1999 Biological Report on the Status of Atlantic Salmon

SECTION 1: EXECUTIVE SUMMARY

The Fish and Wildlife Service and the National Marine Fisheries (the "Services") have defined a Gulf of Maine Distinct Population Segment of Atlantic salmon based upon genetic, biological and life history data. The Gulf of Maine DPS includes all coastal watersheds with native populations of Atlantic salmon north of and including tributaries of the lower Kennebec River (below Edwards Dam) to the mouth of the St. Croix River at the US-Canadian border. There are at least eight rivers in the DPS range that still contain functioning populations. These eight rivers are the Dennys, East Machias, Machias, Pleasant, Narraguagus, Ducktrap, and Sheepscot Rivers and Cove Brook.

In response to a petition submitted to list Atlantic salmon under the Endangered Species Act, the Services conducted a review of the species status in 1995. That review concluded that the species was in danger of extinction. The Services published a proposed rule to list the DPS of Atlantic salmon as threatened and specifically identified threats from poaching, low natural survival of fish during the first winter at sea, and potential impacts from Atlantic salmon aquaculture operations and fish hatcheries to the genetic integrity and disease vulnerability of the DPS. In that proposed rule, the Services invited the State of Maine to prepare a Conservation Plan to eliminate, minimize and mitigate threats to Atlantic salmon and their habitat.

On December 18, 1997, the Services jointly withdrew a proposed rule designating Atlantic salmon in seven Maine rivers as a threatened Distinct Population Segment pursuant to the Endangered Species Act. The withdrawal was based on an evaluation of scientific data, the biological status of the species and consideration of actions ongoing by state, federal, and private entities designed to improve the status of Atlantic salmon and their habitat. One of those actions was the development and implementation by the State of Maine of a comprehensive Atlantic salmon conservation plan for seven river populations within the DPS.

The withdrawal notice required full public review of progress toward implementation of the conservation plan and on January 20, 1999, the Services announced the availability of the first annual conservation plan report and solicited public comment for 45 days. The Services also announced that after the state submitted a final annual report responding to comments that the Services would update the 1995 Atlantic Salmon Status Review. Copies of all public comments were provided to Maine on March 11, 1999. On March 18, the Services provided detailed comments to Maine explaining joint agency concerns and seeking additional information on certain issues. The state response was received on April 26, 1999, and the biological review team (BRT) thoroughly reviewed the state response along with all available information relating to the status of the species. This status review updates the 1995 Status Review and reflects the opinion of the BRT as to the current status of the DPS in the context of all ongoing management efforts and new research and assessment data that has become available since the 1995 status review and the withdrawal notice was published. The Status Review does not make a determination as to whether Atlantic salmon should be listed as threatened or endangered under the Endangered Species Act.

The spawning stocks of Atlantic salmon throughout much of the North Atlantic, including Maine, continue to be very low. This trend is not expected to improve rapidly, due to the current population size of adults that are likely to be a component of spawning in 1999 and beyond. Survival of juveniles to parr stage in several of the rivers has increased, but only due to river-specific stocking activity. However, survival of juveniles to smolt stage, in rivers where measured, is lower than previously estimated.

Conservation hatchery activities have been affected by a recently identified disease (Salmon swimbladder sarcoma virus-SSSV) which resulted in the decision to destroy all captive broodstock for the Pleasant River. SSSV has been identified at very low occurrence levels in captive broodstock populations from three other rivers. Infectious salmon anemia (ISA), though not detected in U.S. waters, now extends within the coastal range of Gulf of Maine Atlantic salmon.

Efforts to implement and enhance habitat protection and restoration are evident throughout the DPS. Watershed councils are in place or being formed; additional riparian areas are being protected through acquisition, easement, and institution of buffer zones; and water withdrawal issues are to be dealt with through water management plans and regulation. Water withdrawal with its immediate impact on juvenile Atlantic salmon production and survival is the habitat issue of greatest concern. Sedimentation, nutrient input, pesticide impacts, process water discharge, low pH, and streambank vegetation removal continue to impair Atlantic salmon production potential.

Ocean harvest of Atlantic salmon continues to be restricted based upon international agreements negotiated among United States, Canadian, and European representatives to the North Atlantic Salmon Conservation Organization. Distant water fisheries have either been completely closed or vastly reduced to subsistence levels. Recreational fishing for salmon in Maine is catch and release only. The interagency Atlantic Salmon Technical Advisory Committee has recommended closing salmon fishing on the DPS rivers. Maine proposed regulations to close Atlantic salmon fishing in the seven rivers plus four others under review by the Services for inclusion in the DPS. Thus far, such closures have not occurred. Poaching, though a concern, has not been a significant problem during the past two years. Additional enforcement presence on the rivers may have helped reduce illegal harvest.

The current practices of a greatly expanded aquaculture industry in the vicinity of the DPS rivers pose a major threat to the recovery of wild salmon populations. The most serious threat to the genetic integrity of wild salmon within the DPS is the interaction with aquaculture escapees. Genetic, health, and ecological interactions have been well documented in Europe and Canada. The BRT believes that current aquacultural practices have the potential to disrupt, displace, and genetically contaminate the DPS through redd superimposition, hybridization, disease transfer, and competition. Although discussions with environmental regulators in Maine are ongoing, to date the Services' efforts to obtain state and industry agreement to address aquacultural use of European stocks, crosses between European and North American stocks, and the importation of European milt have so far been unsuccessful. In fact, the use of European/North American hybrids by the industry appears to be increasing. In 1998, six million Atlantic salmon were raised in sea cages near the mouths of many DPS and other Atlantic salmon rivers, and escapees have been documented in several of these rivers. Additionally, the escape of juvenile Atlantic salmon from aquaculture hatcheries within DPS watersheds creates further concern because they compete with indigenous stock in fresh water, and identification is more difficult. The level of these threats is being elevated due to low spawner abundance and industry expansion.

As indicated above, discussions with environmental regulators in Maine are ongoing, however, comprehensive protective measures to address the threats posed by aquaculture are not in place, and aquaculture practices continue to pose a serious threat to the genetic integrity of the Gulf of Maine DPS. Action to address the use of pure European strains and hybrids is necessary. Additionally, weirs on several of the rivers scheduled for construction since 1996 must be completed to help protect stocks from this threat.

In summary, Atlantic salmon in the Gulf of Maine DPS exhibit critically low spawner abundance, poor marine survival, and are confronted with the increased presence of threats which have been documented to negatively impact salmon stocks including artificially reduced water levels, diseases and parasites, recreational and commercial fisheries, sedimentation, and genetic intrusion by commercially raised Atlantic salmon (particularly non-North American strains). This status review acknowledges the considerable efforts being put forth by the State of Maine and public and private sector partners to protect Atlantic salmon. The fact remains, however, that under current circumstances, it is the opinion of the BRT that the Gulf of Maine DPS of Atlantic salmon is in danger of extinction.

SECTION 2: INTRODUCTION AND BACKGROUND

In 1991, the U.S. Fish and Wildlife Service (USFWS) designated Atlantic salmon in five rivers in "Downeast" Maine (the Narraguagus, Pleasant, Machias, East Machias and Dennys Rivers) as Category 2 candidate species under the ESA. The USFWS then began working with the National Marine Fisheries Service (NMFS) as well as state and private agencies to reverse the decline in salmon abundance. During that same period, NMFS was conducting an exhaustive five year study of the Narraguagus River demonstrating that spawning and nursery habitat appeared suitable and should produce more fish given adequate escapement levels. A timeline displaying the major events is provided in the Appendix.

The USFWS and the NMFS (collectively "the Services") received identical petitions In October and November of 1993 from RESTORE: The North Woods, Biodiversity Legal Foundation, and Jeffrey Elliot to list the Atlantic salmon (Salmo salar) throughout its historic range in the contiguous United States under the Endangered Species Act of 1973, as amended, 16 U.S.C. � 1531 et seq. (ESA). The Services published a notice on January 20, 1994 that the petition presented substantial scientific information indicating that a listing may be warranted and requested information from the public.

The Services concurrently initiated a study of the status of U.S. Atlantic salmon in relation to the ESA. A biological review team consisting of three members from each Service was appointed to review the petition, prepare a formal status review, and make recommendations as to the appropriate joint agency petition response. The Team evaluated the status of Atlantic salmon by analyzing trends in historic and current relative abundance and spawner escapement goals. The status of the distinct population segment was then examined in relation to the ESA which defines an endangered species as one "in danger of extinction throughout all or a significant portion of its range", and a threatened species as one "likely to become endangered in the foreseeable future." Section 4(b)(1)(a) of the ESA provides that the Secretaries of the Interior and of Commerce shall make listing determinations based solely on the basis of the best scientific and commercial data available, after conducting a review of the status of the species and after taking into account those efforts being made by any state or foreign nation to protect such species. A species may be determined to be threatened or endangered because of any of the following factors: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; and (5) other natural or manmade factors affecting its continued existence (ESA Section 4(a)(1)).

The Services drafted a status review in January 1995 to assist in making the 12-month petition finding. It was submitted for peer review and made available for public review. The Services denied the original petition and determined that listing the species throughout its historic range was not warranted. The January 1995 status review concluded that the DPS, comprised of Atlantic salmon populations in seven rivers (the Dennys, East Machias, Machias, Pleasant, Narraguagus, Ducktrap and Sheepscot Rivers) was in danger of extinction. On September 29, 1995, after reviewing state and foreign efforts to protect the species, the Services proposed to list the seven rivers DPS as a threatened species under the ESA. The proposed rule contained a special rule under Section 4(d) of the ESA, which allowed for a State plan, approved by the Services, to define the manner in which certain activities could be conducted without violating the ESA.

The Governor of Maine issued an Executive Order on October 20, 1995, appointing the Maine Atlantic Salmon Task Force and charged that Task Force with preparation of a conservation plan for the protection and recovery of Atlantic salmon in the seven rivers. In the fall of 1996, the State held public hearings on the Conservation Plan and solicited and accepted comments from the public concerning the content of the Conservation Plan. In March of 1997, the Maine Atlantic Salmon Task Force submitted the Atlantic Salmon Conservation Plan for Seven Maine Rivers (Conservation Plan) to the Services.

The Services reopened the public comment period for the proposed threatened designation on May 23, 1997, to obtain public comments on the Conservation Plan and other new information which included adult returns, redd counts, fry stocking, habitat assessments, commercial fishing agreements and management measures (62 FR 28413). The Services reviewed information submitted from the public and current information on population levels and on December 18, 1997 withdrew the proposed rule to list the seven rivers DPS of Atlantic salmon as threatened under the ESA (62 FR 66325). In that withdrawal notice, the Services redefined the species under analysis as the Gulf of Maine DPS. The Services stated that they had considered the current status of the Gulf of Maine DPS of Atlantic salmon and had taken into account those efforts being made to protect the species including development of the Conservation Plan, the extent of implementation of the Conservation Plan to date, private and federal actions to restore the species, and international efforts to control ocean harvest through the North Atlantic Salmon Conservation Organization (NASCO). Based on this review, the Services determined in

December 1997 that the Gulf of Maine DPS was not likely to become endangered in the foreseeable future and therefore an ESA listing was not warranted.

The Governor of Maine issued Executive Orders on December 15, 1997 and April 23, 1997, charging all state agencies with implementing the Conservation Plan. The Executive Order named the Land and Water Resources Council (LWRC) as the entity responsible within the State for implementing the Plan and monitoring its progress. The LWRC is composed of the Commissioners of the Departments of Environmental Protection (DEP), Conservation (DOC), Marine Resources (DMR), Agriculture (DAFRR), Transportation (DOT), Human Services, Economic and Community Development, and Inland Fisheries and Wildlife (IF&W). The LWRC is chaired by the director of the State Planning Office (SPO). The Chair of the Atlantic Salmon Authority (ASA) is a member of the LWRC for all matters that involve or affect Atlantic salmon. To facilitate Conservation Plan implementation, the LWRC created an Atlantic Salmon Committee (LWRC ASC) which includes the Commissioners of DMR, DEP, IF&W, DAFRR, DOC, DOT, the ASA chair, SPO director and representatives from each Watershed Council (Watershed Councils for each river were formed as an outgrowth of the Conservation Plan). On December 15, 1998, the Services also entered into a Statement of Cooperation with Maine in support of implementation of he Conservation Plan.

In the December 18, 1997 Federal Register notice, the Services renamed the seven rivers DPS as the Gulf of Maine DPS to acknowledge the possibility that other populations of Atlantic salmon could be added to the DPS if they were found to be naturally reproducing and to have historical, river-specific characteristics. The Services stated their commitment to make the state's annual reports on implementation of the Conservation Plan available to the public for review and comments and also outlined three circumstances under which the process for listing the Gulf of Maine DPS of Atlantic salmon under the ESA would be reinitiated. The three circumstances which would lead to a reinitiation of the process for listing were as follows: (1) an emergency which poses a significant risk to the well being of the Gulf of Maine DPS is identified and not immediately and adequately addressed; (2) the biological status of the Gulf of Maine DPS is such that the DPS is in danger of extinction throughout all or a significant portion of its range; or (3) the biological status of the Gulf of Maine DPS is such that the DPS is likely to become endangered in the foreseeable future throughout all or a significant portion of its range.

The Services received Maine's 1998 Annual Progress Report on Conservation Plan implementation in January 1999. As indicated in the 1997 Federal Register notice, the Services published a Federal Register notice on January 20, 1999 to request assistance from the public in determining whether the protective measures in place, including the provisions of the Conservation Plan, remained adequate to protect the species in light of current knowledge (64 FR 3067). That comment period closed on March 8, 1999. On March 24, 1999 the Services provided comments to the State on the Annual Progress Report. On April 23, 1999, the State provided the Services with a response that included amendments to the Conservation Plan.

In order to conduct a comprehensive review, the biological status review team (BRT) has updated the 1995 status review for Atlantic salmon. Current team members are as follows: from NMFS - Mary A. Colligan, Fishery Biologist, Protected Resources Division, Northeast Region, Gloucester, MA; and John F. Kocik, Research Fishery Biologist, Population Dynamics Branch, Northeast Fisheries Science Center, Woods Hole, MA; From the Fish and Wildlife Service - Dan C. Kimball, Atlantic Salmon Recovery Specialist, Region 5, Hadley, MA; Jerry Marancik, Maine Fisheries Program Coordinator, East Orland, ME; Joseph F. McKeon, Fisheries Biologist/Project Leader, Office of Fishery Assistance, Laconia, NH; and Paul R. Nickerson, Chief, Endangered Species Division, Region 5, Hadley, MA.

Acknowledgments

Relevant comments and supplemental information submitted by interested parties on the 1995 Status Review and other events since that time were reviewed by the Team and incorporated in this Review, as appropriate. The Team also acknowledges the assistance of the staff of the Maine Atlantic Salmon Authority, Dr. Russell Brown, Dr. Kevin Friedland and Ruth Haas-Castro of the NMFS Northeast Fisheries Science Center, Dr. Robin Waples of NMFS Northwest Fisheries Science Center and Dr. Tim King, USGS-BRD, Leetown Science Center. In addition, the team thanks the Services' reviewers who provided comments on the draft status review.

SECTION 3: BIOLOGICAL INFORMATION

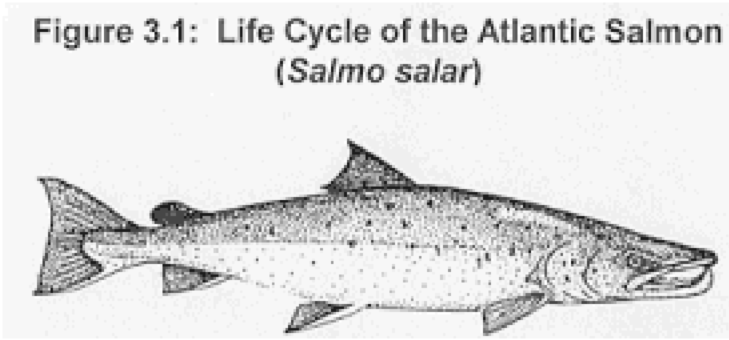
3.1 LIFE HISTORY

Atlantic salmon have a relatively complex life history that includes spawning and juvenile rearing in rivers to extensive feeding migration on the high seas. As a result, Atlantic salmon go through several distinct phases in their life history that are identified by specific behavioral and physiological changes and changes in habitat types (Figure 3.1). The following sections detail the life history typical of Atlantic salmon originating from U.S. rivers, during the periods spent in riverine and marine habitats. General descriptions of the life history of Atlantic salmon can be found in MacKenzie and Moring (1988), Bley and Moring (1988), Stanley and Trial (1995), and Baum (1997).

3.1.1 Riverine Habitat

Adult Atlantic salmon ascend the rivers of New England beginning in the spring, continuing into the fall with the peak occurring in June. According to Baum, historically, the majority of the Atlantic salmon in the Penobscot, Dennys, East Machias, Narraguagus, Kennebec, Androscoggin and Saco Rivers entered freshwater between May and mid July and were therefore called "early run", whereas the majority of those returning to the St. Croix, Machias, and Ducktrap Rivers entered freshwater after mid- July and were called "late run". Some rivers such as the Sheepscot and Pleasant had both an early run and late run of Atlantic salmon (Baum 1997). Salmon that return early in the spring spend nearly five months in the river before spawning, seeking cool deep pools during the summer months. Homing to natal streams is thought to be facilitated with olfactory stimuli (Stasko et al. 1973).

Straying rates (fraction of fish found in rivers other than their natal rivers) for Maine Atlantic salmon were estimated based on a tagging study of 1.5 million Penobscot River hatchery fish. Only 1-2% of these fish was found to enter a river other than the Penobscot (Baum 1997). Once an adult salmon enters a river, rising river temperatures and water flows stimulate upstream migration. However, water temperatures above 22.8^{o} C or dissolved oxygen concentrations below 5 ppm can curtail movement (DeCola 1970).



(full size image)

When a salmon returns to its home river after two years at sea (called a two sea winter or 2SW fish) it is approximately 75 cm long and weighs approximately 4.5 kg. Some salmon, typically males, return after only one year at sea (1SW fish) at a smaller size and are termed "grilse". Occasionally, a large 3SW salmon is found among returning adults. In Maine, 95-98% of the grilse is male while 55-75% of the older fish returning is female (Baum 1997). The ranges are provided as a result of annual variation. For the period of 1970 to 1998, approximately 3% of the wild origin returning adults to the seven DPS rivers were 1 SW fish (USASAC 1999). Once in freshwater, adult salmon cease to feed during their up-river migration, and darken in color. Spawning occurs in late October through November.

Approximately 20% of Maine Atlantic salmon return to the sea immediately after spawning, the majority overwinter in the river and return to the sea the following spring (Baum 1997). A spawned salmon in freshwater is called a kelt or black salmon. Upon returning to salt water, the kelt resumes feeding and recovers its silver color. If the salmon, now a rejuvenated "bright" fish, should be among the minority to survive another 1-2 years at sea, it will return to its home river as a "repeat spawner". Thus, a spawning run of salmon may include several age groups, insuring some level of genetic exchange between generations.

Preferred spawning habitat is a gravel substrate with adequate water circulation to keep the buried eggs well oxygenated (Peterson 1978). Water depth at spawning sites is typically 30 cm to 61 cm and water velocity averages 60 cm per second (Beland 1984). Spawning sites are often located at the downstream end of riffles where water percolates through the gravel or where upwellings of groundwater occur (Danie et al. 1984). The optimal water temperature during the spawning period ranges from 7.2o C to 10.0o C (Jordan and Beland 1981; Peterson et al. 1977). The female moves her tail back and forth to create a depression in the gravel, called a redd, where she deposits eggs. One or more males fertilize the eggs as they are deposited in the redd (Jordan and Beland 1981). Redds in Maine average 2.4 m long and 1.4 m wide (Baum 1997). The female then continues digging upstream of the deposition site, burying the fertilized eggs. In Maine rivers, eggs are buried 12-20 cm on average and on average 240 eggs are deposited per habitat unit (one habitat unit equals 100 square meters of general habitat) (Baum 1997). A single female may create several redds before depositing all her eggs. Female anadromous Atlantic salmon produce a total of 1,500 to 1,800 eggs per kilogram of body weight. An average 2SW Maine Atlantic salmon produces 7,200 eggs. Weight loss in females ranges from 25-45% during spawning.

The eggs hatch in late March or April into a life stage that is called an alevin or sac fry. Alevins remain in the redd for about six weeks and are nourished by their yolk sac. When the alevins emerge from the gravel, about mid-May, and begin active feeding they are termed fry. Studies of fry in Maine reveal that the majority emerge from redds at night (>95%)(Baum 1997). Survival from eggs to the fry stage in Maine rivers has been reported to range from 8-35% (Jordan and Beland 1981; Meister, 1962; Baum 1997). Survival rates are affected by stream gradient, overwintering temperatures and water flows, and the level of predation and competition (Bley and Moring 1988). Within days, the fry enter the parr stage, indicated by vertical bars (parr marks) visible on their sides. These marks act as camouflage (Jones 1959). Survival from fry to parr ranges from 28-44% (Baum 1997). Parr measure from 4-10 cm in length and weigh between 10 and 100 grams (Baum 1997). During their early life in the river, salmon seek the cover provided by rocks and vegetation (Baum 1997).

Parr prefer areas with adequate cover, water depths ranging from approximately 10 cm to 60 cm, water velocities between 30 and 92 cm per second, and water temperature near 16o C (Beland 1984). A territorial instinct, first apparent during the fry stage, grows more pronounced during the parr stage, and the parr actively defend territories (Danie et al. 1984; Mills 1964; Kalleberg 1958; Allen 1940). Some male parr become sexually mature and can successfully participate in spawning with sea-run adult females. These males are referred to as "precocious parr". Water temperature (Elliot 1991), parr density (Randall 1982), photoperiod (Lundquist 1980), and the level of competition and predation (Hearn 1987, Fausch 1986), as well as food supply, influence the growth rate of parr. Maine Atlantic salmon rivers produce from five to ten parr per unit of habitat (Baum 1997). Juvenile Atlantic salmon feed on larvae of mayflies and stoneflies, chironomids, caddisflies and blackflies, aquatic annelids and mollusks as well as numerous terrestrial invertebrates that fall into the river (Scott and Crossman 1973).

In a parr's second or third spring, when it has grown to 12.5-15 cm in length, physiological changes occur that also result in visible morphological and behavioral changes (Schaffer and Elson 1975). This process, called "smoltification", prepares the parr for migration to the ocean and life in salt water. In Maine, the majority of parr remain in freshwater for two years (80%), while the balance remain for three years (Baum 1997). Survival from the parr to the smolt stage has previously been estimated to range from 35-55% (Baum 1997). Research in the Narraguagus River, however, demonstrated a 99% probability that survival was less than 30% (Kocik 1998). The juvenile fish loses its parr markings and its body becomes streamlined and silvery with a pronounced fork in the tail. Orientation in the water column changes from facing upstream to downstream. The biochemical and 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 (Bley 1987; Farmer et al. 1977; Hoar 1939; USFWS 1989; Ruggles 1980). As smolts migrate from the rivers from April to June, they tend to travel near the water surface and contend with changes in water temperature, pH, dissolved oxygen, pollution levels, and predation. Maine smolts range in size from 13-23 cm (Baum 1997). Most smolts in New England rivers enter the sea during May and June to begin their ocean migration. Baum provides the "rule-of-thumb" that Maine salmon rivers produce 19 fry/unit, resulting in 6 parr/unit and ultimately 3 smolts/unit (1997). Survival from fry to smolt, based on results from hatchery fry plantings, is reported by Bley and Moring (1988) to range from about 1% to 12% and survival from egg to smolt stage is reported by Baum (1997) to be approximately 1.25%.

Martin (1995) references Elliot (1991) in reporting lethal water temperatures for salmon in freshwater as 27.8� C for seven days and 32.9� C for 10 minutes.

3.1.2 Marine Habitat

The marine life history of Atlantic salmon of U.S. origin is not as well understood as the freshwater phase. A major obstacle to the study of Atlantic salmon in the marine environment has been the relatively low density of salmon over the extended geographic range in the ocean (Figure 3.1.2) (Hislop and Shelton 1993). However, in the last ten years there has been substantial progress in understanding the marine ecology and population dynamics of Atlantic salmon. Central to this progress has been the work of assessment committees such as the U.S. Atlantic Salmon Assessment Committee (USASAC), the International Council for the Exploration of the Sea (ICES) Working and Study Groups (the North American Salmon Study Group (ICES-NASSG) and the North Atlantic Salmon Working Group (ICES-NASWG). Within the framework of providing scientific advice to the multinational North American Salmon Conservation Organization (NASCO), basic understanding of the marine ecology of the species has been advanced (Windsor and Hutchinson 1994).

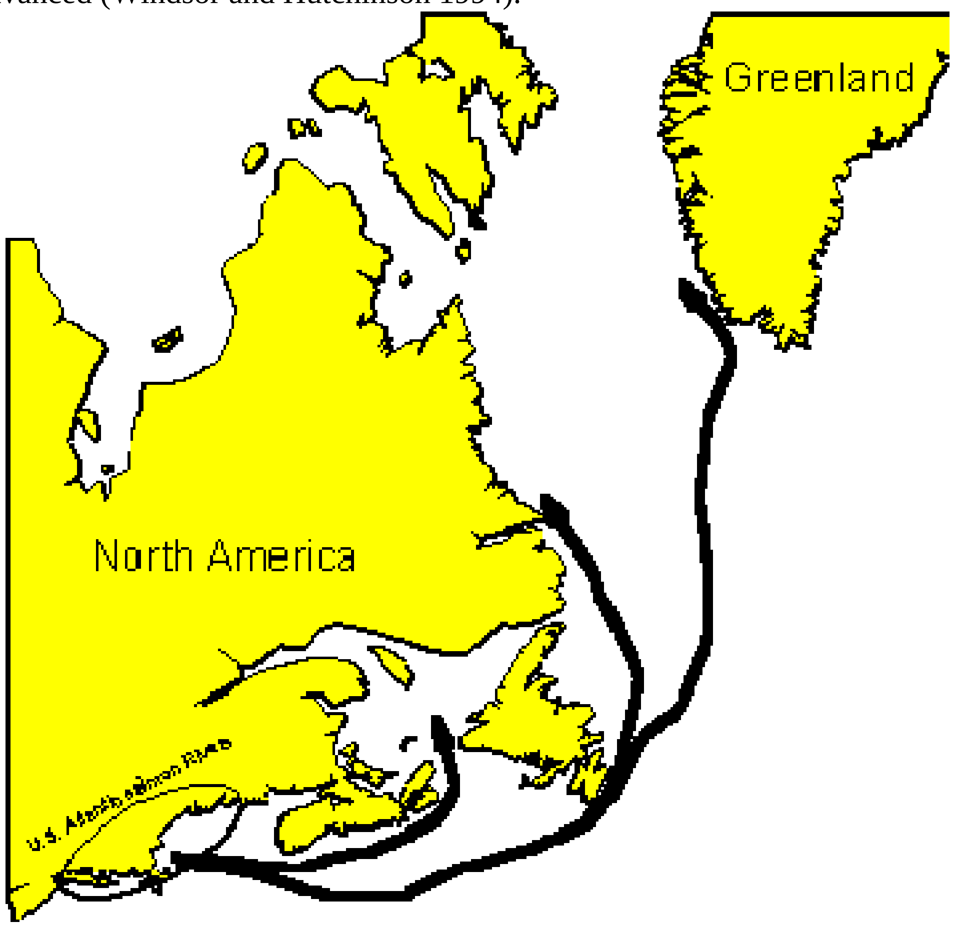


Figure 3.1.2: Generalized marine migration routes of U.S. origin Atlantic salmon

Much of our knowledge of U.S. Atlantic salmon at sea has been derived from marking and tagging studies of fish stocked in the Connecticut, Merrimack, and Penobscot Rivers. Over the history of the U.S. program, marking has progressed from fin clipping (1942-1962), to Carlin tags (1962-1992), to coded-wire tags (CWT) from 1985 to the present (Meister 1984; NASCO 1993b). From these investigations, scientists have gained a better understanding of the movement and exploitation of U.S. Atlantic salmon at sea (Meister 1984; NASCO 1993b; Reddin and Friedland 1993). Scientists have also discovered correlations between natural mortality in the marine environment and abiotic factors, particularly sea surface temperature (SST) (Scarnecchia 1984a, 1984b; Martin and Mitchell 1985; Scarnecchia et al. 1989; Friedland and Reddin 1993; Friedland et al. 1993). Additional studies that have directly sampled Atlantic salmon in the ocean have also provided important insights (Dutil and Coutu 1988; Reddin 1988; Reddin et al. 1991; Ritter 1989). While our understanding of the marine ecology of Atlantic salmon is still incomplete, these investigations have helped discern movements, exploitation, and population dynamics (Meister 1984; NASCO 1993b; Reddin and Friedland 1993; Friedland et al. 1993).

Atlantic salmon of U.S. origin are highly migratory (Figure 3.1.2), undertaking long marine migrations from the mouths of U.S. rivers into the Northwest Atlantic Ocean, where they are distributed seasonally over much of the region (Reddin 1985). The marine phase starts with smoltification and subsequent migration through the estuary of the natal river. Smolt movement in the predominantly freshwater sections of the estuary is relatively passive, progressing seaward on ebb tides and neutral or upstream on flood tides (Fried et al. 1978; Thorpe et al. 1981). As smolts enter the more saline portions of the estuary, their movements are more directed and less affected by tides. They move rapidly seaward at speeds averaging two body lengths per second (La Bar et al. 1978).

Upon completing the physiological transition to salt water, the post-smolts grow rapidly and have been documented to move in small schools and loose aggregations close to the surface (Dutil and Coutu 1988). The post-smolt stage is probably the least understood period during the life history of Atlantic salmon; recaptures of post-smolts are limited because Atlantic salmon fisheries target older, larger fish. Most of the U.S.- origin post-smolt tag recoveries have come from incidental catch in herring and mackerel weirs in the Bay of Fundy and South Shore of Nova Scotia during July (Meister 1984). Tag recoveries from sea-bird colonies have indicated that U.S. post-smolts are also present off eastern Newfoundland by August (Montevecchi et al. 1988; Reddin and Short 1991). Upon entry into the nearshore waters of Canada, the U.S. post-smolts become part of a mixture of stocks of Atlantic salmon from various North American streams. Post-smolts in the northern Gulf of St. Lawrence stay nearshore for much of the first summer. Decreasing nearshore temperatures in autumn appear to trigger offshore movements of these fish (Dutil and Coutu 1988). Post-smolts also occur off the Grand Bank and further North in the Labrador Sea during the summer and autumn (Reddin 1985; Reddin and Short 1991; Reddin and Friedland 1993), where the North American stock complex intermixes with fish from Europe and Iceland. The U.S. stocks of Atlantic salmon thus become a small portion of a larger mixed-stock complex. The U.S. contribution to the stock complex has probably always been relatively low because the basin wide production is modest.

Upon entry to the marine environment, post-smolts appear to feed opportunistically, primarily in the neuston (near the surface). Their diet includes invertebrates, amphipods, euphausiids, and fish (Hislop and Youngson 1984; Jutila and Toivonen 1985; Fraser 1987; Hislop and Shelton 1993). As post-smolts grow, fish become an increasingly dominant component of their diet. Atlantic salmon post-smolts, because of their small size, are preyed upon by cod, whiting, cormorants, ducks, terns, gulls, and many other opportunistic predators (Hvidsten and Mokkelgjerd 1987; Gunnerod et al. 1988; Hvidsten and Lund 1988; Montevecchi et al. 1988; Hislop and Shelton 1993). Predation rates are difficult to estimate because of the wide spatial and temporal distribution of Atlantic salmon at low densities and the large number and variety of potential predators.

Information on the overwintering of post-smolts at sea is limited. Based upon analyses of scales, it appears that growth is minimal during this time (Friedland et al. 1993). The location of stocks during the winter is uncertain, but high spring catch rates of one-sea-winter (1SW) Atlantic salmon in the Labrador Sea caused Reddin and Friedland (1993) to hypothesize that post-smolts overwinter in the southern Labrador Sea. It is also likely that some component of the North American stock complex overwinters in the Bay of Fundy (Reddin and Friedland 1993). Direct sampling during the winter months would be helpful in gaining a better understanding of post-smolt Atlantic salmon distribution in the North Atlantic.

Most U.S. origin salmon spend two winters (2SW) in the ocean before returning to streams for spawning. Fish that return to freshwater after only one year at sea are called grilse, whereas those that spend multiple years at sea are called salmon. The 1SW and multi-sea-winter (MSW) Atlantic salmon are thought to behave similarly to the post-smolts, moving through the top six meters of the water column (Reddin 1985). Aggregations of Atlantic salmon may still occur after the first winter, but most evidence indicates that they travel individually (Reddin 1985). At this stage, Atlantic salmon primarily eat fish (piscivorous), feeding upon capelin (Mallotus villosus), herring (Alosa sp.), and sand lance (Ammodytes sp.) (Hansen and Pethon 1985; Reddin 1985; Hislop and Shelton 1993). Their increasing size makes them decreasingly vulnerable to predation by smaller piscivores that feed upon post-smolts. Although most Atlantic salmon are caught near the surface, several benthic predators such as gadids, skates, and Greenland shark (Simniosus microcephalus) are known to eat them at sea (Hislop and Shelton 1993). This suggests that Atlantic salmon do spend some time in deeper waters and indicates the need for further behavioral studies.

SECTION 4: HISTORIC DISTRIBUTION, ABUNDANCE AND ARTIFICIAL PROPAGATION

4.1 HISTORIC DISTRIBUTION AND ABUNDANCE

4.1.1 Distribution

Anadromous Atlantic salmon were native to nearly every major coastal river north of the Hudson River (Atkins 1874; Kendall 1935). There were likely at least 11 U.S. coastal watersheds outside of Maine that historically supported wild salmon populations. Beland (1984) reported that at least thirty-four Maine Rivers held Atlantic salmon populations at one time. Other sources report the number to be 28 (MacCrimmon and Gots 1979; Kendall 1935). The known historic natural range of Atlantic salmon in U.S. rivers was from the Housatonic River in the south to the St. Croix River in the north (Kendall 1935; Scott and Crossman 1973). Nineteen important historic Atlantic salmon rivers are specifically identified in Figure 4.1.1.

By the early 1800's, the Atlantic salmon runs in New England had been severely depleted, greatly reducing the species' distribution in the southern half of its range. The earliest impacts were from fishing, water quality degradation, and barriers to migration caused by waste disposal and waterpower development associated with the Industrial Revolution. Restoration efforts were initiated in the mid-1800's, but had little success due to the presence of dams and the inefficiency of early fishways (Stolte 1981). Natural Atlantic salmon runs had disappeared from southern New England Rivers by 1865. There was a brief period in the late 19th Century when limited runs were reestablished in the Merrimack and Connecticut Rivers by artificial propagation, but these runs were extirpated by the end of the century (USFWS 1989). Salmon runs in the large rivers south of the Kennebec River, Maine, disappeared during this same period (Atkins 1874; Kendall 1935). By the end of the 19th Century, three of the five largest salmon populations in New England (in the Connecticut, Merrimack, and Androscoggin Rivers) had been eliminated, shifting the southern extent of the species' distribution approximately 2^{o} north in latitude and 4^{o} east in longitude.

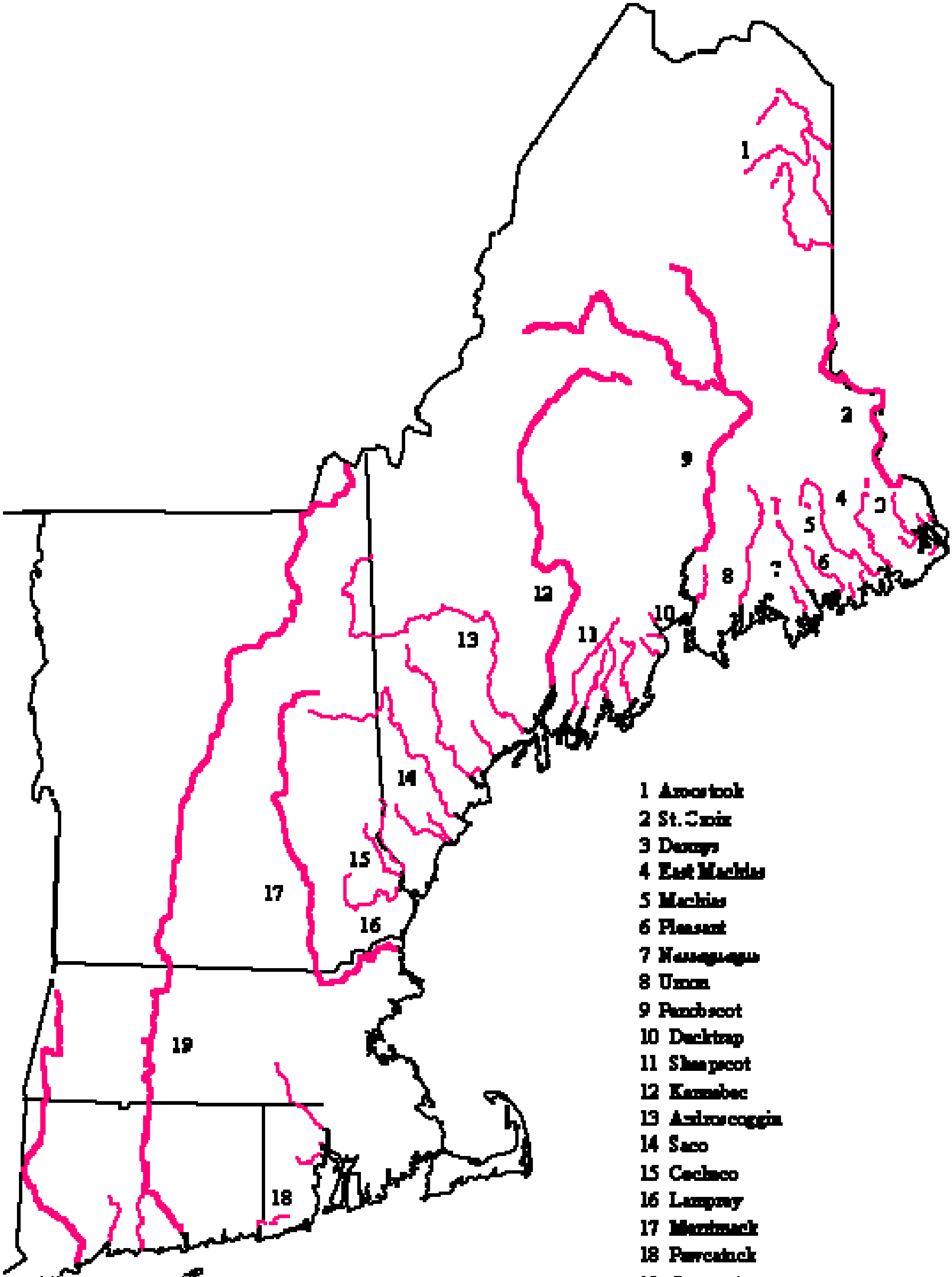
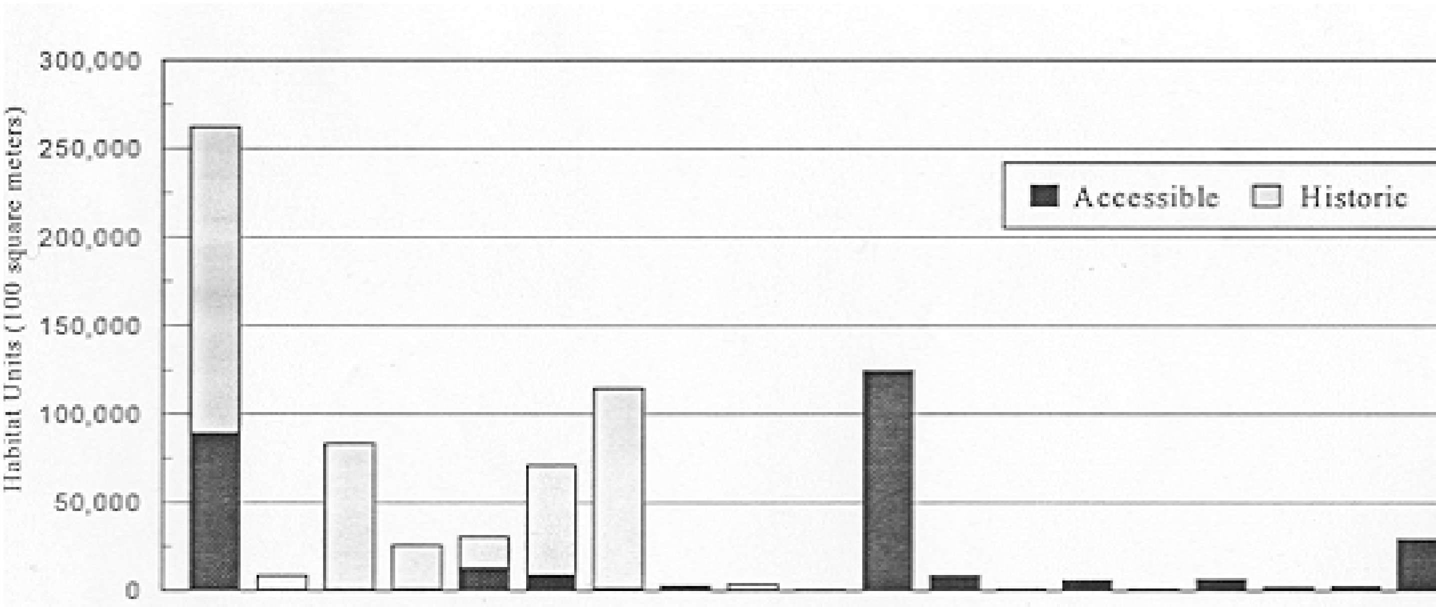

1 Aroostook
2 St. Croix
3 Dennys
4 East Machias
5 Machias
6 Pleasant
7 Narraguagus
8 Union
9 Penobscot
10 Ducktrap
11 Sheepscot
12 Kennebec
13 Androscoggin
14 Saco
15 Cocheco
16 Lamprey
17 Merrimack
18 Pawcatuck

Figure 4.1.1 Major historic New England Salmon rivers.



