp were introduced in ponds in the late 1800's for cultivation purposes and later likely escaped from these ponds into the tidal waters of the Scarborough and Kennebec Rivers (Lucas, 2001). Other species, including northern pike, muskellunge, black crappie, green sunfish, white catfish, and several species of cyprinids have been introduced illegally or through accidental introductions often associated with the transport and release of live bait used for recreational fishing. Species such as chain pickerel and landlocked salmon are native to the state of Maine, though their range has been vastly expanded as these fish have been moved around to enhance angler opportunity.

The current fish community in the Penobscot drainage has shifted from a historically diadromous fish dominated to a resident freshwater fish dominated system. Warm water species widespread throughout the basin are yellow perch, white perch, chain pickerel and smallmouth bass. Other species commonly found are red breasted sunfish, white sucker, creek chub, common shiner, brown bullhead, American eel and sea lamprey. Non-indigenous fish introductions of warm water species have altered the fish community. The first recorded introductions of non-native warm water species into the Penobscot are chain pickerel and smallmouth bass, in 1819 and 1869, respectively (Baum, 1983). Other introduced species have included brown trout, splake, and most recently northern pike (illegal introduction). The introduction or invasion of top predators may be most detrimental to Atlantic salmon populations as these introduction have been shown to have negative effects on native top predators and dramatic cascading effects on lower trophic levels (Vander Zanden *et al.*, 2004). Furthermore, several studies have highlighted the potential predation of introduced fishes on juvenile Atlantic salmon (Barr, 1962; Warner, 1972; van den Ende, 1993).

Smallmouth bass were first introduced into Maine waters from New York in 1868 (Jordan, 2001) and are now found throughout most of the Penobscot SHRU except for much of the West Branch where bass have been excluded by dams. Today bass are considered by Maine's Department of Inland Fisheries and Wildlife to be one of Maine's most important sport fishes, along with brook trout and landlocked salmon (Jordan, 2001), with the Penobscot River considered to provide one of the best recreational small mouth bass fishery in the eastern United States (Maine DIFW 2007). Smallmouth bass are likely aggressive competitors as well as predators to Atlantic salmon as juvenile bass are found consistently in the same habitats as juvenile salmon feeding and utilizing space that would otherwise be utilized by parr. Largemouth bass, not native to New England, are believed to have been incidentally introduced into Maine in the late 1800's along side a planned smallmouth introduction (Jordan 2001). To date, largemouth bass populations in the Penobscot SHRU are largely confined to waters South and West of the Veazie Dam (Jordan 2001).

Brown trout, native to Europe, northern Africa, and western Asia (page and Burr, 1991), were first introduced into U.S. waters in 1883 when fish from Germany were stocked in the Pere Marquette River in Michigan (Mather, 1889; Courtenay *et al.,* 1984). Brown trout were first introduced to Maine in 1885 when they were stocked in Branch Lake in Ellsworth, Maine (Boland, 2001); part of the Union River watershed. In the Penobscot SHRU, Nicatous Lake in the Passadumkeag watershed currently supports a brown trout fishery (Boland, 2001), and in 2001, NOAA Fisheries documented a 36 cm (approx.) brown trout in the lower Penobscot River below the Veazie dam when it was captured in a rotary screw trap used to capture migrating Atlantic salmon smolts (NOAA unpublished data). Brown trout are believed to be responsible for reducing native fish populations, especially salmonids, through predation, displacement, and food competition (Taylor *et al.,* 1984).

Splake is the only salmonid cross capable of reproducing for an infinite number of generations, although they are not known to reproduce successfully in the wild (Obrey, 2001). Splake were first introduced into Maine in Long Pond, Washington County in 1958. In the Penobscot SHRU, roughly 15 lakes and ponds are stocked with splake and are found in the West Branch, East Branch, Piscataquis and Orland river drainages. Splake in Maine are stocked in lakes and ponds where, most frequently there is insufficient quantity and quality spawning habitat for salmonids (Obrey, 2002). Occasionally, splake may utilize stream and river habitats during the cooler periods of the year, but during the summer, most of the splakes water quality requirements cannot be achieved in free-flowing waters within the state (Obrey, 2002). The potential exists for stocked splake to reach a size such that smolt predation becomes possible (Beland, 2001). ASC and IFW biologists sampled splake in Beddington Lake (Narraguagus drainage in the Downeast Coastal SHRU) in 2001 and found one splake that had consumed an Atlantic salmon smolt (Ken Beland, ASC, Personal Communication).

Northern pike were illegally introduced into the Belgrade Lakes in the 1970s (Brautigam, 2001) and were recently illegally introduced into Pushaw Lake, opening up the possibility that they could expand into the mainstem of the Penobscot River and tributaries. Pike are voracious predators on other fishes, and their presence may influence populations of native fishes. In Sweden, a northern pike invasion was believed to have replaced artic char as top predator through a combination of predation and competition (Bystrom *et al.,* 2007). He and Kitchell (1990) documented changes after an experimental northern pike introduction into a lake that was previously piscivore free. Changes occurring in the fish community after northern pike introduction ranged from decreased prey fish biomass, decreased abundance of dominant species and decreased mean size for species most vulnerable to predation (He and Kitchell, 1990).

Landlocked salmon are native to only four river basins in Maine: the St. Croix at West Grand Lake in Washington County; the Union at Green Lake in Hancock County; the Penobscot at Sebec Lake in Piscataquis County; and the Presempscot at Sebago Lake in Cumberland County (Boucher, 2004). Today, landlock salmon are the principle fisheries in approximately 200 lakes across the state, and are widely distributed across the Penobscot [SHRU] (Boucher, 2004). Because sea-run and landlocked Atlantic salmon are the same species, direct competition for food and space is inevitable when the fish are in the same area (Maine ASC and Maine IFW 2002).

3.3 Atlantic salmon habitat

The Penobscot SHRU once contained high quality Atlantic salmon habitat in quantities sufficient to support robust Atlantic salmon populations. The construction of dams in the Penobscot SHRU has greatly diminished both habitat quality and availability. Degradation of habitat quality and availability from forestry, development, and land management practices has also occurred. In the Penobscot SHRU, there are approximately 323,700 units of historically accessible spawning and rearing habitat for Atlantic salmon among approximately 17,440 km of rivers, lakes and streams. Of the 323,700 units of spawning and rearing habitat, approximately 211,000 units of habitat are considered to be currently occupied. The mainstem Penobscot has the highest biological value to the Penobscot SHRU because it provides a central migratory corridor for the entire Penobscot SHRU.

Dams, along with degraded substrate and cover, water quality, water temperature, and biological communities have reduced the quality and quantity of habitat available to Atlantic salmon populations within the Penobscot SHRU. A combined total of twenty FERC licensed hydropower dams in the Penobscot SHRU significantly impede the migration of Atlantic salmon and other diadromous fish to nearly 300,000 units of historically accessible spawning and rearing habitat. Agriculture and urban development largely affects the lower third of the Penobscot SHRU below the Piscataquis River sub-basin by reducing substrate and cover, reducing water quality, and elevating water temperatures. Introductions of smallmouth bass and other non-indigenous species significantly degrades habitat quality throughout the mainstem Penobscot, portions of the Mattawamkeag, Piscataquis, and lower Penobscot sub-basins by altering predator/prey relationships. More recently, Northern Pike introductions threaten habitat for similar reasons as smallmouth bass in the lower Penobscot River below Great Works Dam.

Of the 211,000 occupied units within the Penobscot SHRU we calculated these units to be the equivalent of nearly 66,300 functional units or approximately 20 percent of the historical functional potential (Table 3.3a). This estimate is based on the configuration of dams within the SHRU that limit migration and degradation of physical and biological features from land use activities which reduce the productivity of habitat within each HUC 10. For each SHRU 30,000 fully functional units of habitat are needed in order to achieve recovery objectives for the GOM DPS. The combined quality and quantities of habitats available to Atlantic salmon within the currently occupied areas in the Penobscot Bay SHRU currently meet this objective.

Table 3.3a: Total habitat units and functional equivalents by HUC 10 for the Penobscot SHRU

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quality	Dams Encountered	Functional Equivalent	Management Activities**
105000219	Ducktrap River	Y	862	2	0	575	A, F, C/L, H/S, R, Da, Dr, Q
102000510	Kenduskeag Stream	Y	6,869	2	0	4,579	A, F, C/L, H/S, R, M, Da, Dr
102000512	Marsh River	Y	6,018	2	2	2,899	A, F, C/L, H/S, M, Da, Dr
102000205	East Branch Penobscot River	Y	15,843	3	5	7,029	A, F, C/L, H/S, R, Da
105000218	Belfast Bay	Y	2,245	2	3	919	A, F, C/L, H/S, R, M, Da, Dr
102000506	Penobscot River at Orson Island	Y	5,278	2	3	2,161	A, F, C/L, H/S, R, M
102000401	Piscataquis River	Y	18,914	3	6	7,133	A, F, C/L, H/S, R, Da
102000302	East Branch Mattawamkeag River	Y	3,973	2	4	1,383	A, F, C/L, H/S, R, M
102000406	Piscataquis River	Y	9,669	2	4	3,365	A, F, C/L, H/S, R, M, Da
102000404	Pleasant River	Y	22,346	2	4	7,776	A, F, C/L, H/S, R, Da
102000301	West Branch Mattawamkeag River	Y	11,290	2	4	3,929	A, F, C/L, H/S, R, M, Da
102000513	Penobscot River	Y	10,876	1	0	3,625	A, F, C/L, H/S, R, M, Da, Dr
102000511	Souadabscook Stream	Y	5,507	1	0	1,836	A, F, C/L, H/S, R, M, Da, Dr
102000203	East Branch Penobscot River	Y	6,355	2	5	1,880	A, F, C/L, H/S, R
102000501	Penobscot River at Mattawamkeag	Y	3,408	2	5	1,008	A, F, C/L, H/S, M, Da
102000204	Seboeis River	Y	7,442	2	5	2,201	A, F, C/L, H/S, R, Da
102000202	Grand Lake Matagamon	Y	5,740	2	6	1,443	A, F, C/L, H/S, R, Da
102000509	Penobscot River at Veazie Dam	Y	7,550	1	2	1,818	A, F, C/L, H/S, R, M, Da
102000507	Birch Stream	Y	1,065	1	3	218	A, F, C/L, H/S, R, M
102000505	Sunkhaze Stream	Y	2,335	1	3	478	A, F, C/L, H/S, R
102000503	Passadumkeag River	Y	7,950	1	3.5	1,500	A, F, C/L, H/S, R, M, Da
102000502	Penobscot River at West Enfield	Y	14,098	1	4	2,453	A, F, C/L, H/S, R, M, Da

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

** A = Agriculture; F = Forestry, C/L = Changing Land Use; H/S = Hatcheries and Stocking; R = Roads and Road Crossings; M = Mining; Da = Dams; Dr = Dredging; Q = Aquaculture

Table 3.3a: Continued…

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quality	Dams Encountered	Functional Equivalent	Management Activities**
102000405	Seboeis Stream	Y	5,516	1	4	960	A, F, C/L, H/S, R, Da
102000303	Mattawamkeag River	Y	2,039	1	4	355	A, F, C/L, H/S, R, M
102000305	Mattawamkeag River	Y	10,042	1	4	1,747	A, F, C/L, H/S, R, M
102000307	Mattawamkeag River	Y	5,152	1	4	896	A, F, C/L, H/S, R, M, Da
102000306	Molunkus Stream	Y	4,517	1	4	786	A, F, C/L, H/S, R
102000402	Piscataquis River	Y	8,165	1	4.5	1,310	A, F, C/L, H/S, R, M, Da
102000508	Pushaw Stream	N	5,461	0	3	0	
102000304	Baskahegan Stream	N	3,911	0	4	0	
105000216	Bagaduce River	N	1,103	1	0	368	
105000217	Stonington Coastal	N	1,749	1	0	583	
102000403	Sebec River	N	15,964	2	6	4,014	
105000220	West Penobscot Bay Coastal	N	3,468	1	2	835	
102000107	Nahamakanta Stream	N	5,036	3	9	1,167	
102000104	Caucomgomok Lake	N	4,617	3	10	909	
102000103	W. Br. Penobscot R. at Chesuncook L.	N	14,666	3	10	2,887	
102000110	West Branch Penobscot River	N	4,615	2	8	838	
102000109	West Branch Penobscot River	N	13,476	2	8	2,448	
102000108	Jo-Mary Lake	N	2,568	2	9	397	
102000105	Chesuncook Lake	N	8,830	2	10	1,159	
102000101	North Branch Penobscot River	N	12,541	2	11	1,399	
102000102	Seeboomook Lake	N	13,239	2	11.5	1,362	
102000504	Olamon Stream	N	1,434	0	3	0	
102000106	Nesowadnehunk Stream	I	0			0	
102000201	Webster Brook	I	0			0	

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

** A = Agriculture; F = Forestry, C/L = Changing Land Use; H/S = Hatcheries and Stocking; R = Roads and Road Crossings; M = Mining; Da = Dams; Dr = Dredging; Q = Aquaculture

Table 3.3b: Biological value of Atlantic salmon habitat in HUC 10 watersheds in the Penobscot Bay SHRU.

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quantity Score	Habitat Quality Score	Habitat Score (E x F)	Final Habitat Value	Final Migration Value	**Final Biological Value**
102000404	Pleasant River	Y	22,346	3	2	6	3	3	**3**
102000401	Piscataquis River (1)	Y	18,914	3	3	9	3	3	**3**
102000205	East Branch Penobscot River (3)	Y	15,843	3	3	9	3	3	**3**
102000502	Penobscot River (2) at West Enfield	Y	14,098	3	1	3	2	3	**3**
102000301	West Branch Mattawamkeag River	Y	11,290	3	2	6	3	3	**3**
102000513	Penobscot River (6)	Y	10,876	3	1	3	2	3	**3**
102000305	Mattawamkeag River (2)	Y	10,042	2	1	2	1	3	**3**
102000406	Piscataquis River (4)	Y	9,669	2	2	4	2	3	**3**
102000402	Piscataquis River (3)	Y	8,165	2	1	2	1	3	**3**
102000509	Penobscot River (4) at Veazie Dam	Y	7,550	2	1	2	1	3	**3**
102000506	Penobscot River (3) at Orson Island	Y	5,278	2	2	4	2	3	**3**
102000307	Mattawamkeag River (3)	Y	5,152	2	1	2	1	3	**3**
102000501	Penobscot River (1) at Mattawamkeag	Y	3,408	1	2	2	1	3	**3**
102000303	Mattawamkeag River (1)	Y	2,039	1	1	1	1	3	**3**
102000204	Seboeis River	Y	7,442	2	2	4	2	2	**2**
102000510	Kenduskeag Stream	Y	6,869	2	2	4	2	2	**2**
102000203	East Branch Penobscot River (2)	Y	6,355	2	2	4	2	2	**2**
102000512	Marsh River	Y	6,018	2	2	4	2	2	**2**
102000202	Grand Lake Matagamon	Y	5,740	2	2	4	2	2	**2**
102000302	East Branch Mattawamkeag River	Y	3,973	2	2	4	2	2	**2**
102000503	Passadumkeag River	Y	7,950	2	1	2	1	1	**1**
102000405	Seboeis Stream	Y	5,516	2	1	2	1	1	**1**

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

Table 3.3b: Continued…

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quantity Score	Habitat Quality Score	Habitat Score (E x F)	Final Habitat Value	Final Migration Value	**Final Biological Value**
102000511	Souadabscook Stream	Y	5,507	2	1	2	1	1	**1**
102000306	Molunkus Stream	Y	4,517	2	1	2	1	1	**1**
102000505	Sunkhaze Stream	Y	2,335	1	1	1	1	1	**1**
105000218	Belfast Bay	Y	2,245	1	2	2	1	1	**1**
102000507	Birch Stream	Y	1,065	1	1	1	1	1	**1**
105000219	Ducktrap River	Y	862	1	2	2	1	1	**1**
102000403	Sebec River	N	15,964	3	2	6	3	3	**3**
102000103	W. Branch P. R. at Chesuncook Lake	N	14,666	3	3	9	3	3	**3**
102000109	West Branch Penobscot River	N	13,476	3	2	6	3	3	**3**
102000102	Seeboomook Lake	N	13,239	3	2	6	3	3	**3**
102000101	North Branch Penobscot River	N	12,541	3	2	6	3	3	**3**
102000105	Chesuncook Lake	N	8,830	2	2	4	2	3	**3**
102000107	Nahamakanta Stream	N	5,036	2	3	6	3	3	**3**
102000104	Caucomgomok Lake	N	4,617	2	3	6	3	3	**3**
102000110	West Branch Penobscot River	N	4,615	2	2	4	2	3	**3**
105000220	West Penobscot Bay Coastal	N	3,468	1	1	1	1	1	**1**
102000108	Jo-Mary Lake	N	2,568	1	2	2	1	1	**1**
105000217	Stonington Coastal	N	1,749	1	1	1	1	1	**1**
105000216	Bagaduce River	N	1,103	1	1	1	1	1	**1**
102000508	Pushaw Stream	N	5,461	2	0	0	0	0	**0**
102000304	Baskahegan Stream	N	3,911	2	0	0	0	0	**0**
102000504	Olamon Stream	N	1,434	1	0	0	0	0	**0**
102000106	Nesowadnehunk Stream	I							
102000201	Webster Brook	I							

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

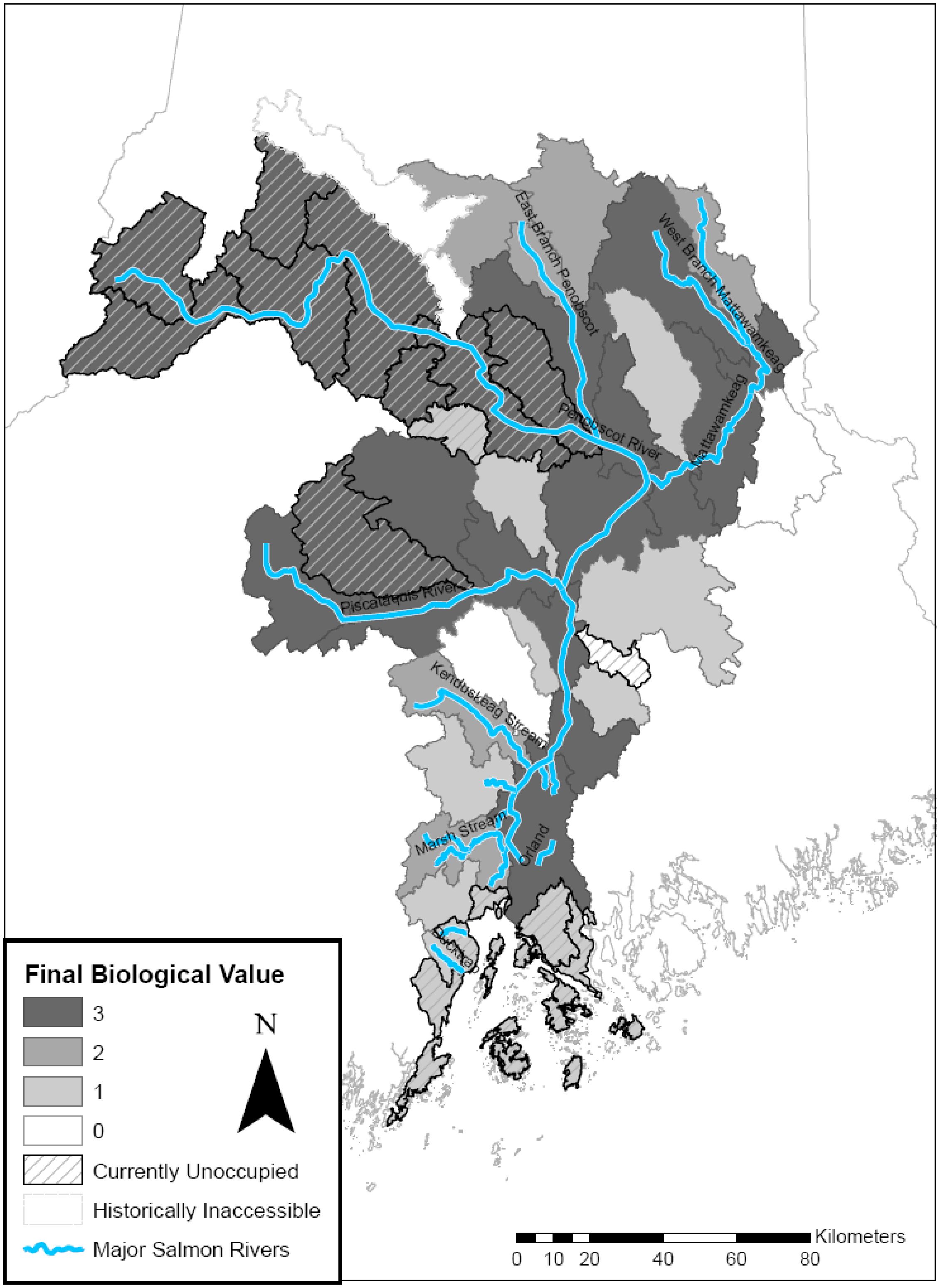

Figure 3.3: Final biological value of HUC 10 watershed in the Penobscot SHRU

Chapter 4: Merrymeeting Bay SHRU Biological Report

4.1 Landscape and hydrological features that shape the physical and biological features within the Merrymeeting Bay SHRU

4.1.1 Geography

The Merrymeeting Bay SHRU extends west as far as, and includes the Androscoggin River watershed, and east as far as, and includes the St. George River watershed. The Kennebec River, the largest watershed in the SHRU, flows 233 km from Moosehead Lake to Merrymeeting bay where it joins with the Androscoggin River (Maine DEP, 1999) and flows another 32 km out to the Atlantic Ocean (Reed & Sage, 1975). The Kennebec watershed drains a land area of 3,771,520 acres, constituting approximately one-fifth of the total land area of Maine occupying much of Somerset and Kennebec County and portions of Franklin, Penobscot, Waldo, Sagadahoc, and Androscoggin Counties (MSPO, 1993).

The Androscoggin River flows 277 km from Umbagog Lake to Merrymeeting bay, and drains approximately 2,208,000 acres (Maine DEP, 1999), occupying much of Oxford and Androscoggin Counties and portions of Kennebec, Franklin, and Cumberland Counties in Maine. The Androscoggin also occupies a portion of Coos County, New Hampshire.

The small coast drainages east of Small Point include the Sheepscot, Medomak and St. George Rivers. These drainages drain approximately 672,127 acres, or roughly 10 percent of the entire Merrymeeting Bay SHRU and occupy much of Knox and Lincoln Counties as well as portions of Waldo and Kennebec County.

4.1.2 Geology and climate

The Merrymeeting bay SHRU south and east of a line extending from roughly Fryburg to Livermore Falls and onward to Skowhegan lies within the Laurentian Mixed Forest ecoregion, which is described as a transitional zone between the broadleaf deciduous and boreal forests (Bailey, 1995). This region has moderately long winters with a frost free season that lasts roughly 100 to 140 days, and moderate precipitation ranging from 61 to 115 cm a year (Bailey, 1995). Average annual precipitation in the Kennebec watershed is 106 cm. However there is a rain shadow from the White Mountains that affects the region from the Moosehead Lake watershead west to Jackman and the river corridor between Skowhegan and Waterville. In the rain shadow the average annual precipitation is below 97 cm (U.S. Fish & Wildlife Service, 1989). North and west of the line, the Merrymeeting bay SHRU lies within the New England Mixed Forest ecoregion, which is primarily composed of a transitional forest between boreal spruce-fir to deciduous forest with vertical vegetation zonation (Bailey, 1995). The climate within this region can be characterized by well defined summer maximum temperatures indicative of the dominating tropical air masses during the summer and winter minimum temperatures dominated by continental-polar air masses during the winter (Bailey, 1995). The average frost free period for this region is approximately 100 days.

The geology of the Merrymeeting Bay SHRU is heterogeneous, including sub-catchments that are typical and atypical of the GOM DPS. In general, Maine's landscape is a result of a mountain building in the middle Devonian period followed by a long period of erosion and recent glaciation, and deposition of related deposits, which primarily include till and marine clay, with sand and gravel deposits in many of the valleys. More specifically, the Merrymeeting Bay SHRU is comprised of two general regions; highlands and lowlands. The upper portion of the Merrymeeting Bay SHRU, including the upper half of the Androscoggin Basin mostly north and west of Livermore Falls and the upper third of the Kennebec Basin mostly north and west of Bingham, is considered to be a high elevation (150 – 300 meters) mountainous region. This portion of the basin is comprised of the Appalachian Mountain belt, a region which borders the Atlantic Ocean. The bedrock of this region consists of a combination of gneiss and schist, and various granite plutons (Simplified Bedrock Geologic Map of Maine, 2002). The presence of these high elevation areas within the upper Kennebec and Androscoggin watersheds distinguishes the majority of the Merrymeeting Bay SHRU from much of the Penobscot and downeast Maine coastal basins. The high elevation areas of Maine are generally well-drained, resulting in lower dissolved organic carbon and low concentrations of dissolved aluminum. Dissolved organic carbon in surface waters plays several significant roles in water chemistry, causing lowered pH but adding buffering capacity at the ambient pH, increasing dissolved aluminum and iron, but reducing the toxic effects of much of the dissolved aluminum. Thus, dissolved organic carbon has both positive and negative effects on aquatic organisms (Steve Norton, Personal Communications, January 2008).

The "lowland" portion of the Merrymeeting Bay SHRU, including the Sheepscot, Medomak and St. George watersheds, consists of coastal lowlands that were depressed by the Laurentide ice sheet, which receded from the area about 15,000 to 10,000 thousand years ago. Following the retreat of the glacier margin, much of coastal Maine extending inland up to as much as about 100 miles fro the present coast was submerged below sea level for up to a few thousand years (Caldwell, 1998). During that time, glacial marine silt and clay were deposited along many of the river valleys and lowlands of coastal Maine (Surficial Geologic Map of Maine, 2003). Today, much of Maine's coastal region has low relief with rolling hills (Bailey, 1995). Common features of the coastal region include moraines, drumlins, eskers, and outwash plains; all of which are typical features of the glaciated region (Bailey, 1995). Much of the bedrock geology throughout this lowland region is comprised of calcareous marine shale and calcareous gneiss and schists, as well as non-calcareous marine sandstone and slate (Simplified Bedrock Geologic Map of Maine, 2002). Bedrock throughout this area typically has a higher chemical weathering rate, and surface waters have higher calcium than in the granite-dominated areas, dominate in the downeast Maine coastal basin and portions of the Appalacian Mountain belt in western Maine. The higher weathering rates and higher calcite concentrations within the bedrock material, in combination with the glacial marine clay, provides greater opportunity for phosphorous release, and thereby results in potentially more productive surface waters in the lower Kennebec and Androscoggin watersheds than those waters east of the Penobscot.