River	CT	PW	MK	SMC	SA	AN	KB	SH	CMC	DT	PB	UN	EMC	NG	PL	MC	EM	DE	SC	SJRW
Accessible	89,250	167	251	586	12,540	8,500	1,000	2,845	502	800	125,000	8,360	1,022	6,015	1,085	6,685	2,145	2,415	29,260	66,175
Historic	173,250	8,611	83,349	24,996	18,152	62,560	113,700	2,845	3,260	800	125,000	8,360	233	6,015	1,085	6,685	2,145	2,415	29,260	5,435

Legend:

Connecticut River (CT)
Pawtucket River (PW)
Merrimack River (MK)
Saco River (SA)
Androscoggin River (AN)
Kebbebec River (KB)
Sheepscot River (SH)
Ducktrap River (DT)
Penobscot River (PB)
Union River (UN)
Narraguagus River (NG)
Pleasant River (PL)
Machias River (MC)
East Machias River (EM)
Dennys River (DE)
St. Croix River (SC)

Southern Maine Coastal (SMC): Salmon Falls, Mousam, Kennebunk, Presumscot and Royal Rivers

Central Maine Coastal (CMC): Pemaquid, Medomak, St. George, Little, and Passagassawaukeag Rivers

Eastern Maine Coastal (EMC): Indian, Chandler, Orange, and Pennamaquan Rivers; Tunk, Hobart and Boyden Streams

St. John River watershed (SJRW): Aroostook and Meduxnekeag Rivers; Prestile stream

Figure 4.1.2. Estimated historical habitat units (one production unit = 100 m^2) and estimated habitat units currently accessible to Atlantic salmon in New England rivers.

4.1.2 Abundance

The annual historic Atlantic salmon adult population returning to U.S. rivers has been estimated to be between 300,000 (Stolte 1981) and 500,000 (Beland 1984). The largest historical salmon runs in New England were likely in the Connecticut, Merrimack, Androscoggin, Kennebec, and Penobscot Rivers. Beland (1984) reported that the total original Atlantic salmon spawning and nursery habitat in Maine rivers was 476,577 units (1 unit = 100 m2). Currently, there are 247,585 units (52%) of the historic Atlantic salmon habitat in Maine, accessible to returning adults (Baum et al. 1995). The amount of historic habitat and habitat currently accessible to Atlantic salmon in New England rivers is given in Figure 4.1.2.

The Penobscot River continued to support a substantial wild population during the late 1800's, with a reported commercial catch of over 10,000 salmon in 1880 (Baum 1997). In subsequent years, a new artificial propagation program initiated in Maine influenced population abundance and distribution. However, the abundance of Atlantic salmon generally continued to decline in all remaining rivers with salmon populations through the last half of the 19th Century and first half of the 20th Century. By the mid 20th Century, the total adult run of Atlantic salmon to U.S. rivers had declined from hundreds of thousands of fish in the early part of the previous century to a probable range of 500-2000 fish, mostly in rivers in eastern Maine (estimated from data reported in the Maine Atlantic Sea-Run Salmon Commission's River Management Report series published in 1983). One of the best years for angling harvest during the period from 1948 through 1970 was 1959 when a total recreational catch of 479 salmon was reported. Of these, 450 (94%) were caught in five rivers in Washington County (Baum 1997). The recreational catch reported for the Penobscot that year was only 2 fish. The primary distribution of Atlantic salmon in the U.S. by the mid-20th Century was, except for a few remnant populations, limited to the eastern third of Maine's coast.

4.2 HISTORIC STOCKING (1866 to 1970)

4.2.1 Stocks Used for Artificial Propagation

The artificial propagation of Atlantic salmon in the United States began with the planting of nearly 70,000 fertilized eggs into the Merrimack River in 1866. The eggs were taken from salmon from the Miramichi River, New Brunswick. This was followed over the next two years with stocking of the headwaters of the Merrimack and Connecticut Rivers with small numbers of fry from Canada. The first stocking of Atlantic salmon in Maine occurred in 1871 with the release of 1,500 parr of Canadian origin into the Sheepscot River. A hatchery was established in the lower Penobscot drainage, and the practice of purchasing adult salmon harvested by commercial trap-netters was initiated, making the Penobscot River the primary source of Atlantic salmon eggs for artificial propagation in New England for the next 50 years. Most of the 9 million eggs collected from the Penobscot from 1871 through 1876 were shipped to the five other New England states, the balance being shipped as far away as Iowa. There was a hiatus on salmon stocking for several years while the results of releasing fry of Penobscot origin into other rivers were evaluated. Adult returns in the Connecticut, Merrimack, and some other rivers without native salmon populations during the mid-1870's demonstrated adequate success to justify the resumption of salmon propagation at the Craig Brook site in Maine. Between 1879 and 1886 about 15 million eggs were taken from Penobscot sea-run salmon. However, most of these were used to stock waters outside of Maine or inland lakes within Maine to create or enhance "landlocked" salmon populations (Baum 1997).

Artificial salmon propagation in Maine continued to use Penobscot-origin fish purchased from commercial trap-netters as the source of eggs into the 20th Century, when declining runs and pricing disputes resulted in a decline in availability of Penobscot salmon for brood stock. Canadian salmon stocks were increasingly used as a source of eggs for the Craig Brook Hatchery in East Orland, Maine, with the Miramichi and Gasp� Rivers becoming the primary sources in the 1920's and 1930's. The use of Canadian eggs declined in the 1940's when the Machias River and, for a brief time, the Penobscot again became a source of brood stock. During the 1950's and 1960's, the lack of Penobscot River fish resulted in Canadian salmon again providing a major source of eggs, supplemented with eggs from Machias and Narraguagus brood stock. Hatchery-produced juveniles were stocked as fry and parr, with poor results. The stocking of hatchery-reared smolts of mostly Miramichi and Narraguagus stock origin in the late 1960's brought about the successful rebuilding of the salmon run in the Penobscot (Baum 1997). The resultant adult returns enabled the Penobscot River propagation program to become self-sufficient for eggs and to support the egg needs of all artificial propagation in Maine by the 1970's. Later, this same stock of fish were transplanted into the Union River and comprised essentially the entire source of brood stock for the contemporary (post-1970) Atlantic salmon stocking program in Maine, until the advent of the river-specific propagation program in 1992. This same contemporary Penobscot stock is also the foundation of essentially all Atlantic salmon stocks now used for artificial propagation in the restoration of runs in historic salmon rivers outside of Maine.

4.2.2 Numbers and Life Stages Stocked in Key Rivers

The early stocking histories of concern in this review are for rivers that currently are known to still support reproducing salmon populations, all of which are in Maine. Extensive historic Atlantic salmon stocking data are available for all Maine rivers and can be found in Appendix 6 of Baum (1997). Information from that source was extracted and summarized in Table 4.2.2.

The stocking strategy from the start of the artificial propagation program in the 1870's through the 1930's in the United States depended heavily on releasing fry. Most records indicate that early fry stocking methods were dominated by cluster stocking of large numbers of fry in limited areas of a river. Numbers released through artificial propagation programs prior to 1970 were greatest during the 40-year period from 1896 through 1936. These fish were released predominantly as fry. After a 60-year period of predominantly fry releases, the strategy shifted to focus on releasing parr and remained so through the 1950's. By the mid-1960's, the production and stocking of smolts replaced parr as the basic strategy of enhancement and conservation stocking programs (Baum 1997).

Numbers produced and stocked changed greatly, undoubtedly out of logistic necessity, when the target life stage for release changed from fry to parr or smolt. Fry production in the millions annually was common when fry were the focus. Numbers declined by an order of magnitude when hatcheries started to retain fry for rearing to the parr stage. The annual stocking of 1-3 million fry fell to 100,000-300,000 parr during and after the transitional decade of the 1930's. The artificial propagation program had only just started to focus on smolt production prior to the initiation of the contemporary salmon restoration program circa 1970. The production of smolts was on the same general level of numbers as parr at the only major facility in the U.S. producing Atlantic salmon at that time, Craig Brook National Fish hatchery in East Orland, Maine.

Table 4.2.2. Summary of historic Atlantic salmon stocking (1872-1969) for each U.S. coastal river basin currently known to support wild Atlantic salmon populations. "Contributing Stocks" Code: D= Dennys R.; M= Machias R.; N= Narraguagus R.;

P= Penobscot R.; NB= New Brunswick; ON= Ontario; Q= Quebec.

KENNEBEC RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	Fry 87.5 Parr Smolt	P	1	100
No Stocking 1900-1969	Fry Parr Smolt			

SHEEPSCOT RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	Fry 1.5 Parr Smolt	ON	1	100
Decade of 1900	NONE Fry			

	STOCKED Parr Smolt			
Decade of 1910	NONE Fry STOCKED Parr Smolt			
Decade of 1920	NONE Fry STOCKED Parr Smolt			
Decade of 1930	NONE Fry STOCKED Parr Smolt			
Decade of 1940	Fry 30.4 Parr Smolt	P,NB	2	73 27
Decade of 1950	Fry 173.8 Parr Smolt	N,M,NB	8	23 77
Decade of 1960	Fry 136.5 Parr 65.7 Smolt	NB,Q	8	100

DUCKTRAP RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1969	NO KNOWN STOCKING OF ATLANTIC SALMON IN DUCKTRAP			

PENOBSCOT RIVER

Period	**Number (1,000's) and Life Stage**	**Contributing Stocks**	**# Years Stocked**	**STOCK ORIGIN (% of Total Stocked)** **Home Other ME. Canadian** **River River Origin**
1872-1899 (29 Yrs.)	5,465.2 Fry 532.8 Parr Smolt	P	13	100
Decade of 1900	12,225.8 Fry 1,861.6 Parr Smolt	P	10	100
Decade of 1910	20,787.7 Fry 232.9 Parr Smolt	P	10	100
Decade of 1920	7,384.6 fry 104.0 Parr Smolt	P,Q,NB	10	26 74
Decade of 1930	1,592.5 Fry 677.4 Parr Smolt	P,NB	8	<1 99+
Decade of 1940	112.5 Fry 435.5 Parr Smolt	P,NB	10	94 6
Decade of 1950	Fry 501.3 Parr Smolt	M,NB	7	14 86
Decade of 1960	Fry 73.1 Parr 189.0 Smolt	M,N,NB	6	65 35

NARRAGUAGUS RIVER

Period	**Number (1,000's) and Life Stage**	**Contributing Stocks**	**# Years Stocked**	**STOCK ORIGIN (% of Total Stocked)** **Home Other ME. Canadian** **River River Origin**
1872-1899 (29 Yrs.)	NO Fry STOCKING Parr Smolt			
Decade of 1900	NO Fry STOCKING Parr Smolt			
Decade of 1910	662.5 Fry Parr Smolt	P	2	100
Decade of 1920	463.7 Fry Parr Smolt	NB,Q	6	100
Decade of 1930	85.0 Fry Parr Smolt	NB	1	100
Decade of 1940	29.3 Fry 56.5 Parr Smolt	M,P, NB	4	66 34
Decade of 1950	35.0 Fry 536.0 Parr Smolt	N,M,P,NB	10	7 7 86
Decade of 1960	Fry 124.9 Parr 256.1 Smolt	N,M,NB	10	34 12 54

PLEASANT RIVER

Period	Number (1000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	NONE Fry STOCKED Parr Smolt			
Decade of 1900	NONE Fry STOCKED Parr Smolt			
Decade of 1910	437.5 Fry Parr Smolt	P	1	100
Decade of 1920	NONE Fry STOCKED Parr Smolt			
Decade of 1930	NONE Fry STOCKED Parr Smolt			
Decade of 1940	NONE Fry STOCKED Parr Smolt			
Decade of 1950	Fry 48.9 Parr Smolt	N,M,NB	5	20 80
Decade of 1960	Fry 42.8 Parr 13.6 Smolt	N,M,NB	5	8 92

MACHIAS RIVER

Period	Number (1000's) and Life Stage	Contributing Stocks	# Years Stocked	<u>STOCK ORIGIN (% of Total Stocked)</u> Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	73.3 Fry Parr Smolt	P	4	100
Decade of 1900	NONE Fry STOCKED Parr Smolt			
Decade of 1910	NONE Fry STOCKED Parr Smolt			
Decade of 1920	50.0 Fry Parr Smolt	NB	1	100
Decade of 1930	NONE Fry STOCKED Parr Smolt			
Decade of 1940	Fry 204.1 Parr Smolt	P,M,NB	6	35 53 12
Decade of 1950	100.2 Fry 359.1 Parr Smolt	P,N,M,NB	7	30 65 5
Decade of 1960	Fry 130.2 Parr 370.0 Smolt	N,M,NB	10	22 38 40

EAST MACHIAS RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	**STOCK ORIGIN (% of Total Stocked)** Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	NONE Fry STOCKED Parr Smolt			
Decade of 1900	NONE Fry STOCKED Parr Smolt			
Decade of 1910	30.0 Fry Parr Smolt	P	1	100
Decade of 1920	NONE Fry STOCKED Parr Smolt			
Decade of 1930	NONE Fry STOCKED Parr Smolt			
Decade of 1940	Fry 7.0 Parr Smolt	D	1	100
Decade of 1950	NONE Fry STOCKED Parr Smolt			
Decade of 1960	Fry Parr 24.9 Smolt	NB	1	100

DENNYS RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	191.4 Fry Parr Smolt	P	8	100
Decade of 1900	NONE Fry STOCKED Parr Smolt			
Decade of 1910	648.0 Fry Parr Smolt	P	2	100
Decade of 1920	Fry 40.0 Parr Smolt	NB	9	100
Decade of 1930	360.0 Fry 30.0 Parr Smolt	NB	2	100
Decade of 1940	Fry 31.2 Parr 3.2 Smolt	P,M	4	100
Decade of 1950	Fry 227.1 Parr Smolt	NB	8	100
Decade of 1960	Fry 201.1 Parr Smolt	N,M,NB	6	43 57

CONTEMPORARY STOCKING (1970-1992)

4.3 CONTEMPORARY STOCKING (1970-1992)

4.3.1 Stocks Used for Artificial Propagation

Contemporary stocking efforts in the DPS from 1970 to 1992, prior to the initiation of the river-specific stocking program, utilized stocks from the Penobscot, Union, Narraguagus and Machias Rivers. As explained in the previous section, the Penobscot River stock was transplanted into the Union River. Therefore, these sources are essentially the same. Green Lake National Fish Hatchery was constructed between 1971 and 1974 and became the major supplier of smolts. In 1992 the ASRSC and FWS drafted a Prelisting Recovery Plan for Maine Wild Atlantic Salmon Populations and prescribed a river specific stocking program. In accordance with this plan, plans began to convert Craig Brook National Fish Hatchery from a single broodstock/smolt production facility to a multiple broodstock/fry production facility.

4.3.2 Numbers and Life Stages Stocked in DPS Rivers

Stocking in the 1970s continued to focus primarily on releasing smolts. During the 1980s and early 1990s fry, parr and smolt were all stocked. Stocking efforts are summarized in Table 4.3.2.

Table 4.2.2. Summary of historic Atlantic salmon stocking (1872-1969) for each U.S. coastal river basin currently known to support wild Atlantic salmon populations. "Contributing Stocks" Code: D= Dennys R.; M= Machias R.; N= Narraguagus R.;

P= Penobscot R.; NB= New Brunswick; ON= Ontario; Q= Quebec.

KENNEBEC RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	Fry 87.5 Parr Smolt	P	1	100
No Stocking 1900-1969	Fry Parr Smolt			

SHEEPSCOT RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	Fry 1.5 Parr Smolt	ON	1	100
Decade of 1900	NONE Fry STOCKED Parr Smolt			
Decade of 1910	NONE Fry STOCKED Parr Smolt			
Decade of 1920	NONE Fry STOCKED Parr Smolt			
Decade of 1930	NONE Fry STOCKED Parr Smolt			
Decade of 1940	Fry 30.4 Parr Smolt	P,NB	2	73 27
Decade of 1950	Fry 173.8 Parr Smolt	N,M,NB	8	23 77
Decade of 1960	Fry 136.5 Parr 65.7 Smolt	NB,Q	8	100

DUCKTRAP RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1969	NO KNOWN STOCKING OF ATLANTIC SALMON IN DUCKTRAP			

PENOBSCOT RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	5,465.2 Fry 532.8 Parr Smolt	P	13	100
Decade of 1900	12,225.8 Fry 1,861.6 Parr Smolt	P	10	100
Decade of 1910	20,787.7 Fry 232.9 Parr Smolt	P	10	100
Decade of 1920	7,384.6 fry 104.0 Parr Smolt	P,Q,NB	10	26 74
Decade of 1930	1,592.5 Fry 677.4 Parr Smolt	P,NB	8	<1 99+
Decade of 1940	112.5 Fry 435.5 Parr Smolt	P,NB	10	94 6

Decade of 1950	Fry 501.3 Parr Smolt	M,NB	7	14 86
Decade of 1960	Fry 73.1 Parr 189.0 Smolt	M,N,NB	6	65 35

NARRAGUAGUS RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	NO Fry STOCKING Parr Smolt			
Decade of 1900	NO Fry STOCKING Parr Smolt			
Decade of 1910	662.5 Fry Parr Smolt	P	2	100
Decade of 1920	463.7 Fry Parr Smolt	NB,Q	6	100
Decade of 1930	85.0 Fry Parr Smolt	NB	1	100
Decade of 1940	29.3 Fry 56.5 Parr Smolt	M,P, NB	4	66 34

Decade of 1950	35.0 Fry 536.0 Parr Smolt	N,M,P,NB	10	7 7 86
Decade of 1960	Fry 124.9 Parr 256.1 Smolt	N,M,NB	10	34 12 54

PLEASANT RIVER

Period	**Number (1,000's) and Life Stage**	**Contributing Stocks**	**# Years Stocked**	**STOCK ORIGIN (% of Total Stocked)** **Home Other ME. Canadian** **River River Origin**
1872-1899 (29 Yrs.)	NONE Fry STOCKED Parr Smolt			
Decade of 1900	NONE Fry STOCKED Parr Smolt			
Decade of 1910	437.5 Fry Parr Smolt	P	1	100
Decade of 1920	NONE Fry STOCKED Parr Smolt			
Decade of 1930	NONE Fry STOCKED Parr Smolt			
Decade of 1940	NONE Fry STOCKED Parr Smolt			

Decade of 1950	Fry 48.9 Parr Smolt	N,M,NB	5	20 80
Decade of 1960	Fry 42.8 Parr 13.6 Smolt	N,M,NB	5	8 92

MACHIAS RIVER

Period	**Number (1,000's) and Life Stage**	**Contributing Stocks**	**# Years Stocked**	**STOCK ORIGIN (% of Total Stocked)** **Home Other ME. Canadian** **River River Origin**
1872-1899 (29 Yrs.)	73.3 Fry Parr Smolt	P	4	100
Decade of 1900	NONE Fry STOCKED Parr Smolt			
Decade of 1910	NONE Fry STOCKED Parr Smolt			
Decade of 1920	50.0 Fry Parr Smolt	NB	1	100
Decade of 1930	NONE Fry STOCKED Parr Smolt			
Decade of 1940	Fry 204.1 Parr Smolt	P,M,NB	6	35 53 12

Decade of 1950	100.2 Fry 359.1 Parr Smolt	P,N,M,NB	7	30 65 5
Decade of 1960	Fry 130.2 Parr 370.0 Smolt	N,M,NB	10	22 38 40

EAST MACHIAS RIVER

Period	**Number (1,000's) and Life Stage**	**Contributing Stocks**	**# Years Stocked**	**STOCK ORIGIN (% of Total Stocked)** **Home Other ME. Canadian** **River River Origin**
1872-1899 (29 Yrs.)	NONE Fry STOCKED Parr Smolt			
Decade of 1900	NONE Fry STOCKED Parr Smolt			
Decade of 1910	30.0 Fry Parr Smolt	P	1	100
Decade of 1920	NONE Fry STOCKED Parr Smolt			
Decade of 1930	NONE Fry STOCKED Parr Smolt			
Decade of 1940	Fry 7.0 Parr Smolt	D	1	100

Decade of 1950	NONE Fry STOCKED Parr Smolt			
Decade of 1960	Fry Parr 24.9 Smolt	NB	1	100

DENNYS RIVER

Period	Number (1,000's) and Life Stage	Contributing Stocks	# Years Stocked	STOCK ORIGIN (% of Total Stocked) Home Other ME. Canadian River River Origin
1872-1899 (29 Yrs.)	191.4 Fry Parr Smolt	P	8	100
Decade of 1900	NONE Fry STOCKED Parr Smolt			
Decade of 1910	648.0 Fry Parr Smolt	P	2	100
Decade of 1920	Fry 40.0 Parr Smolt	NB	9	100
Decade of 1930	360.0 Fry 30.0 Parr Smolt	NB	2	100
Decade of 1940	Fry 31.2 Parr 3.2 Smolt	P,M	4	100

Decade of 1950	Fry 227.1 Parr Smolt	NB	8	100
Decade of 1960	Fry 201.1 Parr Smolt	N,M,NB	6	43 57

The BRT acknowledges that historic stocking practices may have had an adverse effect upon the genetic integrity of local stocks. However, the capabilities of these early programs were limited in technology, distribution capabilities, and knowledge of stocking strategies. Available evidence suggests that these efforts resulted in only negligible adult returns from stocking. In fact, some reports document an increase in small salmon returns during stocking (Kendall 1935) that quickly reversed after broodstock were changed to native stocks. Poor hatchery return rates coupled with remnant natural stocks led the BRT to conclude that while some negative effects upon the genetic integrity of these stocks are possible, introgression could not have supplemented native genotypes within the Gulf of Maine DPS.

SECTION 5: CONSIDERATION AS A "SPECIES" UNDER THE ESA

5.1 DISTINCT POPULATION SEGMENT ANALYSIS

The ESA considers "any subspecies of fish or wildlife or plants, and any distinct population segment [DPS] of any species of vertebrate fish or wildlife that interbreeds when mature" to be a species. One of the purposes of this definition is to conserve genetic diversity. Species sub-structure is particularly important to anadromous salmonines because their strong homing capability fosters the formation of discrete populations (stocks) exhibiting important adaptations to local riverine ecosystems and the watersheds that determine their character (Berst and Simon 1981; Utter 1981; Utter et al. 1993; Nielsen 1998).

In an effort to clarify the definition of species for Pacific salmon (Oncorhynchus sp.) under the ESA, Waples (1991a, b) proposed a more precise definition called the Evolutionarily Significant Unit (ESU). The purpose of this approach was to create a definition of species (DPS) for assessing Pacific salmon populations under consideration for ESA protection. The stock concept is the scientific foundation of the ESU approach. The stock concept has been subjected to critical peer-review and emphasizes the ecological importance of discrete populations in fish (Larkin 1981; Ricker 1981). Differences between stocks are important for management purposes since discrete stocks can vary in their productivity, population dynamics, and adaptations to local ecosystems (Ricker 1981; Hovey et al. 1989; Taylor 1991; Nielsen 1998; Verspoor 1997). The ESU approach facilitates a comprehensive analysis that categorizes units within a nested hierarchy ranging from a single stock level to subspecies. Stocks can be grouped into a comprehensive ESU unless there are clear evolutionarily important differences among stocks. Grouping of stocks does not, in and of itself, prevent river-specific management procedures necessary to protect sub-populations within the larger unit.

In February 1996, the Services published a policy to clarify their interpretation of the phrase "distinct population segment" for the purposes of listing, delisting and reclassifying species under the ESA (51 FR 4722). As related to salmonines, this policy encompasses the ESU policy and expands upon management issues related to jurisdictional issues. This joint NMFS-USFWS policy consists of three elements to be considered in a decision regarding the status of a possible DPS as endangered or threatened under the ESA: 1) the discreteness of the population segment in relation to the remainder of the species or subspecies to which it belongs; 2) the significance of the population segment to the species or subspecies to which it belongs; and 3) the conservation status of the population segment in relation to ESA listing standards. In this section of the status review, the BRT analysis focuses on the delineation of DPS structure for anadromous Atlantic salmon in U.S. Rivers and examines the first two elements - discreteness and significance. The conservation status of Atlantic salmon will be considered in subsequent sections of this status review in relation to the listing factors and efforts underway to protect the species (Section 7.1- 7.5).

Although the ESU approach was developed for Pacific salmon (Oncorhynchus sp.), Atlantic salmon populations have analogous population structure, ecology, and life history strategies. Throughout their range, Atlantic salmon are naturally substructured into genetically differentiated and reproductively isolated populations within and among drainages (Saunders 1981; Thorpe and Mitchell 1981; Stahl 1987; Bermingham et al. 1991; Nielsen 1998; King et al. 1993; 1999). Genetic exchange among stocks is minimized by spatial or temporal isolation during spawning. While straying occurs at low to moderate levels among populations of Atlantic salmon, it is typically not sufficient to prevent genetic divergence (Bermingham et al. 1991). Kendall (1935) first recognized that discrete Atlantic salmon stocks were found between U.S. rivers. Genetic and ecological data from other regions indicate that Atlantic salmon stocks are distinct at the river level and often between sections of larger drainages (Moller 1970; Verspoor et al. 1991; King et al. 1993; Nielsen et al. 1997; King et al. 1999). Given assessments of genetic stock structure and historic accounts of U.S. rivers, it is apparent that locally adapted, river-specific stocks of Atlantic salmon existed in the U.S., and that this structure was important to the overall fitness and productivity of the species (Kendall 1935; Riddell et al.1981; Baum 1997; Nielsen 1998; Thorpe et al. 1998). Furthermore, research on Atlantic salmon in Denmark has illustrated that even populations that have been decimated by anthropogenic factors can contain important genetic materials from ancestral stocks (Nielsen et al. 1997). Given these facts, the BRT concludes that population structure above the stock level is also a functional characteristic of Atlantic salmon stocks. To fully address the question of listing Atlantic salmon as a threatened or endangered species throughout its range, the BRT analyzed all relevant evidence of population structure within U.S. tributaries.

5.2 ANALYSIS OF DPS STRUCTURE WITHIN THE U.S.

The BRT examined genetic, life history, biogeographic, and environmental information in the process of evaluating Atlantic salmon throughout their U.S. range under provisions of the U.S. Endangered Species Act. The BRT found that distribution data, life history information, and ecoregion classification, were most useful for this process. Determining DPS structure is made more difficult by the fact that Atlantic salmon are absent from most (96%) of their historic freshwater rearing habitat in the USA. The Atlantic salmon in rivers south of the Kennebec River were extirpated by the mid-1800's to early 1900's (Atkins 1874; Kendall 1935) (Figure 4.1.1).

Human activities moved the southern range of Atlantic salmon almost 2^o north in latitude and eliminated the species from three of the largest Atlantic salmon rivers in the U.S: the Connecticut, Androscoggin, and Merrimack Rivers.

Some populations north of the Kennebec River have been extirpated as well. These northern rivers were primarily small rivers with one hectare or less of available nursery habitat. The largest of these coastal rivers that lost their remnant stock was the Union River. It is unlikely that Atlantic salmon in all of these small watersheds were able to maintain persistent spawning runs given overall human perturbations of the past century. The small size of many these rivers and streams might have made these populations ephemeral (e.g. supported by low-level straying from larger neighboring populations), even under pre-colonial conditions. However, the unique genetic composition and persistence of the Atlantic salmon population of Cove Brook (Buckley 1999; King et al. 1999) indicates that retention of remnant stocks in these small rivers is possible. An examination by the BRT of the location of small rivers with documented juvenile Atlantic salmon juveniles suggests that the probability of a smaller drainage still having naturally producing populations is enhanced by close proximity to larger populations and overall habitat quality within the small drainage.

5.2.1 Extirpated Populations

Despite the limited historical information, assessing the probable historical structure of extirpated populations is important to categorizing the remaining populations and is informative in delineating their natural historical range. The BRT used the documented absence of wild Atlantic salmon from natal habitat for at least two generations (12 years) as the criterion for the total loss of a native population. We chose this conservative definition because the complex life history of Atlantic salmon often includes a total of six year classes (three freshwater and three marine) extant in the population at any one time. This life history adaptation is an important buffer against ecological disasters, both natural and human induced. We chose two generations to increase the certainty that failure to detect the presence of fish was a result of absence, not low numbers of fish and limited effort.

Because little historical biological data is available for rivers with extirpated populations, it was necessary to use a zoogeographical approach within the context of Atlantic salmon ecology and historical range. To facilitate this analysis, the BRT utilized zoogeographical maps of boundaries between areas that would likely have different selective pressures for Atlantic salmon populations and substantial differences in riverine-marine ecosystem structure and function. Key elements to these determinations were: 1) the spatial arrangements of river systems that create isolation, and 2) watershed location within ecological provinces and subregions that affect the productivity and ecology of riverine-marine ecosystem complexes. Ecological provinces are areas of relatively uniform ecological potential that have been mapped based upon associations of environmental and biotic factors (Bailey 1995; Bailey 1998). These provinces are useful for modeling, strategic planning, and assessment because they synthesize the geoclimatic setting (climate, physical geography, water, soils, air, hydrology). All these geoclimatic factors influence river productivity and the structure and function of aquatic ecosystems and the transfer of energy in aquatic food chains (Vannote et al.1980; Cushing et al. 1983; Minshall et al. 1983; Cummins et al. 1984; Minshall et al. 1985; Waters 1993). The provinces that Bailey (1995) established have been delineated independent of watersheds. Incorporating aquatic ecological units (AEU) into analysis alleviates this weakness because AEUs reflect watershed linkage both to the sea and to other ecosystems. The defining criteria for an AEU in New England are the merging and separation of fish species assemblages caused by glaciation and orogeny (Maxwell et al. 1995). Particularly useful for DPS analysis are the subregions of the AEU. Subregions integrate major drainage systems within a region exhibiting similar endemic fish communities, accounting for historic mixing and isolation of fish populations. Using these ecological maps, the BRT determined that historic U.S. Atlantic salmon populations were minimally comprised of three DPSs that were primarily delineated by geography and juxtaposition.

5.2.1.1 Long Island Sound

A DPS is likely to have been present in the eight rivers that enter the Long Island Sound. These rivers are spatially isolated from the other Atlantic salmon rivers in New England by geographic features (Figure 4.1.1). Additionally, lower reaches of the Connecticut River and the entire watersheds of the others are characterized by the Eastern Broadleaf Forest Oceanic Province (Bailey 1995; Bailey 1998). A temperate deciduous forest dominates vegetation in this ecoregion that is between 0 and 300 m above sea level. Mean rainfall in this province is between 89 and 153 cm and frost free days range from 100 to 140. The upper Connecticut River watershed lies in the New England Mixed Forest Province at elevations above 300 m in regions dominated by mixed forests. Elevation has a substantial local influence on landscape ecology and watershed characteristics in these upper reaches. Most critically, all these systems enter Long Island Sound, a relatively large (175 km long, and 30 km wide) and shallow (24 m average depth) estuary. These tributaries and associated nearshore waters represent an AEU distinct from Gulf of Maine tributaries (Maxwell et al. 1995). All other Atlantic salmon rivers in the U. S. pass through river-dominated estuaries characterized by relatively narrow, short, cylindrical channels, before entering the Gulf of Maine. The more southerly position of Long Island Sound and its shallow nature provide substantially warmer nearshore waters than the Gulf of Maine. These substantial habitat differences, isolation, and interactions with different biotic communities than found in the Gulf of Maine, likely combined to make Atlantic salmon in this region unique. The Long Island Sound DPS was extirpated by the early 1800's, with the loss of Atlantic salmon stocks indigenous to the Connecticut River (Meyers 1994).

5.2.1.2 Central New England

From Buzzards Bay northward along the coast of Massachusetts to the mouth of the Merrimack River, the BRT found no historical accounts of indigenous Atlantic salmon populations. This is likely a result of the small sizes and warm temperatures common to streams in this region. However, A DPS is likely to have existed in waters from the Merrimack River in the south to the Royal River (Yarmouth, Maine) in the north. Atlantic salmon populations in Central New England were probably distinct from those to the north because these populations south of Casco Bay are primarily in the Eastern Broadleaf Oceanic Province (EBOP) (Bailey 1995; Bailey 1998). The characteristic differences between the EBOP and the Laurentian Mixed Forest Province (LMFP) to the north, likely had a strong effect upon Atlantic salmon ecology and production. Elevations in Central New England portions of the EBOP range from sea level to 300 m, compared to the LMFP where elevations range up to 730 m. Additionally, the two largest rivers in this unit, the Merrimack River and the Saco River, extend into the Adirondack-New England Mountain Forest Province for approximately a third of their length. This creates a dramatic range in elevations throughout these drainages with a lower coastal tier to about 300 m rising to a mountainous habitat in the upper watersheds. Rainfall in the EBOP averages 89-153 cm, substantially higher than the 61-116 cm average in the LMFP. The transition from the EBOP to the LMFP is also characterized by a transition from deciduous forests to transitional conifer dominated forest types. All of these differences would influence the structure and function of aquatic ecosystems between these two provinces based on stream ecology theory (Vannote et al.1980; Cushing et al. 1983; Minshall et al. 1983; Cummins et al. 1984; Minshall et al. 1985; Waters 1993). Cumulatively, these differences likely made Atlantic salmon populations of Central New England distinct from those to the north. The Central New England DPS was extirpated in the mid-1800's, as documented by the loss of Merrimack River stocks (Stolte 1981, 1994). Early restoration efforts in the late 1800's had some success but the remnant populations of this region were likely extirpated before 1900 (Stolte 1981).

5.2.1.3 Other Historic DPS Units

In addition to these broader DPSs above, larger rivers like the Connecticut, Merrimack, Androscoggin, Kennebec, and Penobscot likely contained unique stocks that may have contributed to historical DPS structure. These larger systems with unique riverine and lacustrine habitats are more heterogeneous than smaller river systems and this varied geo-physical nature likely fostered the development of unique stocks. Baum (1997) reports that Atlantic salmon in Maine rivers historically exhibited early-run and late-run components thought to be separate stocks. Additionally, it was thought that some of the larger, early-return fish on the Penobscot spawned in large river habitat in the upper reaches of the watershed. This account was based on the hypothesis that larger fish would be the only individuals capable of ascending some of the cascades, rapids, and falls in this river system. This evidence indicates that some of these larger rivers may have had populations that were quite different from coastal stocks and contained multiple DPSs within a river. It is possible that a specific component of a stock complex within a river was closely related to coastal populations while other fragments were quite different. Most of these large river populations, with the exception of the Penobscot, have been extirpated and documentation of ecological traits is scarce. Thus, it is difficult to determine the extent of the genetic resource in the U.S. that has been lost. The BRT's operating hypothesis that larger rivers may have contained unique DPS(s) is consistent with observations of differences between Pacific salmon stocks in coastal versus inland rivers classified in the Pacific Northwest (e.g., Southern Oregon/Northern California Coasts ESU and Lower Columbia River/Southwest Washington ESU of coho salmon). The majority of any unique large-river DPS(s) have been extirpated, with the possible exception of the Penobscot River stock that is in the process of being rebuilt through hatchery enhancement and supplementation (Table 4.2.2)(Baum 1997). Additionally, smaller streams, below the first major dams on lower Penobscot and Kennebec drainages, may have served as refugia for Atlantic salmon blocked from natal mainstem habitat. However, it is likely that decades of isolation from mainstem habitat subjected these populations to different selective pressures, altering their adaptability for large river systems. Thus, remnant populations in these smaller drainages are likely not simply relic populations from larger rivers but part of a larger population unit (DPS or restoration stock).

The loss of naturally reproducing fish in the Connecticut and Merrimack Rivers represented nearly 40% of historic U.S. Atlantic salmon juvenile production habitat (Figure 4.1.2). The loss of these two southern-most rivers and their indigenous Atlantic salmon populations certainly had an influence on the genetic diversity of this species in the U.S. and North America. These rivers are currently the focus of restoration efforts using nonindigenous stocks mostly of Penobscot River origin. While restoration of Atlantic salmon in these rivers is beyond the scope of the ESA, their restoration would represent a significant contribution to the U.S. Atlantic salmon resource. Return rates from stocking in the Connecticut and Merrimack Rivers have been poor relative to other North American stocks (Saunders 1981; Friedland et al. 1993). Reasons for these low return rates appear to be attributable to the loss of local adaptations to unique habitat characteristics associated with the extirpated stocks (Saunders 1981). Other research supports this hypothesis and indicates that when stocks are transferred to new river systems, those from nearby rivers typically exhibit higher return rates than stocks from rivers farther away (Ritter 1975; Reisenbichler and McIntyre 1977; Riddell et al. 1981; Ritter et al. 1986; Hopley 1989). Additionally, stock specific differences in susceptibility to bacterial and viral diseases, underscore the importance of genetic variability not only to the viability of local stocks but as a genetic resource for conservation, restoration, and commercial aquaculture applications (Gjedrem and Gjoen 1995). The loss of locally adapted stocks has made restoration more difficult. Fortunately, salmonine populations show evidence of plasticity when introduced to new environments, and locally adapted and genetically differentiated stocks have developed in less than 20 generations (Krueger et al. 1994). As these restoration programs continue, their focus on the development of river-specific stocks should enhance the genetic resources of Atlantic salmon in the United States.

5.2.2 Extant Populations - Gulf of Maine DPS

The Gulf of Maine DPS includes all coastal watersheds with native populations of Atlantic salmon north of and including tributaries of the lower Kennebec River (below Edwards Dam) to the mouth of the St. Croix River at the US-Canada border. The DPS includes both early- and late-run Atlantic salmon (Baum 1997). Present low abundance levels and limited historical documentation preclude a quantitatively-based separation of these populations based upon run timing.

Historically, the Androscoggin River delimited the DPS to the south, but populations south of the Kennebec River have been extirpated. The BRT delimited the geographical southern limit of the Gulf of Maine DPS as the southern border of the Laurentian Mixed Forest Province (LMFP)(Bailey 1995; Bailey 1998). The characteristic differences between the LMFP and the EBOP to the south likely had a strong effect upon Atlantic salmon ecology and production. Elevations in the LMFP are generally higher, ranging up to 730 m, but do not extend into mountain provinces; annual precipitation is lower, with differing seasonal regimes (Bailey 1995). These differences would influence the structure and function of aquatic ecosystems (Vannote et al.1980; Cushing et al. 1983; Minshall et al. 1983; Cummins et al. 1984; Minshall et al. 1985; Waters 1993) and create a different environment for the development of local adaptations than rivers to the south. Additional, zoogeographical rationales for the southern boundary were presented in the discussion of the Central New England DPS (Section 5.2.1.2).

The northern extent of this DPS likely included the St. Croix River and southwestern New Brunswick coastal tributaries northward to the St. John River. Inner-Fundy Atlantic salmon populations are very distinct from the Gulf of Maine DPS since they are primarily 1SW fish that do not migrate to the Labrador Sea (Marshall 1998). Available information also indicates that St. John River populations were historically dominated (greater than 50%) by 1SW Atlantic salmon;

thus a portion of the population(s) was likely distinct from stocks to the south including the St. Croix River (Baum 1998; Marshall 1998). Additionally, the St. John River is another of the larger Atlantic salmon watersheds that may have contained stocks that were divergent from coastal river populations. The Canadian portion of this DPS is likely extirpated and under restoration. A possible exception is the St. John River population that contains a much larger 1SW component than any U.S. remnant or restoration stock but is largely derived from river-specific broodstock (Marshall 1998; Parrish et al. 1998). These Canadian rivers, including the mainstem St. Croix River, were eliminated from consideration because the joint NMFS-USFWS policy on DPS (61 FR 4722) facilitated separation by international management and exploitation differences for border stocks (62 FR 66325) (Section 5.3.2).

The Penobscot River was not included in the DPS at this time. This decision was based on the lack of a comprehensive genetic survey of the mainstem Penobscot River stock (hatchery and wild returns). Because potentially important and heritable adaptations are needed for larger river systems, it would be premature to determine the status of this population in relationship to the Gulf of Maine DPS without comprehensive genetic data. Sample collections, genetic analyses, and biological information are still being collected by the FWS and will analyzed to make a final determination of the status of the Penobscot River population relative to the coastal Atlantic salmon populations of the Gulf of Maine DPS. Collection of the 1999 samples will be complete in October of 1999 and analyses of these data should be completed by winter of this year. It is important to note that tributaries of the lower Penobscot estuary (south of the Bangor Dam) are considered within the DPS range.

There are at least eight rivers in the DPS range that still contain functioning populations, albeit at substantially reduced abundance levels (Baum 1997; King et al. 1999). The core of these remnant populations is located in the Dennys, East Machias, Machias, Pleasant, Narraguagus, Ducktrap, and Sheepscot Rivers. These watersheds are among the largest of the historic river habitat currently accessible, averaging greater than 300,000 m^2 of juvenile production habitat (Figure 4.2)(Baum 1997). The smallest of these seven populations is the Ducktrap River with 80,000 m2 of juvenile production habitat. Recent survey work also indicates that a naturally producing population that is genetically distinct (alleles only found in that population) remains in Cove Brook as well (Buckley 1999; King et al. 1999). This information demonstrates the ability of an Atlantic salmon population to retain unique genetic material in a relatively small drainage - juvenile habitat area in Cove Brook is estimated at only 23,500 m2 (Ed Baum, Atlantic Salmon Authority, personal communication). Additional surveys have also identified juvenile Atlantic salmon to be present in other river systems with relatively limited juvenile production habitat such as Bond, Togus, Passagassawaukeag, Eaton, Felts, South Branch Marsh, Kenduskaeg, and Pennamaquan Rivers (Buckley 1999)(Figure 5.2.2-1). Future routine fish surveying work and surveys initiated by public inquires may identify more populations that warrant study. The status of these populations relative to their demographic history and genetic legacy (DPS, aquaculture strays, Penobscot restoration stock strays, etc.) is being addressed by the Services on a case-by-case basis. Dams also block several of the drainages in within the historic DPS range, limiting Atlantic salmon recolonization (e.g., Medomak, St. George, and Union Rivers). Of these additional drainages, only the Union River is frequently stocked (Penobscot River origin fish). The other drainages are not targeted for stocking by Maine or Federal fisheries agencies although a few Atlantic salmon fry from educational programs in Maine schools may have been released in isolated cases. A detailed discussion of the factors that make these populations unique is included in Section 5.3.

Figure 5.5.2-1: Gulf of Maine Atlantic Salmon DPS

5.3 ASSESSMENT OF THE GULF OF MAINE DPS

5.3.1 Species Status Elements of the Services' DPS Policy

The joint NMFS-USFWS policy (61 FR 4722) consists of two elements to be considered in a decision regarding the classification of potential vertebrate population segments as endangered or threatened under the ESA:

1. the discreteness of the population segment in relation to the remainder of the species or subspecies to which it belongs, and
2. the significance of the population segment to the species or subspecies to which it belongs. Subsections 5.3.2 - 5.3.4 address these two elements.

5.3.2 Discreteness

According to the Services' DPS policy (61 FR 4722), a population segment may be considered discrete if it satisfies either of the following two conditions:

1. it is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological or behavioral factors; or
2. it is delimited by international governmental boundaries across which there is a significant difference in control of exploitation, management of habitat, or conservation status.