4.1.3 Hydrology

The Merrymeeting Bay SHRU includes two major basins- the Kennebec and Androscoggin, each of which have numerous sub-basins; and three major coastal watershed outside of the Kennebec and Androscoggin basins, which include the Sheepscot, Medomak and St. George watersheds.

In the Kennebec basin, historically important tributaries to Atlantic salmon included the Dead River, Carrabasset River and Sandy River (Atkins and Foster, 1867), which are generally characterized as high elevation tributaries that are dominated by rapids, riffles and the occasional falls with a substrate composed of boulders, cobble, and gravel. The lower Kennebec tributaries, including Messalonskee stream which flows out of the Belgrade Lakes, and the Sebasticook River, which incorporates China Lake, Unity Pond, Moose Lake and Sebasticook Lake, were less important for Atlantic salmon spawning and rearing, yet the Sebasticook drainage was considered first rate by Atkins and Foster (1867) for production of alewives and shad.

The Androscoggin River originates at Umbagog Lake near Errol, New Hampshire and flows roughly 260 km past several towns including, Rumford, Dixfield, Jay, Livermore Falls, and Brunswick as well as the city of Lewiston-Auburn (Maine DEP, 1999). The upper portions of the Androscoggin, like the Kennebec, are high gradient. The Androscoggin River drops over 305 meters from its headwaters to where it meets the sea, with an average gradient of 3.9 meters per km. In the Androscoggin watershed, Rumford Falls was the upper extent of Atlantic salmon migration, while Lewiston Falls was believed to be the upper extent of alewife and shad migrations (Atkins and Foster, 1887). The Little Androscoggin River is the largest major sub-basin of the Androscoggin with historically important salmon habitat that was accessible as far up as Snow's Falls located 3.2 km outside of West Paris (Foster and Atkins, 1867). Prior to its damming, the Androscoggin River provided access to a large and diverse aquatic habitat for great numbers of diadromous and resident fish species (Foster and Atkins, 1867).

The Kennebec River itself originates at Moosehead Lake and falls about 312 meters over a distance of 193 km from its point of origin to Augusta, Maine, averaging a gradient of 4.1 meters per km (MSPO, 1993). Moosehead Lake has two outlets which form the beginnings of the Kennebec River: the East Outlet and West Outlet which converge at Indian Pond – the impoundment to the Harris Dam hydroelectric facility. With the exception of the Harris Dam impoundment, the upper third of the Kennebec River from Moosehead Lake to Wyman Dam is high gradient rocky riffles and rapids with intermittent pools, incorporating a section of river which is known as the Kennebec Gorge (MSPO, 1993). Foster and Atkins (1868) describe a set of falls with a 4.3 meter vertical drop that was roughly 232 km from where the Kennebec entered the sea, putting the fall in the vicinity of what is now Harris dam. Foster and Atkins (1868) believed that these falls represented the upper extent of the Atlantic salmon migration. Though the falls are approximately 0.6 meters shorter in height then Carratunk falls (now the site of Williams Dam), the lack of a plunge pool below the falls prevented salmon from passing.

From Wyman Lake, the Kennebec River flows 13.5 km to Williams Dam in the town of Solon, Maine. Williams Dam sits on top of what was known as Carratunk falls. Of the 13.5 km of river above Williams Dam, the lower 6.8 km make up a shallow impoundment ranging from 0.9 – 4.6 meters in depth in which flow characteristics are more similar to riverine environment rather than lacustrine environment due to its high flushing rate (MSPO, 1993). From Solon, the Kennebec River flows roughly 22.5 km to the Madison Dam – the first dam above the confluence of the Sandy River. The topography through this stretch becomes less hilly and the river channel becomes alluvial and braided with stretches of meandering deadwaters with intermittent gravel bars and associated riffles.

Downstream from the Madison Dam, the river become more or less a series of reservoirs as it passes through the Weston Dam, Shawmut Dam, Hydro-Kennebec Dam and Lockwood – the lower most dam in the Kennebec River. From Lockwood, the Kennebec flows approximately 64 km into Merrymeeting bay where the Kennebec River converges with the Androscoggin River. This stretch of river consists of long stretches of deadwater with intermittent stretches of riffles created by sand and gravel deposits.

The Sheepscot and St. George Watersheds lie easterly of the Kennebec basin and can be generally characterized as low gradient rivers with deadwaters and shallow pools with intermittent stretches of low gradient riffles and runs.

Table 4.1.3: Major HUC 8 sub-basins in the Merrymeeting Bay SHRU

River	Watershed Area (Acres)	Proportion of Kennebec SHRU
Dead River	562,822	8%
Kennebec above Forks	1,015,187	15%
Kennebec Merrymeeting Bay	2,205,245	33%
Upper Androscoggin	876,509	13%
Lower Androscoggin	1,380,093	21%
Coastal Drainages East of Small Point	672,176	10%
Merrymeeting Bay SHRU	**6,712,032**	**Proportion of GOM DPS: 46%**

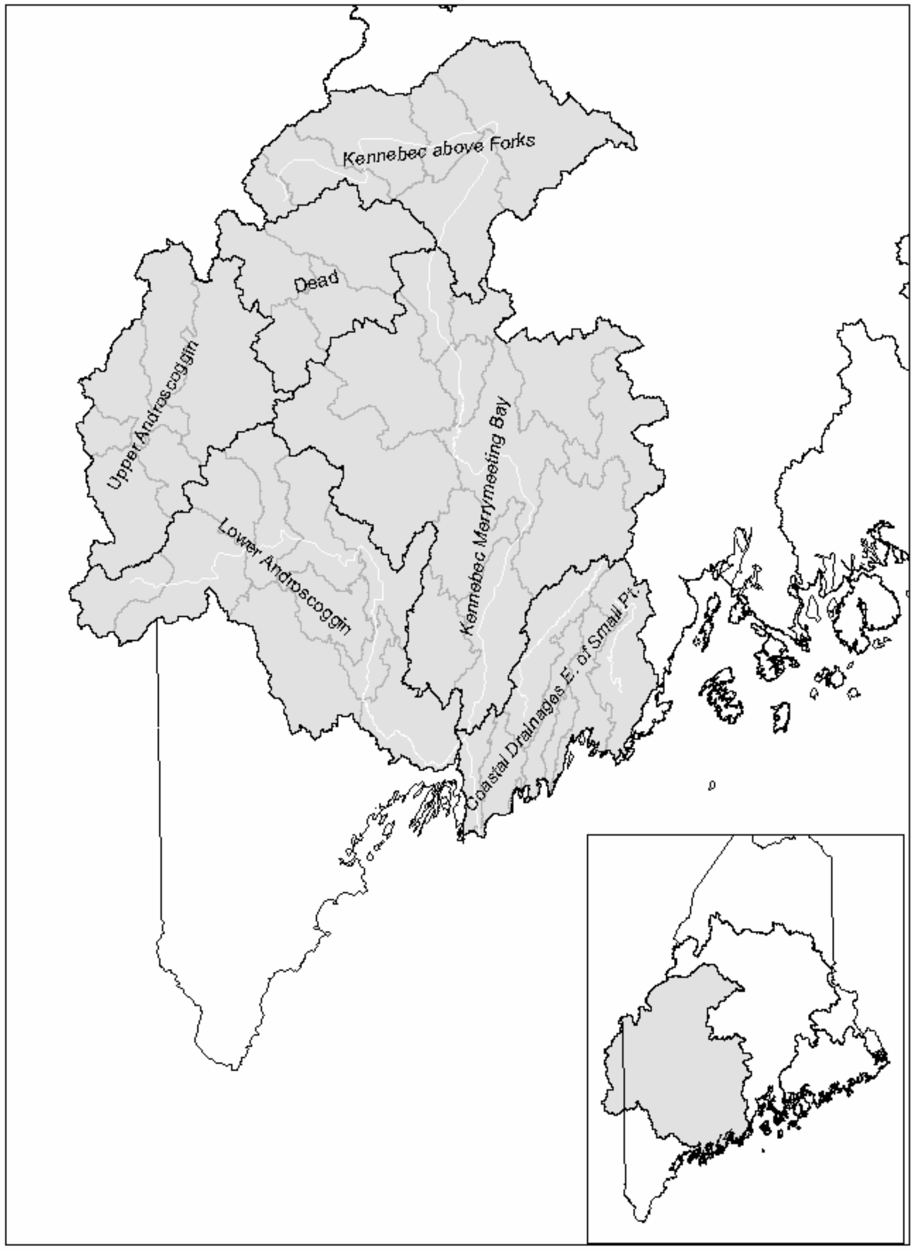

Figure 4.1.3: Map of Merrymeeting Bay SHRU and HUC 8 sub-basins

4.2 Human influence on Merrymeeting Bay SHRU

4.2.1 Current population structure and land use

Most of the human population within the Merrymeeting Bay SHRU is found in the lower portions of the Androscoggin and Kennebec Basins. Major population centers include Lewiston/Auburn (combined population of ~28,000) along the Androscoggin River in Androscoggin County; and Augusta (pop. 18,500) and Waterville (pop. 15,600) found along the Kennebec River in Kennebec County (U.S. Census of Population and Housing, 2000). Moving north and west out of Kennebec and Androscoggin Counties, population densities decline significantly. Kennebec and Androscoggin Counties have population densities of approximately 52 and 85 persons per square km respectively; while Oxford, Franklin and Somerset Counties, to the north and west, have population densities of 10, 7 and 5 persons per square km.

Today roughly 85 to 90 percent of the Kennebec and Androscoggin basins are still in forest land with forest products still being an important component of the SHRUs economy (McWilliams *et al.,* 2003). The paper industry dominates the manufacturing sector of Maine's forest based economy with nine pulp and paper mills across the State (North East State Foresters Association, 2007), of which four (not including one in New Hampshire) are found within the Merrymeeting Bay SHRU. Three paper mills are situated along the Androscoggin River in Berlin, New Hampshire, Rumford and Jay, Maine; and two are found along the Kennebec River in Madison and Skowhegan, Maine.

4.2.2 Dams

Within the Merrymeeting Bay SHRU there are roughly 104 dams of which 15 are FERC licensed mainstem dams used for power generation or storage, resulting in over 59 km of impounded river (Maine DEP, 1999). Therefore, both the Kennebec and Androscoggin watersheds are major power producers. On the Androscoggin below Rumford (the upper extent of the range of Atlantic salmon), major Hydro-power facilities include the upper and lower stations at the Rumford Falls project in Rumford; Riley/Jay/Livermore Projects in Jay, Riley and Livermore; Gulf Island/Deer Rips project in Lewiston-Auburn; Lewiston Falls project in Lewiston/Auburn; the Worumbo Project in Lisbon/Durham; Pejepscot in Topsham/Brunswick; and the Brunswick project in Brunswick/Topsham (DEP, 2007). Today, the upper extent of fish passage in the Androscoggin River is Lewiston Falls 32 km upstream from Merrymeeting Bay (MDMR, 2006).

On the Kennebec River below Moosehead Lake, hydro-power facilities below the Moosehead Dam at Moosehead Lake include the Harris project in Township 1 Range 6; Wyman Project in Moscow/Pleasant Ridge Plantation; Williams Project in Embden and Solon; Abenaki Project in Anson and Madison; Weston Project in Skowhegan; Shawmut Project in Fairfield; Hydro-Kennebec and Lockwood both in Waterville and Winslow. Today, the lowermost project on the Kennebec is the Lockwood Project which currently operates a fish lift. From Lockwood, shad and alewives are released upstream whereas Atlantic salmon are most frequently transported to the Sandy River, which is free of dams.

The Kennebec River diadromous fish restoration project

The Kennebec River Diadromous Fish Restoration Project was initiated in 1986 when the Maine Department of Marine Resources (MDMR) signed a settlement agreement with the Kennebec Hydro-Developers Group (KHDG). A second settlement agreement signed in 1998 by state and federal fisheries resource agencies, non-governmental organizations, and the KHDG resulted in the removal of Edwards Dam in Augusta to provide fish passage for all diadromous fish species, instituted schedules or triggers for fish passage at the seven KHDG dams, and provided additional funding for the stocking program.

From 1837 to 1999 the Edwards Dam in Augusta prevented any upstream fish passage. Removal of Edwards dam restored full access to historical spawning habitat for species like Atlantic sturgeon, shortnose sturgeon, and rainbow smelt, but not for species including alewife, American shad and Atlantic salmon that migrated much further up the river (MDMR, 2007). With the removal of Edwards Dam the first dam on the Mainstem is now the Lockwood Dam in Waterville. Since 2006 there has been fish passage by way of a fish lift. Lockwood will remain the only facility with upstream passage until it lifts 8,000 American shad. Once that threshold has been reached, fish passage on upstream dams will begin.

The Sebasticook River, a tributary to the Kennebec, enters the mainstem on the east bank at Waterville just below the Lockwood dam. Historically the Sebasticook supported large runs of diadromous fish, though was most important for Amercan shad production upstream as far as the town of Newport and alewife production as far up as Wassookeag Lake, Great Moose Pond and Sebasticook Lake (Maine Department of Marine Resources, 2007). Until recently, the Fort Halifax, Benton, and Burnham dams blocked passage of diadromous fish into most of the Sebasticook River (MDMR, 2007). Though the removal of the Edwards dam in Augusta allowed fish passage as far up as far as Lockwood on the Kennebec River, the Fort Halifax dam on the Sebasticook River prevented passage of all diadromous fish into the Sebasticook. In 2000 a fish pump was installed capable of pumping alewives (though not effective at passing other diadromous fish) over the dam (Gail Wippelhauser, e-mail communications, January, 2008). By 2006, fish passage was enhanced at the Benton and Burnham dams allowing for free passage of alewives once above Fort Halifax throughout the mainstem of the Sebasticook River as far up as Sebasticook Lake. Efforts are currently underway to remove the Fort Halifax dam allowing for free, unassisted passage of all Anadromous fish throughout the mainstem of the Sebasticook river, providing access to the largest spawning and nursery habitat area for alewives in the Kennebec River (MDMR, 2007).