5.3.2.1 Separateness From Other Populations

Reproductive isolation does not have to be absolute to allow evolutionarily important differences to accrue in different population units, only strong enough for these differences to develop and be maintained (Wright 1978; Waples 1991). Geographical distance, behavioral differences, and/or temporal segregation of spawners can maintain reproductive isolation. The occurrence of nonindigenous Atlantic salmon in a stream does not necessarily represent a breakdown of reproductive isolation unless these fish spawn successfully, their progeny survive to spawn, and their presence degrades the survival and fitness of native stocks. In fact, some genetic exchange between populations helps to maintain genetic fitness by countering genetic drift (Waples 1991). To examine whether Gulf of Maine populations are separate from other populations, the BRT examined three major indicators: straying of spawners; recolonization rates external to the DPS; and genetic differences observed throughout the range of Atlantic salmon.

The Gulf of Maine DPS of Atlantic salmon is markedly separated from other populations of the same taxon. The zoogeographical basis of this separation within the U.S. is described in detail in Section 5.2. All populations south of this DPS have been extirpated. This separation is the consequence of strong fidelity to natal rivers and adaptations for local conditions that are well documented for all anadromous salmonines (Staahl 1981; Utter 1981; Utter et al. 1993b).

Comprehensive tagging and recovery experiments have been conducted in Maine Atlantic salmon rivers. Baum and Spencer (1990) assessed the homing of 1.2 million Carlin tagged Atlantic salmon stocked as smolts from 1966-1987 in five Maine rivers. Only 2% of the tag recoveries (n= 3,755) were from non-natal (stocking location) rivers. In addition, some fish recorded in one river as strays eventually returned to their natal stream, which indicates that weir and trap recaptures may overestimate the number of fish that actually spawn in non-natal rivers (Baum 1997). Data for discrete wild Atlantic salmon populations in Norway show straying rates ranging from 5% to 8% (Hansen and Jonsson 1994). Other researchers have shown that the straying rate of wild fish is typically lower than that of hatchery fish (Stabell 1984; Piggins 1987; Jonsson et al. 1991). Available information indicates that U.S. Atlantic salmon stocks do not stray far from their natal stream and thus supports the hypothesis that most straying documented between these river systems is limiting to neighboring rivers within the DPS geographical region. As such, the 2% straying rates documented by Baum and Spencer (1990) indicates that interactions between populations in individual DPS rivers and the Penobscot River restoration program are no greater than would be expected in wild populations of similar geographic proximity. The information in the tagging database indicates that specific stocks have persisted in several U.S. river systems and comprise the component parts of the Gulf of Maine Atlantic salmon DPS.

Isolation typically leads to genetic differences among Atlantic salmon stocks and relatively minor genetic differences have been linked to important adaptive morphological and life-history traits (Ritter 1975; Saunders 1981). These traits are important to the survival of individual stocks, DPSs, and the species as a whole. Atlantic salmon populations in Britain and Wales were found to be distinct using mitochondrial DNA analysis; additionally, differences in survival and migration were identified using shifts in clonal frequencies (King et al. 1993). Stahl (1987) stated that "Atlantic salmon are naturally substructured into multiple genetically differentiated and more or less reproductively isolated stocks within as well as between drainages." Given the existence of distinct stocks, creating artificially large gene flow between previously reproductively isolated populations would likely disrupt locally adapted gene complexes and decrease the overall productivity of the species (Stahl 1987).

North American Atlantic salmon stocks have been found to be distinct from European stocks using both electrophoretic and mitochondrial DNA analyses (Stahl 1987; Bermingham et al. 1991; Taggart et al. 1996). Recent data from King et al. (1999) further supports these differences and has provided analytical methods to distinguish continent-of-origin with 100% accuracy. In all these studies, genetic differences are strongly geographically patterned and, while variation is low compared to freshwater fish, it is consistent with results from other anadromous species (King et al. 1999). The genetic differences between North American and European Atlantic salmon are substantial enough that introgression of these stocks is likely to be detrimental (King et al. 1999).

Genetic differences have previously been found between U.S. and Canadian Atlantic salmon stocks using electrophoretic and DNA fingerprinting methods (Moller 1970; Bentzen and Wright 1992). In the most comprehensive survey to date, King et al. (1999) found that while genetic differences between U.S. and Canadian stocks sampled were small, assignment tests correctly classified U.S. fish to U.S. rivers more than 77% of the time. Canadian fish were correctly classified to Canadian rivers over 93% of the time. An additional 6% of the misclassified U.S. fish were classified to Canadian rivers in neighboring New Brunswick and Nova Scotia (i.e., 83% within a narrow geographical area). These data indicate that observed genetic differences between U.S. and Canadian Atlantic salmon stocks might represent important population differentiation. This differentiation is reinforced by the spatial distribution of Atlantic salmon rivers and differences in life history. Differences in life history are best illustrated by examination of the Bay of Fundy Atlantic salmon stocks. These stocks do not undertake extensive ocean migrations, remaining instead in the Bay of Fundy for most of the marine phase of their life cycle that is only 1SW (Marshall 1998). Populations in the St. Croix River and the St. John River, have intermediate life histories with a larger 1SW component than is found in any U.S. stock (Baum 1997). Since age-at-maturity appears to be a trait that is least partially genetically determined (Glebe and Saunders 1986; Ritter et al. 1986; Saunders 1986), this provides further evidence of separateness of U.S. and Canadian Atlantic salmon populations.

Some authors have claimed that the magnitude of past stocking efforts has facilitated introgression and eliminated local variability (Kornfield et al. 1995). While the historic isolation of stocks within the DPS may have been greater and supported higher levels of genetic differences, subtle distinctions between stocks within the DPS remain and differences from populations outside the DPS are clear (King et al. 1999; section 5.3.2.1.1). In particular, different methods have illustrated unique genetic material in two rivers, the Ducktrap River and Cove Brook (Kornfield 1994; King et al. 1999). The majority of stocks utilized for supplemental stocking within the Gulf of Maine DPS have been from within the DPS geographic range in both the USA and Canada (Baum 1997). Because the source of most stocking efforts has been from within the DPS, the genetic effects from stock mixing would be substantially less than from stocks from outside the DPS. These facts indicate that any inter-stock mixing that resulted from hatchery practices could have potentially elevated natural levels of intra-DPS genetic exchange beyond levels observed in the absence of stocking. An alternative hypothesis would be that the low levels of genetic differentiation between stocks is a natural consequence of a historic population structure characterized by low-to-moderate levels of genetic exchange between individual stocks in a metapopulation. Additionally, because most genetic analyses focus on neutral characters, they do not provide a complete and conclusive measure of distinctness or ecological adaptation. Failure to find a significant genetic difference between stocks may be the result of technological and/or sampling limitations and does not necessarily mean that differences with a genetic basis do not exist. The analysis of genetics data only provides some of the evidence for the separateness of DPSs.

The separateness of coastal stocks of the Gulf of Maine DPS and other Atlantic salmon populations outside the DPS are strongly supported by the persistence of these populations, geographic segregation, limited opportunities for stocking from outside the DPS to cause introgression, and current genetic analyses. The BRT concludes that adequate genetic and demographic data demonstrate that an ecologically important separation exists between the Gulf of Maine DPS within its current range and other populations to the north; all naturally occurring populations south of the DPS have been extirpated.

5.3.2.1.1 Intra-DPS Separateness

The examination of the separateness between populations within the DPS is of importance to the conservation of genetic materials within the DPS and ongoing management practices. A discussion of these differences is included here to document the intra-DPS genetic variability and the importance of conserving the component populations of the DPS. Historical accounts indicate that differences existed among river-specific stocks of Atlantic salmon. Kendall (1935) stated that in their natural state, U.S. rivers were "frequented by a sufficient number of salmon each year... and not enough migrants from other birth places entered them to prevent the establishment of somewhat differing races, peculiar to their respective streams." Recent studies examining the genetic differences among U.S. Atlantic salmon stocks have yielded somewhat contradictory and inconclusive results (Roberts 1976; Bentzen and Wright 1992; King and Smith 1994; Kornfield 1994; May et al. 1993, 1994; Schill and Walker 1994; King et al. 1999). Some researchers have found differences between select U.S. Atlantic salmon populations including unique alleles (Bentzen and Wright 1992; Kornfield 1994; King et al. 1999). Other researchers have not been able to demonstrate substantial differences between some of these stocks using different methods (Roberts 1976; King and Smith 1994; May et al. 1994; Schill and Walker 1994). These results are not unexpected given that different techniques often provide differing results (Park and Moran 1994). Collectively these studies indicate that there are differences between populations in the Gulf of Maine DPS and some of these populations contain unique genetic material.

Gene flow between Gulf of Maine populations were estimated by Schill and Walker (1994), who surveyed five random amplified polymorphic DNA (RAPD) markers in nine U.S. Atlantic salmon populations. Their data suggest that a high rate of genetic flow occurs among the Atlantic salmon populations surveyed (2.9 to 4.1 effective migrants per generation). Likewise, May et al. (1994) measured gene flow on the order of 7.1 effective migrants per generation. These results are similar to those reported by King et al. (1999) in their more comprehensive analysis of molecular variance tests of 11 Maine rivers. These data indicate that some gene flow occurs between the populations that are part of the DPS but it does not preclude the maintenance of adaptive differences (May et al. 1994; Schill and Walker 1994; King et al. 1999). Genetic differentiation between stocks can still persist with low levels of gene flow and this gene flow helps to counter (non-adaptive) founder effect changes (Wright 1978; Waples 1991b). While, gene flow can act to inter-mix neutral alleles, selection for locally adapted alleles can counter homogenization and may strengthen the fitness of a population (Slatkin 1987). Since the values reported by King et al. (1999) measure both past and present gene flow between these populations, they may be somewhat elevated due to artificial mixing of stocks through past stocking practices (Section 4: Table 4.1) in this region. However, the temporal stability of allele frequencies and the occurrence of alleles that are unique to Maine indicate that this mixing has not overwhelmed all of the genetic differences between stocks (King et al. 1993; King et al. 1999).

The BRT concludes that while it is unlikely that any U.S. Atlantic salmon populations exist in a genetically pure native form, their continued presence in indigenous habitat indicates that important heritable local adaptations likely still exist. The conservation of the populations within the Gulf of Maine DPS is essential because these Atlantic salmon represent the remaining genetic legacy of ancestral populations that were locally adapted to the rivers and streams of the region. Some disagreements exist in the management of river-specific conservation programs that warrant continued debate (e.g. Kornfield et al. 1995 and Moring et al. 1995)

5.3.2.2 International Boundaries

The Gulf of Maine DPS represents the remaining genetic legacy of a U.S. Atlantic salmon resource that formerly extended from the Housatonic River to the headwaters of the Aroostook River. The northern range of the Gulf of Maine DPS is delimited not only by the natural zoogeographical constraints on local adaptations but by an international boundary. There are substantial differences in the control of exploitation, management of habitat, conservation status, and regulatory mechanisms of Atlantic salmon between the U.S. and Canada (May 1993; Baum 1997). Management and conservation programs in the United States and Canada have similar goals, but differences in legislation and policy support the use of the United States/Canada international boundary as a measure of discreteness for the purposes of evaluating stock status (NASCO 1999). Highlighting these differences is the lack of aboriginal or commercial fisheries for Atlantic salmon in the marine waters of the U.S. (Baum 1997; USASAC 1999). Additional factors that are significant relative to section 4(a)(1)(D) of the ESA are differences in regulatory mechanisms between the federal and state system that exists in the U.S. and the federal and Provincial governments in Canada.

5.3.2.3 Evaluation of Discreteness

Based on the information available, the BRT concluded that the Gulf of Maine DPS of Atlantic salmon meets both criteria for discreteness as outlined in the Services' Policy on DPS evaluation. Only one of these is needed to conclude that the DPS is discrete from other populations.

5.3.3 EVOLUTIONARY AND ECOLOGICAL SIGNIFICANCE

The second element of the Services' policy is the consideration of the population segment's biological and ecological significance to the taxon to which it belongs. This consideration may include, but is not limited to, the following: persistence of the discrete population segment in an ecological setting unusual or unique for the taxon; evidence that the loss of the discrete population segment would result in a significant gap in the range of a taxon; evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range; or evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

5.3.3.1 Persistence and Habitat Characteristics

Riverine habitat occupied by the Gulf of Maine DPS of Atlantic salmon is unique in that it is at the southern extent of the North American range of Atlantic salmon (Saunders 1981; Baum 1997). This habitat is also distinct because it includes core Atlantic salmon populations within a unique ecoregion, the Laurentian Mixed Forest Province of coastal Maine (Bailey 1995; Bailey 1998). With their location at the southern extent of the range, riverine habitat in the DPS rivers provides a more productive juvenile nursery habitat than most Canadian river systems, allowing U.S. rivers to produce proportionately more one and two-year smolts (Meyers et al.1986; Baum 1997; Hutchings and Jones 1998). Despite habitat differences in freshwater range, both U.S. and Canadian Atlantic salmon spend much of their marine life in the northwest Atlantic Ocean. By sharing feeding areas with other North American stocks and migrating from the most southern spawning areas, U.S. salmon undertake the longest oceanic migrations of the species in North America. Occupation of the southern portion of the range exposes U.S. salmon to riverine and oceanic selection factors different from those experienced by more northern stocks.

Within the U.S., Atlantic salmon historically occurred in two general types of drainages: short (<125 km long) coastal rivers with few tributaries and relatively large river systems (>125 km long with most >160 km) with numerous tributaries. The remnant populations of the DPS represent populations from short coastal rivers. The Canadian segment of the historical DPS would have only contained two rivers of similar size to core US populations, the Digdeguash and Magaduavic Rivers. These rivers have significantly higher 1SW returns than U.S. stocks (Marshall 1998), making them more representative of Canadian stocks. Other physical differences also exist among rivers within the DPS and between the DPS and other populations, ranging from soil types, the presence of headwater and mainstem lakes, gradient, and other physiochemical and geographic characteristics. Substantial environmental differences between watersheds typically foster the independent evolution and selection of locally adaptive heritable traits in salmonines (Stahl 1987; Utter 1981; Verspoor 1988; Claytor and Verspoor 1991; King et al. 1993). These processes would have influenced the evolution of U.S. Atlantic salmon stocks into separate populations within discrete DPSs.

To survive at the extreme southern range of the species, U.S. Atlantic salmon populations needed to be adapted to distinct physical and environmental challenges (Saunders 1981). These adaptations contribute to the distinctness of the Gulf of Maine DPS as an important population segment and make its survival important to the species as whole. The BRT determined that a critical factor in determining the status of U.S. Atlantic salmon stocks was the historic persistence of a naturally reproducing legacy stock in each component river. Atkins (1874), Kendall (1894;1935), Rounsefull and Bond (1949), Baum (1997), and USASAC (1999) documented that these stocks as a collective group, the Gulf of Maine DPS, have persisted over time. While some citations suggest localized extinction of individual populations, the basis for this is somewhat speculative given rapid population growth when an impoundment was breached (e.g. Rounsefell and Bond 1949). Additionally, the recolonization of individual stocks appears to be primarily driven by natural processes of recolonization from within river (below impoundment) and within DPS (neighboring river) refugia. The success of stocking efforts prior to 1971 has been evaluated as being extremely poor (Fletcher 1955; Baum 1997). The failure of these early stocking programs was likely a result of the biotechnological inefficiency of early hatchery practices (Baum 1997) and the use of nonindigenous stocks (Saunders 1981). Most stocking efforts since 1970 have used U.S. origin fish (Penobscot River and Gulf of Maine DPS) and all stocking within the Gulf of Maine DPS since 1991 has been river-specific in origin (Baum 1997; USASAC 1999). The overall average run composition from 1970 to present exceeds 80% wild-origin for the seven rivers monitored (USASAC 1999)(Section 5.3.3.4). The balance of hatchery returns in the last 25 years is comprised almost exclusively of Penobscot hatchery origin fish. A single Miramichi River grilse that ascended the Penobscot River in 1974 is the only documented return of a Canadian-origin fish from outside the Gulf of Maine DPS since 1960 (Baum 1997).

The BRT concludes that there is substantial evidence that remnant populations of the Gulf of Maine DPS have persisted in their native range. The unique geographical location and inherent ecoregion differences led the BRT to conclude that the Gulf of Maine DPS occupies an ecological setting that is unique for Atlantic salmon. The loss of this DPS would result in a significant gap in the range of this taxon, moving the range of this population an additional degree of latitude to the north. The loss of these populations would restrict the natural range of Atlantic salmon above the 45th parallel and beyond the borders of the U.S.A.

3.2 Phenotypic Traits

It is difficult to assess the importance of phenotypic characteristics for Atlantic salmon since temporal variation within stocks is extensive (Blouw et al. 1988; Hutchings and Jones 1998). However, Claytor and Verspoor (1991) found meristic and morphometric differences among stocks of Atlantic salmon to be related to environmental variables on a clinal scale in both North America and Europe. The differences among stocks appeared to represent adaptations to environmental conditions that Atlantic salmon encounter throughout their range. Recent studies on phenotypic traits of U.S. Atlantic salmon have focused on juvenile fish. Morphometric and meristic variation indicated that U.S. populations possessed a large number of traits that differed from the population of the St. John River in Canada (Kincaid et al. 1994). Variation in measurements between the seven U.S. rivers surveyed indicated that the potential for stock-specific differences existed for some traits. These data indicate that phenotypic traits are unique among these geographic locations. Atkins (1874) noted historical differences in the size of mature, 2SW adults, among U.S. rivers. In addition, differences in the shape and girth of Atlantic salmon were reported in some rivers (Kendall 1935). The recent studies and historical accounts of phenotypic traits listed above indicate that stock-specific differences existed historically and are now present.

3.3 Life History Characteristics

Differences in life history among U.S. Atlantic salmon stocks and those of Canada were identified as early as 1874 (Atkins 1874). U.S. Atlantic salmon stocks have been composed of predominately 2SW salmon (> 80%) from at least the late 1800's to the present (Atkins 1874; Kendall 1935; USASAC 1999). Alternately, many Canadian stocks and several in Europe have a much higher grilse component with a concurrently lower 2SW component that is frequently less than 50% (Hutchings and Jones 1998). This life history trait is partially controlled by stock genetics (Ritter et al. 1986). Because U.S. stocks have return age composition that differs from Canadian stocks, especially neighboring stocks in the Scotia-Fundy region, it can be inferred that the genetic component of this trait also differs. The predominance of 2SW fish also influences spawning-run timing because they typically enter rivers earlier than grilse. Trends in run timing are difficult to discern due to low abundance and the lack of collection facilities on all rivers, but analyses of the recreational catch in some Maine rivers has indicated that the timing of spawning runs has changed little in the past 50 years (Baum 1997). Atkins (1874) also hypothesized that differences in smolt emigration timing occurred between rivers. Data for recent smolt migration trends are not available. Recent syntheses of juvenile Atlantic salmon data suggest that while environment has a strong influence upon juvenile growth and maturation (precocious parr), heritable differences between stocks also influence growth and performance (Kincaid 1994; Hutching and Jones 1998).

Taking into account all of the foregoing factors, the BRT determined that differences in life history characteristics historically contributed to the distinctness of the Gulf of Maine DPS. Remnant stocks have maintained the most characteristic of these factors: smoltification at a mean age of 2 and predominant adult returns as 2SW fish (age 4). Since the proportion of 2SW fish in an Atlantic salmon stock has a documented genetic basis (Glebe and Saunders1986; Ritter et al. 1986; Hutchings and Jones 1998), the BRT concludes that the DPS has unique life history characteristics that have a heritable basis. The BRT concludes that both environmental and genetic factors make the Gulf of Maine DPS markedly different from other populations of Atlantic salmon in their life history and ecology.

3.4. CONSIDERATION OF HATCHERY PRACTICES

Hatchery practices can have important effects on the genetic structure of fish populations. Artificial propagation has been used in attempts to restore and enhance Atlantic salmon stocks in the U.S. since the 1800's (Atkins 1874; Baum 1997). Atlantic salmon from other rivers have frequently been planted over native stocks, a practice that can affect stock integrity (Hindar et al. 1991). Stahl (1987) observed reduced heterozygosity in hatchery enhanced stocks of Atlantic salmon, presumably a result of genetic drift. Additionally, changes in allele frequencies and loss of low-frequency alleles can occur in cultured Atlantic salmon populations (Tessier et al. 1997). Thus, the consequences of artificial propagation can be deleterious to the survival of locally adapted stocks. Evaluating the effects of past stockings on native Atlantic salmon in DPS rivers is difficult due to the paucity of information regarding the number of fish that returned from stocking efforts and most importantly their contribution to successive breeding populations. The historic stocking records for Maine Atlantic salmon rivers are summarized in Section 4, Table 4.2.2. Baum (1997) builds a strong case that the success of Atlantic salmon stocking efforts prior to 1971 was extremely poor. The conclusions of other authors (Fletcher 1955; Stolte 1981; Baum and Jordan 1982; Fletcher et al. 1982) reinforce his results. The failure of these early stocking programs was likely a result of the biotechnological inefficiency of early hatchery practices (Baum 1997) and the use of nonindigenous stocks (Saunders 1981). The largely unsuccessful or ephemerally successful attempts to stock Pacific salmon in Maine further underscore the state of hatchery technology and the importance of locally adapted stocks as related to anadromous salmonine enhancement (Kendall 1935). With advances in fish culture and better understanding of fish ecology, hatchery practices have improved facilitating larger returns from stocking programs. Most Atlantic salmon stocking efforts in the U.S. since 1970 have used U.S. origin fish (Penobscot River and Gulf of Maine DPS). Starting in 1991, all stocking within the Gulf of Maine DPS has been river-specific in origin and primarily unfed fry are used (Moring et al. 1995; Baum 1997; USASAC 1999). The overall average run composition from 1970 to present exceeds an average of 84% natural-origin (wild production and river-specific fry stocking) for the seven rivers monitored (USASAC 1999). The balance of hatchery returns in the last 25 years is comprised almost exclusively of Penobscot hatchery origin fish with an increasing number of commercial aquaculture escapees in recent years (USASAC 1999). During this time period only a single Canadian-origin fish from outside the Gulf of Maine DPS, a Miramichi River grilse, was documented to have ascended the Penobscot River in 1974 (Baum 1997). The BRT concludes that most of the recolonization of the Gulf of Maine DPS stocks in individual rivers was achieved naturally through processes of recolonization from within river (below impoundment) and within DPS (neighboring river) refugia. The fact that artificial selection of hatchery environments has had some influence upon the present genome of the Gulf of Maine DPS can not be totally negated. Given our current understanding of the genetic composition of these stocks (Bentzen and Wright 1992; Kornfield 1994; King et al. 1999), the documented persistence of native stocks (Kendall 1935; Baum 1997), and the fact that most of the hatchery stocking influences were internal to the Gulf of Maine DPS and the Penobscot River Hatchery stock (Table 4.2.2)(Baum 1997), the BRT concludes that the influence of hatchery fish upon the DPS has not been sufficient to completely or substantially introgress with the remnant populations and genomes of the Gulf of Maine DPS. The BRT believes that there are components of an important genetic legacy remaining in these populations and the loss of these populations would negatively affect the genetic resources of Atlantic salmon as a whole. As the most southerly populations, the genetic resources of these stocks may be vitally important to future stock health in scenarios of climate warming.

SECTION 6: DISTRIBUTION AND ABUNDANCE - STATUS OF ATLANTIC SALMON IN THE GULF OF MAINE DPS

6.1 DESCRIPTION OF THE HABITAT WITHIN THE GULF OF MAINE DPS

The Gulf of Maine DPS encompasses all naturally reproducing remnant populations of Atlantic salmon from the Kennebec River downstream of Edwards Dam northward to the mouth of the St. Croix River. As a complex, these rivers are typically small to moderate sized coastal drainages in the LMFP ecoregion. This commonality of zoogeographic classification makes coarse level descriptions of watersheds very similar between the rivers. The watershed structure, available Atlantic salmon habitat, and abundance of Atlantic salmon stocks at various life stages are best known for the seven largest rivers with extant Atlantic salmon populations. The habitat and population ecology of populations in smaller rivers is less well known with the possible exception of Cove Brook (Meister 1962; Baum 1997). This section focuses on the seven core rivers where the most comprehensive and quantitative information is available.

The Dennys River originates in Lake Meddybemps in the town of Meddybemps, Washington County, Maine. The drainage area of the Dennys River is 34,188 ha, and it flows a distance of 32 km to Cobscook Bay. In addition to Lake Meddybemps, Cathance and Little Cathance Lakes are located in the headwaters of the drainage. The confluence of Cathance Stream, a major tributary, is located approximately 1.0 km upstream from tidewater. The upper reach of the river, from Lake Meddybemps to the falls is flat and slow moving. The reach from the falls to Cathance Stream has flat water stretches and a few riffle areas. The estuary is large, has numerous coves and bays, and numerous peninsulas and islands between Dennysville and the ocean (Beland et al. 1982). Lands within the drainage are sparsely populated and managed for the growth and harvest of forest products and lowbush blueberries. Water quality is generally good, but logging throughout the area has resulted in an abundance of woody debris in some reaches of the river.

The East Machias River originates at Pocomoonshine Lake in the towns of Princeton and Alexander in Washington County, Maine. The river has drainage of 65,009 ha that contains 26 lakes and ponds, and over 50 named tributaries. It flows a distance of 59.5 km to Machias Bay. The watershed is sparsely settled and forested with a mix of spruce and fir. Organic materials from wetlands and bordering lakes and ponds discolor the waters of the river. The East Machias and Machias Rivers enter the same estuary and the lower 3.2 km of the estuary is common to both rivers (Dube and Fletcher 1982).

The Machias River drains an area of over 119,140 ha. It originates from the five Machias Lakes and flows 98 km to Machias Bay. The watershed is located in Washington and Hancock Counties and more than 160 tributaries and 25 lakes and ponds exist in the system. A natural gorge at the mouth of the river in the town of Machias may impede the passage of salmon during periods of extreme high flow. The gorge is being studied by the State of Maine to determine if passage can be improved as part of State rehabilitation efforts for Atlantic salmon in that river. The Machias River headwaters are characterized by rolling hills with forested stream valleys and a number of barren areas, with ground cover typically consisting of shrubs. The lower portion of the basin is composed of large forested areas (Fletcher and Meister 1982). The Machias and East Machias Rivers share a common estuary. The estuary is elongate, approximately 9.6 km in length, but relatively narrow.

The Pleasant River watershed in Washington County originates at Pleasant River Lake in Beddington and drains an area of 22,015 ha. It flows 45 km to the head of tide in the town of Columbia Falls. There are few lakes in the watershed, and the tributaries are a network of small feeder streams with a combined length of 109.4 km (Dube and Jordan 1982). The headwaters are composed mostly of hills and ridges, with forests of spruce, fir, and hardwoods. The river water exhibits a high degree of red-brown coloration caused by leaching of roots, leaves, and other organic materials that originate from extensive peat bogs in the drainage. The bogs provide water during dry periods, storage during wet periods, and moderate discharge in the basin (Dube and Jordan 1982). The Narraguagus River originates at Eagle Lake, flows through Washington and Hancock Counties, and drains an area of approximately 60,088 ha. The main stem drops a total of 124 m over a distance of 69 km to the head of tide in Cherryfield. The West Branch of the Narraguagus, a major tributary, has a drainage area of approximately 18,100 ha and reaches the main stem 3.2 km upstream from the head of tide. There are more than 402 km of streams and rivers in the drainage and about 30 lakes and ponds, with three of the lakes exceeding 162 ha in size (Baum and Jordan 1982). The topography of the headwaters consists of rocky hills and ridges, and forests that are primarily a mix of spruce and fir interspersed with hardwoods. There are large blueberry barrens in the watershed, and lands are primarily managed for berry production and forest products.

The Ducktrap River is relatively small compared to other Atlantic salmon rivers in Maine. It originates in Tilden Pond in Belmont Township, Waldo County, has a drainage area of approximately 9,324 ha, and flows for a distance of 10.7 km to Lincolnville where it enters Penobscot Bay. There are four ponds in the drainage and two major tributaries. The two tributaries, Kendall and Black Brooks, enter the main stem in the lower portion of the drainage. The surrounding area is sparsely settled, and former agricultural lands are either overgrown or reverting to early successional growth. The drainage is rugged and hilly, and in the lower portion the riverbanks rise sharply from the stream to heights that exceed 30.5 m (Bryant 1956).

The Sheepscot River originates as a series of hillside springs in West Montville, Waldo County and flows a distance of 54.7 km to the estuary near Alna. The West Branch of the river originates at Branch Pond in Kennebec County, flows a distance of 24 km and enters the main stem in

Sheepscot. The Dyer River, the largest of the tributaries, has a length of 27.3 km and flows to the estuary. The Sheepscot River drainage includes 24 lakes and ponds and encompasses an area of 59,052 ha. The upper portion of the Sheepscot River estuary resembles a fjord, whereas the lower portion is typical of Gulf of Maine DPS watersheds, with mud flats and salt marsh covering large areas. Sheepscot Falls, located in the upper estuary, is an area composed of ledge, and the site of a former dam (Meister 1982). Land within the watershed was once intensively farmed, but the majority is now forested. Deposited glacial material provides a source of boulder, rubble, and cobble in the drainage.

6.2 SURVEYS OF AVAILABLE FRESHWATER PRODUCTION HABITAT WITHIN THE GULF OF MAINE DPS

The ASA and USFWS have conducted extensive habitat surveys on several rivers within the DPS (Horton et al. 1998). GIS coverages and habitat estimates are now available for all major watersheds of the DPS, with the exception of some minor tributaries with limited juvenile production habitat. Horton et al. (1998) report that from 1994 to 1997, more than 330 km of Atlantic salmon habitat have been surveyed within the DPS. Habitat maps for the rivers within the DPS are critical tools for population assessments, habitat restoration and conservation, watershed management, and fisheries management (Figures 6.2-1 to 6.2-7). Table 6.2 provides a profile of the rivers within the DPS and is derived from several habitat surveys (Beland 1982; Horton et al. 1998; S. Davis, Maine DIFW, Pers. Comm.; E. Baum, ASC, Pers. Comm.). Table 6.2: Juvenile Atlantic Salmon Production Habitat (units = $100m^2$) within the Gulf of Maine DPS including estimated habitat within the geograpical range for smaller coastal drainages presently accessible to Atlantic salmon. (a) see section Figure 5.2.2-1 for complete listing of smaller coastal drainages. (b) see section 6.2.1 for definition and calculation of Conservation Spawning Requirements.

River	Estimated Units of Juvenile Rearing Habitat	Estimated Units of Spawning Habitat	Minimum Conservation Spawning Requirement (b)	Est Po Prod
Dennys	2,414	425	161	
East Machias	3,006	162	200	
Machias	6,156	423	410	1
Pleasant	1,220	152	81	
Narraguagus	6,014	319	401	1
Ducktrap	845	44	56	
Sheepscot	2,797	313	186	
Cove Brook	235	n/a	16	
Smaller Coastal Drainages (a)	3,762	n/a	251	1
Totals	**26,449**	**1,838**	**1,762**	**7**

The ASA and FWS are presently conducting more thorough habitat surveys of Cove Brook and other smaller coastal drainages to better quantify available habitat in those drainages (Buckley, FWS, pers. Comm.). Additionally, the FWS Gulf of Maine Project is currently undertaking a study on the Narraguagus River to use airborne infrared imagery to identify cool water refugia for Atlantic salmon. A spatially continuous temperature profile can be obtained for the river using this technology. One objective is to determine if cold water inputs are predictable on an annual basis regardless of stream flow and water temperature. The imagery is currently being processed so it is too early to state whether this technology will be useful in the future in the Narraguagus River and other rivers within the DPS (Wright 1998).

Figure 6.2-1: Dennys River Watershed
Figure 6.2-2: East Machias River Watershed
Figure 6.2-3: Machias River Watershed
Figure 6.2-4: Pleasant River Watershed
Figure 6.2-5: Narraguagus River Watershed
Figure 6.2-6: Ducktrap River Watershed
Figure 6.2-7: Sheepscot River Watershed

6.3 DESCRIPTION OF POPULATION ABUNDANCE WITHIN THE GULF OF MAINE DPS

Species abundance in a DPS is a critical concern in assessing the population status of a species under the ESA. While the Services have no quantitative guidance for determining if a species is endangered or threatened, an examination of current abundance compared to historical levels and analysis of recent trends was used to determine the status of Atlantic salmon within the Gulf of Maine DPS. As with most anadromous species, Atlantic salmon frequently exhibit large temporal changes in abundance. While the high level of variation that these populations exhibit makes quantitative assessments of changes in abundance difficult, trends in these indices are evident. The relative abundance of Atlantic salmon in several U.S. streams was examined using data from the ASA and the U.S. Atlantic Salmon Assessment Committee (USASAC 1999). Information on adult returns, redd counts, and juvenile population abundance is presented in this section as well as information on broodstock collections and subsequent stocking.

6.3.1 ADULT ABUNDANCE

Documented returns of adult Atlantic salmon to the DPS rivers surveyed remain low relative to conservation escapement goals (USASAC 1999). In considering the numbers reported for the seven wild river populations, one must be cognizant that these data represent minimal counts and not total numbers owing to counting inefficiency and observational bias (USASAC 1999). This is true whether considering adult numbers or redd counts of spawning adults. These numbers can vary greatly year to year in the same river due to factors not related to actual abundance, and probably always underestimate the actual numbers present. In some years, there was no effort to collect count data for several rivers, even though some adults probably did return to those rivers. The accuracy of returning adult counts is a function of the extent and nature of sampling effort (trapping, observation, etc.) on each of the rivers (USASAC 1999; Beland and Dub   1999). The best and most comparable year-to-year data available are on the Narraguagus River because of a long-term intensive study. Other river data on adult counts are the result of vastly differing sampling efforts year-to-year and river-to-river within a year. Direct comparisons of adult counts of one year to another year are subject to the potential for significant and unmeasured error.

For an individual river, most past counts of returning adult wild salmon are of limited value in assessing the population trends because of the inconsistent methods and discontinuous nature of gathering adult return counting data. The exception is the Narraguagus River, where adult counting effort and technique have been relatively consistent over recent years (Beland and Dub 1999). The Narraguagus River adult return data are useful for showing that these wild populations have been low this past decade relative to observations of earlier decades and reasonable expectations of habitat carrying capacity. Given the limitations described, absolute values of adult estimates in a single year cannot be used to assess the immediate condition of a stock in a river or to determine if listing is warranted. However, when individual river data are combined in aggregate they provide a relatively robust indication of population trends within the Gulf of Maine DPS. The development of fixed weirs and other improvements in population assessment included in the Atlantic Salmon Conservation Plan for Seven Maine Rivers will, by the year 2001, upgrade the effectiveness of monitoring adult returns to more accurately index the true state of the wild populations. This will also permit a more precise evaluation of short-term fluctuations in a population. It is important that this increased precision be achieved by that time, because 2001 is when the first significant impact of fry stocking on adult returns should be realized in the Gulf of Maine DPS.

Atlantic salmon documented to have returned to rivers within the DPS through angler catch and trap data from 1970 to 1998 provide the best available composite index of recent adult population trends (Table 6.3.1-1; Figure 6.3.1-1). These indices indicate that there was a dramatic decline in the mid-1980s and populations have remained at low levels since that point.

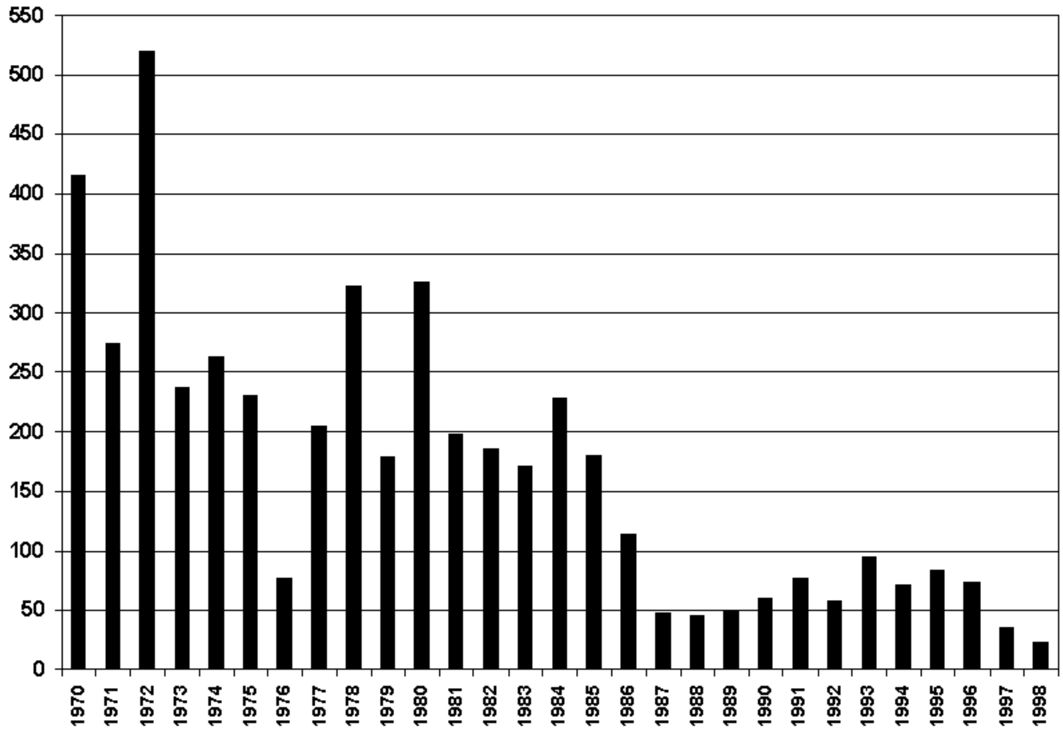


Figure 6.3.1-1 and Table 6.3.1-1: Total Documented Natural (Wild & Fry Stocked) Spawner Returns from USASAC (1999) data (minimal* indices) and escapement goal (e-goal) for each river in the Gulf of Maine DPS.

YEAR	DENNYS	E. MACHIAS	MACHIAS	PLEASANT	NARRAGUAGUS	DUCKTRAP	SHEEPSCOT	TOTAL
1970	49	1	226	1	132	-	6	415
1971	19	5	147	1	73	-	30	275
1972	61	3	191	1	244	-	20	520
1973	40	5	28	2	142	-	20	237
1974	49	1	26	30	137	-	20	263
1975	40	22	41	8	109	-	11	231
1976	20	0	18	1	28	-	10	77
1977	26	20	15	3	117	-	24	205
1978	38	46	90	16	98	-	35	323
1979	38	18	58	8	49	-	8	179
1980	73	38	65	5	115	-	30	326
1981	46	29	34	23	51	-	15	198
1982	20	22	55	7	67	-	15	186
1983	28	5	17	38	71	-	12	171
1984	68	38	25	17	58	-	22	228
1985	14	30	27	31	57	15	6	180
1986	8	8	28	19	25	15	11	114
1987	1	6	4	5	26	0	6	48
1988	6	5	8	-	27	0	0	46
1989	1	9	9	0	27	0	3	49
1990	11	17	1	0	28	3	0	60

1991	6	2	1	0	68	0	0	77
1992	6	0	0	0	47	0	4	57
1993	7	0	13	0	74	0	0	94
1994	6	-	-	1	50	-	15	71
1995	5	-	-	-	56	-	22	83
1996	10	-	-	-	56	-	8	74
1997	0	-	-	1	35	-	0	35
1998	1	-	-	-	22	-	-	23
Total	697	330	1127	216	2089	33	353	4845
Average	24	14	47	9	72	4	13	167
E-goal	139	145	463	72	385	39	111	

* These are considered minimal estimates, a "0" means that no fish were documented to have returned a "-" indicates that no quantitative data were collected in that year. However, it is critical to note that as displayed in table 6.4, the presence of redds indicates that adults were present in the rivers during those same years. To compare rivers within the DPS to each other and to the escapement required for adequate egg deposition, a method developed by Elson (1975) and adopted by the North American Salmon Working Group (NASWG) has been used to estimate escapement goals for each watershed in the DPS (USASAC 1999). Since historical Atlantic salmon abundance data are available, this methodology allows for comparing population abundance to habitat potential within the constraints of adult return data mentioned previously. This method assumes a target egg deposition of 2.4 eggs/m^2 is needed to fully seed a river (Elson 1975). An average female fecundity of 7,200 eggs/female (Baum and Meister 1971; Baum 1997) and a 1:1 male: female ratio (Baum 1997) was used to determine optimal escapement.