Fish passage restoration efforts on the Androscoggin River

On the Androscoggin River, in 1982, Central Maine Power Company (CMP) reconstructed the hydroelectric facility in Brunswick-Topsham, the first upstream dam on the river (Brown *et al*., 2006). CMP installed a slot fishway with a trapping and sorting facility and a downstream passage facility capable of passing anadromous and resident fish species. At that time, the Maine Department of Marine Resources began the Anadromous Fish Restoration Program in the lower Androscoggin River main stem and tributaries below Lewiston Falls. In 1987, the Pejepscot Hydropower Project, the second dam on the Androscoggin River, installed both upstream and downstream fish passage. In 1988, Worumbo installed upstream and downstream passage at the Worumbo Project, the third upstream dam on the river. This provided an opportunity for anadromous species to migrate upstream as far as Lewiston Falls (Brown *et al*., 2006).

4.2.3 Water quality

In addition to the dams within the Androscoggin, poor water quality within certain segments of the Androscoggin is of particular concern for fisheries restoration. The U.S. Environmental Protection Agency noted that two segments of the Androscoggin, including the lower four miles of the Gulf Island dam impoundment and the Livermore Falls impoundment do not attain water quality standards for class C waters (EPA, 2005). The non-attainment status is caused by point source discharges upriver from the 3 paper mills located in Berlin, New Hampshire (Fraser Paper), Rumford, Maine (Mead WestVaco), and Jay, Maine (International Paper); five municipal point sources from locations in Berlin and Gorham, New Hampshire and Bethel, Rumford-Mexico, and Livermore Falls, Maine; and non-point source pollutant loads from land use activities, particularly that related to residential development, silviculture, and agriculture (EPA, 2005).

The Maine Department of Environmental Protection has four standards for classification of freshwater which are not classified as "great ponds". These are class AA, A, B, and C waters, in which class AA is the highest classification in which waters are considered to be "outstanding natural resources and which should be preserved because of their ecological, social, scenic or recreational importance"; and class C waters is the lowest classification in which class C waters "shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited…, navigation, and as a habitat for fish and other aquatic life." (State of Maine, Title 38 *§ 465*).

The Gulf Island Dam impoundment does not meet the Class C standards for dissolved oxygen concentration in the summer at depths of 30 to 80 feet. In addition to the pollution sources upstream from the dam, the dam itself contributes to non-attainment of DO criteria and algae growth by creating an environment of low water movement and low vertical mixing with the deeper water column (EPA, 2005).

The Livermore Falls impoundment does not attain the class C aquatic life criteria in which dissolved oxygen shall not fall below an instantaneous minimum of 5 ppm and 60 percent saturation, and a 30 day average long term minimum of 6.5 ppm (EPA, 2005).

4.2.4 Fisheries and fish introductions in the Merrymeeting Bay SHRU

Historically, the Merrymeeting Bay SHRU was host to a variety of native resident and diadromous fish. The native diadromous communities in Merrymeeting bay and portions of the Kennebec and Androscoggin Rivers included shad, alewives, Atlantic sturgeon, shortnose sturgeon, rainbow smelt, Atlantic salmon, and striped bass (Foster and Atkins, 1867; MSPO, 1993). Other native diadromous species native to coastal Maine and likely native to the Merrymeeting Bay SHRU included American eels, lampreys, brook trout, Atlantic tomcod and blueback herring (Fuller, 1999). Some seasonal marine migrants including, menhaden and bluefish also utilize the lower Kennebec River (MSPO, 1993). Native resident species of the Merrymeeting Bay SHRU likely included brook trout, burbot, lake trout (togue), lake whitefish, brown bullhead, pumpkinseed sunfish, redbreast sunfish, and yellow perch (Page and Burr 1991); as well as numerous species of fish classified by Maine IF&W as "non-sportfish" which include numerous members of the family Cyprinidae (minnows), Catostomidae (suckers) and two species in the family Percidae (perch) – not including the yellow perch (Kramer 2002).

Today, much of Maine's waters are host to a variety of introduced and invasive species of fish. Smallmouth bass were likely first introduced into the Merrymeeting Bay SHRU around 1869 when a contract was made with Livingston Stone of New Hampshire to deliver 15,000 black bass to several points throughout the State, which included the Cobbosseecontee lake in Winthrop (Foster and Atkins, 1869). Largemouth bass were likely incidentally introduced into the Merrymeeting Bay SHRU along side the planned smallmouth introductions around 1869. Landlock salmon, although native to Maine, were not native to the Merrymeeting Bay SHRU. Landlock salmon introductions may have first occurred in the Merrymeeting Bay SHRU around 1869 when three thousand landlock salmon of the Schoodic Lake strain were hatched out and raised at a hatchery in Alna along the Sheepscot River (Foster and Atkins, 1869). Brown trout, splake and rainbow trout have all been introduced as part of an effort to enhance recreational fishing opportunities (Page and Burr, 1991). Carp were introduced in ponds in the late 1800's for cultivation purposes and later likely escaped from these ponds into the tidal waters of the Scarborough and Kennebec Rivers (Lucas, 2001). White catfish, and several species of cyprinids have been introduced illegally or through accidental introductions often associated with the transport and release of live bait used for recreational fishing. Chain pickerel are native to portions of southern Maine, yet their range has been vastly expanded as these fish have been moved around to enhance angler opportunity.

4.3 Atlantic salmon habitat

In the Merrymeeting Bay SHRU, there are approximately 372,600 units of historically accessible spawning and rearing habitat for Atlantic salmon located among approximately 5,950 km of historically accessible rivers, lakes and streams. This habitat was once of high enough quality to support a robust Atlantic salmon population. However, the construction of dams, and to a lesser extent pollution, has degraded habitat quality and accessibility and is likely responsible for the decline of Atlantic salmon populations within the Merrymeeting Bay SHRU. Today, dams are the greatest impediment, outside of marine survival, to the recovery of salmon in the Kennebec and Androscoggin River basins (Fay *et al.,* 2006). Hydropower dams in the Merrymeeting Bay SHRU significantly impede the migration of Atlantic salmon and other diadromous fish and either reduce or eliminate access to roughly 352,000 units of historically accessible spawning and rearing habitat.

In addition to hydropower dams, agriculture and urban development largely affect the lower third of the Merrymeeting Bay SHRU reducing substrate and cover, reducing water quality, and elevating water temperatures. Smallmouth bass and brown trout introductions, along with other non-indigenous species, significantly degrade habitat quality throughout the Merrymeeting Bay SHRU by altering predator/prey relationships..

The Mainstem Kennebec has the highest biological value to the Merrymeeting Bay SHRU because it provides the central migration conduit for much of the currently occupied habitat found in the Sandy River. The Sandy River has the greatest biological value for spawning and rearing habitat within the occupied range of the Merrymeeting Bay SHRU but is currently only accessible to adult salmon through a trap and truck program around the four lowermost dams.

Of the 372,600 units of spawning and rearing habitat, approximately 136,000 units of habitat are considered to be currently occupied. Of the 136,000 occupied units within the Merrymeeting Bay SHRU, we determine there to be nearly 40,000 functional equivalents of habitat or approximately 11 percent of the historical functional potential (Table 2.3a). This estimate is based on the configuration of dams within the SHRU that limit migration and degradation of physical and biological features from land use activities which reduce the productivity of habitat within each HUC 10. For each SHRU 30,000 fully functional units of habitat are needed in order to achieve recovery objectives. The combined quality and quantities of habitat available to Atlantic salmon within the currently occupied areas within the Merrymeeting Bay SHRU currently meet this objective.

Table 4.3a: Total habitat units and functional equivalents by HUC 10 for the Merrymeeting Bay SHRU

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quality	Dams Encountered	Functional Equivalent	Management Activities**
105000301	St. George River	Y	6,929	2	0	4,619	A, F, C/L, H/S, R, M, Da, Dr
105000302	Medomak River	Y	3,164	2	0	2,109	A, F, C/L, H/S, R, M, Da, Dr
105000305	Sheepscot River	Y	6,574	2	0.125	4,295	A, F, C/L, H/S, R, M, Da, Dr
103000306	Kennebec River at Waterville Dam	Y	40,133	2	4	13,966	A, F, C/L, H/S, R, M, Da, Dr
103000305	Sandy River	Y	43,137	2	4	15,012	A, F, C/L, H/S, R, M, Da, Dr
103000312	Kennebec at Merrymeeting Bay	Y	17,360	0	0	0	A, F, C/L, H/S, R, M, Da, Dr, Q
105000306	Sheepscot Bay	Y	506	0	0	0	A, F, C/L, H/S, R, M, Da, Dr
105000307	Kennebec River Estuary	Y	1,279	0	0	0	A, F, C/L, H/S, R, M, Da, Dr
104000210	Little Androscoggin River	Y	16,978	0	3	0	A, F, C/L, H/S, R, M, Da, Dr
103000310	Messalonskee Stream	N	7,210	0	4	0	
103000303	Kennebec River	N	11,957	3	5.5	4,891	
103000304	Carrabassett River	N	26,977	3	5.5	11,036	
105000303	Johns Bay	N	538	1	0	179	
105000304	Damariscotta River	N	1,494	1	1	423	
103000302	Austin Stream	N	4,754	2	6	1,195	
103000309	Sebasticook River at Winslow	N	15,695	1	2	3,780	
103000204	Dead River	N	29,223	2	7	6,246	
103000301	Kennebec River at Wyman Dam	N	16,660	2	7	3,560	
104000207	Androscoggin R. at Nezinscot R.	N	7,085	2	7	1,514	
103000308	Sebasticook River at Burnham	N	7,435	1	3	1,522	
103000106	Kennebec River above The Forks	N	20,537	2	8	3,731	
103000307	Sebasticook River at Pittsfield	N	10,074	1	4	1,753	
104000206	Androscoggin River at Riley Dam	N	7,522	1	7	804	

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

** A = Agriculture; F = Forestry, C/L = Changing Land Use; H/S = Hatcheries and Stocking; R = Roads and Road Crossings; M = Mining; Da = Dams; Dr = Dredging; Q = Aquaculture

Table 4.3a: Continued…

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quality	Dams Encountered	Functional Equivalent	Management Activities**
104000204	Ellis River	N	27,348	2	12	2,593	
104000209	Androscoggin above L. Androscoggin	N	9,518	1	8.5	797	
104000205	Androscoggin R. above Webb R.	N	16,214	1	11	904	
103000311	Cobbosseecontee Stream	N	3,406	0	1	0	
104000208	Nezinscot River	N	12,933	0	7	0	
103000101	South Branch Moose River	I					
103000102	Moose River above Attean Pond	I					
103000103	Moose River at Long Pond	I					
103000104	Brassua Lake	I					
103000105	Moosehead Lake	I					
103000201	North Branch Dead River	I					
103000202	South Branch Dead River	I					
103000203	Flagstaff Lake	I					
104000101	Mooselookmeguntic Lake	I					
104000102	Umbagog Lake Drainage	I					
104000103	Aziscohos Lake Drainage	I					
104000104	Magalloway River	I					
104000105	Clear Stream	I					
104000106	Middle Androscoggin River	I					
104000201	Gorham-Shelburne Tributaries	I					
104000202	Androscoggin at Rumford Point	I					
104000203	Ellis River	I					

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

** A = Agriculture; F = Forestry, C/L = Changing Land Use; H/S = Hatcheries and Stocking; R = Roads and Road Crossings; M = Mining; Da = Dams; Dr = Dredging; Q = Aquaculture

Table 4.3b: Biological value of Atlantic salmon habitat in HUC 10 watersheds in the Merrymeeting Bay SHRU.