For example:

With 100,000 m^2 of accessible habitat, target spawners would be:

100,000m^2 X 2.4 eggs/m^2 = 240,000 eggs;
240,000 eggs / 7,200 eggs/female = 33.333 females; and
33.333 x 2 = 66.67 = 67 Atlantic salmon

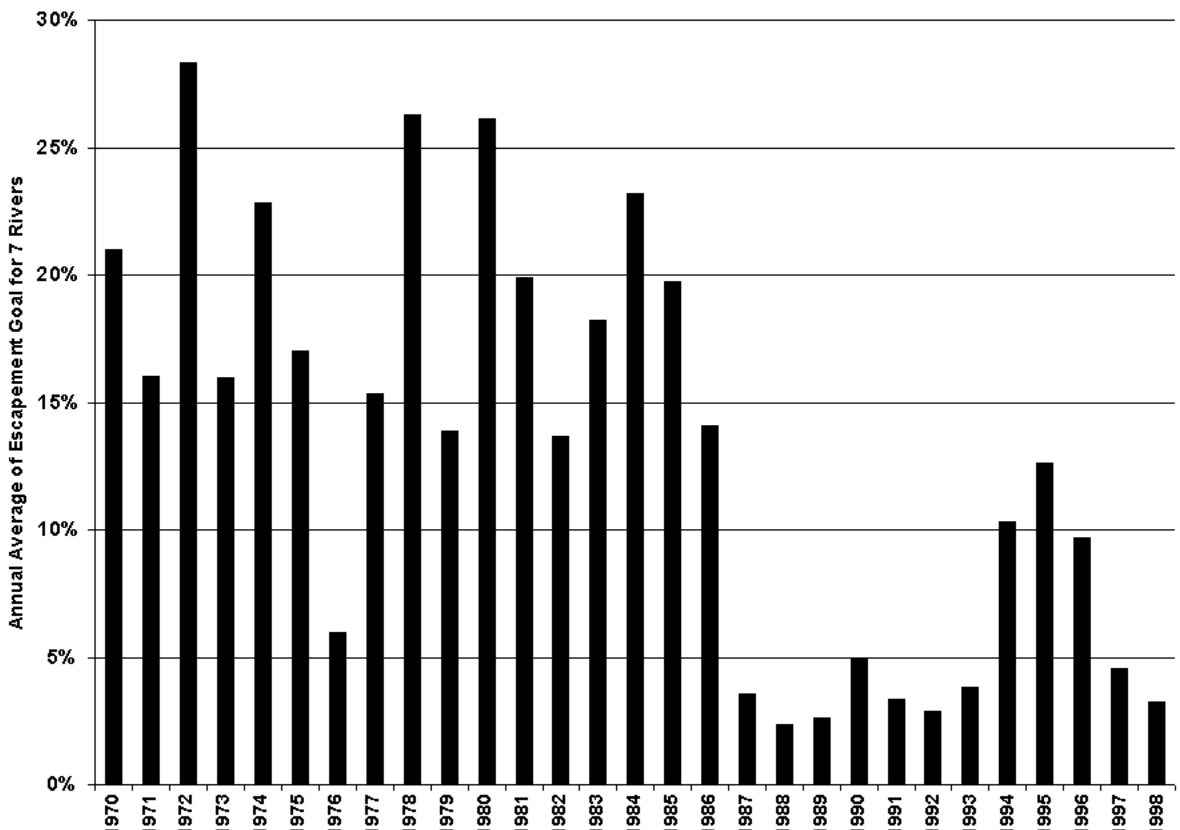
Once the escapement goal is calculated, a standardized comparison can be made among the rivers of different size. The return was calculated as a percentage of the escapement goal to standardize among rivers and compare run size to optimal escapement. This value was simply the percentage of the abundance index (trap count or extrapolated adult return from redd counts) divided by escapement goal. For example:

An escapement goal of 67 spawners and index of 35 spawners:

(35/67) x 100 = 52.23% of escapement goal

Over the past 24 years, the Dennys and Narraguagus Rivers have had the best returns relative to available habitat. However, adult returns in these rivers still average less than 20% of their escapement goal (Table 6.3.1-2 and Figure 6.3.1-2). The Pleasant, Sheepscot, and Machias Rivers averaged between 10% and 12%. However, recent downward trends in abundance put most rivers at less than 10% of their escapement goals. Only the Narraguagus River has exceeded 10% in the past 7 years. While these estimates are based on counts that give a minimal estimate of run strength, the low levels of abundance are disturbing, given the recent declining abundance. It is important to note that during most of these early time series (1970-1985), recreational fisheries were still harvesting adults from these rivers. Thus, these percentages of run size to escapement goals are extremely optimistic because these percentages represent the potential spawning contribution of returning spawners (run size), not actual escapement. Since exploitation during this time series frequently exceeded 50%, spawning escapement through the 1980's was likely significantly less than the escapement goals summarized in Figure 6.3.1-2 and Table 6.3.1-2. However, the contribution of precocious parr to spawning in these rivers is unknown and could serve to increase the effective spawning size of these populations.

Figure 6.3.1-2 and Table 6.3.1-2: Natural Run Size as a Percentage of Escapement Goal for Available Habitat



YEAR	DENNYS	E. MACHIAS	MACHIAS	PLEASANT	NARRAGUAGUS	DUCKTRAP	SHEEPSCOT
1970	35%	1%	49%	1%	34%		5%
1971	14%	3%	32%	1%	19%		27%

1972	44%	2%	41%	1%	63%		18%
1973	29%	3%	6%	3%	37%		18%
1974	35%	1%	6%	42%	36%		18%
1975	29%	15%	9%	11%	28%		10%
1976	14%	0%	4%	1%	7%		9%
1977	19%	14%	3%	4%	30%		22%
1978	27%	32%	19%	22%	25%		32%
1979	27%	12%	13%	11%	13%		7%
1980	52%	26%	14%	7%	30%		27%
1981	33%	20%	7%	32%	13%		14%
1982	14%	15%	12%	10%	17%		14%
1983	20%	3%	4%	53%	18%		11%
1984	49%	26%	5%	24%	15%		20%
1985	10%	21%	6%	43%	15%	38%	5%
1986	6%	6%	6%	26%	6%	38%	10%
1987	1%	4%	1%	7%	7%	0%	5%
1988	4%	3%	2%	0%	7%	0%	0%
1989	1%	6%	2%	0%	7%	0%	3%
1990	8%	12%	0%	0%	7%	8%	0%
1991	4%	1%	0%	0%	18%	0%	0%
1992	4%	0%	0%	0%	12%	0%	4%
1993	5%	0%	3%	0%	19%	0%	0%
1994	4%				13%		14%
1995	4%				15%		20%
1996	7%				15%		7%
1997	0%				9%		
1998	1%				6%		
Average	25	14	47	9	74	4	13
E-goal	139	145	463	72	385	39	111
Avg/goal	18%	9%	10%	13%	19%	9%	12%

The pre-fishery abundance index of North American salmon stocks that migrate to the Greenland region of the North Atlantic Ocean continues to be low in spite of apparently improving marine habitat conditions as reflected by ocean surface temperature data in the past few years (NASWG 1999). The apparent non-response to improving marine habitat is believed to be due, in part, to generally depressed spawning populations in North American home rivers and resultant low number of juvenile salmon entering the ocean. Without adequate numbers of emigrating smolts, North American populations have not responded to improved marine growth and survival conditions. Based on estimates of the pre-fishery abundance of North American salmon stocks in the West Greenland Sea provided by the ICES, relatively low adult returns should be anticipated in many North American salmon rivers again in 1999 (NASWG 1999).

Fall redd counts are also used to estimate adult returns. These counts are particularly useful for rivers that do not have trapping facilities for returning adults. The accuracy of the counts of redds created by spawning adults varies due to water conditions (visibility, discharge, water temperature, etc.) and the amount of observation effort (Beland and Dub   1999). Low, clear water conditions in the fall can provide a high level of efficiency in counting redds by both enhancing river accessibility for observers and the visibility of redds; while high, turbid water limits access and visibility and greatly lowers counting efficiency. Such sampling conditions can vary day-to-day and river-to-river. The value of the past redd counts for assessing the wild populations lies more in the trends of changes in their relative values over a period of years, and less in their absolute values of particular years or rivers. Recent increases in redd counts can be attributed to increased coverage of watershed and supplemental broodstock releases (Table 6.3.1-3; Figure 6.3.1-3). Those releases will be discussed later in this section under the heading of stock enhancement programs.

Declining adult Atlantic salmon returns of the last three decades are best characterized by an early period of relatively high fishing mortality that has declined to minor levels while marine habitat suitability declined severely. As marine habitat indices improved in the early 1990's, the ability of the stocks to respond has been hindered by low spawner abundance caused by previous marine mortality factors. The ability and resilience of Atlantic salmon stocks to return to high abundance is strongly related to the abundance of spawners (i.e., Myers and Barrowman 1996). Since 1970, there has not been a substantial period of time where: marine habitat indices were high; fishing mortality was low; and spawner abundance was at conservation targets for any Atlantic salmon stocks in the Gulf of Maine DPS.

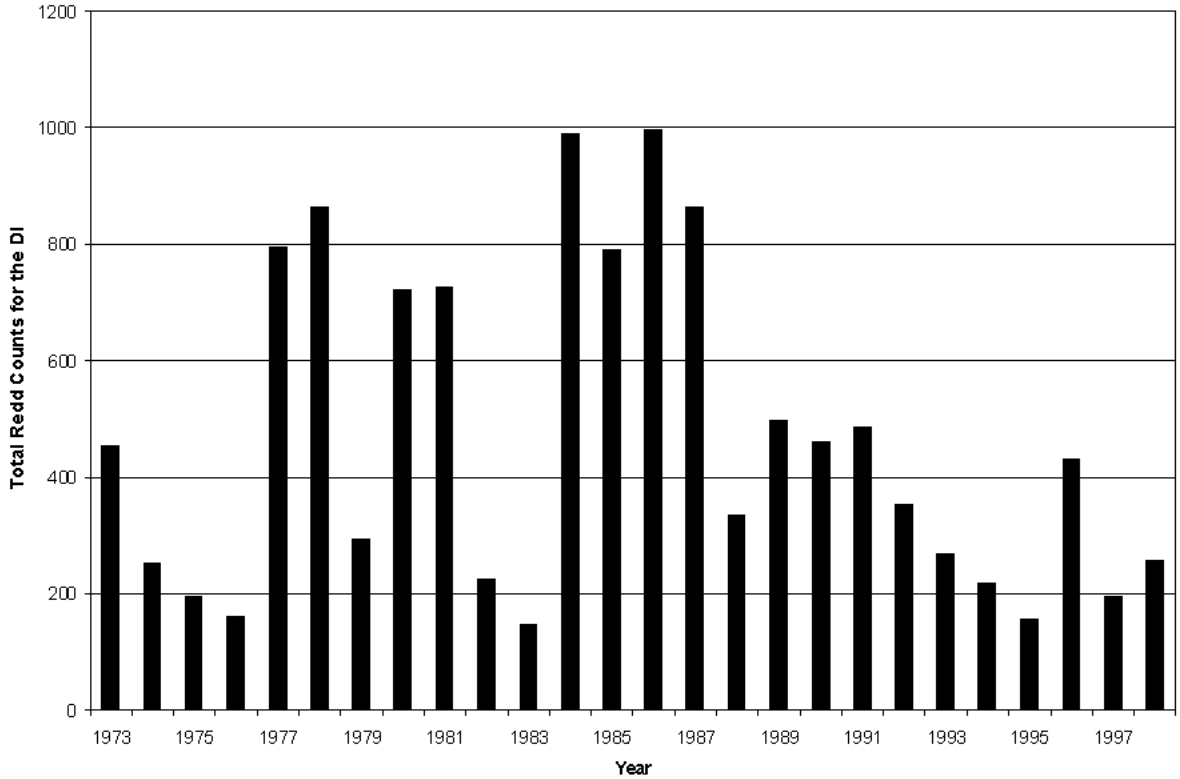


Figure 6.3.1-3 and Table 6.3.1-3: Redd Counts within the DPS

YEAR	DENNYS	E. MACHIAS	MACHIAS	PLEASANT	NARRAGUAGUS	DUCKTRAP	SHEEPSCOT	TOTAL
1973	160	58	137		97			452
1974	100	31	94		26			251
1975		5	110		80			195
1976	45	8	80		27			160
1977	202	18	298		277			795
1978	540	94	227		4			865
1979	165		128					293
1980	217	31	361		113			722
1981	150	117	162		298			727
1982	117	17	23		67			224
1983	25	16	83		22			146
1984	253	102	289		259	6	80	989
1985	249	89	234		201	18		791
1986	143	91	273		345		145	997
1987	108	130	274		210	61	79	862
1988	112	18	50		100	8	46	334
1989	148	8	129		163	29	20	497
1990	89	2	113		201	37	17	459

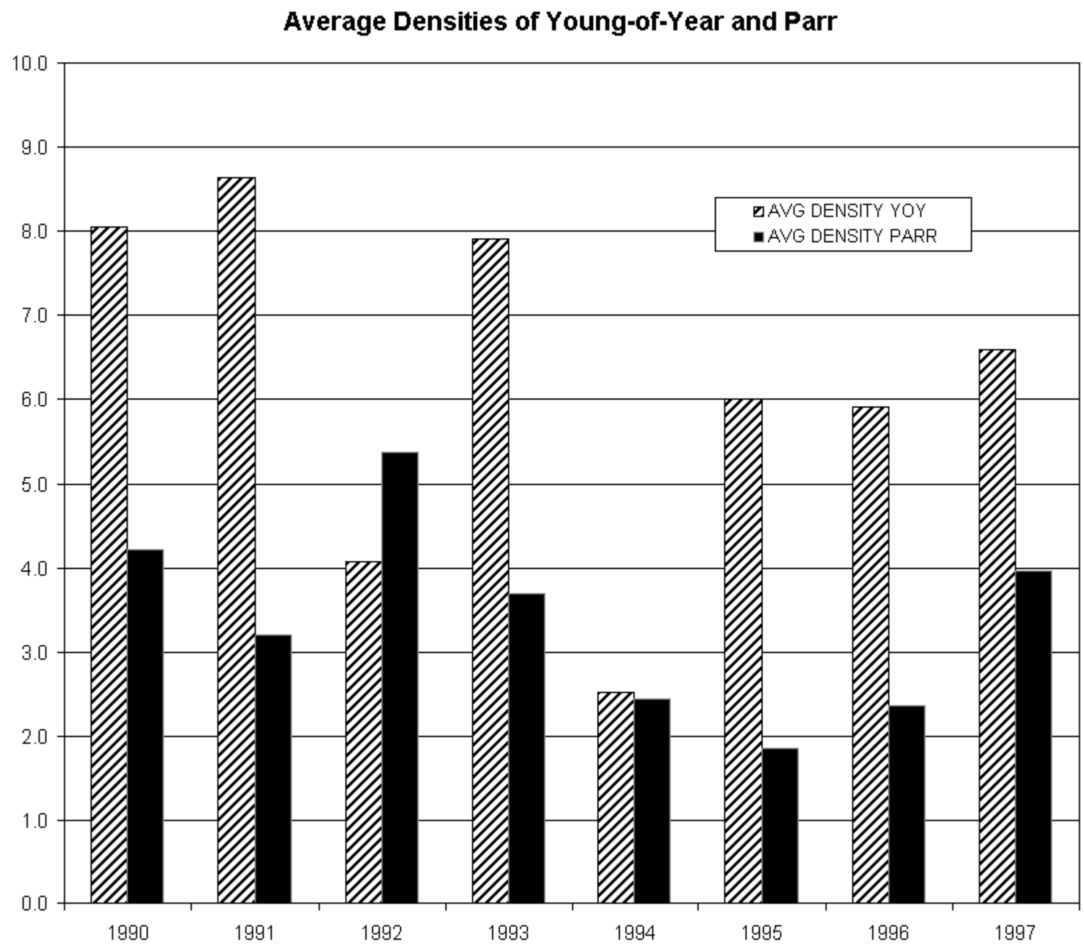
1991	81	0	121	44	186	54		486
1992	63	2	83	17	131	18	40	354
1993	25	17	45	22	105	20	33	267
1994	15	19	50	0	57	36	41	218
1995	49		21	8	61	15	2	156
1996	30	41	102	41	161	44	12	431
1997	35	11	59	1	78	2	8	194
1998	32	74	74	2	63	9	2	256

* The % of the drainage surveyed varies by river and year

6.3.2 Juvenile Abundance

The ASA and FWS annually conduct juvenile population surveys utilizing electrofishing at over 100 index sites within the DPS (Horton et al. 1998; Beland and Dub 1999). Generally speaking, densities of young-of-the-year salmon (0+) and parr (1+ and 2+) remain low relative to potential carrying capacity. These depressed juvenile abundances are a direct result of low adult returns in recent years. The increases reported by the ASA in juvenile populations (0+, 1+ and 2+) in 1997 within the DPS indicate that fry stocking can increase in-river juvenile (parr) populations. Juvenile densities in the unstocked rivers, the Pleasant and the Ducktrap, remained relatively stable compared to the time series of data (Table 6.3.2-1; Figure 6.3.2-1).

Table 6.3.2-1 and Figure 6.3.2-1: Average Densities of Young of the Year (0+) And Parr (1+, 2+ Years) per habitat unit from Horton *et al*. (1998) and Beland and Dubé (1999).



YEAR	DENNYS		E. MACHIAS		MACHIAS		PLEASANT		NARRAGUAGUS		DUCKTRAP		SHEEPSCOT		AVG DENSITY	
	YOY	PARR	YOY	PARR	YOY	PARR	YOY	PARR	YOY	PARR	YOY	PARR	YOY	PARR	YOY	PARR
1990	3.6	3.4	18.9	6.5	7.1	4.4	7	4	1.1	1.4	15.1	8.2	3.5	1.6	8.0	4.2
1991	3.3	2.8	12.8	4.7	14.1	3.7	14.9	4	3.4	1.5			3.3	2.5	8.6	3.2
1992	2.4	2.2			6.7	3.7			4.4	1.9		10.8	2.8	8.3	4.1	5.4
1993	1.9	1.5	10.9	5.6	10.4	5.3	2.6	1	1.8	3.1	27.7	8.2	0.1	1.1	7.9	3.7
1994	1.5	2.4	7.2	6.3	3.8	2.6	0.5	2.4	2.5	1.2	2.1	1.7	0	0.5	2.5	2.4
1995	1.1	1.2	3.4	3.5	3.9	1.2	1.1	3	3.4	1.7	28	2.4	1.1	0	6.0	1.9
1996	0.9	0.5	18.7	2.1	3.9	2.3	3	1.1	4.7	2.7	8.9	6.9	1.3	0.9	5.9	2.4
1997	5.5	1.9	8.7	7.3	6.5	3.4	9.1	3.7	4.3	3.8	11.1	5.2	1	2.4	6.6	4.0
AVERAGE	2.5	2.0	11.5	5.1	7.1	3.3	5.5	2.7	3.2	2.2	15.5	6.2	1.6	2.2	6.2	3.4

A total parr population estimate is not available for the entire DPS; however, the ASA and NMFS have conducted a drainage-wide parr population study on the Narraguagus River since 1991. Electrofishing population estimates at select index sites are extrapolated to a basinwide estimate using a habitat based stratification design (Beland and Dub 1999). The numbers presented in the table below are obtained by electrofishing up to 45 sites annually. The parr population in the Narraguagus River has increased in recent years. This increase is most likely attributed to the river-specific stocking program including both fry stocking and adult broodstock releases (Beland and Dub   1999).

Table 6.3.2-2: Drainage-wide parr population estimates for the Narraguagus River

YEAR	Large Parr (age >1 ± 95% CL)
1991	15,863 " 1,687
1992	14,915 " 1,815
1993	22,901 " 6,916
1994	9,536 " 660
1995	12,737 " 2,962
1996	11,073 " 1,196
1997	26,775 " 4,016
1998	25,382 " 2,832

The 1997 parr population estimate in the Narraguagus River was the highest estimate in the time series of data. In 1997, the basin-wide population estimate of large parr in the Narraguagus was 26,682, an increase of 113% from the 1996 estimate (Beland and Dub   1999). The drainage-wide population of age 1+ and older parr on the Narraguagus River in 1998 was approximately 25,382, a 5% decrease from the 1997 high (USASAC 1999).

6.3.3 Smolt Production and Outmigration

The NMFS and the ASA have been conducting a study on the Narraguagus River monitoring outmigration of smolts by documenting timing of migration, survival, length, weight and number of smolts (Kocik et al. 1998a). This study was initiated to obtain smolt counts on one of the DPS rivers to better partition mortality between freshwater and marine ecosystems. Starting in 1997, four rotary screw fish traps were deployed from mid-April to early June to sample emigrating smolts. The locations of the traps are downstream of approximately 85% of the juvenile rearing habitat in the basin. In 1998, a total of 974 smolts were captured and the emigrant smolt population on the Narraguagus River was estimated at 2,925 (273, which was not significantly higher than the 1997 estimate of 2,871 (539. Smolts trapped in 1998 were significantly shorter and lighter than those observed in 1996 or 1997. Average overwinter survival from large parr to smolt was significantly lower in 1998 (11%) compared to 1997 (24%). There is a 99% probability that overwinter survival from large parr to smolt was less than 30%, the minimum estimate cited in previous studies. Survival estimates in both years are substantially lower than estimates previously reported in scientific literature and previously accepted estimates for this region (Bley 1987; Bley and Moring 1988; Baum 1997; Kocik et al. 1999). These substantially lower survival rates could be negatively impacting population recovery. It is unknown whether these overwinter survival rates are typical for the Narraguagus River on a long-term basis or if they are comparable to other rivers in the Gulf of Maine DPS. The NMFS and ASA expanded smolt trapping to the Pleasant River in 1999 and plan additional coverage in 2000 to answer some of these questions. In addition, smolt traps will be deployed in autumn 1999 in an attempt to investigate the possibility of a fall smolt outmigration which, if present, would lead to an overestimation of mortality. Additional years of study will enhance this database, allow testing of environmental correlates to overwinter survival, and facilitate analysis of a potential overwinter production threshold. If suspect relationships are found, probable causes of mortality can be investigated and studies can be conducted to identify possible habitat rehabilitation or enhancement that could increase survival through the smolt stage. McCarl and Retting (1983) have illustrated the importance of evaluating smolt production as it relates to adult returns to better understand population dynamics and recovery of salmonine stocks.

In addition to using traps to estimate total smolt production in the Narraguagus River, researchers implanted ultrasonic pingers into wild smolts and hatchery smolts to investigate their behavior and fate as they moved downriver and into the estuary in 1997 and 1998 (Kocik et al. 1998). Preliminary data on detection percentages between transects averaged 90% in the riverine section, 91% in the estuary, and dropped to 83% at the marine array, suggesting a zone of increased mortality in Narraguagus Bay. The median transit time for wild smolts from the first detection unit to the marine array (21 km) was 84 hours, yielding a median speed of 0.3 km/h, slower than the speed observed in 1997 (0.5 km/h). Slower outmigration in 1998 may be due to lower stream flows and warmer temperatures (Kocik et al. 1998b). Preliminary estimates of survival indicate that roughly 50% of smolts are presently emigrating from the outer waters of Narraguagus Bay and entering the Gulf of Maine.

NMFS and ASA researchers illustrated that between the 1997 and 1998 smolt runs, a 126% increase in large parr production resulted in less than a 2% increase in smolt production. Additionally, these researchers found that approximately half of these emigrating smolts do not reach the Gulf of Maine. These preliminary data led the BRT to conclude that low overwinter and emigration survival rates may be impeding the recovery of these populations and are an issue of concern.

6.4 Conservation Hatchery Programs

Atlantic salmon stocking in rivers of the Gulf of Maine DPS prior to 1991 is discussed in section 4.2. These programs were conducted primarily using stocks from the Gulf of Maine DPS and neighboring river systems and stocking occurred at relatively low levels. The river-specific stocking program for Atlantic salmon in the Gulf of Maine DPS was initiated in 1991 when the USFWS designated these river populations as Category 2 candidate species under the ESA. Craig Brook National Fish Hatchery (CBNFH) was converted from a single stock smolt production facility to a multiple-stock fry production facility. Broodstock collections began in 1991 and initially focused on the collection of sea run returning adults. However, due to insufficient adult numbers, parr began to be collected in 1992 (Table 6.4-1)(Buckley 1999). The majority of the collections have been parr that were subsequently raised to maturity at CBNFH.

Mating is conducted according to protocols developed and adopted by the Maine Technical Advisory Committee (Beland et al.1997; Copeland et al. 1998). Broodstock for the Dennys, East Machias, Machias, Narraguagus and Sheepscot Rivers are held at CBNFH. These collections have increased the effective population size of these populations (wild and captive) and provide a buffer against extinction for these populations. Parr were collected from the Pleasant River and were transferred to the North Attleboro National Fish Hatchery. These fish were later destroyed due to the presence of a newly discovered Atlantic salmon disease-SSSV (Section 7.3).

Table 6.4-1: River-Specific Broodstock Collections

YEAR	DENNYS		E. MACHIAS		MACHIAS		PLEASANT		NARRAGUAGUS		SHEEPSCOT		TOTAL	
	Adult	Parr	Adult	Parr	Adult	Parr	Adult	Parr	Adult	Parr	Adult	Parr	Adult	Parr
1991					11								11	
1992	6	249				414				232			2	895
1993	6	182		239	11	280				174		87	17	962
1994	4	151		166		313				165		84	4	879
1995		234		145		375		200		361	20	107	20	1422
1996				132		238		81		361	8	87	8	899
1997		150		125		250		-		250		150		925
1998		150		125		250		-		250		150		925

The focus of the river specific program is to produce fry that are then stocked back to the river of their parent's origin. In 1992, fry stocking began with the release of less than 14,000 fry in the Machias River. It was only in 1997 that stocking reached levels where most of the suitable and unutilized habitat is fully stocked at a target density of 100 fry per habitat unit (100 m^2) in the five target rivers (Copeland1998). Egg take and subsequent fry stocking has increased significantly as broodstock numbers increased at CBNFH (Copeland 1998)(Table 6.4-2). Fry stocking occurs in May after most or all of the yolk sac has been absorbed and the fish are ready to begin actively feeding (Copeland et al. 1998). Each year the ASA makes a recommendation to the TAC regarding fry stocking. The TAC then reviews the recommendation and forwards a final recommendation to the ASA, USFWS and NMFS. In 1999, ASA staff provided the TAC with a detailed rationale for their fry stocking recommendations. Primary considerations for selecting river reaches for fry stocking include habitat quality, avoiding direct competition between stocked fry and emerging wild fry, and finally, logistics (ASA Rationale for Fry Stocking Recommendation, ASA staff, 2/1/99). River specific fry releases are displayed in the table below (Table 6.4-3). Parr were collected from the Pleasant River but were not stocked later back into the Pleasant River due to the presence of a disease. This will be discussed later in Section 7.3.

The response of Atlantic salmon populations to supplemental stocking programs can be partially evaluated based on juvenile production but adult returns are the ultimate evaluation stage. It takes about 4 years from initial stocking to evaluate population level responses since there is a lag between removal of parr for brood stock development, the subsequent stocking of their offspring, juvenile assessments, and adult returns. The first opportunities to make a comprehensive evaluation will be when adults of fry-stocked origin (as 2 SW fish) potentially contribute to the 1999 spawning run that ends in October. The 1999 returns are from the moderately high fry stocking levels of 1995 for the Dennys, Machias, and Narraguagus Rivers. It will not be until 2000 that fry-stocked fish will contribute a potentially substantial element to all five rivers with river specific stocking programs in them.

Table 6.4-2: Egg Production at CBNFH (Copeland *et al*. 1998; Copeland, Pers. Comm.)

YEAR	DENNYS	E. MACHIAS	MACHIAS	NARRAGUAGUS	SHEEPSCOT
1991			13,789		
1992	32,700				
1993	23,572		47,119		
1994	109,625		157,476	114,472	
1995	171,797	111,922	332,228	235,660	98,029
1996	231,630	137,961	285,000	297,146	126,362
1997	494,000	394,000	602,600	516,800	375,800
1998	443,200	362,300	547,600	490,000	524,800

Table 6.4-3: River specific fry releases (Copeland *et al*. 1998; Copeland, Pers. Comm)

YEAR	DENNYS	E.MACHIAS	MACHIAS	NARRAGUAGUS	SHEEPSCOT	TOTAL
1992			13,789			13,789
1993	32,700					32,700
1994	19,963		49,969			69,932
1995	84,000		150,000	105,000		339,000

1996	141,602	114,880	232,812	200,808	102,388	792,490
1997	191,552	112,600	235,999	196,319	63,896	800,366
1998	234,000	190,000	300,000	274,000	256,000	1,254,000
1999*	173,000	210,000	169,000	156,000	302,000	1,010,000

*provisional data

Due to space constraints, there is a need to annually remove a portion of the broodstock held at CBNFH. These fish were spawned the previous year in the hatchery and are released prior to the spawning season. Experimentation on the Narraguagus River has verified that these fish do spawn after being released to the wild and that the fry survive to the parr stage. Broodstock for recent releases are provided in the table below.

Table 6.4-4: River specific surplus broodstock releases (Copeland *et al*. 1998)

YEAR	DENNYS	E. MACHIAS	MACHIAS	NARRAGUAGUS	SHEEPSCOT
1996	180	0	215	108	0
1997	118	91	231	127	16
1998	126	119	245	222	37

During the development of the Conservation Plan, the Governor's Task Force voted to transfer eggs from the CBNFH to private hatcheries operated by commercial growers. The transfer was made after the aquaculture industry offered to assist in the recovery of the DPS by raising smolts and/or adults as a supplement to fry releases. A total of 3,000 eggs from three strains were transferred from the CBNFH to the aquaculture industry in 1996, 1997, and 1998. Smolts of the following strains were placed into sea cages in the spring of 1999: Narraguagus River, Machias River, Dennys River and Sheepscot River. Not all of these smolts will be moved to cages, as the adults produced would be far in excess of what would be biologically appropriate for use in the river. The additional smolts could be released in the river. Most hatcheries produce smolts in one year, but within a year class or cohort many fish remain as parr and smoltify in the second year. Thus, parr are a "by-product" of smolt production and are available for stocking into the river. To date, age 0+ fall parr were stocked into the Narraguagus, Machias, Dennys, and Sheepscot Rivers.

Five river-specific stocks (Narraguagus, Machias, East Machias, Dennys and Sheepscot) are currently being reared in sea cages and 2SW adults will be available the next two years. Estimated production of adult fish will be 900 for the Narraguagus (available in 1999); and 1,800 each for the Machias, East Machias, and Dennys Rivers (available in 2000). These numbers are far in excess of any realistic biological needs that would be prudent for experimental release of adults into their rivers of origin. Their numbers are excessive because it is necessary to produce fish at these levels to acclimate them to feed in the sea cages, to make optimal use of cage rearing space, and as insurance against catastrophic losses (e.g. loss of 1,000 Narraguagus River fish last winter to seal predation). The NMFS, USFWS and ASA will tag these fish so that release options can be evaluated. The TAC has advised that the release of adults in rivers with limited adult assessment capabilities should be restricted since little is known of impacts (positive or negative) upon ongoing restoration efforts.

6.5 Determination of Population Status

Given the data reviewed in this section, the BRT concludes that naturally producing Atlantic salmon populations in the Gulf of Maine DPS are at extremely low levels of abundance. This conclusion is based principally on the facts that spawner abundance is below 10% of the number required to maximize juvenile production, juvenile abundance indices are lower than historical counts, and smolt production is less than a third of estimated capacity.

Adult counts and redd counts in all rivers continue to show a downward trend from these low abundance levels. Given recent estimates of spawner-recruitment dynamics some researchers suggest that adult populations may not be able to replace themselves and populations would be expected to decline further (Beland and Friedland 1997). Preliminary evaluations indicate that fry stocking is enhancing juvenile production in these rivers and utilization of available nursery habitat has increased. While hatchery supplementation is an important demographic and genetic conservation tool for these stocks, the evaluation of the status of these populations need to be based on the population trends of wild stocks. Because the present hatchery program utilizes primarily fry stocking and no effective non-lethal fry mark has been developed, the BRT could not assess only the wild component of juvenile or adult populations. However, given that the overall status of these stocks is so poor that the BRT concludes that the wild element of combined natural (wild and fry stocked) Atlantic salmon presmolts are at precariously low levels of abundance. Additionally, data from Kocik et al. (1998a) suggest that presmolt overwinter mortality may be substantially greater than values used in previous population modeling exercises (Beland and Friedland 1997). Given this information, the BRT concludes that the abundance of naturally produced Atlantic salmon in the Gulf of Maine DPS is continuing the downward trend in abundance that began in the late 1980's and is characteristic of the entire North American stock complex (NASWG 1999; USASAC 1999).

The demographic and genetic consequences of these low abundance levels coupled with declining abundance trends leads the BRT to conclude that the conservation status of the population segment in relation to ESA listing standards is in danger of extinction.

SECTION 7: ANALYSIS OF LISTING FACTORS

The ESA defines an endangered species as any species in danger of extinction throughout all or a significant portion of its range; and a threatened species as any species likely to become endangered within the foreseeable future. Section 4(b)(1)(a) of the ESA requires that determinations of whether a species is threatened or endangered be based solely on the best scientific and commercial data available and after taking into account those efforts, if any, being made to protect the species.

A species may be determined to be endangered or threatened due to any one or more of the following five factors described in section 4(a)(1) of the ESA:

1. The present or threatened destruction, modification, or curtailment of habitat or range;
2. Overutilization for commercial, recreational, scientific, or educational purposes;
3. Disease or predation;
4. The inadequacy of existing regulatory mechanisms;
5. Other natural or manmade factors affecting its continued existence.

Each of these five factors is examined in the following sections for its historic, current and/or potential impact on the Gulf of Maine DPS of Atlantic salmon. It should be noted that current and potential threats, along with current species distribution and abundance determine present vulnerability to extinction.

7.1 PRESENT OR THREATENED DESTRUCTION, MODIFICATION, OR CURTAILMENT OF HABITAT OR RANGE

7.1.1 Water Quality

The Maine Department of Environmental Protection (DEP) operates the program that designates water classifications within Maine. The rivers within the DPS are either class "AA" or "A", although the classification is not always consistent throughout the entire watershed. In some cases, streams are classified lower than the waterbody into which they flow. The water quality standards for class AA waters state that habitat must be free flowing and natural and class A standards state that habitat should be natural. Permits can be issued for activities affecting the water quality of rivers and streams but the existing uses of the habitat must be maintained. The DEP and EPA issue permits for point source discharges of water pollutants into waters of Maine. Licenses issued specify effluent limitations and conditions with the goal of ensuring that water quality classification standards are attained. The fact that the rivers within the DPS are in the highest categories within the water quality classification system in the State should afford them additional protection. As described below, there are some examples of water quality problems on the rivers that warrant further investigation and action.

The Conservation Plan included a task to set up an ongoing water quality monitoring program on each river within the DPS as appropriate. DEP has conferred with the ASA, Land Use Regulatory Commission (LURC), Project SHARE (Salmon Habitat and River Enhancement), FWS, U.S. Geological Survey (USGS), and University of Maine at Orono and proposed a four part monitoring plan that began in 1998. The four parts of that plan are as follows: (1) initiate a regional low flow study; (2) provide ASA with multi-parameter data monitoring systems so that they can measure temperature, dissolved oxygen, conductivity, pH and depth while conducting population estimates at over 100 sites within the DPS; (3) collect and analyze nutrient data; and (4) analyze the impact of land use on macroinvertebrates and habitat characteristics such as sediments, temperature and other water quality parameters. Funding has not yet been secured for all portions of this monitoring plan. DEP has identified the need for a regional low flow study which would provide data to determine appropriate aquatic base flows for a number of Maine rivers. DEP also identified the lack of adequate flow information as the biggest gap in knowledge of baseline data for the salmon rivers (LWRC 1999). DEP noted that the Instream Flow Incremental Methodology (IFIM) studies ongoing would provide important information in that they will determine how much water is needed for salmon, but cautioned that they would not determine the ability of the watershed to support that flow. Secondly, the IFIM studies are specific only to the particular rivers and therefore cannot substitute for a regional low flow study.

As reported in the state's 1998 Annual Progress Report on Conservation Plan Implementation, DEP has identified sediment pollution as one of the more serious threats to stream health and developed a methodology "Assessment of In-Stream Sedimentation for Atlantic Salmon Conservation Plan" as a tool to help assess sediment pollution (LWRC 1999). DEP intends to work with the watershed councils to test the utility of this methodology (LWRC 1999). During the past year, DEP also reviewed the classification of State surface waters. The annual progress report states that several segments of water bodies within the salmon rivers will be recommended to be upgraded in assigned classification although the specific segments are not named and the process for finalizing this is not detailed (LWRC 1999). The Maine Department of Transportation (MDOT) also considers Atlantic salmon waters as extremely sensitive to impacts from erosion and sedimentation and proposes and implements controls accordingly. MDOT created an Atlantic Salmon Conservation Plan Committee to identify activities within their Department that could potentially impact Atlantic salmon and to develop strategies to avoid and minimize those impacts (LWRC 1999). The Maine Department of Agriculture, Food and Rural Resources has identified a need for an environmental toxicologist to be able to assess the potential impacts of any pesticide residues detected in the state water sampling program (LWRC 1999). Project SHARE worked with the Watershed Council Coordinator to secure a grant from DEP to correct water quality problems resulting from nonpoint source pollution. In addition, Project SHARE and the State worked together to contract with the River Watch Network for assistance in establishing a program of training volunteers in water quality monitoring and also to evaluate the organizational structure of the Watershed Councils, Project SHARE, the Downeast Salmon Federation and others involved in salmon management and habitat protection in Maine (LWRC 1999).

The EPA is currently completing an evaluation and will begin cleanup of a superfund site on the Dennys River. Site evaluation and remedial clean up is also scheduled for the Smith Junk Yard site also on the Dennys River. Both of these actions were given high priority within the Conservation Plan and are underway. Taylor (1973) measured nutrients and other water quality characteristics at two sites in the Machias River and at sites in nine other rivers, streams, and hatchery water sources. At the head of tide, the Machias River was found to have the highest concentrations of aluminum ions of all salmon rivers in the state of Maine. Waters of the Machias River were found to be acidic, with a pH in the range of 5.5-7.0 units. Similar to the East Machias River, the Machias River has a distinct water color that may be attributed to peat bogs as well as bark wastes and detritus from logging operations.

Hexazinone (velpar), a herbicide used during blueberry farming, has been detected at sites in the Narraguagus River. The herbicide was initially detected during routine sampling for an array of pesticides conducted in the spring and fall of 1991. Although the concentrations detected are low, its presence throughout the summer and fall at low flow periods suggests that it is entering the river through groundwater flow rather than storm runoff (Beland et al. 1993). Recent studies to determine the long-term changes in macroinvertebrate abundance, diversity, and taxa richness at sites in the river suggest that a deterioration in water quality has not occurred at these sites (Siebenmann and Gibbs 1994). These studies demonstrated that the river was capable of producing Atlantic salmon and the production was at a level considered normal given the adult abundance at that time. In the time since these early studies, fry abundance has increased dramatically without a commensurate increase in parr and smolt. This indicates that there may be a factor limiting production and affecting survival. Sedimentation, as identified by DEP, may be a potential cause and warrants further investigation to determine if and how it is affecting overwinter survival.

Water quality is acceptable for supporting Atlantic salmon in the Ducktrap and Sheepscot Rivers, but low flows in summer may result in high water temperatures increasing the potential for problems associated with low dissolved oxygen. Seasonal low flows limit access to spawning habitat and reduce rearing habitat which likely results in annual fluctuations in salmon production.

7.1.2 Dams and Obstructions to Migration

The construction of hydroelectric dams with either inefficient or non-existent fishways was a major cause for the decline of U.S. Atlantic salmon. In the late 1800's Atkins stated: "The disappearance of salmon from so many rivers appears to have been entirely the result of artificial causes, chief among which is the obstruction of the way to the breeding grounds by impassable dams" (1874). Ruggles (1980) identified the following unnatural conditions created by dams that can threaten anadromous salmonid populations: passage over spillways; passage through turbines; passage through impoundments; exposure to atmospheric gas saturation; exposure to pollutants, predators and disease organisms; and vulnerability to angling. Smolts are vulnerable to the impacts of dams and may become impinged or entrained on their migration downstream. Dams can alter the flow pattern of rivers, create ponds and reservoirs, increase water temperature and concentrate pollutants, all of which are factors that can adversely affect resident parr and migrating smolts (Foerster 1937; Saunders 1960).

Historical records link the decline of Atlantic salmon with the construction of dams. Kendall (1935) reported that Atlantic salmon were plentiful in the Connecticut River until 1797, when a dam was built just below the mouth of Miller's River. Kendall (1935) also reported that the Merrimack River was one of the best Atlantic salmon rivers in the United States prior to the construction of dams at Lowell and Lawrence, MA and Manchester, NH. Rounsefell and Bond (1949) state that the Atlantic salmon run in the Dennys River was almost always in peril because of dams. The presence of dams on the Narraguagus, Machias, East Machias, and Pleasant Rivers was identified in the late 1940's as a threat to the continued existence of Atlantic salmon in those rivers (Rounsefell and Bond 1949). However, historic records suggest that many of the old, low-head timber crib dams had significant leakage and were not complete barriers to fish passage. Currently, there are no hydroelectric dams on rivers that support Atlantic salmon populations in the DPS. The Machias and Dennys Rivers have natural falls that have the potential to hinder the migration of Atlantic salmon at certain flows. The Prelisting Recovery Plan included a condition for a detailed engineering study of the Machias River gorge to determine if modifications would improve fish passage. All other obstructions on these rivers have been equipped with fishways, but to date the efficiency of these fishways has not been well documented (Baum et al. 1992).

Many of these rivers have numerous beaver dams and debris dams. These dams are typically partial obstructions and are ephemeral in nature (Havey and Fletcher 1956). However, these dams have the potential to temporarily alter habitat and reduce the production of salmonids. The ASA, USFWS, and Project SHARE (Salmon Habitat and River Enhancement) document obstructions on the seven rivers and their tributaries. Selected obstructions and dams within the DPS are displayed in Figure 7.1.2. Obstructions located on rivers that provide spawning habitat are breached to facilitate access to upstream habitat. In 1995, a total of 155 beaver dams and 19 debris dams were identified and of those 138 were breached. In 1996, a total of 85 obstructions were recorded, 71 of which were beaver dams. All that were located downstream of useable spawning habitat, 74, were breached or removed at least once in October. In 1997 and 1998, there were 114 (102 beaver and 12 debris) and 137 (103 beaver and 34 debris) obstructions identified, respectively. This resulted in the alteration of 96 obstructions in 1997 and 82 in 1998 (USFWS 1999 unpublished data). In the fall of 1998, Champion International Inc., ASA and Project SHARE removed a debris blockage on the Narraguagus River that was blocking adult migration. Generally, the ASA has determined that beaver dams are not limiting to upstream migration for adult Atlantic salmon in the mainstem of the Dennys, East Machias, Machias and Narraguagus Rivers. Tributaries to the East Machias, Machias and Narraguagus Rivers contain additional spawning habitat that may be blocked by beaver dams. The combination of low water levels and beaver dams in the mainstem in 1997 could have prevented access to some spawning areas in the Pleasant and Sheepscot Rivers. Dams in tributaries of all rivers may alter habitat by blocking sediment transport and degrade water quality by raising water temperatures (ASA 1998).

Figure 7.1.2: Selected Lowermost Dams or Restrictions

In 1815, a dam was constructed at Millseat near the mouth of the Dennys River that partially obstructed the passage of Atlantic salmon (Kendall 1894). The dam was destroyed by fire in 1858, and a fishway was built when a new dam was constructed in 1860. The fishway was modified periodically and in 1898 it was rebuilt (Goodwin 1942). By 1930, obstructions to fish passage on the main stem had been removed, and by 1962, either fishways had been constructed at barriers, or barriers had been removed on all tributaries in the drainage (Beland et al. 1982). Existing habitat for salmon exceeds that which was available historically. Construction of a fishway at the falls on Cathance Stream provides fish access to upstream reaches. A water control structure installed in 1974 at Meddybemps Lake provides storage and control of releases of water during summer low flow periods. Dam repair for flow augmentation and fishway restoration or replacement is currently planned at Marion Falls, Great Works Flowage and Cathance Lake. Funding for these projects is being provided by NRCS, Project SHARE, ASF and the NFWF (LWRC 1999).

Records suggest three dams built in East Machias and Jacksonville in the 1800's resulted in a decrease in the number of salmon that returned to the river. In early years, existing fishways were inefficient, but once repaired, salmon runs were reported to increase (Atkins 1874). Dams were also constructed in the upper reaches of the river for the storage and transport of logs and these may have impeded the migration of salmon. In 1935, Kendall noted that salmon persisted in the river and that spawning occurred in Chase's Mill Stream at the outlet of Gardner Lake. Rounsefell and Bond (1949) reported that salmon were taken below the dam in East Machias each spring. They cited easy poaching, an inadequate fishway, and a large unscreened power diversion as reasons for a depressed run. Numerous beaver dams were located on Northern Stream, but juvenile salmon were found upstream from the dams indicating that fish passage was not completely obstructed (ASRSC unpublished data). Plans are currently underway to remove the East Machias dam and power station in the town of East Machias. Funding for this removal will likely come from the U.S. Department of Agriculture Natural Resource Conservation Service (USDA NRCS) through its Wildlife Habitat Incentive Program (WHIP), U.S. Army Corps of Engineers, and the National Fish and Wildlife Foundation (LWRC 1999).

Salmon populations were greatly reduced following the construction of dams in the late 18th century (Atkins 1874). Kendall (1935) reported that the number of salmon returning to the Machias River had dropped dramatically, and that dams had significantly decreased their abundance. However, salmon persisted in the river, and it was anticipated that the Machias River offered a promising chance for the development of a large run of salmon (Rounsefell and Bond 1949). Two dams in the system, Harwood and Whitneyville Dams, were breached in 1963. A third dam at Machias gorge was breached by ice and spring freshets in 1970, and since that time the river has remained free flowing, affected by no man-made obstructions (Fletcher et al. 1982). Seventy-three obstructions to fish passage have been documented; the obstructions, primarily beaver dams and log jams, have been breached or removed where possible. Beaver dams and log jams are often temporary, but if they persist, they may pose problems for salmon and adversely affect habitat by inundating riffle-pool complexes and runs. Champion also installed six arch pipes on the Machias River in 1998 at stream crossings of existing roads to improve fish passage and protect water quality (LWRC 1999).

The construction of a dam on the Pleasant River at Columbia Falls impeded the upstream migration of Atlantic salmon. Rounsefell and Bond (1949) reported that salmon production in the Pleasant River was in jeopardy because of a three meter-high dam with no fishway located at the mouth of the river in Columbia Falls. The dam was not a barrier when opened at the discretion of the owner, an action that usually occurred in late fall. North Branch Stream is the only tributary that has a major natural obstruction to upstream fish migration, a 3.7 meter high vertical ledge falls. The falls are located a short distance from the stream confluence with the Pleasant River at Columbia Falls. A bypass channel and Denil fishway were constructed at Saco Falls on the mainstem in 1955 and provided access for the salmon to additional habitat. Pleasant River Lake Dam had also been equipped with a Denil fishway to provide fish access to the lake, but by 1982 the fishway was no longer functional for sea-run salmon. A new dam was constructed in 1982 at the Old Hathaway site in Columbia Falls. The dam was 3.7 m high and was equipped with a vertical slot fishway. The dam was subsequently breached in 1989 to enhance upstream fish passage. Remnants of the Pleasant River Dam in Columbia Falls were removed in 1998 by the Downeast Salmon Federation supported financially by the USDA NRCS WHIP . The primary benefit of this removal was for sea run smelt, however it does enhance the Pleasant River ecosystem (LWRC 1999).

As early as 1874, there were five wooden dams in Cherryfield located within 1.6 km of tidewater in the Narraguagus River. The dams were used to control river flow for the operation of mills and for the storage and transport of logs. It was not until the early 1900's that the river was reopened to anadromous fish as a result of the construction of fish passage facilities at the dams in Cherryfield. In the spring of 1942, ice and high flows destroyed the dams in Cherryfield and the number of salmon returning to the river increased considerably (Rounsefell and Bond 1949). Beddington Lake Dam, located in the headwaters was the last obstruction for Atlantic salmon, and was breached in 1951. The only artificial impoundment on the system is an ice control dam located in Cherryfield. A Denil fishway was installed at the dam, but during periods of high flow salmon have been observed to swim over the spillway (Baum and Jordan 1982). Recent modifications to the dam reduced fish passage over the spillway and directed them to the ladder and trap facilities. The ASA, Army Corps of Engineers (ACOE), and Town of Cherryfield are developing plans to modify the dam to facilitate salmon management (LWRC 1999). Champion also installed three arch pipes on the Narraguagus River in 1998 at stream crossings of existing roads to improve fish passage and protect water quality (LWRC 1999).

Historical information about riverine obstructions in the Ducktrap River is limited. Wells (1869) reported that a wooden dam approximately 4 m high and located 201m from tidewater was constructed in 1852. There is no mention of the date when the dam was removed. Bryant (1956) documented 12 natural and man-made obstructions in the drainage, which included weirs, ledges, debris jams and low-head stone dams. Many obstructions were partial barriers to anadromous fish, whereas others were intermittent barriers and impassable during low flows. Rounsefell and Bond (1949) reported that in 1880 some of the most successful salmon weirs in Penobscot Bay were close to the mouth of the river in Lincolnville. They suggested that if water could be impounded during the spring, then flows could be augmented in summer, and the quantity and quality of salmon habitat improved with the expectation of increasing adult runs.

Typical of other rivers in the region, salmon populations in the Sheepscot River were adversely impacted by the construction of dams. Dams were located at Sheepscot Falls and Head Tide by the late 1800's, and they obstructed the passage of anadromous fish. Remnant runs of anadromous fish may have relied on limited spawning and nursery areas downstream from the Head Tide Dam in Alna. Bryant (1956) identified 24 obstructions in the drainage. The Head Tide Dam was opened to fish passage in 1952 and subsequently breached in 1968. A fishway was provided at Coopers Mill Dam in 1960, eliminating a significant barrier to salmon migration on the main stem (Meister 1982). All historic Atlantic salmon habitat is currently accessible. The dam at Coopers Mills is currently leaking which causes the fishway to be inoperable. The NRCS, ACOE, ASA, DMR and Town of Coopers' Mills are working together to design a plan and secure funding for removal of this dam or rehabilitation of the fishway and restoration of upstream habitat (LWRC 1999). Investigations are also ongoing into the potential removal or breaching of a dam at the head of tide on the Sheepscot River (LWRC 1999).

7.1.3 Agricultural practices

Agricultural products grown in the Gulf of Maine DPS include the following: hay, silage corn, livestock (horses, dairy cows, beef cattle, sheep), Christmas trees, market vegetables, blueberries, cranberries, landscape and horticultural plants (Conservation Plan 1997). The primary form of agriculture in the Dennys, East Machias, Machias, Pleasant and Narraguagus Rivers is blueberry culture. Livestock production is the dominant form of agriculture in the Sheepscot River watershed.

Agricultural practices have the potential to destroy, modify or alter habitat of importance to the Gulf of Maine DPS of Atlantic salmon. Normal farming practices are exempt from Wetland Alterations permit requirements under the Maine Natural Resources Protection Act (NRPA). Exemptions such as these for agricultural practices may not adequately protect the riparian zone and could lead to negative impacts on Atlantic salmon and their habitat. Pumping sites and water withdrawals are regulated by two agencies within the State of Maine. The Land Use Regulatory Commission (LURC) regulates these activities in unorganized towns and the Department of Environmental Protection (DEP) regulates them in organized towns. In order to obtain a permit to withdraw water from a waterway, an applicant must demonstrate that the withdrawal (volume, timing and rate of withdrawal) will not adversely affect existing uses and natural resources. Water quality and quantity can be affected by the withdrawal of water for irrigation, the discharge of process water, the input of pesticides, and the input of nutrients and sediment. Adequate water flow is critical to all life stages of Atlantic salmon, spawning, egg survival, fry emergence, juvenile survival, and smolt emigration. Currently, water withdrawals pose a threat to Atlantic salmon and their habitat in the Machias, Pleasant and Narraguagus Rivers. This threat, if unregulated, is likely to grow in the future based on industry projections of expansion of berry production and processing. As reported in the Conservation Plan, approximately 6,000 acres of blueberries are irrigated annually. The blueberry industry plans to double production by the year 2005. Current cranberry production is limited to less than 100 acres; however, there are plans to significantly increase production over the next five years.

Farming practices can also result in the discharge of nutrients, sediments and/or pesticides which could lead to habitat degradation and ultimately affect survival and recovery of Atlantic salmon. One of the most obvious and immediate impacts of sediment discharge in rivers is the filling of spaces between gravel and cobble, greatly reducing the value of the habitat for spawning and decreasing survival of early life stages.

The Conservation Plan identifies the following pesticides used on blueberries in Maine: herbicides include fluazifo-P, glyphosate, Hexazinone, Sethoxidm, Terbacil, 2,4-D Ester; insecticides include Azinophos-Methyls Sniper 2E, Javeline, Carbaryl, Diazinon, Malathion, Methoxychlor, and Phosmet; and fungicides include Benomyl, Captan, Captec and Triflorine. The Board of Pesticides Control (BPC) regulates the disposal, storage and application of pesticides in Maine. The BPC has the authority to designate areas where pesticide use is restricted to protect the health, welfare and the environment. The only areas currently designated are the Deblois Fish Hatchery and one section of the Dennys River. In setting levels of application, the LC50 is used which is the level that would be lethal to 50% of a sample population over a given period of time. Exposure at critical life stages such as fry emergence and smoltification has not been fully investigated. Further, the effects of chronic exposure to one or a number of these pesticides are largely unknown and need further study.

Lowbush blueberry agriculture is an important land use in eastern Maine watersheds. Water extraction and diversion associated with the production of blueberries and other agricultural products can make habitat unsuitable for Atlantic salmon. The herbicide hexazinone (velpar) is typically applied to blueberry fields prior to budding to eliminate competing vegetation. Fungicides are applied to prevent disease and a variety of insecticides are applied to kill pests. Extensive chemical spraying can cause immediate mortalities to juvenile Atlantic salmon or can have indirect effects when chemicals enter waterways. The chemicals also may cause mortalities of aquatic insects that contribute to the food base of salmon. Habitat studies conducted by the ASRSC have documented the repeated presence of hexazinone in the Narraguagus and Pleasant Rivers (ASRSC unpublished data). The impacts of hexazinone on Atlantic salmon in these rivers are uncertain at this time. Numerous measures are implemented to reduce the potential for contamination of waterways from blueberry agriculture. Measures include the maintenance of vegetation throughout the year to reduce erosion and sedimentation and the maintenance of riparian buffers to protect streams.

Best management practices (BMPs) have been developed, and farmers are encouraged to voluntarily adopt these to minimize nonpoint source pollution. The State has also worked with farmers to encourage the adoption of Integrated Crop Management that includes Integrated Pest Management. Maine has developed a Generic State Management Plan for Pesticides and Ground Water, a Strategy for Managing Nonpoint Source Pollution from Agricultural Sources and Best Management System Guidelines, and a Coast Nonpoint Source Control Program. These programs address sediments, nutrients, pesticides, manure, grazing management, and wastewater from confined animal facilities as potential pollutants. There is a mandatory compliance provision of the nonpoint source pollution program. Complaints can be submitted to the Maine Department of Agriculture, Food and Rural Resources (DAFRR). In response, the DAFRR investigates complaints and recommends site-specific BMPs. Failure by a farmer to adopt the BMPs can result in the case being referred to DEP for enforcement under the Water Discharge Law.

The DEP permits discharges into Maine waterways. In order to obtain a permit, an applicant must demonstrate that the discharge will not lower the water quality classification of the receiving waterbody. As reported in the Conservation Plan, there are two berry processing plants on the Narraguagus and one on the Machias all of which discharge directly into the river. The volume of agricultural process water discharged to the Narraguagus River is allowed to reach 627,000 gallons per day, up to 100,000 gallons per day is allowed to attain a discharge temperature of 26o C. Water temperatures in the vicinity of the discharge have not been monitored. Up to 70,000 gallons per day of agricultural process water is allowed to be discharged into the Machias River with a maximum temperature of 32o C. Although this temperature is, as reported in the Conservation Plan, lethal to both juveniles and adults, no monitoring of the effect on the river temperature and on Atlantic salmon has been conducted. Reports from ASA staff indicate that elevated water temperatures could affect habitat in some rivers within the DPS (Beland et al. 1995; Horton et al. 1995). Specifically, available data indicates that high water temperature may be a problem in some years in Cathance Stream in the Dennys River, and certain sections of the mainstem East Machias (ASA 1997).

The Conservation Plan identified the following actions addressing threats to salmon: (1) integrated crop management and best management practices for blueberry and cranberry production; (2) non-point source pollution program and Coastal Zone Management program; (3) the Generic State Management Plan for Pesticides and Ground Water and the Hexazinone State

Management Plan for Protection of Ground Water; (4) Soil and Water Conservation Districts? technical assistance to farmers; and the (5) cooperative relationship between Department of Environmental Protection, Land Use Regulation Commission and Worcester Peat Company, the owner of the Denbo Heath Peat Mine. Actions proposed for enhanced protection from agriculture include the following: (1) develop and implement Total Water Use Management Plans for each watershed; (2) develop a watershed specific non-point source program for the Sheepscot River; (3) target integrated crop management (ICM) education programs and promote use of BMPs; (4) identify for protection wetlands with functions that are important for maintaining the integrity of Atlantic salmon habitat; (5) enhance Board of Pesticide Control programs that evaluate and mitigate the threats to Atlantic salmon associated with pesticide use; (6) improve the permit review process and standards for erosion control for Peat Mines; and (7) evaluate the threat to Atlantic salmon from water quality changes associated with peat mining.

The Conservation Plan recommended increased attention to best management and integrated crop management programs in the salmon watersheds. Further, it was stated that a watershed-specific nonpoint source pollution plan was being drafted by the State for the Sheepscot River watershed. It was suggested that a survey should be conducted on embeddedness and that a sedimentation monitoring program should be established to determine the effectiveness of BMPs in restoring or maintaining productive Atlantic salmon habitat. A need for an additional $30,000 a year was identified in order to develop a targeted non-point source pollution program for the Sheepscot. The Conservation Plan suggested that the BPC consult with other state agencies in order to identify resources for an environmental toxicologist. Further, it was suggested that a systematic review be conducted of all pesticides used in the salmon watersheds (aquatic risk assessment) and that a monitoring program be established. It was also suggested that BMPs be developed for all the pesticides used in the watersheds and that these be updated annually.

The Conservation Plan concluded that there is sufficient annual flow in the rivers to support the needs of Atlantic salmon and the agricultural industry and therefore characterizes the problem not as a water shortage problem but rather a water management challenge. That challenge emerged as a major issue to be dealt with during the first year of Conservation Plan implementation. In 1998, the LWRC established a workgroup to review a request to withdraw water from the Pleasant River and recommend a limit on that withdrawal. The workgroup, composed of representatives from state and federal agencies, recommended that permit conditions be based on individual monthly median flows. The LURC subsequently issued a permit for direct water withdrawal from the Pleasant River by Cherryfield Foods with a condition that withdrawal would cease if water levels reached 23 cfs. This level was reached in 1998 and pumping ceased. The permit that was issued was for only one year as it was hoped that a water use management plan for the Pleasant River would be completed in time for the 1999 summer/fall season. The State contracted with a consulting firm to gather and analyze the technical data necessary to set minimum flow requirements for Atlantic salmon at all life stages and seasons in the Machias, Pleasant and Narraguagus Rivers. A steering committee has been formed to review that material and design a water use management strategy. The work of that steering committee will not be completed prior to the 1999 summer/fall season so it is not clear at this time how permit conditions will be drafted. Rules to address water withdrawals on a statewide basis are currently being developed by the DEP.

The annual report on Conservation Plan implementation reported the following actions related to agricultural practices: (1) establishment of an enforceable limit on water withdrawals from the Pleasant River in the summer/fall 1998; (2) acquiring data and creating steering committees to draft water management plans for the Machias, Pleasant and Narraguagus Rivers; (3) drafting of rules to address water withdrawals on a statewide basis by the DEP; (4) Maine Cranberry Growers Association providing low cost consultation to growers interested in expanding cranberry beds and including design considerations to protect Atlantic salmon habitat; and (5) the preparation of a sediment methodology by DEP for watershed councils to measure sedimentation in their river. The USDA-NRCS provided funding in 1998 through its Environmental Quality Incentive Program (EQIP) to encourage integrated crop management for blueberries, forest erosion control and animal waste management. In FY98, the Sheepscot River Watershed was designated as a priority area for EQIP, and as a result, over $100,000 was allocated to 19 projects in the watershed focusing on nonpoint source pollution reduction from animal wastes and erosion reduction on agricultural lands and streambanks (LWRC 1999).

Lands in the Dennys, East Machias, Machias, Pleasant and Narraguagus River watersheds are managed for the production of lowbush blueberries that may result in point and non-point source pollution. Insecticides, herbicides, and preservative chemicals used in agricultural activities, water withdrawals and discharges have the potential to adversely impact salmon. Habitat studies conducted by the ASRSC have documented the repeated presence of hexazinone in the Narraguagus and Pleasant Rivers (ASRSC unpublished data). It is unknown whether chronic exposure to these background levels would adversely affect Atlantic salmon. A permit was issued in 1997 to Cherryfield Foods for development of a cranberry bog project in the Pleasant River watershed. In 1998, violations under the Natural Resources Protection Act occurred and following site reviews and assessments, the DEP and Cherryfield Foods ultimately entered into a Consent Agreement, which specified action to correct the violation.

Agriculture is most prevalent in the Sheepscot River watershed. The Sheepscot Valley Conservation Association (SVCA) has detected bacterial contamination in the river, the ASA has noted elevated water temperatures in some years, and the Sheepscot River Watershed Council, DEP and the Soil and Water Conservation District have worked with farmers to keep livestock out of the river. During 1998, the DEP provided technical assistance to the SVCA to conduct volunteer watershed surveys to identify significant sources of nonpoint source pollution in a portion of the West Branch of the Sheepscot River. DEP also provided technical and financial support to Knox-Lincoln County Soil and Water Conservation District for a project demonstrating four different livestock exclusion / alternative watering facility types and methods of revegetating riparian areas where livestock previously had free access to the Sheepscot River. Funds were also provided by DEP to the SVCA to establish conservation easements to protect riparian areas and to facilitate implementation of BMPs at sites previously prioritized during watershed surveys in 1996 and 1997. The DEP sends all applications for sludge spreading in the Sheepscot River watershed to the ASA for review and comment. The Conservation Plan stated that a land-use oriented watershed specific non-point source management program would be developed for the Sheepscot River. The program was to include the following components: (1) refinement and publication of BMPs specifically developed for Atlantic salmon; (2) monitoring of ground water and rivers for nutrients, pesticides and bacteria; (3) an on-site survey of farmers to determine the percentage adopting BMPs; and (4) an educational and technical assistance program to assist farmers in adopting BMPs. In the annual progress report, the Maine Department of Agriculture, Food, and Rural Resources, reported that funding was not available for many of these activities and that the Department needed a position dedicated to this effort with additional funding for monitoring and surveys (LWRC 1999).

7.1.4 Forestry

One of the predominant land uses of central and northern coastal Maine watersheds is the growth and harvest of forest products. These practices have short and long term impacts that may adversely affect Atlantic salmon. The Report of the Commission to Study Atlantic Salmon (Harrington 1946) stated that deforestation had destroyed the water retention of watersheds resulting in inadequate river flows. Other potential impacts from forestry may include an increase in water temperature due to the removal of vegetation along streambanks and the introduction of large amounts of woody debris and silt into waterways. Poor logging practices and road construction can cause erosion resulting in the deposition of silt and sediment in habitat occupied by juvenile Atlantic salmon. Poorly placed or ill-designed culverts placed as part of road construction can negatively impact access to habitat. Clear cutting of large areas can alter the hydrologic characteristics of watersheds and result in greater seasonal and daily variation in stream discharge. In addition, herbicides that are used to suppress vegetative competitors can negatively impact aquatic and riparian vegetation.

Forestry is the dominant land use in the watersheds of the Dennys, East Machias, Machias, Pleasant and Narraguagus Rivers. The Conservation Plan reports that Champion International Corporation owns approximately 433,000 acres within the five eastern river watersheds. Georgia Pacific Corporation owns a large amount of land in the Dennys and East Machias watersheds. Timber harvest in the Ducktrap and Sheepscot Rivers is conducted primarily by smaller wood lot owners. Champion International Corporation developed and has implemented a riparian zone management program that exceeds state and federal regulations as part of its Stewardship and Sustainability Initiative in the Northeast. The Champion policy recognizes the wildlife diversity of riparian zones and strives to protect water quality and accommodate the needs of wildlife. A 100-foot-wide protection zone is established for both sides of first and second order streams. A 330-foot-wide protection zone is established for both sides of third-order streams and a 660-foot wide protection zone is established for both sides of fourth- and fifth-order streams.

The Conservation Plan noted that forest practices have the potential to affect Atlantic salmon habitat by producing non-point source pollution, altering stream temperatures and hydrology, directly disturbing habitat, blocking fish passage with poorly designed road crossings, or depositing woody debris in streams. The Conservation Plan identifies the following initiatives addressing threats from forestry practices: Project SHARE, Sustainable Forestry Initiative, Riparian Management Zones imposed by Champion, Maine Non-point Source Management Program, Code Enforcement Training and local shoreland zoning technical assistance, Sheepscot Valley Conservation Association, and Ducktrap River Coalition. Additional actions proposed in the Conservation Plan for enhanced protection include the following: implement best management practices to control non-point source pollution, protect important habitat through landowner agreements, maintain shade, and monitor pesticide use.

The Conservation Plan contained a goal of assuring that 80% of harvesters would use forestry BMPs by 1999. The exact number and percentage of foresters using BMPs is not available at this time, but an effort was made in 1998 to assign field foresters to train and assist watershed councils on BMPs, work with code enforcement officers, and consider the Plan in harvest site reviews. The Maine Department of Conservation initiated monitoring of forestry BMPs in the Dennys, East Machias, Machias, Pleasant and Narraguagus River watersheds (LWRC 1999). The Conservation Plan also included a goal of correcting 80% of the shore land zone harvesting violations by December 1999. The Maine DEP has recommended that benchmark be changed to a commitment to increase oversight of compliance of shoreland harvesting restrictions by providing additional training and increasing the number of code enforcement officers (LWRC 1999). During the first year of Conservation Plan implementation, numerous training workshops on proper forestry BMPs were conducted for foresters working in the DPS watersheds. In addition, DEP has established a new requirement, beginning in January 1999, that town enforcement officers of each town within the seven watersheds report annually to the DEP on shoreland zoning activity.

A recent study conducted by the Canadian Department of Fisheries and Oceans and Environment Canada identified a relationship between chemical use and salmon survival. The insecticide Metacil(1.8D was applied to forests in Atlantic Canada between 1975 and 1985 to control the spruce budworm (Choristoneura fumiferana). One of the insecticides sprayed during that time, Matacil(1.8D, is known to contain a high concentration of 4-nonylphenol (4-NP) which is an endocrine disrupting chemical. Estimated concentrations of 4-NP in water fell within a range where effects on fish might be anticipated. Spraying was timed to coincide with the development of the spruce budworm larvae which is also the time of the critical parr-smolt transformation for Atlantic salmon. The Canadian study confirmed that nonylphenol concentrations can interfere with the smoltification process, preventing some fish from successfully making the transition from fresh to salt water. These studies have direct application to the United States as similar insecticides were used in Maine to combat spruce budworm. Also, if it is the estrogen potential of 4-NP that is causing disruption of smoltification, then other endocrine disrupting chemicals in the environment must be examined for their effect. The researchers speculated that the effects of Matacil(1.8D could range from an altered chemical perception of home stream odor to direct or indirect effects on smolt growth or hypo-osmoregulatory ability. Although Metacil(1.8D is no longer used, current potential sources of 4-NP include pulp and paper mills, textile manufacturing plants, petroleum production and leather manufacturing. The USGS-BRD is conducting studies on Maine Atlantic salmon for detection of endocrine disrupters (Fairchild et al. 1998).

Lands in the Dennys, East Machias, Machias, Pleasant and Narraguagus River watersheds are managed for the production of forest products. Large scale land alteration has occurred from logging operations and there is use of pesticides and herbicides by forest products industries. Deforestation, road construction, water withdrawals, and chemical applications have the potential to adversely affect salmon in the watershed. A four hectare bark dump in Whitneyville, the product of pulp debarking during the period 1949-1969, may continue to alter the chemistry of waters in the lower Machias River by leaching tannin and lignin products (Fletcher et al. 1982). Further investigation is warranted to determine the effect on salmon.

Timber harvesting in the Sheepscot and Ducktrap River watersheds is conducted by smaller woodlot owners. There is some evidence in the Sheepscot River watersheds of woody debris from logging and the forest products industry. Aerial spraying to control insect infestations has occurred periodically throughout the years in these watersheds, and pesticides could enter the aquatic environment if not properly applied.

7.1.5 Peat mining

Many eastern Maine river watersheds hold deposits of peat. There is one peat mine in the Narraguagus River watershed in Deblois at Denbo Heath. There has been interest expressed in opening a new mine on Brandy Heath in the Machias River watershed. The LURC regulates peat mines in unorganized towns and the DEP regulates peat mines in organized towns. The Denbo Heath is located between the West Branch and the mainstem Narraguagus and can therefore affect habitat in both reaches. Atlantic salmon and their habitat in the Narraguagus River could be negatively impacted by peat mining in that watershed through the discharge of low pH water containing suspended peat silt and dissolved metals and pesticides. Farm Pond and McCoy Brook trap sediment before it reaches the mainstem Narraguagus River; however, sedimentation has been found in both the West Branch and the mainstem Narraguagus River. From 1990 to 1993, the ASA conducted an extensive pH monitoring program in the Narraguagus River drainage and the Pleasant River, which has peat bogs that are not mined (Beland et al. 1993; Beland et al. 1994). The ASA found that both the mined Denbo Heath on the Narraguagus and the unmined Great Heath on the Pleasant River have locally depressed pH. While conducting habitat studies on the Narraguagus River, the ASRSC discovered the repeated occurrence of pH below 5.0 on the West Branch, a factor that suggests the potential for negative effects upon juvenile salmon abundance. Fluctuations in the pH level of freshwater environments have been identified as a limiting factor for Atlantic salmon (Peterson et al. 1980). As part of the studies, juvenile abundance was found to be lower in the West Branch than elsewhere in the Narraguagus River.

Six sedimentation basins were built during the winter of 1995 in an attempt to curb peat laden discharges from disturbed areas of Denbo Heath. A water quality monitoring program at Denbo Heath indicates that runoff from this area is 1-2 pH units lower than the Narraguagus River into which it flows. Partial failures of the new sedimentation basins were reported in the spring of 1996 and 1997 after which further corrections were made to the sedimentation ponds and collection systems. No berm failures, water quality or other problems were observed in 1998 (LWRC 1999).

Action items identified in the Conservation Plan included the development of guidelines for peat mining permit application reviews by LURC and DEP staff. Secondly, it was suggested that a team of qualified engineers and/or erosion control specialists review the literature, evaluate erosion control methods used at peat mines, and develop and/or revise standards to be included as permit conditions. The annual progress report on Conservation Plan implementation in 1998 states that staff from the Department of Inland Fisheries and Wildlife will be convening a group of state agencies to consider the issues surrounding sediment control from commercial peat mining operations. The last permit issued by the State for peat operations was issued in 1977. The Maine DEP recommended that the goal contained in the Conservation Plan of improving permit review and required standards be modified to maintain compliance with existing mining permits which would be implemented by conducting annual inspections of each facility and including the results in the annual progress report on Conservation Plan implementation (LWRC 1999).

7.1.6 Habitat Protection within the DPS

Watershed Councils: The Conservation Plan creates a very important role for watershed councils in protecting, enhancing and rehabilitating habitat within the DPS for Atlantic salmon. With financial assistance from the State and support from Project SHARE and ASF, Watershed Councils have formed on rivers within the DPS and are emerging as powerful local stewards of the resource. Much of the first year was spent organizing the Councils and establishing a purpose and plan of action for those Councils. State funding was provided for a Watershed Council coordinator who is working cooperatively with Project SHARE to assist in the formation and operation of the Watershed Councils in Washington County. A Downeast Rivers Coalition was formed to serve as a steering committee among the Dennys, East Machias, Machias, Narraguagus, and Pleasant Rivers. The purpose of the Coalition is to provide opportunities for communication and coordination among the watershed councils and assist with many of the administrative tasks that tend to stall progress of small groups such as grant writing and computer support.

Watershed Councils have been formed on the Dennys, East Machias, Machias, Pleasant, and Narraguagus Rivers. All five councils have adopted bylaws and Boards have been established for Dennys and Pleasant River Watershed Councils and are in the process of being developed for the East Machias, Machias and Narraguagus River watersheds. Actions being undertaken by all five of these watersheds include the following: participating in water use planning committees; impact assessment of forestry and other land uses on salmon habitat; and removal of beaver dams to facilitate salmon access to habitat (LWRC 1999). Watershed Councils on the Sheepscot and Ducktrap Rivers grew out of existing coalitions and therefore avoided many of the initial stumbling blocks the other five Councils faced.

The Pleasant River Watershed Council has formed, elected officers, passed bylaws, completed administrative organizational tasks, and expanded its Board of Directors during 1998. Actions of the Pleasant River Watershed Council during 1998 included the following: collection of water quality baseline data; requested pesticide water analysis by the Board of Pesticide Control; supported the construction of a fish weir on the Pleasant River; easement and buffer protection for a canoe landing on the Pleasant River; and cooperated with other Watershed Councils and organizations to build and place educational kiosks on the rivers.

The Ducktrap Coalition serves as the watershed council for the Ducktrap River watershed. The Ducktrap Coalition is responsible for administration of the watershed council activities and one of its member organizations, Coastal Mountains Land Trust, coordinates administrative tasks for the Coalition. During 1998, the Ducktrap Coalition conducted the following activities: assessed riparian buffer areas and water quality conditions; began plans for an assessment of the status of vegetative cover of the riparian zone of the Ducktrap River using aerial photography and site surveys; identified a source of silt, sand and gravel discharge to the Ducktrap River (this property was purchased by the Trust and a corrective action plan for that site has been designed and is being implemented); and development and implementation of a plan for permanent conservation protection of the riparian area of the Ducktrap River, working cooperatively with landowners and using both conservation easements and fee simple acquisitions (LWRC 1999).

The Sheepscot River Watershed Council was able to build on the history of the Sheepscot Valley Conservation Association and get an early start by forming during the development of the Maine Conservation Plan. It identified the following critical information needs within the watershed: a survey of agricultural land use; a survey of nonpoint source pollution in the watershed; a survey of riparian buffers along the river and stream corridors in the watershed; and a survey of stream segments in the watershed which lack adequate canopy cover. The Council has secured funding for a watershed coordinator, installation of BMPs for nonpoint source pollution (primarily agricultural sources), salmon habitat protection activities, and the purchase of property adjacent to critical spawning, rearing and adult holding habitat on the West Branch and mainstem Sheepscot River. The Council has initiated a nonpoint source program by conducting a survey of the watershed to identify problem areas. The Sheepscot River Watershed Council has facilitated remediation on a few sites but identified the following limitations on remediation and installation of BMPs: willingness of landowners to adopt BMPs, availability of funding to pay for BMPs, and availability of staff and volunteer time to identify, design and implement appropriate action strategies. The Watershed Council has identified expanded participation by state agencies in the activities of the Council as a priority task.

Watershed Councils on the Narraguagus, Machias, East Machias and Dennys Rivers have also been formed and adopted bylaws and are at various stages of development.

In 1994, Project SHARE (Salmon Habitat and River Enhancement) was created by landowners, businesses, government officials, researchers, educators and conservation organizations to conserve and enhance Atlantic salmon habitat and populations in Downeast Maine. Over the past five years, Project SHARE has led, funded and participated in a number of projects to increase understanding of Atlantic salmon habitat and to improve access to and the quality of habitat. Meetings of Project SHARE are held every other month to provide presentations of current information on Atlantic salmon and their habitat and also to provide opportunities for open discussions of ways to protect and enhance salmon habitat for the Dennys, East Machias, Machias, Pleasant and Narraguagus River watersheds. A key objective in the Conservation Plan is the identification of critical habitat for Atlantic salmon and the protection of that habitat. Conservation easements and land acquisitions have been secured for some of this habitat although the priority and strategy varies among watersheds. Progress in protecting habitat within the DPS is displayed in the table below (Table 7.1.6). Habitat is considered "protected" if a management agreement or conservation easement is in place, or if it is directly owned by an organization that has secured it for the purpose of habitat protection.

Table 7.1.6: Riparian Habitat Protection

RIVER	Riparian Habitat Adjacent to Spawning Habitat (linear meters)				Riparian Habitat Adjacent to Rearing Habitat (linear meters)		
	Total Amount	Amount Protected	% Protected		Total Amount	Amount Protected	% Protected
Dennys	12,756	306	2.4%		31,572	1,705	5.4%

East Machias	13,156	0	0%		39,892	3,231	8.1%
Machias	25,044	1,653	6.6%		71,798	2,298	3.2%
Pleasant	6,688	0	0%		21,508	215	1.0%
Narraguagus	24,754	248	1.0%		95,644	574	0.6%
Ducktrap	7,424	4,484	60.4%		14,798	6,644	44.9%
Sheepscot	16,212	276	1.7%		36,096	1,263	3.5%

Although the amount of habitat currently being protected appears low, there has been considerable progress made in the last year through a variety of sources, such as the watershed councils and grants, and the mechanisms are in place to protect more habitat.

The State Planning Office (SPO) contracted with a private consultant during 1998 to prepare a scientific riparian buffer methodology that could be used to determine the appropriate size of a buffer to protect salmon habitat. The methodology incorporates information about local conditions such as soil type, slope, and vegetation to tailor the size of the buffer to the habitat conditions. The goal is to be able to use the methodology when working with landowners to secure long term protection agreements. The SPO has also prepared a database of riparian landowners (LWRC 1999).

7.1.7 Other Habitat Issues

The January 1, 1947, Report of the Commission to Study Atlantic Salmon documented that the resource had been depleted by dams, deforestation, pollution, overfishing, water diversions, and drought. In the Strategic Plan for Management of Atlantic Salmon in the State of Maine (1984), Beland reported that: "As colonization and development accelerated during the 17th and 18th centuries, the salmon habitat was degraded, destroyed, and/or made inaccessible. By 1947, less than 10% of the original habitat remained accessible to Atlantic salmon." The substrate and water quality of a river or stream must meet certain criteria in order for it to be suitable as Atlantic salmon spawning and nursery habitat. Specific conditions are discussed in detail in Section 3.0. The egg, alevin, fry, and parr stages of Atlantic salmon are especially sensitive to impacts associated with watershed development. During smoltification, salmon are particularly vulnerable. Potential impacts to habitat quality include alterations in water temperature, reductions in dissolved oxygen, the introduction of pollutants and sediment, and other factors that may alter substrate or river discharge. Water temperature can be impacted by introductions of heated effluent, reductions in riparian vegetation, or by impounding water. Water quality can also be affected by the introduction of chemicals such as chlorine added during sewage treatment, metals discharged with industrial effluent and herbicides and pesticides used in agriculture. The level of dissolved oxygen in water is reduced when biological activity increases to digest organic matter. Sources of organic matter could be domestic sewage, industrial waste, or livestock waste. Elson (1975) reported that growth and development of Atlantic salmon require dissolved oxygen concentrations of at least 6 mg/l. Respiration of adult Atlantic salmon is depressed at dissolved oxygen levels less than 5 mg/l (Kazokou and Khalyapina 1981).

Habitat may also be made unsuitable for Atlantic salmon by acid precipitation. Salmon streams in New England typically lack sufficient buffering capacity and therefore are sensitive to acid rain (USFWS 1989). Acid precipitation, either in the form of rain or melting snow, can decrease the pH of a river or stream below the 4.7 level that could affect successful reproduction (USFWS 1989). Low pH (<5.0) has been demonstrated to cause pathological changes in Atlantic salmon eggs (Peterson et al. 1982; Haines 1981). Depressed pH levels (<4.7) have prevented salmon reproduction in several streams in Nova Scotia (Watt et al. 1983). Low pH has also been demonstrated to hinder the salmon's ability to transition from fresh to saltwater (McGee in press).

Erosion and watershed development can contribute sediment to the riverbed thus embedding particulate in gravel and making it unsuitable as spawning habitat. The overall productivity of the stream can be impacted by increased turbidity in the water column. Fry and parr find shelter in the interstitial spaces provided by gravel and cobble; sediments can clog spaces and, consequently, decrease survival and limit production at these critical life stages (McCrimmon 1954).

7.1.8 Summary of Habitat Issues

Demonstrated and potential impacts to Atlantic salmon habitat within the DPS watersheds result from the following causes: (1) water extraction; (2) sedimentation; (3) obstructions to passage caused by beaver and debris dams, poorly designed road crossings, and dams; (4) input of nutrients; (5) chronic exposure to insecticides, herbicides, fungicides, and pesticides (in particular, those used to control spruce budworm); (6) elevated water temperatures from processing water discharges; and (7) removal of vegetation along streambanks. The most obvious and immediate threat is posed by water extraction. Work is underway to address that threat through the creation of water use management plans and the promulgation of regulations by DEP to control extractions. Until those processes are completed, however, the threat of excessive or unregulated withdrawal remains.

The threat of blocked passage due to debris or beaver dams is an annual one and the ASA, Project SHARE, and the Watershed Councils have demonstrated an ability to annually remove or reduce that threat. Impacts from chronic exposure to chemical residues in the water are a potential threat and one that warrants further investigation. In particular, potential impacts during the process of smoltification should be examined. Sedimentation from a variety of sources also warrants closer review as it may be altering habitat and rendering it incapable of supporting Atlantic salmon. Water temperatures in the vicinity of processing water discharges should be monitored to determine if they make habitat unsuitable for Atlantic salmon. Permitting exemptions for agriculture should evaluated to determine if they are or could result in inadequate protection of riparian habitat.

All of these potential impacts to Atlantic salmon habitat need to be examined in more detail for their individual and cumulative impacts. Study results on the Narraguagus River demonstrate that full freshwater production is not being achieved despite fry stocking efforts. These results could mean that one or a combination of factors within the rivers is negatively impacting freshwater habitat for Atlantic salmon. The relationship between these factors and freshwater production and survival of salmon needs to be studied in detail so that cause and effect connections can be determined or ruled out. Corrective actions can then be implemented as appropriate to enhance recovery.

Although there does not appear to be one particular habitat issue which poses a significant threat by itself, the cumulative impacts from habitat degradation discussed above may reduce habitat quality and limit habitat quantity available to salmon within the DPS at various stages in their life history within freshwater. Given current low levels of abundance, it is critical that efforts be undertaken to better understand, avoid, minimize and mitigate these factors.

7.2 OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC, OR EDUCATIONAL PURPOSES

7.2.1 Foreign Interceptory Fisheries

Atlantic salmon smolts leave their natal rivers in New England in the spring and begin their extensive ocean migration. The migration brings them into Newfoundland waters in the spring, along the Labrador and Greenland coasts in summer, and on what is believed to be a return migration back into Newfoundland waters by early fall. After their first winter in the ocean, North American Atlantic salmon stocks have historically been the target of marine fisheries in the Labrador Sea-West Greenland and Atlantic Canada regions (M ller Jensen 1986; O'Connell et al. 1992). The historical sea-age composition of the West Greenland catch has averaged approximately 93.5% 1SW fish, 5.8% 2SW fish, and less than 1% post-smolts (M ller Jensen 1986). From 1994 to 1998, the sea-age composition of North American fish has averaged 96.1% 1 SW fish, 2.0% 2SW fish, and 1.9% previous spawners (ICES NASWG 1999). Tagging evidence indicates that U.S. origin Atlantic salmon occur in the West Greenland fishery primarily as 1SW fish (ICES-NASWG 1993).

The fisheries in Canada, primarily those along the North Shore of Newfoundland and Labrador, also harvested 1SW Atlantic salmon of U.S. origin (ICES-NASWG 1996). In addition, a fraction of the U.S. stock were also vulnerable to exploitation by fisheries in Newfoundland, Labrador and Greenland as 2SW fish; it is believed that these fish represent those destined to mature after three sea-winters (Rago et al. 1993). This likely impacts only a small fraction of the U.S. stock since the majority of the MSW fish have returned to the rivers or the nearshore areas around the rivers by the time these fisheries are prosecuted in the spring and summer. Movements of older Atlantic salmon are thought to be directed around feeding areas in the Labrador Sea and off the coasts of West Greenland and Canada during the growing season and in the southern Labrador Sea during the winter (Friedland et al. 1993). Commercial fisheries in Newfoundland have been closed since 1992 and fisheries in Labrador were closed in 1998. Some Aboriginal food fisheries still exist in Newfoundland, Labrador and Quebec, but these fisheries target local stocks and do not intercept U.S. origin salmon at sea.

Because salmon caught in interception fisheries have been at sea from 12-15 months at the time of their capture, most of the natural mortality that impacts a particular year-class of smolts has occurred earlier in the life cycle. It is therefore generally accepted that the majority of salmon harvested by interception fisheries would have survived to return to their home waters had they not been captured (Beland 1984, ICES-NASWG 1999). The marine exploitation of U.S. stocks of Atlantic salmon occurs almost exclusively in foreign fisheries (Chadwick 1993).

The general distribution of U.S. origin Atlantic salmon in marine fisheries has been assessed through the use of Carlin tags and Coded Wire Tags (CWT) (Meister 1984; ICES-NASWG

1993). Through the nearly 30-year tagging record, it has been determined that U.S. origin Atlantic salmon are caught primarily by fisheries operating out of West Greenland and the Atlantic provinces of Canada (Labrador, New Brunswick, Newfoundland, and Nova Scotia). Meister (1984) reported that 53% of returns from 1SW or older Atlantic salmon tagged in Maine from 1963 to 1984 came from West Greenland, while 47% were captured in Canada. Of those tags recovered in Canada, Newfoundland accounted for 73% of tag returns, Labrador 19%, and Nova Scotia 7%. Of the relatively low numbers of post-smolt Atlantic salmon recovered, most came from Nova Scotia (88%), with the balance coming from Newfoundland (6%) and New Brunswick (5%). Recent assessments by the ICES-NASWG have taken a more analytical approach to analyses of these fisheries to allow improved harvest estimates (ICES-NASWG 1999). The historic catch and current status of these fisheries is described by country in the following sections.