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quantity Score	Habitat Quality Score	Habitat Score (E x F)	Final Habitat Value	Final Migration Value	**Final Biological Value**
103000305	Sandy River	Y	43,137	3	2	6	3	3	**3**
103000306	Kennebec R. at Waterville Dam	Y	40,133	3	2	6	3	3	**3**
103000312	Kennebec at Merrymeeting Bay	Y	17,360	3	0	0	0	3	**3**
104000210	Little Androscoggin River	Y	16,978	2	0	0	0	3	**3**
105000307	Kennebec River Estuary	Y	1,279	1	0	0	0	3	**3**
105000301	St. George River	Y	6,929	2	2	4	2	2	**2**
105000305	Sheepscot River	Y	6,574	2	2	4	2	2	**2**
105000306	Sheepscot Bay	Y	506	1	0	0	0	2	**2**
105000302	Medomak River	Y	3,164	1	2	2	1	1	**1**
103000204	Dead River	N	29,223	3	2	6	3	3	**3**
104000204	Ellis River	N	27,348	3	2	6	3	3	**3**
103000304	Carrabassett River	N	26,977	3	3	9	3	3	**3**
103000106	Kennebec River above The Forks	N	20,537	3	2	6	3	3	**3**
103000301	Kennebec River at Wyman Dam	N	16,660	2	2	4	2	3	**3**
104000205	Androscoggin R. above Webb R.	N	16,214	2	1	2	1	3	**3**
104000208	Nezinscot River	N	12,933	2	0	0	0	3	**3**
103000303	Kennebec River	N	11,957	2	3	6	3	3	**3**
104000206	Androscoggin R. at Riley Dam	N	7,522	2	1	2	1	3	**3**
104000207	Androscoggin R. at Nezinscot R.	N	7,085	2	2	4	2	2	**2**
103000309	Sebasticook River at Winslow	N	15,695	2	1	2	1	1	**1**
103000307	Sebasticook River at Pittsfield	N	10,074	2	1	2	1	1	**1**
104000209	Androscoggin R. above L. Andro.	N	9,518	2	1	2	1	1	**1**
103000308	Sebasticook River at Burnham	N	7,435	2	1	2	1	1	**1**

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

Table 4.3b: Continued…

HUC Code	Watershed Name	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Habitat Units	Habitat Quantity Score	Habitat Quality Score	Habitat Score (E x F)	Final Habitat Value	Final Migration Value	**Final Biological Value**
103000302	Austin Stream	N	4,754	1	2	2	1	1	**1**
105000304	Damariscotta River	N	1,494	1	1	1	1	1	**1**
105000303	Johns Bay	N	538	1	1	1	1	1	**1**
103000310	Messalonskee Stream	N	7,210	2	0	0	0	0	**0**
103000311	Cobbosseecontee Stream	N	3,406	1	0	0	0	0	**0**
103000101	South Branch Moose River	I							
103000102	Moose River above Attean Pond	I							
103000103	Moose River at Long Pond	I							
103000104	Brassua Lake	I							
103000105	Moosehead Lake	I							
103000201	North Branch Dead River	I							
103000202	South Branch Dead River	I							
103000203	Flagstaff Lake	I							
104000101	Mooselookmeguntic Lake	I							
104000102	Umbagog Lake Drainage	I							
104000103	Aziscohos Lake Drainage	I							
104000104	Magalloway River	I							
104000105	Clear Stream	I							
104000106	Middle Androscoggin River	I							
104000201	Gorham-Shelburne Tributaries	I							
104000202	Androscoggin at Rumford Point	I							
104000203	Ellis River	I							

*Y = Currently occupied; N = Currently unoccupied but historically accessible; I = Historically inaccessible to Atlantic salmon

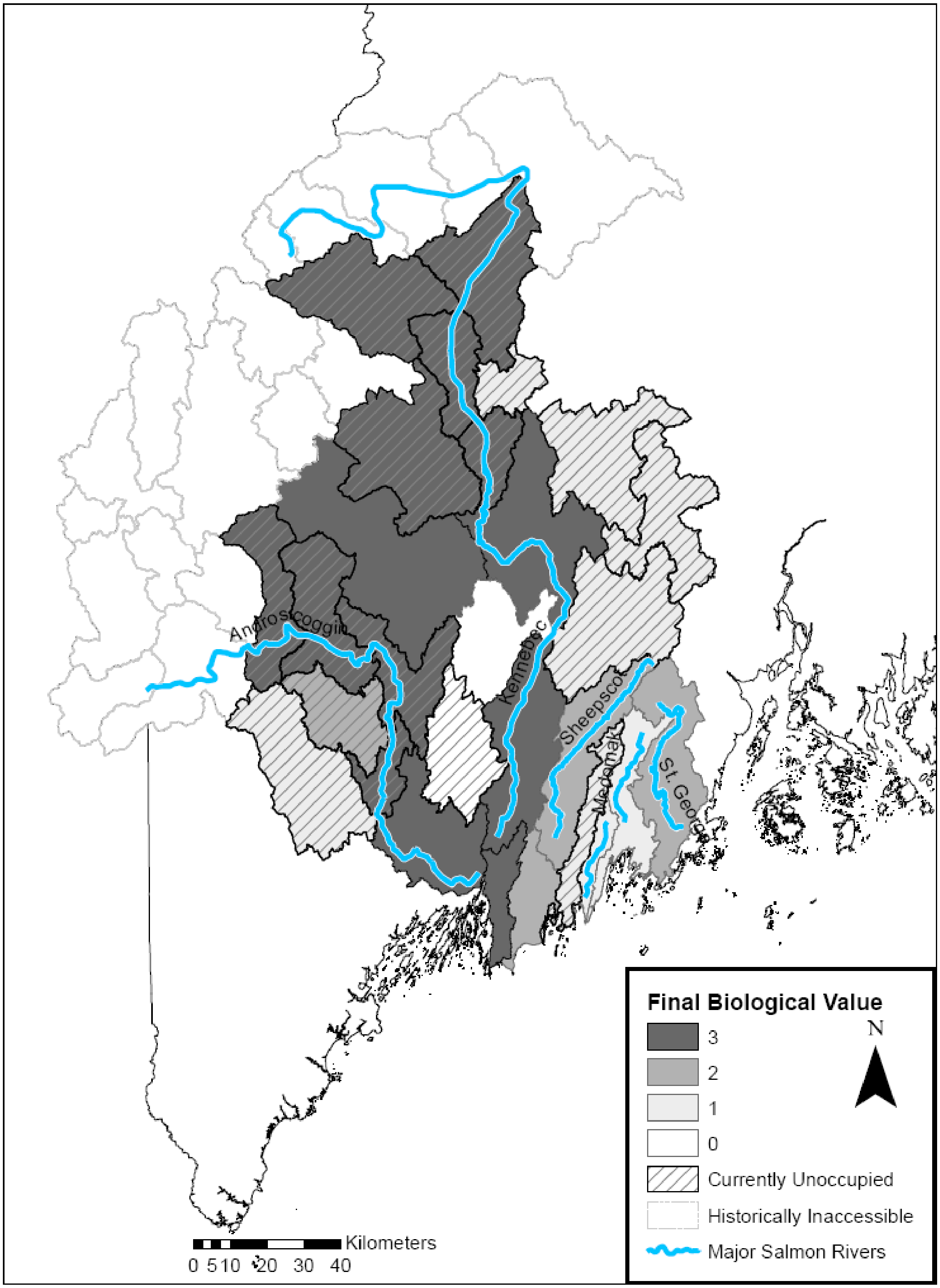

Figure 4.3: Final biological value of HUC 10 watershed in the Merrymeeting Bay SHRU

References:

Allen, R. 1940. Studies on the biology of the early stages of the salmon (Salmo salar): growth in the River Eden. Journal of Animal Ecology **9(1):** 1-23.

Allendorf, F.W., Luikart, G.. 2007. Conservation and the genetics of ppulations. Blackwell Publishing. Malden, Massachusetts. USA.

Annear, T., I. Chisholm, H. Beecher, A. Locke, and 12 other others. 2004. Instream Flows for riverine resource stewardship, revised edition. Instream Flow Council, Cheyenne, WY.

American Rivers, Friends of the Earth, and Trout Unlimited. 1999. Dam Removal Success Stories: Restoring Rivers Through Selective Removal of Dams That Don't Make Sense. American Rivers, Washington D.C.

Anthony, V.C. 1994. The significance of predation on Atlantic salmon. In: Calabi, S. and A. Stout [eds.] A Hard Look at Some Tough Issues. NE Atlantic Salmon Mgmt. Conf. Silver Quill, Camden Maine, p. 240 – 288

Armstrong, J. D., Kemp, P., Kennedy, G., Ladle, M., Milner, N., 2002. Habitat requirements of Atlantic salmon and brown trout in rivers and streams. Fisheries Research 1428, 1-28.

Atkins, C.G. & N.W. Foster. 1867. Report of Commission on Fisheries. *In* Twelfth Annual Report of the Secretary of the Maine Board of Agriculture 1867. Stevens and Sayward Printers to the state, Augusta, ME. Pages 70 – 194

Atkins, C. G. & N. W. Foster. 1868. Second Report of the Commissioner of Fisheries of the State of Maine for the year 1868. Augusta, Maine. December 31, 1868.

Atkins, C. G. 1887-1889. The River Fisheries of Maine. IN The Fisheries and Fisheries

Atkins, C.G. Fourth Report of the Commissioner of Fisheries of the state of Maine for the year 1870. Sprague, Owen and Nash, Printers to the State, Augusta, Maine.

Bachman, R. 1984. Foraging behavior of free ranging wild and hatchery brown trout in a stream. Trans. Am. Fish. Soc. **113**:1-32.

Bailey, R.G. 1995. Description of the ecoregions of the United States. 2d. ed. Misc. Publ. No. 1391(rev.), Washington DC: USDA Forest Service. 108p.

Barr, L.M. 1962. A life history study of the chain pickerel, *Esox niger LeSueuer*, in Beddington Lake, Maine. MS Thesis, Univeristy of Maine, 88pp. (unpublished).

Baum E.T., and A.L. Meister. 1971. Fecundity of Atlantic salmon (*Salmo salar*) from two Maine Rivers. Journal of the Fisheries Research Board of Canada **28(5):** 764-767.

Baum, E.T. 1997. Maine Atlantic Salmon: A National Treasure, 1st Ed. Hermon, ME: Atlantic Salmon Unlimited.

Baum, E.T. 1983. The Penobscot River; an Atlantic salmon river management report. Maine Atlantic Sea Run Salmon Commission. State of Maine. 67pp.

Baum, E.T., and R.C. Spencer. 1990. Homing of adult Atlantic salmon released as hatchery-reared smolts in Maine rivers. Working paper 1990-17. Working Group on North Atlantic Salmon, International Council for the Exploration of the Sea. 9 pp.

Baum, E.T., and R.M. Jordan. 1982. The Narraguagus River; an Atlantic salmon river management report. Atlantic Sea Run Salmon Commission. State of Maine.

Beland, K. F. 2001. Memo: Beddington Lake Splake. April 6, 2001.

Beland, K. F., N. R. Dube, M. Evers, R. C. Spencer, S. Thomas, G. Vander Haegen, and E. T. Baum. 1995. Atlantic salmon research addressing issues of concern to the National Marine Fisheries Service and Atlantic Sea Run Salmon Commission. Annual Report, Grant NA29FL0131-01, Final Report. Maine Atlantic Sea Run Salmon Commission, Bangor, ME.

Beland, K.F., J.S. Fletcher, A.L. Meister. 1982a. The Dennys River; an Atlantic salmon river management report. Atlantic Sea Run Salmon Commission. State of Maine.

Beland, K.F., Jordan, R.M., Meister, A.L. 1982b. Water depth and velocity preferences of spawning Atlantic salmon in Maine rivers. N. Am. J. Fish. Man. 2: 11-13

Benson J. and R. Sherwood. 2004. Maine's changing population. A summary of structural changes, mobility and regional variations. White paper prepared by The Maine State Planning Office for REALIZE! Maine, Augusta, ME.

Bjornn, T. C., D. W. Reiser. 1991. Habitat requirements of salmonids in streams. In *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats*. American Fisheries Society Special Publication 19:83-138.

Bley, P. W. and J. R. Moring. 1988. Freshwater and ocean survival of Atlantic salmon and steelhead: A synopsis. Maine Cooperative Fish and Wildlife Research Unit. University of Maine. Biological report 88 -(9).

Boland, J. 2001. Brown Trout Management Plan. Department of Inland Fisheries and Wildlife, Division of Fisheries and Hatcheries. Augusta, Maine.

Boucher, D. P. 2004. Landlocked Salmon Management Plan. Department of Inland Fisheries and Wildlife, Division of Fisheries and Hatcheries. Augusta, Maine.

Brautigam, F. 2001. Northern Pike Assessment. Maine Department of Inland Fisheries and Wildlife, Division of Fisheries and Hatcheries. Region A. Updated by Jim Lucas, January 2008.

Brodeur, J.C., F. Okland, B. Finstad, D.G. Dixon, and R.S. McKinley. 2001. Effects of Subchronic Exposure to Aluminum in Acidic Water on Bioenergetics of Atlantic Salmon (*Salmo salar*). Ecotoxicology and Environmental Safety 49: 226-234

Brokaw, R. K. 2001. Pickerel Management Plan. Department of Inland Fisheries and Wildlife, Division of Fisheries and Hatcheries. Augusta, Maine.

Brown, M.E., Maclaine, J., Flagg, L., 2006. Androscoggin River Anadromous Fish Restoration Program; Annual Report. State of Maine Department of Marine Resources. Augusta, Maine.

Byström, P., J. Karlsson, P. Nilsson, T. Van Kooten, J. Ask and F. Olofsson. 2007. Substitution of top predators: effects of pike invasion in a subartic lake. Freshwater Biology. **52(7)**: 1271-1280

Caldwell, D. W. 1998. Roadside Geology of Maine (Book). Mountain Press Publishing Company. Missoula, MT. June 1998.

Chamberlin, T. W., R. Harr, and F. Everest. 1991. Timber harvesting, Silviculture, and watershed processes. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication. **19:** 181-205

Commissioner of Fisheries. 1873. Seventh report of the Commissioner of Fisheries of the State of Maine for the year 1873. Sprague Owen and Hash, Printers to the State. Augusta, Maine.

Courtenay, W. R., Jr., D. A. Hensley, J.N. Taylor, and J. A. McCann. 1984. Distribution of exotic fishes in the continental United States. Pages 41-77 in W. R. Courtenay, Jr., and J. R. Stauffer,, Jr., editors. Distribution, biology and management of exotic fishes. Johns Hopkins University Press, Baltimore, MD.

Cunjak, R. A. 1988. Behavior and microhabitat of young Atlantic salmon (*Salmo sala*r) during winter. Canadian Journal of Fisheries and Aquatic Sciences **45(12)**: 2156-2160.

Cunjak, R. A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences **53**(Suppl.1): 267-282

Cunjak, R.A., E.M.P. Chadwick, and M. Shears. 1989. Downstream movements and estuarine residence by Atlantic salmon parr (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences. **46(9):**1466-1471.