7.2.1.1 The West Greenland Fishery

The modern era of the Greenland fishery began in the 1950's, experienced rapid growth during the 1960's, and peaked in 1971 with a total catch of 2,689 mt (M ller Jensen 1986). Almost all of the historic catch comes from the West Greenland fishery, with the East Greenland fishery accounting for 0.4% of catches from 1977 to 1998 (ICES NASWG 1999). Since 1972, this fishery has been managed under a quota system. The initial quota was set at 1,100 mt in 1972 and increased to 1,265 mt in 1981 and then gradually decreased to 840 mt by 1991. However, reported catches were well below the quotas after 1989; the fleet was unable to harvest the quotas from depleted stocks (M ller Jensen 1984).

Private organizations purchased the allocated quotas in 1993 and 1994 (89 and 137 mt, respectively), resulting in a suspension of the fishery. An agreement could not be reached in the West Greenland Commission in 1996 and Greenland officials subsequently established a quota of 174 mt. However, the fishery only harvested 53% of the established quota (92 mt) in 1996. From 1998-2000, Greenland officials have agreed to restrict catches to what will be used for internal consumption only (estimated not to exceed approximately 20 mt.).

The fishery in West Greenland is truly a mixed stock fishery, with fish recorded from the U.S., Canada, Iceland, and nine European countries (M ller Jensen 1986). U.S. origin Atlantic salmon from the Connecticut, Merrimack, and Penobscot Rivers are harvested in the West Greenland fishery (Meister 1984; ICES-NASWG 1993). The ICES-NASWG has used three methods (Proportional Harvest Model, Carlin Tag Harvest Model, and Coded Wire Tag (CWT) Harvest Model - described below) based on tag recoveries and stock identification data to estimate the harvest of U.S. origin fish in West Greenland fisheries (ICES-NASWG 1989). While estimates from the methods differ somewhat, they have followed the same general trend during the period of overlap.

The Proportional Harvest and Carlin Tag Harvest Models estimate the number of Maine origin Atlantic salmon harvested at West Greenland. The Proportional Harvest model apportions the number of 1SW Maine origin fish caught in the fishery based on the relative production of smolts in U.S. and Canadian hatcheries (ICES-NASWG 1989, 1992). This model estimated harvest averaged 7,524 fish between 1976 and 1992. The estimate ranged from a minimum of 1,950 Atlantic salmon in 1992 to a maximum of 30,492 in 1980. The Carlin Tag Harvest Model raises all 1SW tags collected in the fishery (year I) to harvest estimates using the ratio of tagged to untagged 2SW returns to Maine rivers the following year (I+1). Estimates using the Carlin Tag Harvest Model averaged 1,534 Maine Atlantic salmon (1967-1991) and ranged from 216 fish in 1967 to 3,797 fish in 1989.

The CWT Harvest Model estimates the number of U.S. origin Atlantic salmon from the Connecticut and Merrimack Rivers as well as the Maine rivers. This method was only used from 1988 to 1994, when large CWT programs began (ICES-NASWG 1988). The CWTs were recovered in sampling programs in the West Greenland fishery and in homewaters. The CWT estimate is similar to the Carlin method in that the number of CWTs collected in the fishery is raised by the ratio of CWTs to 2SW Atlantic salmon returning to the Connecticut River, Merrimack River, or all Maine Rivers (ICES-NASWG 1993). Estimates using this method averaged 3,685 U.S. origin Atlantic salmon from 1988-1992. Estimates from the CWT model ranged from 2,173 fish in 1992 to 5,673 fish in 1988. The CWT estimates are considered to have the highest accuracy and precision because they are based on direct fishery samples.

7.2.1.2 The Canadian Fisheries

Historically, Atlantic salmon fisheries in Canada operated in all of the Atlantic Provinces. These fisheries intercepted fish of Canadian or U.S. origin (ICES-NASWG 1999). The Canadian fishery went through a substantial period of growth in the early 1900's, peaking in 1930 with a harvest of slightly over 6,000 mt (Chadwick 1993; ICES-NASWG 1999). From this peak, harvests declined to less than 1,500 mt by the mid-1950's (ICES-NASWG 1999).

The regulation of Canada's Atlantic salmon fisheries began with the dual objectives of conservation and allocation (May 1993). Despite conservation measures, the Atlantic salmon harvest grew to almost 3,000 mt by 1966. For the last 20 years, conservation measures to protect Atlantic salmon in the Canadian fishery have become more stringent, limiting seasons, restricting gear, and eliminating entire fisheries to reduce marine exploitation (Chadwick 1993; May 1993). These measures were initiated in 1972 with a ban on the Newfoundland drift net fishery and a complete ban on commercial fishing in New Brunswick and Quebec (May 1993). Buyback and compensation programs were incorporated into these bans. From the middle 1970's to 1985, restrictions were further tightened, resulting in the closure of all Maritime Provinces' fisheries (May 1993).

The 1984 management plan was enacted to assist in the rebuilding of depressed populations of Atlantic salmon in mainland Canada and southwestern Newfoundland (O'Connell et al. 1992). In addition to restrictions on targeted Atlantic salmon fisheries, Canada has also regulated other fisheries (alewife, herring, and mackerel) with historic Atlantic salmon bycatch to reduce incidental take (May 1993). In 1989, a quota system was first introduced for the remaining commercial fisheries of Labrador and Newfoundland, designating a total Atlantic salmon harvest of 1,300 mt. By 1992, the total quota was reduced to 193 mt and a 5-year moratorium on commercial landings in Newfoundland was announced (May 1993; DFO 1993). The moratorium and reduced quotas are also part of an estimated $40 million program to purchase licenses and buy out commercial fishers. In 1999, Canada announced continuation of the Newfoundland and Labrador fisheries moratoria for an additional three years , leaving several native subsistence fisheries as the only commercial fisheries remaining in Canada.

Historically, U.S. origin Atlantic salmon have been documented in the harvests of New Brunswick, Nova Scotia, Newfoundland, and Labrador fisheries (Meister 1984). The New Brunswick and Nova Scotia tag returns were mostly from herring and mackerel weir fisheries, and changes in the regulation of these fisheries have reduced the bycatch of Atlantic salmon (Meister 1984; May 1993). Thus, the most important fisheries were those of Newfoundland and Labrador because they constituted most of the harvest and the highest percentages of U.S. origin Atlantic salmon (Meister 1984; ICES-NASWG 1993). These fisheries have historically caught U.S. Atlantic salmon from the Connecticut, Merrimack, and Maine Rivers (ICES-NASWG 1993). The catch of U.S. fish was nearly four times higher in the southern Newfoundland fishery than in the northern Labrador fishery (Meister 1984).

7.2.1.3 Combined Harvest of U.S. Atlantic Salmon

Assessing the effects of the West Greenland and Canada fisheries upon U.S. Atlantic salmon is complicated by the differential geographic distribution of multiple stocks between years, differential distribution of individual stocks within years, and the varying age of maturation (1SW, 2SW). To address these difficulties in assessment, Rago et al. (1993) developed a run reconstruction model for the 2SW component of the North American stock. This model uses nonlinear equations to simultaneously constrain exploitation estimates in each fishery and the fraction of the population present in Canada and West Greenland waters to be internally consistent with observed catches and returns to rivers. In addition, the model takes into account the variable abundance of grilse and 2SW Atlantic salmon in different regions of North America. While the U.S. component is only a fraction of the North American stock complex, it appears to follow the same general trends in relative abundance and return rates as the entire stock complex (Friedland et al. 1993). This model provides an unbiased estimator of the ranges of exploitation rates for the North American stock complex. However, ranges of exploitation are not provided for individual stock components: the migration route of a specific stock may lead to differential exploitation because of different relative availability to fisheries.

Estimated exploitation of the non-maturing component of North American salmon as 1SW salmon in West Greenland has been quite variable, but has declined significantly since 1992. Between 1971 and 1992, exploitation averaged approximately 30% in the West Greenland fishery. Exploitation rates in 1983 and 1984 were particularly low (< 15%), and were reinforced by low harvest levels (ICES-NASWG 1999)(see figure 7.2.1.3). In contrast, exploitation rates between 1985 and 1988 were nearly double 1983-1984 levels, despite quotas in place to limit total harvest (M ller Jensen 1988; ICES-NASWG 1993). The increase in exploitation rate was likely due to a lower abundance (Rago et al. 1993). Since 1992, exploitation rates have remained below 15% in the West Greenland fishery (ICES-NASWG 1999).

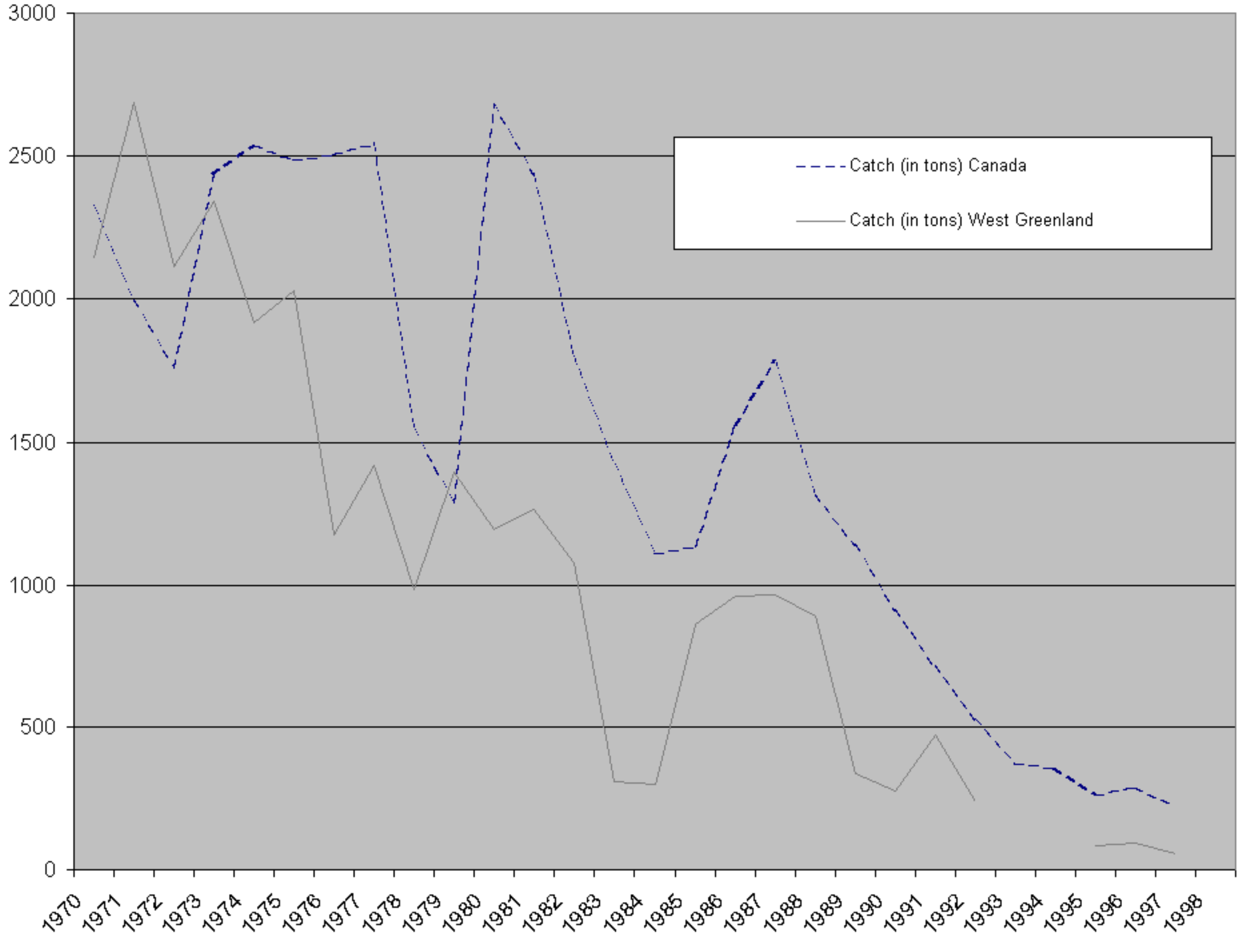
The average minimum and maximum exploitation in the Newfoundland fishery (Salmon Fishing Areas (SFA) 3-7 and 14a) were 52% and 72% for the North American stock complex. These rates declined in the early 1970's and then leveled off at lower levels for the remainder of the time series. Despite higher exploitation rates in the Newfoundland fishery, compared to the West Greenland fishery, the range of non-maturing 1SW Atlantic salmon caught in Newfoundland was too small to account for a large fraction of the total 2SW returns to North American streams (Rago et al. 1993).

The run reconstruction model also provides minimum and maximum estimates of the abundance of North American maturing and non-maturing 1SW recruits in West Greenland (Rago et al. 1993). The estimated abundance of the North American stock complex decreased dramatically from a mid-point estimate of 1.6 million in 1974, and reached it's lowest levels (midpoint estimate = 0.4 million) in 1997 (ICES-NASWG 1999).

Since the 2SW fisheries of Newfoundland occur when some component of the U.S. Atlantic salmon stock is nearing their natal streams, these fisheries could have a variable effect on U.S. stocks depending on their geographic distribution when the fisheries commence (O'Connell et al. 1992; Rago et al. 1993). The scenario that unfolded from 1984 to 1992 in the West Greenland fishery was especially alarming. During a period of general declines in the abundance of Atlantic salmon, the exploitation rate of the West Greenland fishery increased (Rago et al. 1993). These models indicate that while there has been a reduction in the prefishery abundance of Atlantic salmon, the execution of fisheries has further depressed the North American stock complex and, likely, the U.S. stock component.

To put the effects of alternate harvest levels into perspective, the combined harvest of 1SW Atlantic salmon of U.S. origin in the fisheries of West Greenland and Canada averaged 5,060 fish and returns to U.S. rivers averaged 2,884 fish from 1968 to 1989 (ICES-NASWG 1993). To indicate the extent of exploitation, the ICES-NASWG calculated the potential return to these rivers in the absence of the West Greenland and Canada fisheries. The ICES-NASWG estimates that returns of spawners to U.S. rivers could have potentially been increased by 2.5 fold in the absence of West Greenland and Labrador fisheries (ICES-NASWG 1993).

Figure 7.2.1.3 and Table 7.2.1.3: Commercial Exploitation of Atlantic Salmon



YEAR	Catch (in tons)		YEAR	Catch (in tons)	
	Canada	West Greenland		Canada	West Greenland
1970	2323	2146	**1985**	1133	864
1971	1992	2689	**1986**	1559	960
1972	1759	2113	**1987**	1784	966
1973	2434	2341	**1988**	1311	893
1974	2539	1917	**1989**	1139	337
1975	2485	2030	**1990**	911	274
1976	2506	1175	**1991**	711	472
1977	2545	1420	**1992**	522	237
1978	1545	984	**1993**	373	0 *
1979	1287	1395	**1994**	355	0*
1980	2680	1194	**1995**	260	83
1981	2437	1264	**1996**	290	92
1982	1798	1077	**1997**	229	58

1983	1424	310	**1998**	149	11
1984	1112	297	**1999**		

* reported catch was not inclusive of internal use only fisheries

7.2.1.4 Regulation of Commercial Fisheries

The United States joined with other North Atlantic nations in 1982 to form the North Atlantic Salmon Conservation Organization (NASCO) for the purpose of managing salmon through a cooperative program of conservation, restoration and enhancement of North Atlantic stocks. NASCO achieves its goals by controlling the exploitation by one member nation of Atlantic salmon that originated within the territory of another member nation. The United States' interest in NASCO stemmed from its desire to ensure that interception fisheries of U.S. origin fish did not compromise the long-term commitment by the states and federal government to rehabilitate and restore New England Atlantic salmon stocks. The International Council for the Exploration of the Sea (ICES) is the official research component of NASCO. Its role is to provide NASCO members with scientific advice to be used as a basis for formulating biologically sound management recommendations for the conservation of North Atlantic salmon stocks. Three NASCO Commissioners for the U.S. are appointed by the President and work under the auspices of the U.S. State Department. The U.S. Atlantic Salmon Assessment Committee (USASAC) was created to assess the status of U.S. Atlantic salmon and provide advice and input to the Commissioners.

Commercial harvesting of U.S. origin Atlantic salmon on the high seas historically contributed to the depletion of the stock (Section 6.2.1). However, ongoing harvesting restrictions, described below, have greatly reduced this threat to U.S. Atlantic salmon. In 1993, NASCO's West Greenland Commission unanimously accepted the West Greenland Fishery Regulatory Measure (NASCO 1993b; Windsor and Hutchinson 1994). This agreement resulted in the setting of quotas based on the best available scientific advice, provided by ICES to NASCO, with the goal of reaching target spawning escapements for North American stocks (Windsor and Hutchinson 1994).

There are four parts to the quota setting process. First, ICES scientists estimate the prefishery abundance of 1SW fish of North American origin. Second, a target spawning escapement is reserved to return to rivers. Third, the spawning escapement is subtracted from the prefishery abundance to determine the number of Atlantic salmon available for harvest. The parties agreed it would be difficult to obtain the total required escapement immediately; they phased in this value at 72% of total escapement for 1993, 85% in 1994, and 100% by 1995. In the fourth part of the process, the surplus fish are allocated to the harvesting nations based on historical shares of the fishery from 1986-1990.

The agreed upon quota for the West Greenland fishery in 1993 was 213 mt. However, the North Atlantic Salmon Fund, a private interest concerned with Atlantic salmon conservation, purchased West Greenland's 1993 and 1994 quota. This action effectively reduced the quota to a 12 mt subsistence fishery (NASCO 1993b). In 1995, the quota was set in accordance with the 1993 quota agreement. No agreement was reached in 1996 regarding the appropriate quota and parties entered negotiations during the winter of 1996/1997 resulting in an addendum to the 1993 agreement. The addendum allowed for a limited reserve quota when the prefishery abundance was calculated to be less than the target spawning escapement. The addendum also stated that in the event the prefishery abundance was estimated to be less than 100,000, the only harvest of MSW North American fish would be in subsistence fisheries and in individual rivers where the target spawning escapement was exceeded (WGC(97)10). The quota in 1997 was set in accordance with the 1993 agreement and addendum and in 1998 in light of the prefishery abundance, agreement was reached to limit the fishery in West Greenland to internal consumption only. In 1999, a two year agreement (for 1999 and 2000) was reached to continue limitation of the fishery in West Greenland to internal consumption only.

Over the past decade, only 90,000 wild 2SW Atlantic salmon (on average) have returned annually to spawn in U.S. and Canadian rivers. Fishery managers believe that the number of returning spawners needed to sustain these stocks currently is 184,000 (ICES-NASWG 1999). In Canada, the Newfoundland fishery was placed under a five year moratorium in 1992 and licenses were purchased by the government. Quota management was initiated in the Labrador fishery in the early 1990s. Following a series of quota reductions, Canada closed the commercial fishery in Labrador in 1998. In February 1999, Canada announced a three-year Atlantic Salmon Management Plan which continues the moratorium on commercial harvest in Newfoundland and Labrador and further restricts the recreational fishery in these areas as well.

7.2.2 Domestic Commercial and Recreational Fisheries

7.2.2.1 Commercial Fishery

In the last 40 years, commercial fisheries for Atlantic salmon have been pursued primarily in offshore waters outside of the U.S. Exclusive Economic Zone (NEFSC 1998). Historically documented commercial fisheries within the U.S. were predominantly freshwater fisheries consisting of nets and weirs. The most complete records of domestic commercial harvesting of Atlantic salmon in the U.S. are for the Penobscot River. It is assumed that the trends and practices seen in the Penobscot are indicative of what occurred in other Maine Rivers. Historical records also mention commercial salmon fisheries in the Dennys (New England Fishery Management Council 1987; Beland 1982), Androscoggin (Beland 1984) and Kennebec (Kendall 1935), among others, but data on location, time and volume of catch is generally not available. Stolte (1981) reported that nearly 200 pound nets were operating in Penobscot Bay in 1872. A record commercial catch of 200,000 pounds of salmon was recorded for the Penobscot River in 1888. By 1898, it had been reduced to 53,000 pounds. The directed commercial fishery was eliminated following the creation of the Atlantic Sea Run Salmon Commission (ASRSC) in 1948. The commercial harvest in the Penobscot that year was a mere 40 fish, weighing a total of 400 pounds.

In October 1987, the New England Fishery Management Council prepared a Fishery Management Plan (FMP) to establish explicit U.S. management authority over all Atlantic salmon of U.S. origin. The NASCO Convention of 1982 defines territorial seas as being the 0-12 mile zone contiguous to the coastline for the signatory nation. In contrast, the U.S. has established only a 0-3 mile territorial sea zone. Consequently, the 3-12 mile zone off the U.S.

coastline was not explicitly under the management authority of NASCO or the coastal states. The FMP was intended to address this deficiency and safeguard U.S. Atlantic salmon, protect the U.S. investment in the State/Federal restoration program, and strengthen the U.S. position in international negotiations. The FMP prohibits possession of Atlantic salmon in the Exclusive Economic Zone (EEZ). The FMP for Atlantic salmon recognizes that although there is no directed commercial fishery for Atlantic salmon in U.S. waters, the by-catch during commercial fishing for other species has the potential to be a significant source of mortality. The FMP further presents data to indicate that commercial by-catch in state waters is low. This is supported by Beland (1984) who reported that fewer than 100 salmon per year were caught incidental to other commercial fisheries in the coastal waters of Maine.

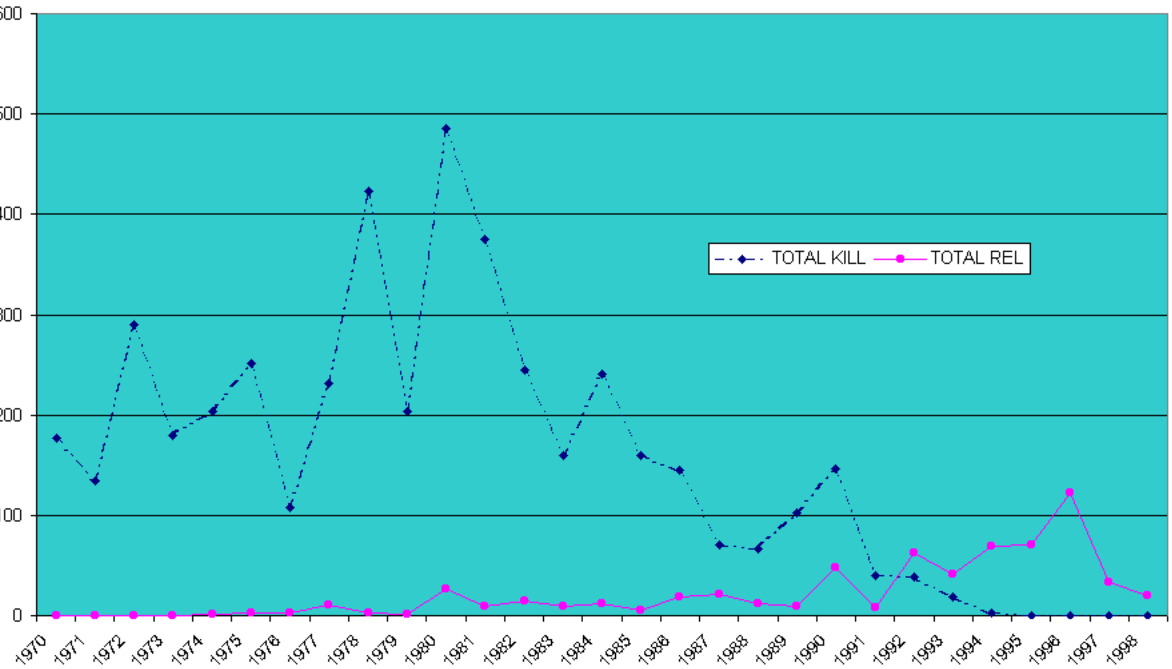
7.2.2.2 Recreational harvest

In 1874, Atkins reported that the Dennys and Narraguagus Rivers were the only rivers where fly fishing for Atlantic salmon commonly occurred. The sport fishery increased as reports spread of the 1882 catch in the Bangor Pool on the Penobscot River. Recreational catches were recorded for the Narraguagus, Pleasant, Machias, and East Machias Rivers. The Dennys River has the reputation of being the only Maine river where angling for Atlantic salmon preceded the erection of impassable dams (Beland et al. 1982). Kendall (1935) cites Forest and Stream sportsman's journal which reported that recreational catch for Atlantic salmon on the Penobscot River dropped in 1889 due to chemicals in the water from pulp mills, dams, and excessive netting downstream from Bangor. As the 1980's progressed and runs decreased, the ASRSC imposed increasingly restrictive regulations on the recreational harvesting of Atlantic salmon in Maine. The allowable annual harvest for these rivers was reduced by the state from ten salmon in the 1980's to one grilse in 1994. In 1995, regulations were promulgated to allow only catch and release fishing for Atlantic salmon in Maine, closing the last remaining recreational harvest opportunities for sea run Atlantic salmon in the U.S. However, a fishery for reconditioned domestic broodstock kelts was initiated in the Merrimack River beginning in 1993 and continued through 1999.

Historically, the average exploitation rate in Maine rivers has been estimated to be approximately 20% of the run (Beland 1984). Exploitation rates on returning Atlantic salmon averaged more than 25% of the annual run in the Narraguagus River from 1962-1974 and 20% of the annual run in the Machias River from 1962 to 1972 (Baum 1997). In retrospect, this level of harvest was likely too high, especially in light of the extensive intercept commercial harvest. The documented sport catch of sea-run Atlantic salmon in Maine during 1993 was 659 fish, with 152 killed and 507 released (USASAC 1994). The U.S. Atlantic Salmon Assessment Committee reported that in 1993 the exploitation rate, based on documented rod catches, on the Penobscot River was 7% compared to 6% the previous year. In 1998, only 233 salmon were caught and released, the lowest level of catch since the ASRSC was created in 1948. The recreational angling results documented for seven rivers in the DPS are shown in Table 7.2.2.2 and Figure 7.2.2.2.

Atlantic salmon parr remain vulnerable to harvest by trout anglers, and mortality associated with this activity has not been documented. Recent indications are that poaching activity occurs at fairly low levels on Maine rivers. Recent low returns of wild adult salmon to Maine rivers highlight the importance of continuing assessment of any source of mortality that may pose a risk to the DPS.

Figure 7.X2.2.2 and Table 7.X2.2.2: Recreational Harvest of Atlantic salmon within the DPS



YEAR	Total			YEAR	Total			YEAR	TOTAL	
	Kill	Rel			Kill	Rel			Kill	Rel
1970	177	0		**1980**	486	27		**1990**	146	48
1971	134	0		**1981**	375	9		**1991**	40	8
1972	290	0		**1982**	245	14		**1992**	38	62
1973	179	0		**1983**	159	9		**1993**	19	41
1974	203	1		**1984**	241	12		**1994**	3	69
1975	251	2		**1985**	160	5		**1995**	NA	70
1976	108	3		**1986**	145	19		**1996**	NA	122
1977	232	11		**1987**	71	21		**1997**	NA	33
1978	423	3		**1988**	67	12		**1998**	NA	20
1979	203	1		**1989**	103	9		**1999**		

The Conservation Plan stated that until recently, the greatest threat to Atlantic salmon was legal harvest through directed fishing, but that based on existing data, a regulated catch-and-release fishery would have little impact on the species. In addition, poaching was identified as a continuing problem and it was hypothesized that the problem could perhaps increase as runs increased. Additional actions proposed for enhanced protection included the following: (1) modify catch-and-release program to further restrict dates, locations, and gear allowed; (2) institute a reporting and monitoring program to better estimate any incidental take; (3) limit fishing within the seven rivers from July to September 30 to artificial lures only and a minimum length of 8 inches on all trout; (4) make the maximum length for brown trout and landlocked salmon 25 inches within the Sheepscot River and estuary; (5) within all Washington County waters, except West and East Grand Lakes, make maximum length 25 inches for landlocked salmon; (6) eliminate size and bag restriction on black bass on the Dennys River and Cathance Stream; (7) close cold water adult Atlantic salmon areas to all fishing, where necessary; (8) increase law enforcement with the addition of two seasonal wardens; and (9) propose increased penalties for Atlantic salmon poaching.

Directed Catch and Release Fishing

In 1997, the ASA promulgated new regulations closing all Maine rivers to angling for Atlantic salmon during July and August. These regulations continued the restriction of catch and release only, fly fishing only in inland waters, hook and line only in coastal waters, prohibition on the use of tailers in landing and releasing salmon, and restrictions limiting landing nets to knotless materials, not to exceed 1/2 inch mesh. A salmon license is required to fish for Atlantic salmon. As noted by the TAC, the effectiveness of these measures in protecting Atlantic salmon is unknown because of the low overall adult returns and a lack of information about the fate of salmon that are caught and released.

In February 1998, the TAC presented the ASA Board with a report entitled "Recommendations Regarding the Appropriateness of Catch and Release Angling for Atlantic Salmon in the Seven Downeast Rivers in 1998". This report was submitted by the TAC in response to a request from the ASC to examine the following factors in formulating a recommendation regarding the appropriateness of catch and release fishing: parr densities, sea surface temperature index developed by ICES, adult returns and redd counts, availability of hatchery fry, and incidental mortality related to catch and release. The TAC report stated that densities of Atlantic salmon parr in 1997 were low or below average on all rivers except for a few sites that had densities near long-term averages due to recent fry stocking efforts. The report attributed low juvenile densities to insufficient spawning escapement in recent years and sub-optimal survival of stocked fry.

The report noted improvements in the ocean thermal habitat index, but noted that marine habitat conditions were still not highly favorable to Atlantic salmon. It further noted that adult returns and redd counts in the seven Maine rivers in 1997 were among the lowest ever observed. The TAC report cited recent studies (Brobell et al. 1996; Wilkie et al. 1997; Tufts, et al. 1998; Whoriskey 1998) that demonstrated survival of Atlantic salmon caught and released in sports fisheries could be 95% or higher. Conditions cited as contributing to increased mortality include water temperatures in excess of 22oC, exposure of the fish to air after it has been captured, extremely soft water, and low oxygen levels. The TAC summary of the status of Atlantic salmon stocks in the DPS rivers included acknowledgement of low parr abundance, continuation of the downward trend in adult returns, the lack of a guarantee that fry stocking would result in a significant increase in adult returns, the lack of sufficient data available to quantitatively evaluate the potential impact of Maine's sports fishery regulations on catch and release fishing and finally, recognition that given current adult population levels, any measurable bycatch mortality could be high enough to cause harm to these populations. The TAC stated that they could not scientifically justify the harvest (direct or indirect through catch and release) of any Atlantic salmon in these seven rivers given the extremely low Atlantic salmon population levels. The TAC stated that a conservation management strategy was justified due to the increasing advantage of each additional spawner.

The ASA Board received the recommendation of the TAC but voted in June 1998 that additional restrictions upon angling were not warranted. The ASA Board stated that they believed the 1997 restrictions achieved the objective of minimizing the potential "take" associated with the catch and release fishery. The ASA stated that it would like to monitor the catch and release fishery but did not have the resources and therefore would attempt to work locally to obtain available information. Subsequently, the ASA reconsidered its earlier position and voted to go forward with a proposal to eliminate the directed catch and release fishery for Atlantic salmon. A proposed rule was issued and public hearings were held in the winter of 1999. The state later determined that the hearings were not legal, as the required number of Board members was not present.

Canada summarized available information on the effects of hook-and-release angling practices in 1998. According to the Canadian report, it is assumed in Newfoundland that 10% of the hooked-and-released salmon died and in the Maritimes values up to and including 10% are used. The Canadian report summarized the findings of a number of studies which collectively examined the following variables for their potential to affect the level of hook-and-release mortality: temperature, water flow, season, time of day, size of fish, sex of fish, fishing and handling practices, and water chemistry. The Canadian paper concluded that hook-and-release angling could be an effective conservation and management tool under the right conditions. The Canadian report attempted to analyze the impact of hook-and-release angling on potential egg deposition of the Saint John River stocks above Mactaquac Dam, New Brunswick. The estimated impact of the fishery was not found to increase when salmon runs declined, but the authors cautioned that a small stock could possibly be reduced below a viable population size. The management recommendation of the paper was that although hook-and-release angling is a conservation measure relative to retention angling, caution must still be exercised when considering implementation (DFO Science Stock Status Report DO-03 1998).

A study was conducted in New Brunswick to examine the magnitude of the physiological disturbance in different sizes of wild Atlantic salmon angled in the late season, assess survival under these conditions and investigate the effects of angling on gamete viability. That study concluded that the likelihood of delayed mortality is minimal and that there are not significant consequences on gamete viability resulting from angling and release of Atlantic salmon in the late fall (Booth et al. 1995).

Another study on the Miramachi River in New Brunswick compared the effects of catch and release fishing on kelts and bright salmon and concluded that the physiological disturbance from angling is smaller in kelts than in bright salmon. This study indicated that the stage of freshwater migration had a large influence on the magnitude of the physiological disturbance in Atlantic salmon following exhaustive angling. It was determined that compared to kelts, bright salmon had a greater capacity for exhaustive exercise, were more disturbed by angling, and were more likely to suffer mortality. The authors hypothesized that several factors, such as degree of starvation, osmoregulatory status, and environmental temperature probably influenced the physiological response of Atlantic salmon at different migratory stages (Brobbel et al. 1996).

The recreational fisheries subgroup of the Governor's Task Force concluded that the minimal incidental take of salmon from a catch and release fishery would have no impact on recovery. While it is true that some studies conducted under controlled or laboratory settings have resulted in a zero mortality to Atlantic salmon caught and properly released, it is highly unlikely that such favorable conditions would be present in the natural environment. Elevated water temperatures, low river flow, and improper handling all could result in significantly higher mortality rates which, given low adult returns, could negatively impact recovery of the DPS. The Conservation Plan cited a number of benefits to Atlantic salmon from angler presence on the river including protection of the resource and observation of violations. No data were provided in the Conservation Plan or elsewhere to demonstrate that the claimed benefits outweigh the potential of mortality from a catch and release fishery.

Illegal In-River Harvest of Atlantic Salmon

The Maine Conservation Plan reported that during the mid-1980s there were 10-15 poaching cases reported each year; however, only 4 cases were reported between 1992 and 1996 (CP 1997). With low numbers of adults returning to the DPS, there is a concern that even low levels of poaching will adversely affect Atlantic salmon populations. In 1998, the one documented returning Atlantic salmon to the Dennys River was killed by vandals. Using funds provided by the Main Outdoor Heritage Program, Maine IFW added two additional seasonal wardens during 1997 and 1998 to focus on enforcement of angling regulations for the protection of Atlantic salmon. Funds for the continuation of this expanded surveillance work in 1999 and beyond are not secured at this time (LWRC 1999). The Conservation Plan also recommended that IFW increase the fines associated with poaching of Atlantic salmon. Fines have not been increased at this point and IFW has advised that they are not the appropriate lead for this item. IFW suggested that the ASC coordinate with the legislative and judicial branches of Maine government on this issue (LWRC 1999). The Annual Progress Report stated that the State increased fisheries enforcement staff and found no evidence of poaching activity and discussed plans of the Warden Service to use surveillance equipment to monitor key areas on each river.

Potential by-catch of Atlantic salmon in State Recreational and Commercial Fisheries

A number of recreationally important species including white perch, chain pickerel, and smallmouth bass are present in the Sheepscot, Ducktrap, Narraguagus, Machias, East Machias, and Dennys watersheds. White perch and smallmouth bass are present in the Pleasant River watershed. Largemouth bass have been introduced into the Sheepscot, Ducktrap, and East Machias watersheds in past years (CP 1997). Brook trout are indigenous to all seven rivers in the DPS. Landlocked salmon are present in lakes in the Sheepscot, Narraguagus, Pleasant, Machias, East Machias and Dennys watersheds. Splake (hybrid of a (lake trout and a (brook trout) were stocked in 1995 in lakes in the Sheepscot, Narraguagus, Pleasant, and Machias watersheds. Brown trout are stocked in the East Machias and Machias watersheds and naturally reproduce in the Sheepscot River.

The Conservation Plan included the goal of reducing incidental take mortality by 50%. The IFW has stated that there is no way of estimating the number of Atlantic salmon caught as bycatch in other recreational fisheries or to estimate the resultant mortality (LWRC 1999). The IFW suggested that the effectiveness of regulatory changes should be evaluated based on scientific studies and the knowledge of the ASA regarding salmon survival and mortality, rather than a survey of anglers or another monitoring effort due to concerns about angler identification of juvenile Atlantic salmon. The potential exists for anglers to misidentify juvenile Atlantic salmon as brook trout, brown trout, or landlocked salmon. A minimum size (8 inches) restriction on trout caught after June 30 of each year reduces the potential for keeping salmon parr misidentified as other salmonine species. Atlantic salmon kelts may also be taken by ice fishermen who mistake them for landlocked salmon. A maximum length for landlocked salmon and brown trout (25 inches) was adopted in an attempt to avoid this potential source of accidental sea-run Atlantic salmon harvest. There is also concern that as striped bass populations increase, the potential for striped bass anglers to catch Atlantic salmon in estuaries will likewise increase.

Commercial fisheries for white sucker, alewife, and American eel conducted in state waters have the potential to incidentally catch Atlantic salmon. New regulations were passed in Maine for 1998 which set a maximum length of fyke nets used in the elver fishery and prohibited fyke nets from the middle third of any waterway to provide a zone of safe passage for migratory fish. No Atlantic salmon bycatch was reported by DMR biological staff who fished elver fyke nets with the required finfish excluder panel during 1998. Biologists from DMR closely monitored the alewife fishery on the Sheepscot River and did not observe any salmon in the fishway during the alewife fishery. The alewife fishery on the Pleasant River was restricted to hand dip net and personal use only in 1998 which eliminated the potential for Atlantic salmon bycatch. There is no commercial alewife fishery on the Machias River. The alewife fishery on the East Machias is conducted upstream of Atlantic salmon spawning and nursery habitat and therefore there is no bycatch. The alewife fishery was closed in 1998 on the Ducktrap, Narraguagus, and Dennys Rivers, which precluded any potential bycatch of Atlantic salmon. In its 1998 annual report, the State concludes that bycatch related to commercial sucker, alewife, or elver fishing does not appear to be a problem for Atlantic salmon.

7.2.3 Summary of Overutilization

Both commercial and recreational harvest of Atlantic salmon historically played a role in the decline of the DPS of Atlantic Salmon. The Canadian fishery in Newfoundland and Labrador is under a moratorium for the next three years and the West Greenland commercial fishery will continue as an internal use only fishery through the 2000 fishing season. Continuation of the internal use fishery in Greenland poses a reduced but continuing threat to Atlantic salmon in the DPS. The best available scientific data supports the advice of technical experts in Maine that no directed catch and release fishery should be carried out given existing stock conditions. Continuation of the existing directed catch and release fishery poses a threat of mortality or injury to Atlantic salmon within the DPS. Recreational fisheries targeting other species also have the potential to incidentally catch various life stages of Atlantic salmon that could result in their injury or death. These fisheries also pose a potential threat to Atlantic salmon. The one documented poaching event in 1998 indicates that poaching continues to pose a potential threat to Atlantic salmon. Continued enforcement efforts and adequate penalties are essential to minimize this threat.

7.3 PREDATION, DISEASE, AND COMPETITION

7.3.1 Predation

During their various life history stages, Atlantic salmon are preyed upon by numerous species of fish, birds, and mammals, and also may compete with these species for other ecological resources. The results of predation and competition can greatly affect and influence the population dynamics of Atlantic salmon. Anthony (1994) provided a review and summary of the significant predators and identified those that affect the specific life stages of salmon.

Once salmon eggs are extruded by the female, goldeneyes, brook trout, and Atlantic salmon parr may feed on them (White 1939a). Fry and parr are preyed upon by brown trout, brook trout, eels, burbot, northern pike, chain pickerel, largemouth and smallmouth bass, yellow perch, belted kingfishers, herons, mergansers, barred owls, otter, and mink (White 1936; White 1939a; White 1939b; Godfrey 1957; Warner 1972; Larsson 1985; Amiro 1993; Kalas et. al. 1993).

During the smolt stage, physiological changes occur that allow Atlantic salmon to make the transition from freshwater to saltwater. The process of smoltification occurs during spring, at a time when juvenile salmon or smolts migrate to the ocean. In New England, smolts encounter lakes and ponds, dams, water diversion structures and canals. These structures and areas provide habitat for predators and may also delay the migration of smolts, and increase their vulnerability to predation (Ruggles 1980; Saunders 1960). Smolts may be preyed upon by pickerel, smallmouth bass, northern pike, burbot, red-breasted merganser, ospreys, and black-backed gulls (White 1939b; Blair 1956; Barr 1962; Warner 1972; Larsson 1977, 1985; van den Ende 1993).

During their seaward migration, smolts enter estuaries and may not exit to the sea immediately (Fried et al. 1978; Danie et al. 1984). Extended residence in estuaries increases their vulnerability to predators (Bley 1987). Estuarine predators include striped bass, cod, American pollock, whiting, garfish, double-crested cormorant, European cormorant, and harbor seals (Carlin 1954; Bigelow and Schroeder 1953; Thurow 1966; Rae 1969, 1973; Hvidsten and Mokkelgjerd 1987; Hvidsten and Lund 1988; Barrett et al. 1990; Greenstreet et al. 1993; Massachusetts Cooperative Fish and Wildlife Research Unit unpublished data). There is evidence to suggest that predation by cormorants in the Machias River estuary may adversely affect salmon in the river. Meister and Gramlich (1967) provided evidence of predation by cormorants on salmon in the estuary. They documented that double-crested cormorants consumed an estimated 8,000 tagged smolts during the period 1966-1970. The potential impact of striped bass predation on Atlantic salmon was discussed at the 1999 Annual Meeting of the U.S. Atlantic Salmon Assessment Committee. Evidence was presented that striped bass are now spawning in the Kennebec River and it was hypothesized that spawning could expand to other northern river systems. It was also noted that striped bass seem to be arriving in New England waters earlier in the spring and more fish may even be overwintering in New England (USASAC

1999). Results from a study on the Merrimack River were presented and provided evidence of striped bass consuming Atlantic salmon just below the Essex Dam. In 1997, stomach content analysis was conducted on 41 striped bass, and 32 salmon smolts were documented and another 28 were suspected. Only 16 of the 389 striped bass stomachs analyzed in 1998 contained salmon smolts. The difference between the two years may be explained by the timing and availability of river herring as an alternative prey species (USASAC 1999). In spite of the fact that the period of transition from freshwater to life in the sea is probably one of the most critical episodes in the life history of Atlantic salmon, comparatively little information is available about their behavior and factors affecting survival during this life stage (Hislop and Shelton 1993).

From the time they leave the river and estuary to the end of their first winter at sea, Atlantic salmon are termed post-smolts. Hislop and Shelton (1993) refer to the work of Jarvi (1989) who found that during the initial period of adjustment in the ocean, post-smolts are under physiological and osmotic stress, and both their tendency to shoal and the speed with which they react to predators are suppressed. Sea trout as well as gadoid fishes such as cod, saithe and pollock are known to feed on post-smolts (Rae 1966, 1967, 1969; Hvidsten and Mokkelgjerd 1987; Hvidsten and Lund 1988). Pelagic seal populations such as harp seals, which typically feed on small schooling fish such as capelin, herring and mackerel, may represent a significant post-smolt predation factor as well. These seals move north and south with the ice edge.

Atlantic salmon grow rapidly while in the ocean; an increase in size reduces vulnerability to predators. Little is known about the predator-prey interactions involving salmon in the high seas. Many of the documented cases of predation in the ocean show that benthic feeders including shark, skate, ling, and Atlantic cod prey on Atlantic salmon (Hislop and Shelton 1993).

Hislop and Shelton (1993) report that marine mammals including harbor seals, gray seals, harp seals, and ringed seals may be the only significant predators of maturing salmon (salmon returning to natal rivers) in home waters. Among all seals, the gray seal is of greatest concern to fishers and fish farmers due to encounters with Atlantic salmon, salmon nets, and salmon farms (Anthony 1994; Rae and Shearer 1965; Rae 1960). The population of North Atlantic gray seal in U.S. waters increased from about 30 in the early 1980's to about 500-1000 animals in 1993 (NOAA unpublished data). A recent spring survey in Massachusetts counted 2035 gray seals. In the EEZ of the eastern U.S. abundance is likely increasing, but the actual trend is not known. The number of harbor seals along the New England coast has increased nearly fivefold since 1972. The estimated number of harbor seals in New England waters was 28,810 based on aerial survey and haul-out counts conducted in summer 1993 along the coast of Maine (Kenney and Gilbert 1994). The harp seal population has also increased dramatically to approximately three million animals in 1990 (NOAA unpublished data).

The predator-prey interactions involving salmon are complex. Anthony (1994) explores the theoretical beneficial aspects of predator control programs that may minimize impacts to salmon in riverine and coastal environments. Such analyses are complicated by the fact that these predator-prey systems were historically in balance or dynamic equilibrium. Reestablishing this balance requires consideration of the numerous predator and prey species that interact in food webs and function within very large ecosystems. Atlantic salmon abundance and the number and type of predators may vary annually in rivers, estuaries, and marine environments. Hislop and

Shelton (1993) suggest that it may be unrealistic to believe that it will ever be possible to address the problem of predation in the open ocean.

7.3.2 Disease

Atlantic salmon are susceptible to a number of diseases and parasites which can result in high mortality. Disease related mortality is primarily documented for hatcheries and aquaculture facilities. Disease epizootics in wild salmon are uncommon in New England (Secombes 1991); furunculosis is the only documented source of mortality in wild Atlantic salmon (Bley 1987).

The most well known freshwater external parasites of Atlantic salmon are the gill maggot, Salmincola salmonea, the freshwater louse, Argulus foliaceus, and the leech, Piscicola geometra. Gyrodactylus salaris is an ectoparasite that has, in the last decade, resulted in serious problems for Atlantic salmon populations in Norway (Johnsen and Jensen 1991, Bakke et al. 1990). Hastein and Linstad (1991) report that this parasite is a major disease problem in Norwegian salmon rivers, and has caused almost total eradication of young salmonids in some rivers. Farmed fish are amenable to treatment. Bakke (1991) reports that G. salaris now occurs in Russia, Finland, Sweden and Norway. There is evidence to suggest that susceptibility to G. salaris varies among stocks, and water temperature is an important variable with respect to reproduction and transmission of this parasite. In Norway the parasite is now reported in 34 rivers and about 35 hatcheries and its distribution in wild salmon populations is associated with the stocking of fish from infected hatcheries (Johnsen and Jensen 1991). Internal parasites include trematodes (flukes), cestodes (tapeworms), acanthocephalans (spiny-headed worms) and nematodes (round worms) (Mills 1971; Bley 1987; Hoffman 1967; Jones 1959).

Once in the sea, Atlantic salmon lose their freshwater parasites but acquire others from the marine environment. The variety of parasites may increase for Atlantic salmon in the sea. For most ocean fishes the increase is related to the variable food source, the assortment of intermediate hosts found in the ocean, the vast area of migration which increases exposure, the tendency of fishes to school in the ocean during various life stages, and/or the increase in size of the host body (Polyanskii and Bykhovskii 1959).

The sea louse, Lepeophtheirus salmonis, is one of the more common ocean parasites of Atlantic salmon. With severely infested fish, often the skin is loose, and flesh may be exposed. In Norway, the level of sea lice infestation on wild fish in some areas where Atlantic salmon farming is concentrated, has been found to be ten times greater than in areas where there are no farms (NASCO 1993).

The most important vertebrate parasite is probably the sea lamprey, Petromyzon marinus. The impacts of sea lamprey on Great Lakes fishes and introduced salmonine species is well documented, but there is a paucity of information regarding its effect on sea-run Atlantic salmon (Mills 1971). Sea lampreys are anadromous and enter New England rivers in the mature stage, in spring, when Atlantic salmon are migrating to home waters (Scott and Crossman 1973).

Atlantic salmon are susceptible to numerous bacterial, viral, and fungal diseases. The more common bacterial diseases to New England waters include furunculosis, bacterial kidney disease (BKD), enteric redmouth disease (ERM), coldwater disease (CWD), and vibriosis (Mills 1971;

Gaston 1988; Olafsen and Roberts 1993; Egusa 1992). Furunculosis can be a problem in both the freshwater and marine life stages of Atlantic salmon. It is so widespread that no natural waters with resident fish populations are considered to be free of it. Because of the high incidence of this pathogen in some Atlantic salmon rivers in the U.S., many returning mature salmon carry it (Gaston 1988). Furunculosis can be treated in hatchery populations through the administration of antibacterial medicated feed and/or intraperitoneal (IP) injections. Control measures include commercial vaccines and surface disinfection of eggs with iodophore. Furunculosis can be a source of significant mortality in wild populations if river water temperatures become unusually high for extended periods.

Bacterial kidney disease is a chronic infection of salmonine fishes in culture environments. The bacterium is vertically transmissible even with egg disinfection measures, and once established, it can be difficult to control and virtually impossible to cure. Control in hatcheries depends on ensuring that eggs and smolts are from non-infected stocks; control in farms requires that fish be nutritionally fit (Olafsen and Roberts 1993; Gaston 1988; Egusa 1992). Although present in Canada as well as the US, there has not a high frequency of occurrence of BKD in the Northeast. Its occurrence in federal and most state trout hatcheries in New England has been limited.

Enteric redmouth disease (ERM) is caused by the bacterium Yersinia ruckeri. It occurs in salmonids throughout Canada and much of the U.S. and has been documented in cultured as well as captive sea-run Atlantic salmon in Maine and Connecticut (Gaston 1988). Generally this disease results in sustained low-level mortality, but large scale epizootics can occur if chronically infected fish are stressed during hauling, or exposed to other poor environmental conditions. This disease is amenable to treatment in hatcheries using medicated feeds or, for recaptured wild adults, intraperitoneal injections. Control in cultured populations is accomplished through commercially available vaccines and surface disinfection of eggs.

Coldwater Disease, caused by the bacterium Flavobacterium psychrophilum, has recently been found to be a potentially serious problem to Atlantic salmon in New England waters. Ongoing studies by the Biological Research Division of the USGS at their Leetown Science Center have shown that the pathogen induces pathology and subsequent mortality among juvenile Atlantic salmon, and that the pathogen is vertically transmitted from carrier sea-run adults to offspring via the eggs. Intra-ovum CWD transmission influences egg quality and affects early life stage survival (personal communication, Rocco Cipriano).

Vibriosis occurs in many species and is likely ubiquitous in marine and estuarine waters. In infected salmonine species, red necrotic or boil-like lesions occur in the musculature. Hemorrhages may occur in the viscera, and the intestinal track becomes inflamed. Typically, outbreaks and the level of severity escalate with an increase in water temperature. There have been recent reports of cold water vibriosis infection in farmed Atlantic salmon in Norway and Scotland. The infection occurs during winter at water temperatures below 9o C, and resembles the condition referred to as "Hitra disease" in Norway (Gaston 1988). A commercially available vaccine is utilized extensively in the salmon aquaculture industry to reduce losses to Vibriosis.

Atlantic salmon exhibit a limited number of viral diseases in culture; common ones include infectious pancreatic necrosis (IPN) and salmon papilloma (Olafsen and Roberts 1993). IPN is endemic in New England and in the Canadian Maritime Provinces. The IPN virus has generally not been found to be a serious source of mortality in Atlantic salmon in North America but has caused serious mortality in cultured European stocks. The disease can not be treated effectively in the hatchery and avoidance is the most effective control mechanism. Salmon papilloma or pox is a benign condition that can occur on wild and farmed fish in the first or second year of life.

Infectious Salmon Anemia (ISA)/Hemorrhagic Kidney Syndrome (HKS) was found in Canadian (New Brunswick) net pen sites in the Bay of Fundy in 1996. This was the first occurrence of this virus in North America although it had been in Norway since 1984 and has subsequently been detected at a number of sites in Scotland and the Shetland Islands. The Scottish and Shetland outbreaks of ISA have been linked to a single primary source and the spread of the disease has been associated with farming practices and interfarm transfers. An investigation is ongoing in Canada in an attempt to identify the source of the virus. There is currently no treatment or effective preventive vaccine available for this disease. Norway and Scotland have pursued a strategy of eliminating the disease by slaughter of infected fish, long-term fallowing of infected sites and, since effluent from processing plants and transport barges was identified as a high risk for spread of the disease, treatment of slaughter effluent. Known occurrences of the disease have been limited to aquaculture operations. Mortalities associated with ISA have been high in Canada and similar eradication management measures were initially adopted in response to the presence of the disease, including destroying infected fish, removing all fish from these infected zones and financial compensation to growers. More recently, Canada appears to have moderated their strategy from eradication to containment (reduction or elimination of financially compensated destruction). The disease was detected in 1998 at two land-based facilities in Nova Scotia that have no obvious ties to the infected New Brunswick sites. Some US pen sites in Cobscook Bay are close enough to fall within the ISA virus positive "quarantine zones" in New Brunswick waters, so there is great concern over the potential for this disease to infect US aquaculture stocks.

The ISA virus has not been found in any wild salmon populations to date, though over 1,000 wild salmon have been tested in Canada and the US to date. In 1998 the USFWS began monitoring captured sea run salmon mortalities for ISA virus and it has not been detected. The aquaculture industry in Maine has also completed a testing program and reports that it is not present in farm fish. The Maine Fish Health Advisory Board, consisting of disease specialists from state and Federal agencies, the University of Maine and private aquaculture has reviewed the information from Canada, prepared an action plan for detection of the ISA virus in Maine, and recommended against the importation of smolts from ISA positive zones in Canada. Although ISA has not been observed as a problem for wild stocks, there is great concern as it directly affects pre-spawning adults.

In 1998, a lethal retrovirus was detected in wild Atlantic salmon that had been captured as parr in the Pleasant River and reared at North Attleboro National Fish Hatchery (NANFH) in Massachusetts. In 1995 (180 parr), 1996 (80 parr) and 1997 (164 parr) were held in isolation at the North Attleboro National Fish Hatchery and a private hatchery in Deblois, Maine for the purposes of rearing the fish to sexual maturity, spawning them, and returning progeny back to the Pleasant River. Mortalities began in two of three rearing units holding these salmon at North Attleboro in 1997 and continued in 1998. (Salmon in the third unit were never found to contain the virus or exhibit symptoms.) Necropsy revealed massive tumors in the swimbladder. Pleasant River fish at Deblois were also found to be positive for the virus, though no disease was present and no mortality occurred. Cornell University scientists identified the causative agent as a cancer-causing retrovirus known as Salmon Swimbladder Sarcoma Virus. This disease and a presumptively causative retrovirus were first reported from sub-adult farmed Atlantic salmon in Scotland (Duncan 1978: McNight 1978) and it was named SSSV by Wolf (1988). The disease has not been reported from Scotland since, and the relationship between this and the Maine retrovirus has not been determined.

Virus-positive fish from North Attleboro were moved to a quarantine facility at the USGS-Biological Resources Division facility in Leetown, WV, to obtain detailed information on the pathogenicity of the virus, and the remaining stocks at North Attleboro and Deblois hatchery were destroyed. A non-lethal test for detection of this virus was developed by Cornell and testing of wild salmon stocks from other Maine rivers held at the Craig Brook National Fish Hatchery in Maine was carried out. Of 510 salmon of various ages from five rivers, 7 were found to be carriers of SSSV. These infected fish came from three rivers; Machias (1 adult, 4 smolt), East Machias (1 adult), and Narraguagus (1 smolt). Samples from the Sheepscot and Dennys were negative for the virus. No fish at Craig Brook NFH has ever demonstrated symptoms of the disease in the seven years wild stock have been held at that hatchery. However, the virus has demonstrated that it can cause lethal disease in salmon under the conditions existing in the Massachusetts hatchery. Results of this preliminary testing of captive Downeast Rivers wild stocks at CBNFH exhibiting no signs of disease indicates that the virus may be widespread at a low level in the environment. Expressions of the disease such as observed at North Attleboro may only occur under extremely adverse environmental and/or nutritional conditions.

A togavirus isolated in tissue culture has been detected in Atlantic salmon from farms in Maine and New Brunswick. The virus appears to be in New Brunswick and has been found in the Cobscook Bay area of eastern Maine. There has been no disease found associated with this virus at present, but it is monitored as part of the routine health inspection process for aquaculture operations in Maine. Most salmon encounters fungi during their various life stages. Saprolegnia is the only fungal disease of Atlantic salmon, and is primarily found in adult males. It invades the epidermis and is associated with the presence of high levels of androsteroids (Olafsen and Roberts 1993; Gaston 1988).

7.3.3 Competition

Species that have similar ecological requirements often exhibit interspecific competition to the detriment of one or all of the species (Jones 1991). Competitive interactions of Atlantic salmon with nonsalmonine fish, especially introduced species, are not well understood. Interactions with other salmonines have been examined more actively. Most research on competition has focused on interactions between salmonine species (Hearn 1987; Fausch 1988). Interactive behavior between salmonines that are either defending discrete territories or establishing dominance hierarchies can lead to increased mortality and decreased growth (Fausch and White 1986). Both Hearn (1987) and Fausch (1988), in reviews of competition between riverine salmonids, concluded that species that were not co-evolved often exhibited adverse interspecific competition. Introduced salmonids occur in rivers where programs have been initiated to restore Atlantic salmon. However, introduced salmonids are generally absent from U.S. rivers containing wild Atlantic salmon with the exception of limited brown trout populations in some rivers.

Interactions between wild Atlantic salmon and other salmonids are mostly limited to interactions with brook trout and, occasionally, brown trout. Interactions with these species indicate that their habitat use varies between allopatric and sympatric populations (Gibson 1973; Randall 1982). The result of interactions and shifts in habitat use are related to food availability; when food was scarce, segregation increased (Gibson 1973). Competition appears to play an important regulatory role shortly after fry emerge from redds, when fry densities are at their highest (Hearn 1987). These interactions may cause Atlantic salmon and brook/brown trout populations to fluctuate from year to year. Since these species co-evolved, wild populations should be able to coexist with minimal long-term effects (Hearn 1987; Fausch 1988). The fact that species have co-evolved suggests that their coexistence involves a dynamic interaction which can affect population structure. Information is presented below regarding species that share rivers within the DPS with Atlantic salmon. In most cases, conclusions cannot be drawn regarding the effects and magnitude of competition between these species and Atlantic salmon as no data is currently available.

Smallmouth bass and landlocked salmon inhabit headwater lakes in the Dennys River watershed. Largemouth bass were illegally introduced to headwater lakes in the Dennys River watershed. Brook trout are found in the main stem and are known to frequent the estuary. Other fish, birds, and mammals are found in the estuary and may compete with salmon for forage or space. Stocking of landlocked salmon in Meddybemps Lake may impact anadromous Atlantic salmon. Splake are also stocked into Old Stream on the Dennys River and have the potential to impact Atlantic salmon and their habitat.

Landlocked salmon are found in the East Machias River watershed. The river and estuary have a diverse assemblage of fishes, birds, and mammals that may compete with salmon for food or space.

The Machias River and estuary have a diverse assemblage of fishes, birds, and mammals that may compete with salmon for food or space. Landlocked salmon, pickerel, and smallmouth bass are found in the watershed.

With the exception of brook trout and landlocked salmon, there are few primary competitors or predators that would affect Atlantic salmon during their riverine residence in the Pleasant River. The river and estuary have a diverse assemblage of fishes, birds, and mammals that may compete with salmon for food or space.

There are few species that are likely to compete with salmon in the Narraguagus River. Landlocked salmon are found in lakes within the drainage but predation and competition is not considered to be a major threat to sea-run salmon stocks. The river and estuary have a diverse assemblage of fishes, birds, and mammals that may compete with salmon for food or space.

Warmwater fishes inhabit headwater ponds and may be found in the Ducktrap River. The river and estuary have a diverse assemblage of fishes, birds, and mammals that may compete with salmon for food or space.

Landlocked salmon and warmwater fishes including pickerel and smallmouth bass are present in the Sheepscot River drainage. Splake are stocked into Sheepscot Pond. Landlocked salmon are also present in Sheepscot Pond as are naturally reproducing populations of brown trout. The river and estuary have a diverse assemblage of fishes, birds, and mammals that may compete with salmon for food or space.

7.3.4 Summary

Predation has always been a major factor influencing salmon numbers, but under conditions of a healthy population, would not be expected to threaten the continued existence of that population. The threat of predation to the DPS is significant today because of the very low numbers of adults returning to spawn and the dramatic increases in population levels of some predators known to prey on salmon. These include cormorants, striped bass, and several species of seals. Most rivers within the DPS do not contain dams that delay and concentrate salmon smolts and make them more vulnerable to cormorant attacks. Also, the great expansion of striped bass populations over the past decade is concentrated more in rivers south of the DPS area. Further, cormorants and striped bass are transitory predators impacting migrant juveniles in the Lower River and estuarine areas. Seals, however, have reached previously unknown high population levels and salmon remain vulnerable to seal predation through much of their range.

Fish diseases have always represented a source of mortality to Atlantic salmon in the wild, though the threats of major loss due to disease are generally associated with salmon culture. The level of threat from disease has remained relatively static until the last three years. Three recent events that have increased our concern for disease as a threat to the DPS include 1) the appearance of ISA virus in 1996 on the North American continent within the range of possible exposure of migrant DPS salmon, the discovery in 1998 of the retrovirus SSSV within the DPS population, and the new information available in 1999 on the potential impact of CWD on salmon. The ISA virus a causes fatal disease among sub-adult and adult salmon in aquaculture environments and can be laterally transmitted through salt water over distances of several kilometers. This situation represents a new potential threat to wild salmon but is difficult to gauge, as the virus has not been found in Canadian wild stocks where the disease is prevalent.

The discovery of SSSV within four wild populations in the DPS and at least one occurrence of disease observed in a hatchery situation represents a new potential disease threat to the DPS. The presents of this pathogen, apparently for several years, in other hatchery situations without the occurrence of any disease makes it difficult to assess the degree of risk to the DPS. The recent findings relative to the impact of CWD at early life stages in salmon and the transmissibility of the pathogen from adult to egg, even when eggs are disinfected by standard hatchery procedures, raises the potential threat of the long-known pathogen to a higher level, but more information will be necessary to fully assess its impact on the DPS. Our assessment of the overall threat to the DPS from disease is increased by these recent developments.

The nature of these three specific developments in terms of direct loss to the DPS from disease in the wild is difficult to assess, but circumstances to date suggest that direct mortality may not be the major threat to the DPS. However, there is an indirect threat through the impact of these diseases on the river-specific fish cultural program implemented on five rivers to enhance maintenance and recovery of these imperiled populations. The impacts of ISA, SSSV, and CWD appear to focus on the fish cultural environments. They can pose a significant new hurdle to the enhancement program's ability to function effectively, thereby significantly degrading a major tool and strategy for recovery. The level of threat to the perpetuation and recovery of the DPS from salmon disease has significantly increased in the past three years.

Interactions between wild Atlantic salmon and other salmonids are mostly limited to interactions with brook trout and, occasionally, brown trout. The rivers and estuaries of the DPS have diverse assemblages of fishes, birds, and mammals, some of which are contemporary introductions and did not co-evolve with Atlantic salmon. Some of these species may compete with salmon for food or space. The effects and magnitude of competition by these species is not known. The introduction or transfer of other salmonids, especially landlocked salmon and brown trout, under management by the state fishery agencies should be done cautiously, with a conscious effort to avoid negative impacts to DPS populations.

7.4 INADEQUACY OF EXISTING REGULATORY MECHANISMS

7.4.1 International, National and State Laws, Treaties and Agreements

A number of state and federal laws have the ability to affect the abundance and survival of Atlantic salmon in the Northeast United States. Measures taken on the international, national and state levels to restrict the harvest of U.S. origin Atlantic salmon are discussed in Section 7.2 and consequently will not be repeated in this section. Despite their breadth, these laws have not prevented the observed declines in salmon stocks. Applicable regulatory mechanisms are briefly summarized in Table 7.4.1 and they are explained in greater detail on subsequent pages. Regulations that are either inadequate or not being enforced are summarized at the end of the section.

<u>Convention for the Conservation of Salmon in the North Atlantic Ocean</u>
This treaty, ratified by the United States in 1982, provides a mechanism for managing the international commercial fishery for Atlantic salmon for the purpose of conserving and restoring salmon stocks. The Convention provides a forum for coordination among members, proposing regulatory measures, and for making recommendations regarding scientific research. The Treaty was adopted by the U.S., Canada, Greenland as represented by Denmark), Iceland, Faroes Islands, Norway, and the EC. Russia joined later. The North Atlantic Salmon Conservation Organization (NASCO) was formed by this treaty.

The U.S. became a charter member of NASCO in 1984. NASCO is charged with the international management of Atlantic salmon stocks on the high seas. The NASCO is composed of three geographic Commissions: Northeast Atlantic, West Greenland, and North American. Each signatory appoints three Commissioners, and the three Commissioners sit on the Commissions that impact the salmon from their area. NASCO seeks scientific advice from the International Council for the Exploration of the Seas. The three U.S. Commissioners are appointed by the President and function under the auspices of the U.S. State Department. The U.S. Commissioners seek advice and input from scientists involved in Atlantic salmon research and management throughout New England, which comprise the U.S. Atlantic Salmon Assessment Committee (USASAC). The USASAC was formed by the Federal and New England state fishery agencies for this purpose.

<u>Convention for the International Council for the Exploration of the Sea (ICES) (24 U.S.A. 1080; T.I.A.S. 7628)</u>
The Convention was established in 1973 and its purpose is to: a) promote and encourage research and investigations for the study of the sea, particularly those related to the living resources thereof; b) draw upon programs required for this purpose and to organize such research and investigations as may appear necessary; and c) publish or otherwise disseminate the results. ICES is the official research arm of NASCO, and is responsible for providing scientific advice to be used by NASCO members as a basis for formulating biologically sound management recommendations for the conservation of North Atlantic salmon stocks. ICES delegates responsibilities for the collection and analysis of scientific data on Atlantic salmon to the North Atlantic Salmon Scientific Working Group, which is then used by the ICES Advisory Committee for Fishery Management to formulate advise to NASCO annually.

<u>Fishery Conservation and Management Act of 1976, (16 U.S.C.(1801 et seq.)</u>
This Act, commonly referred to as the "Magnuson Act," gives regional fishery management councils the authority to prepare plans for the conservation and management of each federally managed fishery in the EEZ, including the establishment of necessary habitat conservation measures. As discussed in Section 7.2.2.1, a fishery management plan for Atlantic salmon was implemented by the New England Fishery Management Council (NEFMC) and the Assistant Administrator for Fisheries in 1987.

The 1996 amendments to the Magnuson-Stevens Fishery Management and Conservation Act set forth a number of new mandates for the NMFS, regional fishery management councils, and other federal agencies to identify and protect important anadromous fish habitat (16 U.S.C. (1855(b)). The fishery management councils, with assistance from NMFS, are required to delineate "essential fish habitat" (EFH) for all managed species. Federal action agencies which fund, permit or carry out activities that may adversely impact EFH are required to consult with NMFS regarding the potential effects of their actions on EFH, and respond in writing to the NMFS' recommendations. In addition, NMFS is required to comment on any state agency activities that would impact EFH.

The NEFMC promulgated a fishery management plan for Atlantic salmon in 1985. In accordance with the 1996 amendments, the NEFMC has designated EFH for Atlantic salmon. EFH is defined in the Magnuson-Stevens Act as "...those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." As required by the Magnuson-Stevens Act, NMFS promulgated regulations to provide guidance to the Councils for EFH designations. The regulations further clarify EFH by defining "waters" to include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; "substrate" to include sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" to mean the habitat required to support a sustainable fishery and the managed species? contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" to cover a species' full life cycle.

Essential fish habitat for Atlantic salmon is described as all waters currently or historically accessible to Atlantic salmon within the streams, rivers, lakes, ponds, wetlands, and other water bodies of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut and that meet conditions for eggs, larvae, juveniles, adults and/or spawning adults. Atlantic salmon EFH for eggs, larvae, juveniles and adults includes all aquatic habitats in the watersheds of rivers where salmon are currently present (26 rivers total), including all tributaries, to the extent that they are currently or were historically accessible for salmon migration.

The regulations also direct the Councils to consider a second, more limited habitat designation, Habitat Areas of Particular Concern (HAPCs). HAPCs are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area. Designated HAPCs are not afforded any additional regulatory protection under the Magnuson-Stevens Act; however, federal projects with potential adverse impacts to HAPCs will be more carefully scrutinized during the consultation process. Considering the unique habitat associations and requirements of Atlantic salmon, the Council has designated the habitat of eleven rivers in Maine as HAPCs for Atlantic salmon. The habitat of the Dennys, Machias, East Machias, Pleasant, Narraguagus, Ducktrap, Sheepscot, Kennebec, Penobscot, St. Croix Rivers and Tunk Stream was identified as serving the following two important purposes in terms of being habitat areas of particular concern: (1) they provide a unique and important ecological function; and (2) they are sensitive to human-induced environmental degradation.

The NMFS has committed to attempt to incorporate EFH consultations into interagency procedures previously established under the National Environmental Policy Act, Endangered Species Act, Clean Water Act, Fish and Wildlife Act, or other applicable statutes. Once the NMFS learns of a federal or state project that may have an adverse effect on EFH, NMFS is required to develop EFH Conservation Recommendations for the project. These recommendations may include measures to avoid, minimize, mitigate, or otherwise offset adverse effects on EFH. Federal agencies are required to respond to EFH Conservation Recommendations in writing within 30 days. Councils are also authorized to comment on federal and state projects and are required to comment on any project that may substantially impact anadromous fish habitat. Federal action agencies are required to prepare an EFH Assessment which must include the following: (1) a description of the proposed action; (2) an analysis of the effects, including cumulative effects of the actions on EFH, the managed species, and associated species by life history stage; (3) the federal agency's views regarding the effects of the action on EFH; and (4) proposed mitigation, if applicable.

<u>The Maine Atlantic Salmon Commission</u>
The Maine Atlantic Salmon Commission (ASC) was formed by the Maine Legislature in June of 1999, replacing the Atlantic Salmon Authority. The ASC consists of three members appointed by the Governor: Commissioner of IFW; Commissioner of DMR; and one At-Large public Member. The Commission appoints an executive director for a five year term. The ASC, like its

predecessor the Atlantic Salmon Authority, is granted sole authority and responsibility to manage the Atlantic salmon fishery in the state.

Cooperative Agreement: USFWS, NMFS and the AS

The USFWS and Maine had an agreement initiated on May 9, 1962, and renewed through 1997 to create a program of Atlantic salmon hatchery production and stocking for the purpose of furthering restoration of Atlantic salmon in the State of Maine. To assist in technical matters and marshal scientific expertise for addressing appropriate research, a Technical Advisory Committee (TAC) was established as part of the Agreement. The USFWS, NMFS, and ASA entered into a Cooperative Agreement effective January 1, 1998, through December 31, 2003, to further their common goal of protecting and recovering Atlantic salmon in Maine. The Cooperative Agreement maintains the TAC for the purpose of advising the Parties on any technical matter relative to the Atlantic salmon restoration and rehabilitation programs in Maine, pledges cooperation in activities to implement the Conservation Plan, continues FWS? commitment to the river-specific stocking program, and contains an agreement to cooperate on salmon population and habitat inventories, management investigations, and other activities of shared concern.

Cooperative Agreement: NMFS and the Maine Atlantic Sea Run Salmon Commission

This Agreement was created in 1990 to address research issues of concern relative to the rivers of eastern Maine that have predominately wild Atlantic salmon populations.

Fish and Wildlife Coordination Act (6 U.S.C. 661-66; 48 Stat. 401), as amended

Under this Act the federal regulatory and construction agencies must give consideration to fish and wildlife resources in their project planning and in the review of applications for federal permits and licenses. These agencies must consult with state and federal fish and wildlife agencies regarding the possible impacts of proposed actions and obtain recommendations for fish and wildlife protection and enhancement measures. The USFWS and the NMFS provide recommendations to federal action agencies that include measures to protect fish and wildlife resources. The FWCA consultation requirement applies to water-related activities for which federal permits are required, the most significant of which are Section 404 and discharge permits under the Clean Water Act, and Section 10 permits under the River and Harbors Act. Agency recommendations are to be given full consideration by the permitting agency, but are not binding.

Federal Power Act (16 U.S.C. 791a-8254; 41 Stat. 1063), as amended

This act, as amended, established several processes intended to protect and restore anadromous fishes impacted by hydroelectric facilities regulated by the Federal Power Commission and its successor agency, the Federal Energy Regulatory Commission (FERC). Section 18 of the Act assigns to the Commission a responsibility to require hydroelectric licensees to construct, maintain, and operate at their expense fishways prescribed by the Secretaries of Interior or Commerce. The Electric Consumers Protection Act of 1986 strengthened the position of the fish and wildlife agencies by requiring FERC to include conditions in licenses to protect, mitigate, and enhance fish and wildlife resources.

Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1251-1376)
Section 402 requires permits from the Environmental Protection Agency for the discharge of pollutants into navigable waters. Section 404 also provides for the Corps of Engineers to issue permits for the discharge of dredge or fill materials into navigable waters. Permit applications must be reviewed by the USFWS and the NMFS for impacts on fish and wildlife.

Fish and Wildlife Act of 1956 (16 U.S.C. 742a-742j; 70 Stat. 1119), as amended
Section 7(a), among other things, authorizes the Secretary of Interior to initiate measures required for the development, enhancement, management, conservation, and protection of fishery resources.

Federal Aid in Fish Restoration Act (16 U.S.C. 777-77k; 64 Stat. 430), as amended
This act, commonly referred to as the "Wallop-Breaux Act", provides federal funds to states for management and restoration of fish in connection with sport or recreation in the marine and/or fresh waters of the United States.

Anadromous Fish Conservation Act (16 U.S.C. 757a-757f; 79 Stat.) as amended
Public Law 89-304 authorizes the Secretaries of the Interior and Commerce to enter into cost sharing agreements with the states and other non-federal interests for conservation, development, and enhancement of the nation's anadromous fish (such as Atlantic salmon, Pacific salmon, shad, and striped bass). Investigations, engineering and biological surveys, research, as well as the construction, maintenance and operations of hatcheries are authorized.

National Environmental Policy Act of 1969 (42 U.S.C. 4321-4347; 83 Stat. 852)
Public Law 91-90 requires federal agencies to consult with each other and to employ systematic and interdisciplinary techniques in planning and decision making. It also requires federal agencies to include in every major Federal action significantly affecting the quality of the human environment a detailed statement on a) the environmental impact of the proposed action; b) any adverse environmental effects which cannot be avoided should the proposal be implemented; c) alternatives to the proposed action; d) the relationship between local short-term uses and enhancement of long-term productivity; and e) any irreversible and irretrievable commitments of resources involved in the proposed action.

INTERSTATE AND INTERAGENCY COMMITTEES

In accordance with various interagency cooperative agreements, the following governmental agencies participate directly in New England salmon programs: USFWS, NMFS, U.S. Forest Service, Maine Department of Marine Resources, Maine Department of Inland Fisheries and Wildlife, Maine Atlantic Salmon Commission, New Hampshire Fish and Game Department, Massachusetts Division of Marine Fisheries, Massachusetts Division of Fish and Wildlife, Rhode Island Division of Fish and Wildlife, Vermont Department of Fish and Wildlife, and the Connecticut Department of Environmental Protection.

The committees listed below have the potential to significantly influence issues related to Maine-origin Atlantic salmon.

Maine Technical Advisory Committee - established 1980
This committee succeeded an earlier group (Research Committee) and is an interagency committee with members from the three state fishery agencies in Maine, the University of Maine, the Penobscot Indian Nation, and the Services. The Technical Advisory Committee reviews activities associated with Atlantic salmon management in Maine and recommends appropriate actions to the ASA, FWS and NMFS.

New England Atlantic Salmon Committee - established 1984
This committee is composed of all state and federal fishery agency directors in New England. It addresses broad policy issues related to salmon restoration and interacts regularly with the U.S. Commissioners to the North Atlantic Salmon Conservation Organization.

New England Salmonid Health Committee - established 1985
This group of fish health specialists was originally established by the New England Atlantic Salmon Committee to address policy issues and provide guidelines related to Atlantic salmon disease management and other health needs related to salmon culture and restoration. Originally established only to address Atlantic salmon, their charge was expanded to all regional salmonid health issues in 1987.

U.S. Atlantic Salmon Assessment Committee (USASAC)
This committee is composed of state and federal fishery staff who provide advice and input to the three U.S. Commissioners to NASCO. The USASAC focuses on preparing annual stock assessments and the proposal and evaluation of research needs.

STATE REGULATIONS

The state of Maine has numerous laws that regulate the diversity of activities that could potentially affect anadromous Atlantic salmon. Development is regulated by the Model Shoreland Zoning Act, the Land Use Regulation Commission and Natural Resource Protection Act. Three agencies have authority over forest practice regulations: the Land Use Regulation Commission, the Department of Environmental Protection, and the Maine Forest Service. Maine also has regulations regarding non-point source pollution control and pesticide application control.

State laws that offer Atlantic salmon and their habitat protection are contained in the Conservation Plan. In March 1998 the Maine legislature passed a new law, which has the potential to reduce nonpoint source pollution from Maine agriculture. That law, "An Act Regarding Nutrient Management" (7 MRSA Ch 747) requires all Maine farms with more than 50 animal units (1 unit = 1000 lbs of body weight) to develop a whole farm nutrient management plan by January 1, 2001. The law also prohibits winter spreading of manure. The Commissioner of Agriculture is granted authority for enforcing these regulations (LWRC 1999).

Table 7.4.1 Existing Regulatory Mechanisms	**Habitat Protection**	

Law or Agreement	Water Quality	Physical Alteration	Access - Fish Passage	Harvest Regulation	Stock Conservation	Fish Health	Mgmt. Coord.	Research	Aquaculture
North Atlantic Salmon Conservation Organization (NASCO)				international	X	X	X	X	X
Conservation for the International Council for the Exploration of the Sea (ICES)								X	
Fishery Conservation and Management Act of 1976				national					
The Atlantic Sea Run Salmon Commission (ASRSC)				state	X		X	X	
Cooperative Agreement: USFWS and the State of Maine					X		X	X	
Cooperative Agreement: NMFS and the ASRSC					X			X	
Fish and Wildlife Coordination Act	X	X	X						X
Federal Power Act			X						
Federal Water Pollution Control Act	X	X							X
Fish and Wildlife Act of 1956					X			X	
Federal Aid in Fish Restoration Act					X		X	X	
Anadromous Fish Conservation Act					X		X	X	
National Environmental Policy Act	X	X	X						
New England Atlantic Salmon Committee (NEASC)							X		
U.S. Atlantic Salmon Assessment Committee (USASAC)					X			X	
New England Salmonid Health Committee						X			
State of Maine Dept. of Marine Resources									X

Aquaculture Lease Requirements (PL 1991, c. 381, subsection 2)									

7.4.2. Regulations and Permitting for Aquaculture

The U.S. aquaculture industry is subject to the state and federal laws and regulations discussed below. There are also fish health guidelines available to the industry. The New England Salmonid Health Guidelines published in 1995 were developed by a committee to address fish health of salmonids in New England. The guidelines identify requirements for the prevention and control of serious fish pathogens. The guidelines were designed to unify and coordinate the fish pathogen control efforts of member agencies. They include a system for inspecting fish culture facilities and references to the technical procedures to be used (New England Salmonid Health Committee 1997. New England Salmonid Health Guidelines. On file: Connecticut Department of Environmental Protection, Fish Health Laboratory, Burlington, Connecticut).

The laws applying in the State of Maine include: Maine Department of Marine Resources aquaculture lease requirements: PL 1991, c. 381, subsection 2; and Federal regulations and laws include:

> a) 50 CFR 16.16, Injurious Wildlife: importation of fish or fish eggs;
> b) Rivers and Harbors Appropriation Act of 1899, Section 10; construction of structures in navigable waters;
> c) Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1341-1345; 86 Stat.877), as amended, established the National Pollutant Discharge Elimination System Permits; and
> d) Fish and Wildlife Coordination Act (16 U.S.C. 661-667e; 48 Stat. 401), as amended; authority for U.S. Fish and Wildlife Service to comment on the effects on fish and wildlife of activities proposed to be permitted by the U.S. Army Corps of Engineers.

These guidelines, regulations and laws address and/or govern the importation of finfish and their eggs, define the location and size of aquaculture facilities, and establish monitoring requirements for disease and environmental impacts.

The Legislature for the State of Maine has amended Public Law 1991, c. 381, subsection 2, specific to aquaculture to prohibit the importation or introduction into any waters of the state, of any Atlantic salmon, live or as eggs, that originate in any Icelandic or European territorial water, or any other species of salmon, exclusive of rainbow trout, originating west of the North American Continental Divide. This law initially provided for the introduction of salmon originating from outside of North America, excluding stocks from west of the Continental Divide, until January 1, 1995.

A joint Federal and State of Maine permit processing procedure has been established to facilitate the processing of applications for net-pen aquaculture permits. At the federal level, permits for placement of cages in marine waters are issued by the U.S. Army Corps of Engineers (ACOE) under Section 10 of the Rivers and Harbors Act of 1899. Standard Siting Requirements and Permit Conditions issued by the ACOE (1/17/97) state that no live finfish of any species at any stage of development post hatching whose source is outside of the North American continent shall be introduced or transported to marine waters within the State of Maine and also that no live anadromous Atlantic salmon whose original source as fertilized eggs or gametes was outside of the North American continent shall be introduced or transported to marine waters within the State of Maine (conditions B2 and B3). An additional requirement states that applicants must provide documentation that they understand that no live finfish species at any stage of development post hatching whose source is outside of the North American continent and that no live Atlantic salmon whose original source as fertilized eggs or gametes was outside of the North American continent shall be introduced or transported to marine waters within the State of Maine (condition C10d). The NMFS has requested ACOE assistance to investigate and ensure compliance with these siting and permit conditions at all existing cage sites. The ACOE, NMFS and FWS are engaged in discussions with the State of Maine on this issue, but it remains unresolved at this time.

The North American Commission (NAC) of NASCO (comprised of the U.S. and Canada) has recognized the potential for adverse fish health, genetic, and ecological effects on native Atlantic salmon stocks. The NAC formally adopted protocols in 1992 (amended 1994) for the introduction and transfer of salmonids that include a zoning concept for the introduction and transfer of salmonids in the Commission area and specific actions regarding fish health and genetic issues, including a prohibition on the use of reproductively viable European or Icelandic stocks. The protocols per se are not legally enforceable regulations, but each NAC country, as a signatory to the treaty, has a commitment to take whatever measures are necessary to implement the protocols in their respective country. An updated revision of the protocols is currently out for public review.

Three Zones are identified in the current NAC protocols, and two are applicable to the coastal waters of Maine. Maine, east of Rockland, lies within Zone II and the area west of Rockland lies within Zone III. The proposed revision to the protocols would place rivers within the State of Maine from the Kennebec River drainage eastward in Zone II and west of the Kennebec River drainage in Zone III. Key aspects of protocols that apply to all Zones, and that are recommended by NAC for protection of native Atlantic salmon stocks, include:

1. Atlantic salmon of European origin, including Icelandic origin, are not to be released or used in aquaculture in the NAC area.
2. Salmon, eggs, gametes, or fish products are not to be imported from IHN enzootic areas without thoroughly demonstrating the absence of IHN.
3. Prior to transfer of eggs or fish, at least three health inspections of the donor facility must be completed within a two-year period preceding the transfer to ensure the absence of restricted fish pathogens.
4. Prior to movement of non-native fishes to rivers or rearing sites inhabited by Atlantic salmon, the potential for adverse impacts on the productivity of wild salmon populations must be reviewed and evaluated.
5. Hatchery rearing programs to support the introduction, re-establishment, rehabilitation and enhancement of Atlantic salmon should comply with identified selection, spawning and mating procedures.

Within Zone II, reproductively viable non-indigenous species (except Arctic char and Brook trout) and reproductively viable Atlantic salmon stocks, non-indigenous to the NAC area, are not to be introduced into watersheds or into the marine environment.

Atlantic salmon restoration, enhancement, and aquaculture activities are permitted in the freshwater and marine environments. Domesticated broodstock should be developed using local stocks or nearby stocks; non-indigenous stocks may be introduced into the wild or used in cage rearing operations if fish are reproductively sterile, and the risk of adverse ecological interactions is minimal. Preferred locations for cage culture are at least 20 km from watersheds managed for Atlantic salmon production.

Within Zone III, indigenous and non-indigenous salmonine and non-salmonine (except reproductively viable Atlantic salmon stocks non-indigenous to the NAC Area) fishes may be considered for introduction or transfer if fish health and genetic protocols are followed, and negative impacts on Atlantic salmon can be shown to be minimal. Use of local stocks in cage culture or salmon farms is preferred, but non-indigenous stocks may be cultured. Cage culture or salmon farming can be widely practiced yet preferred locations are at least 20 km from watersheds managed for Atlantic salmon production.