Cutting. R. E.. 1959. Penobscot River Salmon Restoration. Maine Atlantic Sea-Run Salmon Commision. 73 pp and appendices.

Danie, D., J. Trial, J. Stanley, L. Shanks, and N. Benson. 1984. Species profiles: life histories and environmental requirements of coastal fish and invertebrates (North Atlantic): Atlantic salmon. USFWS, report FWS/OBS-82/11.22

Davis, R.B., and D.A. Anderson. 2001. Classification and distribution of freshwater peatlands in Maine. Northeastern Naturalist 8:1-50.

Decola, J. N. 1970. Water quality requirements for Atlantic salmon, USDI. Federal Water Quality Administration, N.E., Region, Boston, Mass. 42 pp.

Dempson, J.B., M.F. O'Connell, and M. Shears. 1996. Relative production of Atlantic salmon from fluvial and lacustrine habitats estimated from analyses of scale characteristics. Journal of Fish Biology 48: 329-341

Department of Marine Resources (DMR) and Department of Environmental Protection (DEP). 2008. Report to the Joint Standing Committee on Marine Resources and the Joint Standing Committee on Natural Resources in response to Resolve Chapter 109 (LD 1528, LR 1911). State of Maine.

Dittman, A.H. and T.P. Quinn. 1996. Homing in Pacific salmon: Mechanisms and ecological basis. Journal of Experimental Biology. **199**:83-91.

Doudoroff, P., and C.E. Warren. 1965. Environmental requirements of fishes and wildlife: dissolved oxygen requirements of fishes. Oregon Agricultural Experiment Station Special Report 141.

Dube N.R., and R.M. Jordan. 1982. The Pleasant River; an Atlantic salmon river management report. Atlantic Sea Run Salmon Commission. State of Maine.

Dudley R. W. and G. J. Stewart. 2006. Estimated effects of ground-water withdrawals on streamwater levels of the Pleasant River near Crebo Flats, Maine, July 1 to September 30, 2005: U.S. Geological Survey Scientific Investigations Report 2006-5268, 14 pp.

Dudley, Robert W. 2005. Streamflow statistics for the Dennys River at Dennysville, Maine. 1955-2004. U.S. Dept. of Interior, U.S. Geological Survey. Open-File Report 2005-1297.

Duston, J., Saunders, R.L. 1990. The entrainment role of photoperiod on hypoosmoregulatory and growth-related aspects of smolting in Atlantic salmon (*Salmo salar*). Can. J. Zool. 68:707-715

Dutil, J.D, and J.M. Coutu. 1988. Early marine life of Atlantic salmon, *Salmo salar*, postsmolts in the northern Gulf of St. Lawrence. Fishery Bulletin 86; 197 – 212.

Eisler, R., Copper hazards to fish, wildlife, and invertebrates: a synoptic review. 1998. U.S. Geological Survey, Biological Resources Division, Biological Science Report

Elliott, J. M. 1991. Tolerance and resistance to thermal stress in juvenile Atlantic salmon, *Salmo salar*. Freshwater Biology. **25**:61-70

Elson, P. 1975. Atlantic salmon rivers, smolt production and optimal spawning: an overview of natural production. *In*: J. Bohne and L. Sochasky (eds.), New England Atlantic salmon Restoration Conference. Sp. Pub. 6:96 -119. Int. Atl. Salm. Ged. St. Andrews, N.B., Canada.

Erkinaro, J., E. Niemelä, A. Saari, Y. Shustov, and L. Jøgensen. 1998. Timing of habitat shift by Atlantic salmon parr from fluvial to lacustrine habitat: analysis of age distribution, growth, and scale characteristics. Can. J. Fish. Aquat. Sci. **55**: 2266-2273.

Erman, D.C., and D. Mahoney. 1983. Recovery after logging in streams with and without bufferstrips in northern California. Contribution 186. Water Resources Center, Universtiy of California Berkeley, Berkely, CA

Everhart, W., J.E. Watson, and R. E. Cutting. 1955. The Penobscot River – river restoration. Maine Atlantic Salmon Commission and Department of Inland Fisheries and Game. Augusta, ME. 12pp.

Everhart, W. H. and R. E. Cutting. 1967. The Penobscot River, Atlantic salmon restoration: Key to a model river. PEN. 1967.1. 22pp.

Farmer, G. J., R.L. Saunders, T.R. Goff, C.E. Johnston and E.B. Henderson. 1989. Some physiological responses of Atlantic salmon (*Salmo salar*) exposed to soft acidic water during smolting. Aquaculture, **82:** 229-244.

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

FERC (Federal Energy Regulatory Commission). 1997. Final Environmental Impact Statement Lower Penobscot River Basin. Office of Hydropower Licensing. Washington, D.C. 388. and appendices.

Field, D, B. Blumenstock, and D. Edson. 1994. The Forest of Maine. Geographical Digest Series, University of Maine, Orono, ME. 16pp.

Fletcher, J.S., R.M. Jordan, K.F. Beland. 1982. The Machias River: An Atlantic salmon river management report. Atlantic Sea Run Salmon Commission. State of Maine.

Foster, N.W. and C.G. Atkins. 1869. Second report of the Commissioners of Fisheries of the state of Maine 1868. Owen and Nash, Printers to the Sate, Augusta, ME.

Franklin I. R.. 1980. Evolutionary change in small populations. *In* M. E. Soulé & B. A. Wilcox (Eds.), Conservation Biology: An evolutionary –ecological perspective. (pp. 135-149). Sunderland, Massachusetts: Sinauer Associates, Inc.

Fried S.M., J.D. McCleave, G.W. LaBar. 1978. Seaward migration of hatchery – reared Atlantic salmon, *Salmo salar*, smolts in the Penobscot River estuary, Maine: riverine movements. J. Fish. Res. Board Can. **35:** 76 – 87.

Friedland, K.D., D.G. Reddin, and M. Castonguay. 2003. Ocena thermal conditions in the post-smolt nursery of North American Atlantic salmon. ICES Journal of Marine Scienc. **60**: 343-355.

Friedland, K.D., D.G. Redding, and J.F. Kocik. 1993. Marine survival of N. American and European Atlantic salmon: effects of growth and environment. ICES J. of Marine Sci. **50:** 481- 492.

Friedland, K.D., J.-D. Dutil, and T. Sadusky. 1999. Growth patterns in postsmolts and the nature of the marine juvenile nursery for Atlantic salmon, *Salmo salar*. Fish. Bull. **97:** 472-481.

Flanagan, S. M., M. G. Nielsen, K. W. Robinson, and J. F. Coles. 1999. Water quality assessment of the New England coastal basin in Maine, Massachusetts, New Hampshire, and Rhode Island: Environmental settings and implications for water quality and aquatic biota. U.S. Dept. of the Interior - U.S. Geological Survey. Water-Resources Investigations Report 98-4249

Furniss, M.J., T. D. Roelofs, and C. S. Yee. 1991. Road construction and maintenance. Influences of forest and rangeland management on Salmonid fishes and their habitats. American Fisheries Society Special Publication 19: 297-323

Gharrett, A.J. and W.W. Smoker. 1993. A perspective on the adaptive importance of genetic infrastructure in salmon populations to ocean ranching in Alaska. Fisheries Research **18:** 45-58.

Gibson, R. J. 1993. The Atlantic salmon in freshwater: Spawning, rearing and production. Reviews in Fish Biology and Fisheries **3(1):** 39-73.

Giger, R.D. 1973. Streamflow requirements of salmonids. Oregon Wildlife Commission, Job Final Report, Project AFS-62-1, Portland, OR.

GNP (Great Northern Paper, Inc). 1995. 1995 Report on the effectiveness of the permanent downstream passage system for Atlantic salmon at Weldon Dam. Mattaceunk Project – FERC No. 2520. Great Northern Paper, Inc. Millinocket, ME. 93pp.

GNP (Great Northern Paper, Inc). 1997. 1997 Report on the effectiveness of the permanent downstream passage system for Atlantic salmon at Weldon Dam. Mattaceunk Project – FERC No. 2520. Great Northern Paper, Inc. Millinocket, ME. 61pp. and appendices.

Grant, J.W.A., S. Ó. Steingrĭmsson, E.R. Keeley, and R.A. Cunjak. 1998. Can. J. Fish. Aquat. Sci. **55**(suppl. 1): 181-190.

Greene C. H. and A. J. Pershing. 2007. Climate Drives Sea Change. Science Magazine. Vol. 315

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. Bioscience **41:**540-551.

Gustafson-Marjenan, K. I., and H. B. Dowse. 1983. Seasonal and diel patterns of emergence from the redd of Atlantic salmon (*Salmo salar*) fry. Canadian Journal of Fisheries and Aquatic Sciences **40:** 813-817

Gustafson-Greenwood, K. I., and J. R. Moring. 1991. Gravel compaction and permeabilities in redds of Atlantic salmon, *Salmo salar* L. Aquaculture and Fisheries Management 22:537-540.

Haines, T. A. 1992. New England's rivers and Atlantic salmon. Pages 131-139 in R. H. Stroud, ed. Stemming the tide of coastal fish habitat loss. National Coalition for Marine Conservation, Savannah, Georgia.

Haines, T. A., J. Akielaszek. 1984. Effects of acidic precipitation on Atlantic salmon rivers in New England. Technical Report. Air Pollution and Acid Rain Report 18. Fish and Wildlife Service, Orono, ME. And Columbia National Fisheries Research Lab. FWS/OBS-80/40.18

Haines, T.A., S.A. Norton, J.S. Kahl, C.W. Fay, and S.J. Pauwels. 1990. Intensive studies of stream fish populations in Maine. Ecological Research Series. U.S. Environmental Protection Agency. 354pp

Halvorsen, M. & Svenning, M.-A. 2000. Growth of Atlantic salmon parr in fluvial and lacustrine habitats. Journal of Fish Biology **57:** 145–160.

Hansen, L.P. and B. Jonsson. 1989. Salmon ranching experiments in the River Imsa: effect of timing of Atlantic salmon (*Salmo salar*) smolt migration on survival to adults. Aquaculture. **82:** 367 – 73.

Hansen, L.P. and T.P. Quinn. 1998. The marine phase of the Atlantic salmon (Salmo salar) life cycle, with comparisons to Pacific salmon. Can. J. Fish. Aquat. Sci. **55(S1):** 104 – 118.

He X., and J.F. Kitchell. 1990. Direct and Indirect Effects of Predation on a Fish Community: A Whole-Lake Experiment. Transactions of the American Fisheries Society 119(5): 825–835.

Heggenes, J. 1990. Habitat utilization and preferences in juvenile Atlantic salmon (*Salmo salar*) in streams. Regulated Rivers: Research and Management 5(4): 341-354

Heggenes, J., J. Bagliniere, and R. Cunjak. 1999. Spatial niche variability for young Atlantic salmon (*Salmo salar*) and brown trout (*S. trutta*) in heterogeneous streams. Ecol. Freshw. Fish 8: 1-21

Heinz Center. 2002. Dam Removal: Science and Decision Making. The John Heinz III Center for Science, Economics, and the Environment. Washington, D.C.

Hiscock, M. J., D. A. Scruton, J. A. Brown, and C. J. Pennell. 2002. Diel activity pattern of juvenile Atlantic salmon (*Salmo salar*) in early and late winter. Hydrobiologia **483**: 161-165.

Hoar W.S. 1988. The physiology of smolting salmon. In: W.S. Hoar and D.J. Randall, Editors, *Fish Physiology XIB*, Academic Press, New York. pp. 275–343.

Holbrook, C. M. 2007. Behavior and survival of migrating Atlantic salmn (Salmo salar) in the Penboscot River and estuary. Maine acoustic telemetry studies of smolts and adults. Masters Thesis. University of Maine.

Holm, M., I Huse, E. Waatevik, K. Doeving, J. Aure. 1982. Behavior of Atlantic salmon smolts during seaward migration. 1: Preliminary report on ultrasonic tracking in a Norwegian fjord system. ICES; Copenhagen (Denmark); ICES Council Meeting 1982. (Collected Papers) 17.

Hornbeck, J.W., R.S. Pierce, and C.A. Federer. 1970. Streamflow changes after forest clearing in New England. Water Resources Research 6:1124-1132.

Houtman, N. 1994. Natural Resources Highlights: Penobscot River Watershed. Water Resources Program, University of Maine, Orono, ME.

Hutchings, J.A. 1986. Lakeward migrations by juvenile Atlantic salmon, *Salmo salar*. Can. J. Fish. Aquat. Sci. **43(4):** 732-741.

Hyvarinen, P., P. Suuronen and T. Laaksonen. 2006. Short-term movement of wild and reared Atlantic salmon smolts in brackish water estuary – preliminary study. Fish. Mgmt. Eco. 13(6): 399 – 401.

IEc (Industrial Economics). 2009. Economic Analysis of Critical Habitat Designation for the Gulf of Maine Distinct Population Segment of Atlantic Salmon. Cambridge, MA.

Irland, L. 2000. Maine Forests: A Century of change, 1900-2000…and elements of policy change for a new century. *In* Maine Policy Review. Winter 2000. pp. 66-77

Jackson, J.K., A.D. Huryn, D.L. Strayer, D.L. Courtemanch, B.W. Sweeney. 2005. Atlantic Coast Rivers of the Northeaster United States. *In* A.C. Benke and C.E. Cushing (Eds.). *Rivers of North America* (p21-62) Boston: Elsevier Academic Press.

Johnson, K. and J.S. Kahl. 2005. A systematic survey of water chemistry for Downeast area rivers. Project final report to Maine Atlantic Salmon Commission.

Johnston, C. E., and Saunders, R.L. 1981. Parr-smolt transformation of yearling Atlantic salmon (*Salmo salar*) at several rearing temperatures. Can. J. Fish. Aquat. Sci. **38:** 1189-1198.

Jordan, R. M. and Beland, K. F.. 1981. Atlantic salmon spawning and evaluation of natural spawning success. Atlantic Sea Run Salmon Commission. Augusta, ME. 26 pp.

Jordan, R. M. 2001. Black Bass Management Plan. Department of Inland Fisheries and Wildlife, Division of Fisheries and Hatcheries. Augusta, Maine.

Kalleberg, H., 1958. Observations in a stream tank of territoriality and competition in juvenile salmon and trout (*Salmo salar* L. and *S. trutta* L.). Rep. Inst. Freshw. Res. Drottningholm 39, 55-98.

Klemetson, A., P.A. Amundsen, J.B. Dempson, B. Jonsson, N. Jonsson, M.F. O'Connell, and E. Mortensen. 2003. Atlantic salmon *Salmon salar* (L.), brown trout *Salmo trutta* (L.) and Arctic charr *Salvelinus alpinus* (L.): a review of aspects of their life histories. Ecology of Freshwater Fish 12(1): 1-59\

Kramer, N. 2002. Non-sport and commercial management plan. Maine Department of Inland Fisheries and Wildlife, Division of Fisheries and Hatcheries. Region F.

Kroglund F. and M. Staurnes. 1999. Water quality requirements of smolting Atlantic salmon (*Salmo salar*) in limed acid rivers. Can. J. Fish. Aquat. Sci. **56**: 2078-2086.

LaBar, G.W., J.D. McCleave, and S.M. Fried. 1978. Seaward migration of hatchery-reared Atlantic salmon (*Salmo salar*) smolts in the Penobscot River estuary, Maine: open-water movements. Journal du Conseil. International Council for the Exploration of the Sea. 38(2):257-269.

Lacroix, G. L, McCurdy, P., Knox, D.. 2004. Migration of Atlantic salmon post smolts in relation to habitat use in a coastal system. Trans. Am. Fish. Soc.. **133(6):** pp. 1455-1471.

Lacroix, G. L. and D. Knox. 2005. Distribution of Atlantic salmon (*Salmo salar*) postsmolts of different origins in the Bay of Fundy and Gulf of Maine and evaluation of factors affecting migration, growth and survival. Can. J. Fish. Aquat. Sci. 62(6): 1363- 1376.

Lacroix, G.L., D. Knox and M.J. W. Stokesbury. 2005. Survival and behavior of postsmolt Atlantic salmon in coastal habitat with extreme tides. J. Fish Bio. 66(2): 485-498

Lacroix, G.L. and McCurdy, P. 1996. Migratory behavior of post-smolt Atlantic salmon during initial stages of seaward migration. J. Fish Biol. **49**, 1086-1101.

Laitta, M. T., K.J. Legleiter, K.M. Hanson. 2004. The national watershed boundary dataset. Hydroline. Online newsletter of ESRI. *Available at* http:www.esri.com/library/newsletter/hydroline/hydroline_summer2004.pdf. *Accessed* August 2005.

LePage, C.A., M.E. Foley, and W.B. Thompson. 1991. Mining in Maine: Past, Present, and Future. Maine Geological Survey Open-File 91-7. Department of Conservation, Maine Geological Survey, State of Maine. http://www.maine.gov/doc/nrimc/mgs/explore/mining/minemaine.htm

Larsson, P.O. 1985. Predation on migrating smolt as a regulating factor in Baltic salmon, Salmo salar L., populations. J. Fish Bio. 26(4): 391-397

Larsson, P.O. 1977. The importance of time and place of release of salmon and sea trout on the results of stocking. ICES CO 1977/M: 42. 10 pp.

Legault, C.M. 2004. Salmon PVA: a population viability analysis model for Atlantic salmon in the Maine Distinct Population Segment. Ref. Doc. 04-02. Woods Hole, MA. 88pp.

Lucus, J. 2002. Minor Sportfish Management Plan. Maine Department of Inland Fisheries and Wildlife, Division of Fisheries and Hatcheries. Region B.

Lundqvist, H. 1980. Influence of photoperiod on growth in Baltic salmon parr (*Salmo salar* L.) with special reference to the effect of precocious sexual maturation. Canadian Journal of Zoology **58(5):** 940-944

MASCP (Maine Atlantic Salmon Conservation Plan). 1997. Maine Atlantic Salmon Task Force. Atlantic Salmon Conservation Plan for Seven Rivers. State of Maine, Augusta, ME. 435pp.

Maine DEP. 1999. Biomonitoring Retrospective. Maine DEPLW 1999-26

Maine Department of Marine Resources. 2007. Kennebec River Diadromous Fish Restoration Project. Augusta, Maine. http://www.maine.gov/dmr/rm/stockenhancement/kennebec/fishpass.htm Date accessed: 12/05/2007

Maine Atlantic Salmon Commission and Maine Inland Fisheries and Wildlife. June 2002. Memorandum of agreement regarding fisheries management activities in certain Maine rivers.

MSPO (Maine State Planning Office), 1993. Kennebec River Resource Management Plan. Augusta, Maine. February 1993. 196 pp.

Maine State Planning Office. 2005. Maine County Economic Forecast. Maine State Planning Office, Augusta, ME

Marschall, E.A., T.P. Quinn, D.A. Roff, J. A. Hutchings, N.B. Metcalfe, T.A. Bakke, R.L.Saunders and N.LeRoy Poff. 1988. A Framework for understanding Atlantic salmon (*Salmo salar*) life history. Can. J. Fish. Aquat. Sci. **55(Suppl. 1):** 48-58.

Marvinney, R. G., and Thompson, W. B., 2000, A geologic history of Maine, *in* King, V. T.(editor). Mineralogy of Maine: Volume 2 - Mining history, gems, and geology: Maine Geological Survey, p. 1-8

Mather, F. 1889. Brown Trout in America. Bulletin of the U.S. Fish Commission. 7(1887):21-22.

McCleave, J.D., 1978. Rythmic aspects of estuarine migration of hatchery-reared Atlantic salmon, *Salmo salar*, smolts. J. Fish Biol. **12**, 559-570.

McCormick S.D., L.P. Hansen, T. Quinn, and R. Saunders. 1998. Movement, migration, and smolting of Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. **55**(Suppl. 1): 77-92.

McCormick S.D., R.A. Cunjak, B. Dempson, M. O'Dea, J. Carey. 1999. Temperature-related loss of smolt characteristics in Atlantic salmon (*Salmo salar*) in the wild. Can. J. Fish Aquat. Sci. **56:** 1649-1658

McCormick, S.D., J. M. Shrimpton, S. Moriyama, and B. T. Björnsson. 2002. Effects of an advanced temperature cycle on smolt development and endocrinology indicate that temperature is not a zeitgeber for smolting in Atlantic salmon. Journal of Experimental Biology. **205:** 3553-3560.

McCormick, S.F. and R.L. Saunders. 1987. Preparatory physiological adaptations for marine life of salmonids: Osmoregulation, growth, and metabolism. Common Strategies of Anadromous and Catadromous Fishes. Proceedings of an International Symposium held in Boston, Massachusetts, USA, March 9-13, 1986. American Fishereis Society Symposium. 1: 211-229.

McLaughlin, E. and A. Knight. 1987. Habitat criteria for Atlantic salmon. Special Report, U.S. Fish and Wildlife Service, Laconia, New Hampshire.

McWilliams, W.H., Butler, B.J., Caldwell, L.E., Griffith, D.M., Hoppus, M.L., Laustsen, K.M., Lister, A.J., Lister, T.W., Metzler, J.W., Morin, R.S., Sader, S.A., Stewart, L.B., Steinman, J.R., Westfall, J.A., Williams, D.A., Whitman, A., Woodall, C.W., 2005. The forests of Maine: 2003. Resource Bulletin NE-164. U.S. Department of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, PA. 188 p.

Meister, A.L. 1958. The Atlantic salmon (*Salmo salar*) of Cove Brook, Winterport, Maine. M.S. Thesis. University of Maine. Orono, ME. 151 pp.

Milligan, C.L. and Wood, C.M.. 1982. Disturbances in haematology, fluid volume distribution and circulatory function associated with low environmental pH in the rainbow trout, *Salmo gairdneri*. Journal of Experimental Biology **99**: 397-415

Montgomery, D. R., and J. M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. TFW-SH10-93-002, Prepared for the SHAMW committee of the Washington State Timber Fish & Wildlife agreement. Timber Fish & Wildlife, Seattle, Washington.

Moore, A., E.C.E. Potter, N.J. Milner, S. Bamber. 1995. The migratory behavior of wild Atlantic salmon (*Salmo salar*) smolts in the estuary of the River Conway. North Wales. Can J. Fish. Aquat. Sci. 52: 1923-1935

Moring, J. R., J. Marancik, and F. Griffiths. 1995. Changes in stocking strategies for Atlantic salmon restoration and rehabilitation in Maine, 1971-1993. Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society Sumposium No. 15. Bethesda, MD. Pages 38 -46.

Morantz, D., R. Sweeney, C. Shirvell, and D. Longard. 1987. Selection of microhabitat in summer by juvenile Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 44:120-129

Morse C. and S. Kahl. 2003. Measuring the impact of development on Maine surface waters. The University of Maine – Senator George J. Mitchell Center for Environmental and Watershed Research. UMaine.edu/WaterResearch

Murphy, M. L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska – requirements for protection and restoration. NOAA Coastal Ocean Program Decision Analysis Series No. 7. NOAA Coastal Ocean Office, Silver Spring, MD. 156 pp.

Nelson, R.L., M.L. McHenry, and W.S. Platts. 1991. Mining. *In* Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication. **19:**425-457.

New England Fisheries Management Council, 1998. Atlantic salmon (*Salmo salar*) Life History and Habitat Requirements. Essential Fish Habitat Source Document. Saugus, MA.

Nightingale, B. and C.A. Simenstad. 2001a. Dredging Activities: Marine Issues. Overwater Whitepaper prepared for Washington State Transportation Commission, Department of Transportation and in cooperation with U.S. Department of Transportation, Federal Highway Administration. Research Project T1803, Task 35. 182pp.

Nightingale, B. and C.A. Simenstad. 2001b. Overwater Structures: Marine Issues. Overwater Whitepaper prepared for Washington State Transportation Commission, Department of Transportation and in cooperation with U.S. Department of Transportation, Federal Highway Administration. Research Project T1803, Task 35. 181pp.

Nislow, K.H., C.L. Folt, and D.L. Parrish. 1999. Favorable foraging locations for young Atlantic salmon: Application to habitat and population restoration. Ecological applications. 9(3): 1085-1099.

NMFS (National Marine Fisheries Service). 2009. Designation of Critical Habitat for Atlantic Salmon (Salmo salar) in the Gulf of Maine Distinct Population Segment: ESA Section 4(b)(2) Report. Gloucester, MA.

NMFS and FWS (National Marine Fisheries Service) and (United Stated Fish and Wildlife Service). 1999. Review of the status of anadromous Atlantic salmon (*Salmo salar*) under the US Endangered Species Act. National Marine Fisheries Service, Silverspring, MD. 230pp

NMFS and FWS (National Marine Fisheries Service) and (United Stated Fish and Wildlife Service). 2005. Final Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (*Salmo salar*). National Marine Fisheries Service, Silverspring, MD. 325pp.

North East State Foresters Association. 2007. The economic importance and wood flows from Maine forests, 2007. www.nefainfo.org

NRC (National Research Council). 2003. Atlantic Salmon in Maine. National Academy Press. Washington, D.C. 304pp.

Obrey, T. C. 2001. Splake Management Plan. Department of Inland Fisheries and Wildlife, Division of Fisheries and Hatcheries. Augusta, Maine.

O'Hara F. and J. Benson. 1997. The cost of sprawl. 010-07B-2906-012. October, 1991. Executive Department - Maine State Planning Office, Augusta, ME

Page, L.M. and B.M. Burr. 1991. A field guide to freshwater fishes of North America north of Mexico. The Peterson Field Guide Series, volume 42. Houghton Mifflin, Boston.

PCSWCD (Penobscot County Soil and Water Conservation District). 2005. Kenduskeag Stream Watershed Project.

Pepper, V.A. 1976. Lacustrine nursery areas for Atlantic salmon in Insular Newfoundland. Fishereis and Marine Service Technical Report 671. xiii+61 pp.

Pepper, V.A., N.P. Oliver, R. Blunden. 1984. Lake surveys and biological potential for natural lacustrine rearing of juvenile Atlatnic salmon (Salmo salar) in Newfoundland. Canadian Technical Report of Fisheries and Aquatic Sciences 1295. iv+ 72 pp.

Peterson, R. H.. 1978. Physical characteristics of Atlantic salmon spawning gravel in some New Brunswick streams. Fish. Mar. Serv. Tech. Rep. No. 785. iv+28 pp.

Power, G. and G. Shooner. 1966. Juvenile salmon in the estuary and lower Nabisipi river and some results of tagging [Québec]: Ministère du tourisme, de la chasse et de la pêche, Province de Québec

Pratt, V.S. 1946. The Atlantic salmon in the Penobscot River. M.S. Thesis. University of Maine. Orono, ME. 76. pp. and appendices.

Randall, R.G. 1982. Emergence, population densities, and growth of salmon and trout fry in two New Brunswick streams. Canadian Journal of Zoology **60(10):** 2239-2244.

Reddin, D.G and K.D. Friedland. 1992. Marine environmental factors influencing the movement and survival of Atlantic salmon. 4th Int. Atlantic Salmon Symposium. St. Andrews, N.B. Canada.

Reddin, D.G and P.B. Short. 1991. Postsmolt Atlantic salmon (*Salmo salar*) in the Labrador Sea. Can. J. Fish Aquat. Sci.. **48**: 2-6.

Reddin, D.G. 1988. *Ocean* life of Atlantic salmon *(Salmo salar L.*) in the Northwest Atlantic. pp. 483 – 511. *In* D. Mills and D. Piggins [eds.] *Atlantic Salmon: Planning for the Future.* Proceedings of the 3rd International Atlantic Salmon symposium

Reddin, D.J., D.E. Stansbury, P.B. Short. 1988. Continent of origin of Atlantic salmon (*Salmo salar* L.) caught at West Greenland. Journal du Conseil International pour l'Eploration de la Mer, **44:** 180-8.
.
Reddin, D.G. and W.M. Shearer. 1987. Sea-surface temperature and distribution of Atlantic salmon in the Northwest Atlantic Ocean. Am. Fish. Soc. Symp.

Reddin, D.G. 1985. Atlantic salmon (*Salmo salar*) on and east of Grand Bank. J. Northwest. Atln. Fish. Sci. **6:** 157 – 164.

Reed, W.C. and K.J. Sage. 1975. Merrymeeting Bay; a guide to conservation of an unique resource. Prepared for The Maine Department of Marine Resources by Read & D'Andrea, South Gardiner, Maine.

Reiman, B. E. & F. W. Allendorf. 2001. Effective population size and genetic conservation criteria for bull trout. N. Am. J. Fish. Mgt. **21:**756-764.

Reisenbichler, R.R. 1988. Relation between distance transferred from natal stream and recovery rate for hatchery coho salmon. N. Am. J. Fish. Mgt. **8(2):** 172-174.
Research Station, Newtown Square, PA. 188 p.

Riddell, B. E. and W. C. Leggett. 1981. Evidence of an adaptive basis for geographic variation in body morphology and time of downstream migration of juvenile Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. **38:** 308-320.

Rimmer, D.M., U. Paim, and R.L. Saunders. 1984. Changes in the selection of migrohabitat by juvenile Altantic salmon (*Salmo salar*) at the summer-autumn transition in a small river. Can. J. Fish. Aquat. Sci. **41(3):** 469-475.

Ritter, J.A. 1989. Marine migration and natural mortality of North American Atlantic salmon *(Salmo salar L.*). Can. MS Rep. Fish. Aquat. Sci.. No. 2041. 136 p.

Rizzo, B. 1983. Preliminary report on fish passage facilities modifications proposed at hydrodams on the Penobscot River, Maine: Veazie Dam, Great Works Dam, Milford Dam, Mataceunk Dam. U.S. Fish and Wildlife Service, Region 5. 25pp.

Rosseland B.O. and O.K. Skogheim. 1984. A comparative study on salmonid fish species in acid aluminum-rich water II. Physiological stress and mortality of one-and two-year-old fish. Inst. Freshwater Res. Drottningholm Rep. **61**: 186-194.

Rosseland B.O., T.D. Eldhuset, and M. Staurnes. 1990. Environmental effects of aluminum. Environ. Geochem. Health. **12**: 17-27.

Roundsefell, G.A., and L.H. Bond. 1949. Salmon restoration in Maine. Research report No. 1. Augusta, ME: Atlantic Sea Run Salmon Commission. 52pp.

Ruggles, C.P. 1980. A review of the downstream migration of Atlantic salmon. Canadian Technical Report of Fisheries and Aquatic Sciences No. 952. Freshwater and Anadromous Division Research Branch, Department of Fisheries and Oceans. Halifax, NS. 39 pp.

Saunders, R., M. A. Hachey, C. W. Fay. 2006. Maine diadromous fish community: past, present, and implications for Atlantic salmon recovery. Fisheries. 31(11): 537-547

Schaffer, W.M. and P.F. Elson. 1975. The adaptive significance of variations in life history among local populations of Atlantic salmon in North America. Ecology **56:** 577-590

Schulze, M. B. 1996. Using a field survey to assess potential temporal and spatial overlap between piscivores and their prey, and a bioenergetics model to examine potential consumption of prey, especially juvenile anadromous fish, in the Connecticut River estuary. M.S. Thesis. University of Massachusetts, Amherst, MA. 133 pp.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin 184. Fisheries Research Board of Canada. Ottawa, Ca.

Seaber, P.R., F.P. Kapinos, & G.L. Knapp. 1994. Hydrologic Unit Maps. U.S.Geological Survey water supply-paper; 2294. Supt. of Docs. No.: I 19,13:2294.

Shelton, R.G.J., J.C. Holst, W.R. Turrell, J.C. MacLean, I.S. McLaren. 1997. Young Salmon at Sea. *In* Managing Wild Atlantic Salmon: New Challenges – New Techniques. Whoriskey, F.G and K.E. Whelan. [eds.]. Proceedings of the Fifth Int. Atlantic Salmon Symposium, Galway, Ireland.

Shepard, S. L. 1991. Evaluation of upstream and downstream fish passage facilities at the West Enfield hydroelectric project (FERC #2600-010). Report to the US Federal Energy Regulatory Commission. Bangor Hydro-Electric Company.

Spence, B.C., G.A. Lomincky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmon conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, Or.

Spicer, A.V., J.R. Moring, and J.G. Trial. 1995. Downstream migratory behavior of hatchery-reared, radio-tagged Atlantic salmon (Salmo salar) smolts in the Penobscot River, Maine, USA. Fisheries Research 23:255-266.

Sprague, J., P. Elson, and R. Saunders. 1965. Sublethal copper-zinc pollution in a salmon river – A field and laboratory study. International Journal of Air and Water Pollution. 9: 531-543

Stabell, O.B. 1984. Homing and olfaction in salmonids: A critical review with special reference to the Atlantic salmon. Biological Review of the Cambride Philosophical Society **59(3):** 333-338.

Staurnes M., L.P. Hansen, K. Fugelli, and O. Haraldstad. 1996. Short-term exposure to acid water impairs osmoregulation, seawater tolerance, and subsequent marine survival of smolts of Atlantic salmon (*Salmo salar* L.). Can. J. Fish. Aquat. Sci. **53**: 1695-1704.

Staurnes, M., Blix, P., and Reite, O. B. 1993. Effects of acid water and aluminum on parr smolt transformation and seawater tolerance in Atlantic salmon, *Salmo salar*. Canadian Journal of Fisheries and Aquatic Sciences **50**: 1816-1827.

Staurnes, M., F. Kroglund, and B.O. Rosseland. 1995. Water quality requirement of Atlantic salmon (*Salmo salar*) in water undergoing acidification or liming in Norway. Water Air and Soil Pollution **85**: 347-352.

Stefansson, S.O., B. T H. Björnsson, K. Sundell, G. Nyhammer, S.D. McCormick. 2003. Physiological characteristics of wild Atlantic salmon post-smolts during estuarine and coastal migrations. J. Fish. Bio. **63(4)**: 942-955.

Stein, S. M., R.E. McRoberts, R.J. Alig, M.D. Nelson, D.M. Theobald, M. Eley, M. Dechter, and M. Carr. 2005. Forests on the edge: housing development on America's private forests. Gen.Tech. Rep. PNW-GTR-636. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Stevenson, C.H. 1898. The Shad Fisheries of the Atlantic Coast of the United States. Report of the Commissioner for the year ending June 30, 1898 Part XXIV. U.S. Commission of Fish and Fisheries. 101-269

Stewart, G. J., J.M. Caldwell, A.R. Cloutier, and L.E. Flight. 2006. Water Resources Data Maine Water Year 2005. WDR-ME-05-1. U.S. Geological Survey, Augusta, ME.

Swansburg, E., G. Chaput, D. Moore, D. Caissie, and N. El-Jabi. 2002. Size variability of juvenile Atlantic salmon: links to environment conditions. Journal of Fish Biology **61:** 661-683.

Symons, P. and M. Heland. 1978. Stream habitats and behavioral interactions of underyearling and yearling Atlantic salmon (*Salmo salar*). J. Fish. Res. Bd. Can. 35: 175-183

Tallman, R.F. and M.C. Healey. 1994. Homing, straying, and gene flow among seasonally separated populations of chum salmon (Onchorhynchus keta). Can. J. Fish. Aquat. Sci. **51(3):** 577-588.

Taylor, J.N., W.R. Courtenay Jr., and J.A. McCann. 1984. Known impacts of exotic fishies in the continental United States. *In*: Distribution, biology, and management of exotic fishes. W.R. Courtenay Jr. and J.R. Stauffer Jr. eds. The Johns Hopkins Universtiy Press, Baltimore, MD. Pages 322-373

Thorpe, J.E. and Morgan, R.I.G., 1978. Periodicity in Atlantic salmon *Salmo salar* L. smolt migration. J. Fish Biol. **12**, 541-548.

Trombulak, S.C. and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14(1): 18-30

U.S. Environmental Protection Agency. 2000. National Water Quality Inventory – 2000 Report. Assessment and Watershed Protection Division. 1200 Pennsylvania Ave. N.W. Washington D.C.

U.S. Census of Population and Housing, 2000. Summary Population and Housing Characteristics: Maine. Washington: http://www.census.gov/census2000/states/me.html Date accessed: 12/05/2007

USEPA (United States Environmental Protection Agency). 2003. National Management Measures for the Control of Nonpoint Pollution from Agriculture. Office of Water (4503T), 1200 Pennsylvania Avenue, NW, Washington, D.C. 20460. EPA-841-B-03-004

EPA (U.S. Environmental Protection Agency). 2005. EPA New England's TMDL Review. Boston, MA. Letter and Report to Maine Department of Environmental Protection. July 18th, 2005.

U.S. Fish and Wildlife Service. 1989. Restoration of Atlantic Salmon to New England Rivers; Final Environmental Impact Statement 1989-2021.

USDA (United States Department of Agriculture). 2002 Census of Agriculture. Maine State and County Data. U.S. Department of Agriculture AC-02-A-19. Issued June 2004.

USACOE (United States Army Corp of Engineers). 1990. Penobscot River Basin Study. USACOE New England Division. Waltham, MA. 48 pp. and appendices.

USASAC (United States Atlantic Salmon Assessment Committee Report). 2004. Annual Report of the U.S. Atlantic Salmon Assessment Committee Report No. 16 – 2003 Activities. Annual Report 2004/16. Woods Hole, MA – February 23-26, 2004. 74 pp. and appendicies.

USASAC (United States Atlantic Salmon Assessment Committee Report). 2005. Annual Report of the U.S. Atlantic Salmon Assessment Committee Report No. 17 – 2004 Activities. Annual Report 2004/16. Woods Hole, MA – February 28-March 3, 2005. 110 pp. and appendicies.

USFWS (United States Fish and Wildlife Service). 1989. Final environmental impact statement 1989 – 2021: restoration of Atlantic salmon in New England. Department of Interior, U.S. Fish and Wildlife Service, Newton Corner, MA. 88 pp. and appendices.

USGS (United States Geological Survey). 2006. Mineral Industry Surveys. U.S. Peat Producers in 2005. **Internet:** http://minerals.usgs.gov/minerals

Van den Ende, O. 1993. Predation on Atlantic salmon smolts (*Salmo salar*) by smallmouth bass (*Micropterus dolomiue*) and chain pickerel (*Esox niger*) in the Penobscot River Maine. MS Thesis, University of Maine. (unpublished).

Vander Zanden, M.J., J.D. Olden, J.H. Thorne, and N.E. Mandrak. 2004. Predicting occurrences and impacts of smallmouth bass introductions in north temperate lakes. Ecological Applications 14(1): 132-148.

Waples, R. S. & M. Yokota. 2007. Temporal estimates of effective population size in species with overlapping generations. Genetics **175**: 219-233.

Warner, K. 1972. Further studies of fish predation on salmon stocked in Maine lakes. Progressive Fish Culturist 344(4):217-221.

Warner, K. and K. A. Havey. 1985. The Landlocked salmon in maine: Life history, ecology, and management of Maine Landlocked salmon (*Salmo salar*). Maine Department of Inland Fisheries and Wildlife. Augusta, ME. 127 pp.

Waters, T.W. 1995. Sediment in streams: Sources, biological effects, and control. American Fisheries Society Monograph 7 (Book).

Whalen, K. G., D. L. Parish, and M. E. Mather. 1999a. Effect of ice formation on selection habitats and winter distribution of post-young-of-the-year Atlantic salmon parr. Canadian Journal of Fisheries and Aquatic Sciences 56(1): 87-96.

Whalen, K. G., D. L. Parrish, and S. McCormick. 1999b. Migration timing of Atlantic salmon smolts relative to environmental and physiological factors. Trans. of the Amer. Fish. Soc. 128:289-301.

White, H.C. 1942. Atlantic salmon redds and artificial spawning beds. J. Fish. Res. Bd. Can. **6**:37-44.

Wickett, W.P. 1954. The oxygen supply to salmon eggs in spawning beds. J. Fish. Res. Board. Can. **6:** 933-953.

Wildish, D. J., and J. Power. 1985. Avoidance of suspended sediments by smelt as determined by a new "single fish" behavioral bioassay. *Bull. Environ. Contam.Toxic.* no. 34: 770-774

Yarborough, D.E. 1998. Wildblueberry Culture in Maine. University of Maine Cooperative Extension. Fact Sheet No. 220. UMCE No. 2088.