The Maine Conservation Plan stated that threats to wild salmon may occur if farmed salmon transmit diseases or parasites to Atlantic salmon stocks within the seven rivers or the nearshore marine environment when wild salmon migrate through marine waters adjacent to sea cages; if farmed salmon escapees interbreed with wild salmon and cause reduced fitness for survival; if farmed salmon superimpose redds on wild salmon redds, thus disrupting the egg incubation process; or if farmed salmon escape as juveniles into the salmon rivers and compete for food and space with wild stocks. It was further stated that potential threats from any poor hatchery practices in freshwater fish culture operation could affect wild salmon in the Sheepscot, Pleasant and East Machias Rivers and potential threats from cage rearing operations would likely impact Atlantic salmon populations in the Dennys, East Machias, Machias, Pleasant and Narraguagus Rivers.

The Conservation Plan identified the following actions addressing threats: maintenance of current state, federal and New England fish health inspection protocols; vaccination of farmed fish prior to stocking in sea cages; enforcement of private insurance standards; harvesting of farmed salmon before maturation; escape control efforts; minimization of seal induced escapes through the use of predator guard nets, and acoustic and visual deterrent devices; and screening intakes and discharges of freshwater facilities to minimize escape of juveniles. Proposed actions for enhanced protection identified in the Conservation Plan include the following: maintenance and improvement of the current state and federal fish health protocols; development of an emergency disease eradication program; expansion of an ongoing epidemiological monitoring program to determine the type, incidence and geographic distribution of salmonid pathogens in Maine; documentation, evaluation and compilation of industry practices into a Fish Health Code of Practices; complete adoption of an Industry Code of Practices to minimize escapes of farmed fish; development and adoption of a Fish Culture Code of Practices for culture in freshwater and sea cage cites; rearing of river-specific stocks in cages for stocking back to their river of origin;

weir construction; development of a marking system proposal; and initiation of research into seal behavior around sea cages and site and cage vulnerability to seal attack.

The 1998 Annual Progress Report on the Conservation Plan identified the following actions related to aquaculture: adoption of a Loss Control Code of Practices; State/industry cooperation to develop a system of compliance monitoring; permits for a fish weir on the Pleasant River; drafting by the Fish Health Advisory Board of rules for instituting fish health protocols and disease eradication measures; and an intention by the Department of Marine Resources to finalize rules on fish health standards and protocols governing the intrastate movements of salmon and disease detection and eradication measures binding on fish farmers. Application of an effective code of practice has proven in Norway to reduce losses and therefore risks to wild stocks. Improved containment alone, however, cannot prevent impacts to wild stocks but rather slow the rate at which changes would occur (DFO 1999).

7.4.3 SUMMARY

A variety of state and federal environmental statutes and regulations seek to address potential threats to Atlantic salmon and their habitat. These laws are complemented by international actions under NASCO and many interagency agreements and state-federal cooperative efforts. Implementation and enforcement of these laws and regulations could be strengthened to further protect Atlantic salmon. The appropriate state and federal agencies have established coordination mechanisms and have joined with private industries and landowners in partnerships for the protection of Atlantic salmon. These partnerships will be critical to the recovery of the species. Existing regulatory mechanisms either lack the capacity or have not been implemented adequately to decrease or remove the threats to wild Atlantic salmon. The discussion that follows will focus on those laws which are not sufficient to deal with threats or, if they are adequate, are not being applied or enforced. Major threats continue to be poor marine survival; water withdrawals; recreational fishing mortality; disease and aquaculture impacts, especially interaction with European strain and hybrid (Euro/North American) salmon. Efforts to reduce marine harvest are discussed at length in Section 7.2 and will not be repeated here. Drastic reductions in ocean harvest have occurred in Canadian and Greenland waters, but the numbers of adult spawners has not increased in response.

Water withdrawals: Maine has made substantial progress in regulating water withdrawal for agricultural use. The Land and Water Resource Council and the Land Use Regulatory Commission must approve requests for withdrawals for irrigation, and can curtail withdrawals if water levels go below what is considered necessary for the well being of the species. The State Department of Environmental Protection is developing a rule to address withdrawals on a statewide basis. At this point, water withdrawals in unorganized towns are not regulated.

Recreational Fishing Mortality: Maine currently allows catch and release salmon fishing in the DPS rivers. The Atlantic Salmon Commission can promulgate regulations governing salmon fishing, and in the past its predecessor, the Atlantic Salmon Authority, reduced the season by closing it in July and August when water temperatures are normally highest, thus increasing the risk of mortality. Recent efforts to close the DPS rivers to all salmon fishing were unsuccessful, however Maine is reconsidering that option along with closing parts of some of the rivers to all fishing to protect salmon parr as well as adults. The legal means to do these things exist, but they have not yet been fully applied.

Disease: A number of State and Federal laws exist to reduce the threats to both wild and cultured fish from disease. Maine has very stringent fish health requirements, and the FWS monitors hatchery fish at Craig Brook and Green Lake with extreme care. Cultured fish are vaccinated against various diseases and screened continuously. However, in spite of regulations, the European ISA virus has become established in North American aquaculture fish in proximity to DPS salmon. Also, the occurrence of a here-to-fore unknown retrovirus, SSSV is not yet specifically addressed by any regulations. These recent disease episodes have compromised the Services' river specific stocking program in that Pleasant River broodstock had to be destroyed and brood stock for three other wild river populations has been compromised.

Aquaculture: The risks inherent in wild stocks interacting with aquaculture escapees has increased significantly from what was believed to be the case three years ago when certain restrictions on the importation and use of foreign salmon stocks were believed by the BRT and the Services to be in place and enforced. Regulations governing import and placement of aquaculture fish fall short on two counts; (1) the Maine state law (PL 1991 c381 sub section 2) regulating import fails to restrict European milt from entering the state as it does fish or eggs, thus enabling expansion of the use of hybrids between European and North American salmon in aquaculture; and (2) the Corps of Engineers continues to not enforce permit conditions under Section 10 of the Rivers and Harbors Act which prohibit placing European strain or hybrids in sea cages. Failure to adequately enforce certain existing regulations or correct deficiencies identified in others significantly increases risks to the survival of the severely depressed existing U.S. wild salmon populations. The BRT concludes that the Gulf of Maine DPS is in danger of extinction.

7.5 OTHER NATURAL OR MANMADE FACTORS AFFECTING ITS CONTINUED EXISTENCE

7.5.1 Aquaculture: Atlantic Salmon Farming

7.5.1.1 Production and Location of Sites

The development and expansion of Atlantic salmon aquaculture has occurred in the North Atlantic since the early 1970's. Worldwide production of farmed Atlantic salmon in 1998 was 710,342 tons, over 295 times the nominal catch of Atlantic salmon in the North Atlantic (ICES WG 1998). Production in the North Atlantic area in 1998 was 538,011 tons, of this Norway produced 64% and Scotland produced 21% (ICES WG 1998). In the United States, Atlantic salmon aquaculture occurs predominantly in the states of Washington and Maine. In the Gulf of Maine, the industry has grown rapidly in the last decade. Annual Atlantic salmon aquaculture production in Maine increased from an estimated 10 mt in 1984, to 454 mt in 1988, to 12,250 mt in 1997 (Honey et al. 1993; Baum 1998).

The Maine Atlantic salmon aquaculture industry is currently composed of 12 companies, at 33 sites with a total of 773 cages covering 800 leased acres of water. Farms are concentrated in Cobscook Bay near Eastport, Maine but are located as far south as the Sheepscot River, although that site currently does not grow Atlantic salmon. The industry in Canada, just across the border, is approximately twice the size of the Maine industry.

Five freshwater hatcheries in the United States provide smolt to the sea cages and produce up to four million smolt per year. Locations of cages and freshwater hatcheries are displayed in Figure 7.5.1.1. It takes approximately 18 months to grow a market-sized fish and annual production in Maine is about six million salmon or 12,000 mt (Baum 1998). Three broodstock lines are used for farm production. The lines include fish from the Penobscot River, St. John River, and an industry strain from Scotland. The Scottish strain was imported into the U.S. in the early 1990s and is composed primarily of Norwegian strains, frequently referred to as Landcatch. In recent years, milt of Norwegian origin has been imported by the industry from Iceland (DFO 1999). It is estimated that there is European genetic influence in approximately 30 to 50% of the production fish in Maine (Baum 1998)

Figure 7.5.1.1: Commercial Aquaculture Hatcheries and Pen Sites

7.5.1.2 Threats to Wild Salmon

Atlantic salmon that escape from farms and hatcheries pose a threat to native Atlantic salmon populations in coastal Maine rivers. Escapement and resultant interactions with native stocks are expected to increase given the continued operation of farms and growth of the industry under current practices. There is a potential for escaped farmed salmon to disrupt redds of wild salmon, compete with wild salmon for food and habitat, interbreed with wild salmon, transfer disease or parasites to wild salmon and/or degrade benthic habitat (Clifford 1997; Youngson et al. 1993; Webb et al. 1993; Windsor and Hutchinson 1990; Saunders 1991). A comparison study in Canada revealed that survival of wild post-smolts moving from Passamaquoddy Bay to the Bay of Fundy was inversely related to the density of cages (DFO 1999). Finally, there has been recent concern over potential interactions when wild adult salmon migrate past closely spaced cages, creating the potential for behavioral interactions, disease transfer or interactions with predators (DFO 1999; Crozier 1993; Skaala and Hindar 1997; Carr et al. 1997; Lura and Saegrov 1991).

Farm raised Atlantic salmon have been documented to exist in the wild because of escapement and release from salmon aquaculture facilities (ICES-NASWG 1994; NASCO 1993; Bergan et al. 1991; Lura and Saegrov 1991; Hansen et al. 1993; Skaala and Hindar 1997; Stokesbury and Lacroix 1997). In Norway, the number of salmon that escape from sea cages is thought to be greater than the number of salmon in the wild (Gausen and Moen 1991). Monitoring on 30 rivers in Norway in 1997 documented farmed fish in 26 rivers. Between 1992 and 1997, the total stock size of wild and hatchery origin adult Atlantic salmon returning to the Canadian Maritimes was between 115,000 and 229,000. During that same time, the number of salmon in net pens in the Bay of Fundy exceeded fifteen million. It is estimated that 25-40% of the fish in the North Atlantic Ocean is of aquaculture origin (Jonsson 1997). In Atlantic Canada, most Atlantic salmon aquaculture occurs in the lower portion of the Bay of Fundy. There are an estimated 60 aquaculture facilities (farms) in the area, and salmon that have escaped from farms have been documented in New Brunswick rivers (ICES-NASWG 1994).

Reports of large-scale escapes are rare; however, in 1994 there was one reported escape in New Brunswick of between 20,000 and 40,000 fish which was equal to the total estimated wild returns to Nova Scotia and New Brunswick that same year. Since the aquaculture industry began in 1979 in the Maritimes, escapees have been documented in 14 rivers in New Brunswick and Nova Scotia (DFO 1999). The Magaguadavic River is monitored for interactions between wild and farmed fish in Canada. In at least two years, over 90% of the adult salmon entering the Magaguadavic River were of farmed origin. This data has been used to demonstrate the fact that the three aquaculture hatcheries in the watershed are leaking farmed juveniles. Emigrating smolts in 1996 were 51-67% farm-origin and those exiting the river in 1998 were 82% farm-origin (DFO 1999). Analysis of eggs taken from the Magaguadavic River in 1993 revealed that at least 20% of the redds were constructed by females of farm or cultured origin, and another 35% were of possible cultured origin (Carr et al. 1997).

Atlantic salmon that either escaped or were released from farms have been found in the St. Croix, Penobscot, Dennys, East Machias, and Narraguagus rivers in the U.S. (Baum 1991; USASAC 1996, 1997). In 1994 and 1997, escaped farmed fish represented 89% and 100% respectively, of the documented run for the Dennys River, and in 1995, 22% of the documented run for the Narraguagus River (Table 7.5.1.2). Escaped farmed salmon have also been documented as an incidental capture in the recreational fishery, or observed in additional rivers: Boyden, Hobart, and the Pennamaquan Rivers. The first aquaculture escapee in the State of Maine was documented in 1990 and the first sexually mature escapee was documented in 1996. Escaped farmed fish are of great concern in Maine because even at low numbers they can represent a substantial portion of the returns to some rivers. Also, populations at low levels are particularly vulnerable to genetic intrusion or other disturbance caused by escapees (DFO 1999, Hutchings 1991). Preliminary results from the 1999 wild smolt assessment project in the Pleasant River, Washington County, suggest that several outmigrating smolts were of hatchery origin based on fin condition (Kocik et al. 1999, unpublished data). Genetic and scale samples were collected to better determine the origin of these fish.

Table 7.5.1.2. Number and percentage of the total run of farmed salmon found in the Dennys and Narraguagus rivers, 1993-1997.

	DENNYS		NARRAGUAGUS	
YEAR	Number	% of Run	Number	% of Run
1993	20	45%	1	2%
1994	42	89%	0	0%
1995	4	44%	8	22%
1996	21	68%	0	0%
1997	2	100%	1	4%

Because of selection in the hatchery or culture environment, farmed salmon are expected to be less fit for life in the wild. However, they may have competitive advantages at certain life stages (Gross 1999). Experimental tests of genetic divergence between farmed and wild salmon indicate that farming generates rapid genetic change as a result of both intentional and unintentional selection in culture and that those changes alter important fitness-related traits (McGinnity et al. 1997; Gross 1998). This change was identified as a threat to wild populations when cultured fish escape, and compete and breed with wild salmon (Hindar et al. 1991; Fleming and Einum 1997). Farmed salmon in Scandanavian countries have been documented to spawn successfully, but later in the season than wild salmon (Lura and Saegrov 1991; Jonsson et al. 1991), a factor that increases the potential for limiting the success of wild spawners through redd superimposition. Culture or artificial propagation selects for attributes that affect the behavior of farmed salmon (Hindar et al. 1991; Utter et al. 1993).

Study results were presented at the 1997 joint ICES/NASCO Symposium on Interactions between Salmon Culture and Wild Stocks of Atlantic salmon which demonstrated that spawning between wild and cultured fish would have negative consequences for the wild stock since the offspring of the cultured fish occupied juvenile habitat and displaced wild fish (CNL (97)27). Escapees in Europe provide evidence of spawning success and also of redd superimposition (DFO 1999). Mork (1991) characterized the potential permanent effect of one generation burst immigrations, resulting from large scale escapes from farms near spawning rivers, on the genetic differentiation among wild stocks. He reported that small Atlantic salmon populations may be most vulnerable to burst immigrations, and these events could be the most significant way in which farmed salmon affect the genetic structure of wild populations. Natural selection may be able to purge wild populations of maladaptive traits but may be less able to if the intrusions occur regularly year-after-year. Under this scenario, population fitness is likely to decrease as the selection from the artificial culture operation overrides wild selection (Fleming and Einum 1997; Hindar et al. 1991). Genetic interactions between wild and farmed fish can disrupt local adaptations, threaten stock viability and character, and lower recruitment (DFO 1999; Einum and Fleming 1997; Fleming and Einum 1997; Grant 1997; Saegrove et al. 1997).

A study was conducted in a natural spawning tributary of the Burrishoole River system in western Ireland to compare the performance of wild, farmed, and hybrid Atlantic salmon progeny. Survival of progeny of farmed fish to the smolt stage was significantly lower than that of wild salmon. The progeny of farmed fish, however, grew faster and displaced native fish downstream (McGinnity et al. 1997). This study demonstrated that both farmed fish and hybrids can survive in the wild. It also indicates that escaped farmed salmon can produce long term genetic changes in natural populations (McGinnity et al. 1997). The authors caution that repeated intrusions of escaped farmed salmon will depress smolt productivity in a cumulative fashion potentially creating an extinction vortex (McGinnity et al. 1997).

Initial studies in Ireland had focused on the potential for adults to escape from sea cage sites, locate and enter a wild river, and interbreed or otherwise interact with the wild population. However, recently the focus has been expanded to include concerns over escapes from freshwater hatcheries in Ireland on rivers with wild populations, and potential competition and interaction between these escapees and wild stock from early life stages to spawning adults. A relationship has been demonstrated between the reproductive success of cultured fish and the time the fish has lived in nature before reaching sexual maturity (Jonsson 1997). Consequently, escapees from freshwater hatcheries may pose a larger threat to wild populations than escapees from sea cage sites.

Experiments have been conducted in rearing triploid Atlantic salmon with the hope that the use of these sterile fish in commercial culture would eliminate concerns for genetic interaction with wild stock. While growth and survival in freshwater has been demonstrated to be comparable to diploid strains, mortality during the transition to marine cages has been higher and deformities among triploids remain a major concern (O'Flynn et al. 1997). A comprehensive evaluation of the use of sterile triploid Atlantic salmon was undertaken from 1994-1998 by the Marine Laboratory in Aberdeen. Performance trials in Ireland and Norway demonstrated that triploids grew similarly and survived as well as diploids in freshwater. In sea water, triploids grew similarly to diploids but suffered higher losses in half of the trials (Marine Laboratory Aberdeen 1998).

Given current aquaculture practices, the Services have opposed the use of reproductively viable European strains (pure and hybrid) of Atlantic salmon within North America. This opposition is based on genetic studies that demonstrate that there are significant differences between North American and European Atlantic salmon (King et al. 1999), and the advice from geneticists that interbreeding among genetically divergent populations negatively impacts natural populations (Utter 1993; Verspoor 1997; Youngson and Verspoor 1998). The introgression by non-North American Atlantic salmon stocks presents a substantial threat of disrupting the genetic integrity of North American stocks and threaten fitness through outbreeding depression.

Disease epizootics in wild Atlantic salmon populations are not common, but in culture operations where fish are artificially propagated under high densities, they can pose a significant threat (NASCO 1993; Saunders 1991). Diseases affecting Atlantic salmon reared in captivity include bacterial, parasitic, viral, fungal and nutritional diseases (Roberts 1993). The development of a disease epizootic results from an interaction between the host, environment and the disease agent. In farmed salmon, the occurrence of disease is generally due to the high densities at which fish are reared (Hastein and Lindstad 1991). Bacteria may be released to the environment during and after epizootic diseases and may survive and persist (Olafsen 1993; Egusa 1992). The occurrence and spread of infectious diseases increases due to the high densities at which farmed salmon are raised (Institute of Aquaculture 1988; Lura and Saegrov 1991; Hastein and Lindstad 1991; Mork 1991; NASCO 1993; Olafson 1993).

The disease interaction between wild and farmed salmon will likely occur through the water, fish, and other sources such as nets and fishing or handling gear. The transmission of diseases through water can take place over long distances, and transmission has been documented to occur over at least seven km (Hastein and Lindstad 1991). Incidences of disease transmission from Atlantic salmon farms to wild stocks are not well documented, but investigations are becoming more numerous. The greatest risk associated with diseases is the introduction of an exotic disease into a new area where local stocks have no innate resistance (McVicar 1997, DFO 1999). In Norway, over thirty populations of salmon have extirpated by the parasite Gyrodactylus salaris (Heggberget et al. 1993).

In response to the presence of Infectious Salmon Anemia (ISA) in Canadian aquaculture sites, the Maine aquaculture industry initiated a biosecurity audit to identify strengths and weaknesses in farm-level disease prevention procedures, to prevent the spread of ISA into Maine and to detect the potential emergence of ISA at the cage level. The Maine Aquaculture Association has also reported that emergency eradication procedures for exotic disease events have been adopted and updated state regulations governing the importation and movement of live fish and gametes are nearing completion.

As discussed above, ecological interactions between wild and cultured Atlantic salmon can occur at any life stage through competition for food and habitat, and during spawning. There is also the potential for cage sites to negatively impact the benthic habitat from discharge of wastes and excess food. In 1992, Maine initiated the Finfish Aquaculture Monitoring Program (FAMP) to evaluate the impact of marine cages on benthic habitat. The program is funded by a one cent per pound tax on production. While there have been isolated examples of degradation below particular sites, they were fallowed and found to recover quickly. There was also no evidence of negative impacts to wild salmon habitat, water quality or benthic organisms from wastes or the use of drugs and chemicals in the Maine aquaculture industry (Baum 1998).

In 1998, the Department of Fisheries and Oceans convened a workshop to assess the potential impacts of aquaculture on wild stock and to recommend ways to minimize the risks (DFO Maritimes Regional Habitat Status Report 99/1 E CITE FORMAT). Concern was heightened by the drastic drop in wild stocks in areas where aquaculture was conducted. For example, the spawning run in the Magaguadavic River decreased from 293 in 1992 to 31 in 1998. Egg deposition during that same time decreased from 80% to 2.3% of the conservation requirement. Workshop participants identified the following potential interactions between farmed and wild Atlantic stocks (relative risk to wild stocks is in parenthesis): competition in the ocean (unknown); disruption of migration by interference (unknown); redd superimposition (medium); competition for food and space in freshwater (high); habitat displacement in freshwater (high); altered predator-prey relations (high); disruption of migration by cages and hatcheries (unknown); and hybridization (medium-high) (DFO 1999).

The summary of this workshop recommended application of a precautionary approach for management of the Maritimes salmon stocks and their interaction with escaped farmed salmon. This approach was based on documentation of local interactions, evidence of genetic and behavioral interactions between escapees and wild salmon in Europe, predictions of a regional model assessing risk, and the potential for negative interactions. The following priority action items were identified to minimize the risk of interaction between wild and farmed salmon: improving containment; improving fish health management; upgrading the policy for introductions and transfers of fishes and improving related enforcement; enhancing education and training of aquaculture workers; maintaining wild stocks at or above their conservation requirements; continuing the use of local stocks as donors; and incorporating risk analysis into the process for siting hatcheries and farms (DFO 1999). A further recommendation was given that counting fences be used for all rivers with unique stocks in which escapees are found to be compromising a significant portion of the total returns (DFO 1999).

The Maine Aquaculture Association has developed and adopted a Code of Practice for the Responsible Containment of Farmed Atlantic Salmon in Maine Waters (October 1998). The Code focuses on net strength, equipment integrity and predator control measures. An annual four-point stress test is required for all nets greater than three years old. Cages are also to be marked with the name of the manufacturer, year produced, field assembler, date deployed, and an inventory control number. Written maintenance records are to be kept on site for all nets and cages. Additional components of the Code discuss moorings and freshwater hatchery containment. Operating procedures for fish transfers, predator control and storm preparation are specified to minimize the risk of escapement. However, the details of the reporting, monitoring and enforcement of the Code remain to be worked out at this point.

An additional action to be taken in an attempt to prevent opportunities for aquaculture escapees to interact with wild stock is the placement of weirs in wild salmon rivers. A trapping facility is already located on the Narraguagus River so migrating adults can be examined and obvious aquaculture escapees can be denied passage upstream to spawning sites. Currently, aquaculture escapees are identified primarily by condition of the fins and body shape. There has been discussion of pursuing a universal tag that could be placed on all aquaculture fish to ensure that identification at weir and other sorting sites would be absolute. Such a mark has not been developed at this time.

Permits have been secured for the placement of weirs on the Dennys and Pleasant rivers and the State plans to install these weirs by October 1999. Design work for a weir on the East Machias River is ongoing and construction is planned to begin this fall. The decision has been made to design a fish trap for the Machias River Gorge instead of a weir and the ASC and FWS are currently working on that design.

7.5.2 Natural Mortality in the Marine Environment

Natural mortality in the marine environment can be attributed to four general sources: predation, starvation, disease/parasites, and abiotic factors. While our knowledge of the marine ecology of Atlantic salmon has increased substantially in the past decade, we cannot partition total natural mortality into these categories. Consequently, investigations of natural mortality are currently based upon an examination of return rates or total marine survival. Estimates of total mortality can be made by relating either hatchery smolt stocking rates or estimates of wild smolt production to the return of adult spawners. This method integrates all natural mortality factors and, if applicable, fishing mortality. If smolts are enumerated near the marine environment, the return rate indexes only marine survival. If the smolts are enumerated as they are stocked into upstream reaches, then assessment of return rate will include outmigration mortality.

Reported survival rates of Atlantic salmon during the marine phase range from 0-20%, based upon a review of 20 studies by Bley and Moring (1988). Our review of additional studies found that this range is realistic for Atlantic salmon survival and that most return rates fall in the lower quartile of this range (Reddin 1988; Ritter 1989; Scarnecchia et al. 1989). In the U.S., return rates have generally been less than 1.5% in the Penobscot River and even lower in the Connecticut and Merrimack Rivers. In fact, return rates for Connecticut and Merrimack River hatchery stocks average 12% and 27% of that of the St. John River in Canada, which is one of the closest Canadian rivers to the U.S. The average Penobscot River return rate is about 89% of the St. John River average. The Connecticut and Merrimack River Atlantic salmon return rates are very low compared to the rates observed in other predominantly 2SW populations. Wild stocks and stocks returning after one sea winter typically return at higher rates (Bley and Moring 1988). Lower return rates might be expected for U.S. stocks, which are primarily 2SW fish and have been the result of smolt releases for most of the restoration period. However, in a comparison to only the hatchery stocks of the St. John River, survival was still lower in the more southern U.S. systems (Porter and Ritter 1984).

Some investigators have suggested that Atlantic salmon stocks that utilize longer migration routes typically have lower marine survival (Bley and Moring 1988). The authors also note a north to south gradient of decreasing marine survival that is consistent with this hypothesis. This hypothesis also helps to explain the typically high survival seen in several of the northern (Icelandic and Irish) stocks of Atlantic salmon with limited migratory routes. As such, the lower return rates of U.S. stocks may be a result of their relatively long migrations. If this is the case, these lower return rates may simply reflect the geographic location of these stocks in the southern extent of the range of Atlantic salmon. It is important to note that there is also a north-south trend of decreasing smolt-ages. This trend results in higher freshwater productivity in the southern extent of Atlantic salmon range that would offset the higher marine mortality.

On an interannual basis, marine survival rates can be more variable than freshwater survival rates. Reddin (1988) evaluated the freshwater (egg to smolt) and marine (smolt to spawner) survival for seven cohorts of Atlantic salmon in West Arm Brook. He found that marine survival was typically higher (5.51%) than freshwater (1.67%). However, the variation in marine survival, as measured by the coefficient of variation, was nearly four times greater in the ocean (63%) than in the stream (14%). These results were partly confounded by the fact that these stocks are exploited at sea, albeit only lightly. However, unexploited Icelandic stocks had similar variation (62%) in marine survival (Scarnecchia 1984a; Scarnecchia et al. 1989). Thus, the production potential and population dynamics of Atlantic salmon may be determined by year-to-year variability of oceanic natural mortality as well as the average level of natural mortality in the marine environment.

The year-to-year variation in return rates of U.S. stocks is generally synchronous with other Atlantic salmon stocks although at lower absolute levels (Friedland et al. 1993). Recent return rates have been decreasing for several North American Atlantic salmon stocks. This suggests that while some factors distinct to the U.S. stocks may be causing low return rates, the general trend is being driven by a factor that occurs when the stocks are mixed. Friedland et al. (1993) documented a common pattern of return rates for five North American stocks, including the Penobscot River and Connecticut River stocks, suggesting that all of these stocks responded equally to variation in survival. This observation provides an alternate hypothesis to conventional thinking that the most significant natural mortality occurs in the river, estuary, and close to the river mouth (Larsson 1985; Wood 1987; Hvidsten and Lund 1988; Magnhagen 1988). The correlations between the survival rates suggest that an important cause of mortality may act upon the stocks when they are mixed and utilizing a shared habitat. Since North American Atlantic salmon are migrating from geographically distinct rivers to common ocean feeding grounds, the likelihood that their distributions will begin to overlap increases with the length of marine residency. Thus, autumn and winter are the most likely seasons when post-smolt survival is determined. Similar recruitment cohesion has been described in other Atlantic salmon stocks and salmonine species (Scarnecchia 1984a; Koslow et al. 1987; Cohen et al. 1991). This observation indicates that factors occurring in the North Atlantic, and particularly the Labrador Sea, may be important to the survival of many Atlantic salmon stocks.

Survival rates are likely to be a function of growth patterns. Friedland et al. (1993) found that the survival rate for the Penobscot River stock was correlated to a growth index defined by intercirculi spacing over the winter period, suggesting that the first winter at sea regulates annual recruitment. This agrees with the analyses of Reddin and Shearer (1987) and Ritter (1989). This growth index also provides insight into the relationship between mortality and growth. Friedland et al. (1993) found an association between growth and survival such that in years of poor growth, a greater proportion of the stock died. When growth was better, so was survival. This suggests that the functional relationship between growth and survival may not be a threshold phenomenon. If a threshold was necessary for survival, the sample of scales from Atlantic salmon returning to rivers would only be obtained from those fish above a critical length (Friedland et al. 1993).

Sea surface temperature (SST) may be an important feature of the marine environment that affects Atlantic salmon survival. Saunders (1986) and Reddin and Shearer (1987) found that SST influenced Atlantic salmon marine distribution. Atlantic salmon were common in 4o to 10o C waters, a temperature range thought to be ideal for growth (Saunders 1986). Scarnecchia (1984a and 1984b) showed that temperatures were related to Icelandic Atlantic salmon production for both 1SW and 2SW groups. Reddin and Shearer (1987) tested Dunbar and Thomson's (1979) hypothesis that sea temperatures and distributions influenced Atlantic salmon abundance in West Greenland. They found that below-normal surface temperatures in the Labrador Sea over the winter were responsible for low catches in West Greenland in 1983 and 1984. Because homewater catches for the same stocks that occurred in West Greenland were also low, they postulated that the low temperatures decreased overall production. Friedland et al. (1993) and Reddin et al. (1993) found that the pattern of stock production was related to the area of winter habitat available to North American post-smolts. The lack of a relationship for spring, summer, and autumn suggests that habitat during these seasons may not be limiting. As such, these researchers concluded that a significant proportion of the variation in recruitment was the result of post-smolt survival. The area of habitat could be related to intraspecific competition for space and food resources and to predation effects on post-smolts (Friedland et al. 1993). While these investigations have indicated the importance of SST to Atlantic salmon recruitment, the mechanisms responsible for reduced survival are still unknown. Mortality could arise from stress, starvation, predation, disease, and, perhaps, other unknown mechanisms. Further research needs to be undertaken to fully understand the processes involved

In summary, based upon recent research, major seasonal events influence post-smolt survival in Atlantic salmon. It appears that survival of the North American stock complex of Atlantic salmon is at least partly determined when they are concentrated during the winter months in the habitat formed at the mouth of the Labrador Sea and east of Greenland (Reddin and Shearer 1987; Friedland et al. 1993; Reddin et al. 1993). The habitat may limit total North American stock production through intraspecific competition during this period, but the post-smolt year is not growth-limiting to individual fish. Limitations result in annual variation in survival and growth that are correlated to SST. Until more direct observation on the marine ecology of post-smolts during winter can be made, researchers must assume that mortality is controlled by the interaction of growth and predation.

7.5.3 Artificial Propagation and Atlantic Salmon

In 1992, the ASRSC and the USFWS implemented a river-specific stocking program for Maine rivers. The program was initiated for the following two reasons: runs were declining in the seven rivers in the DPS and numerous studies indicated that restocking efforts are more successful when the donor population comes from the river to be stocked. This river-specific stocking policy is consistent with the goal of the Maine Atlantic salmon program to maximize production of wild smolts by restocking river specific stocks and emphasizing fry releases (Moring et al. 1995). The natural Atlantic salmon population in these seven rivers is very low and artificial propagation, by eliminating significant mortalities in vulnerable early lifestages, has potential to increase the number of fish in a short time period, thereby avoiding extinction. Collection of wild parr and captive rearing also acts as a multiplier of spawner numbers increasing effective population size. The ultimate goal is to reach the stage where stocking is no longer necessary on a continual basis. The Prelisting Recovery Plan (Baum et al. 1992) formalized the commitment to manage the Downeast rivers as genetically viable and distinct stocks.

The Prelisting Recovery Plan included the recovery objective of using restocking efforts with river-specific fry as a means to stabilize or increase river populations in the seven rivers in the DPS. The immediate need for action was justified by the apparent fragile status of the existing wild Atlantic salmon stocks in Maine. Returns of Atlantic salmon to Maine rivers from 1970 to 1993 were analyzed and the percentage of the run that was of natural origin was calculated. Atlantic salmon determined to be natural, either could have spent their entire lives in the wild, truly wild fish, or could have been stocked in the river as fry. The average return rate was calculated for years in which no adults could have returned from fry stocking and this was termed the wild return. Secondly, the average return rate was calculated for years in which returns from fry stocking would be possible, and this was termed the natural return. This analysis could lead one to conclude that fry stocking would not aid in the recovery of these runs. However, fry stocked during those years originated out of the basin. When this same analysis was conducted for the Penobscot River the opposite trend was observed. The percentage of the Atlantic salmon run of natural origin was higher during years influenced by previous fry stocking. The Penobscot River, unlike the rivers in the DPS, has had a predominately river-specific stocking program. Consequently, the Services have reason to believe that the DPS rivers will benefit from river-specific fry stocking.

The BRT has determined that artificial propagation, with river-specific stocks in conservation hatchery mode, is an appropriate tool for rebuilding naturally reproducing Atlantic salmon populations in the DPS. The purpose of the ESA is to conserve endangered species or threatened species and the ecosystems upon which they depend. Consequently, the goal is to restore the species to a point where it is self-sustaining without the aid of hatcheries. The Act defines conservation as the following: "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary." The definition goes on to state that one such method is propagation. The NMFS has analyzed the role of artificial propagation under the ESA in relation to Pacific salmon (Hard et al. 1992). That analysis cautions that artificial propagation, as a conservation tool, must be conducted in a manner so as to maintain the distinctness of the species unit. The current policy, to adhere to river specific stocking in the DPS rivers as long as a minimum effective population size is maintained, is consistent with maintaining distinctness of these stocks (Waples 1990).

The NMFS and FWS have issued a draft policy addressing the role of controlled propagation in the conservation and recovery of species listed as endangered or threatened under the ESA (61 FR 4716). While the Gulf of Maine DPS of Atlantic salmon is currently listed only as a candidate species by the NMFS, and not as threatened or endangered, the river-specific Atlantic salmon program was still evaluated to determine if it was consistent with the policy. The proposed policy sanctions the controlled propagation of listed species when recommended in an approved recovery plan and supported by an approved genetics management plan. The Atlantic salmon river specific rearing program was an essential component of the pre-listing recovery plan drafted for the species and is operated according to the broodstock collection and spawning protocols designed to maintain the genetic diversity of the DPS. These protocols were adopted by the TAC in 1997 (Beland et al. 1997).

In determining whether or not the hatchery fish should be considered part of the listable entity on the west coast, the NMFS asked the question of whether there were appreciable differences between the hatchery and wild fish in characteristics believed to have a genetic basis (Hard et al. 1992). The decision to use river-specific stock is predicated on the belief that recovery has the greatest likelihood of success if the stock in the hatchery has the same genetic makeup as the wild stock in the river. Consequently, it is the Team's position that the hatchery-held river-specific stocks of Atlantic salmon from the DPS rivers of Maine should be included in the DPS. The Atlantic salmon from these rivers currently being held for artificial propagation, as well as their progeny, should be included in the DPS under review. It is important to note that listing decisions and recovery are based on the viability of the stock in the natural environment. Artificial propagation is not to be used as a substitute action for addressing the factors threatening the survival of the species in its natural environment but rather as a tool to prevent extinction while other threats are addressed, thereby allowing natural recovery to occur.

7.5.4 Other

Based on concern over low returns in 1997, the Department of Fisheries and Oceans (DFO) in Canada convened a workshop to examine trends in abundance of Atlantic salmon and factors that could have contributed to low returns (Atkinson et al. 1998). The following potential factors affecting sea survival of salmon were identified: (1) environmental conditions such as temperature and salinity; (2) removals in legal and illegal fisheries; (3) predation by cod, seals, seabirds, etc.; (4) diseases or parasites; or (5) a suite of other factors including changes in biological characteristics of stocks and effects of escaped aquaculture salmon. Freshwater production and abundance of smolts was not found to be the cause of the low returns in 1997. Commercial catches and/or bycatches in inshore and offshore fisheries were also eliminated as potential causes of low returns in 1997. Likewise, the availability of forage, ocean climate, pollution, disease, poaching, age at maturity and age of spawners were eliminated as causes for low returns in 1997. Predation by birds, seals, and cod was the remaining factor that could not be discounted as a potential cause of the low returns. The BRT believes that these analyses are equally true for Atlantic salmon of the Gulf of Maine DPS since marine ecology issues are similar and marine habitat overlaps substantially with Canadian stocks.

7.5.5 Summary of Other Factors

Farm-raised Atlantic salmon can escape from both sea cages and freshwater hatcheries and enter rivers within the Gulf of Maine DPS as sexually mature adults. Available genetic data and visual observations indicate that aquaculture escapees may have successfully interbred with wild Atlantic salmon. Under current aquaculture practices, this problem will persist because the escapement of aquaculture salmon, and their interactions with wild stocks, is expected to increase with the continued operation and growth of the industry in the State of Maine.

There is a significant potential for escaped aquaculture salmon to disrupt redds of wild salmon, compete with wild salmon for food and habitat, interbreed with wild salmon, and transfer disease or parasites to wild salmon. Comprehensive protective solutions to minimize the threat of interactions between wild and aquaculture salmon have not been implemented. The threat of these interactions is considered critical, given the fact that wild salmon stocks within the DPS are at low abundance levels, and are particularly vulnerable to genetic intrusion or other disturbances caused by escaped aquaculture salmon.

Studies have characterized the potential permanent effect of salmon escapes from farms on the genetic differentiation among wild stocks. Small Atlantic salmon populations, similar to those found in the DPS, are the most vulnerable to immigrations from aquaculture escapees. These immigration events may be one of the most significant ways in which aquaculture salmon affect the genetic structure of wild populations. While natural selection may be able to purge wild populations of maladaptive genetic traits, regularly occurring intrusions of aquaculture salmon into wild populations make this considerably less likely. Thus, scientific information indicates that interactions between wild and aquaculture salmon in the DPS may lead to decreased numbers of wild Atlantic salmon, and in the extreme, to extinction of the wild stock.

Marine survival rates continue to be low for U.S. stocks of Atlantic salmon, and the subsequent low abundance of salmon impedes recovery of the DPS. Scientists have attributed natural mortality in the marine environment to sources that include stress, predation, starvation, disease and parasites, and abiotic factors. In addition, scientific studies indicate that year-to-year variation in return rates of U.S. salmon stocks is generally synchronous with other North Atlantic stocks. This aspect suggests that the trend in return rates is the result of factors that occur when the stocks are mixed in the North Atlantic, particularly the Labrador Sea. Scientists have concluded that a significant proportion of the variation in recruitment or return rate is attributed to post-smolt survival. However, the mechanisms responsible for reduced post-smolt survival are still not well understood.

There is agreement among scientists that additional research should be conducted to better understand the processes or mechanisms responsible for reduced post-smolt survival, and such research is being pursued. There is also consensus that action necessary to ensure survival of salmon stocks and to rebuild stocks within the DPS includes artificial propagation. The Atlantic salmon river-specific recovery program has been identified as an essential component of the strategy to rebuild salmon stocks in the DPS. This program has been designed and implemented to maintain the genetic diversity and distinctness of the DPS. Because the abundance of wild salmon stocks in the DPS is so very low, artificial propagation, through a river-specific stocking program is considered an important tool to maximize the production of natural smolts with genetic traits necessary for survival of the species.

SECTION 8: CONCLUSION

The Gulf of Maine DPS of Atlantic salmon is discrete and significant and therefore meets the Services' criteria for separateness as outlined in the Services' joint policy on DPS delineation. There was a dramatic decline in spawner abundance in the mid 1980s and the number of returning adult Atlantic salmon to the Gulf of Maine DPS remains low. Critically low adult returns make the DPS especially vulnerable and genetically susceptible to threats. Early juvenile abundance has increased due to fry and broodstock stocking but based on results in the Narraguagus River, does not directly translate into commensurate increases in abundance of smolts. Marine survival rates continue to be low for U.S. stocks of Atlantic salmon, and the low abundance of naturally spawning Atlantic salmon impedes recovery of the DPS. The Gulf of Maine DPS of Atlantic salmon has persisted in a unique setting in the U.S. and its loss, as the only naturally spawning stock in the U.S., would constitute a significant loss. The existence and integrity of the gene pool of the DPS must be preserved and allowed to naturally adapt with changing future conditions in the freshwater and marine environment.

As discussed both in the 1995 Status Review and this review, dams and overfishing are major factors contributing to the past precipitous decline of Atlantic salmon that resulted in its current low abundance. The analysis of the listing factors in 1999 clearly indicates that all threats to the species have not been removed and identify the existence of threats from disease and freshwater production. There is currently no clearly identifiable cause for the critically low abundance of Atlantic salmon in the Gulf of Maine DPS. A single threat cannot be identified as the factor for the current state of the DPS; the focus is more properly placed on the cumulative effect of the multiple threats identified. At current levels of abundance, it is difficult to discuss any threat to the species and its habitat as negligible.

Under the first listing factor, present or threatened destruction, modification, or curtailment of habitat or range, the following threats to Atlantic salmon habitat within the DPS watersheds were identified: (1) water extraction; (2) sedimentation; (3) obstructions to passage caused by beaver and debris dams, poorly designed road crossings, and dams; (4) input of nutrients; (5) chronic exposure to insecticides, herbicides, fungicides, and pesticides (in particular, those used to control spruce budworm); (6) elevated water temperatures from processing water discharges; and (7) removal of vegetation along streambanks.

Efforts are underway to better understand and balance the needs of Atlantic salmon and the water use needs of the agriculture industry. Until this process is completed, the threat of excessive or unregulated withdrawal remains. Chronic exposure to chemical residues in the water negatively affects Atlantic salmon and since these chemicals have been used within the Gulf of Maine DPS, there is a substantial threat from these chemicals. Sedimentation from a variety of sources also warrants closer review as it may alter habitat and render it incapable of supporting maximum Atlantic salmon production. Recent studies indicate that full freshwater production potential is not being achieved despite fry stocking efforts. These results suggest that a factor or factors within the rivers may be negatively impacting freshwater habitat for Atlantic salmon. Although it is difficult to isolate and evaluate the impact of individual habitat issues, the available information indicates that cumulative impacts from habitat degradation issues discussed above pose a significant threat to Atlantic salmon stocks.

Historically, under the second listing factor, both commercial and recreational harvest of Atlantic salmon played an important role in the decline of the DPS of Atlantic salmon. Continuation of the internal use fishery in Greenland poses a reduced but continuing threat to Atlantic salmon in the DPS. Continuation of the existing directed catch and release fishery may cause mortality or injury to Atlantic salmon within the DPS. Recreational fisheries targeting other species also may incidentally catch various life stages of Atlantic salmon sometimes resulting in their injury or death. Mortality from fishing increases the threat to Atlantic salmon survival.

The impact of predation and disease was examined under the third listing factor and was found to have increased since the 1995 Status Review. Predation has always been a factor influencing salmon numbers, but under conditions of a healthy population, would not be expected to threaten the continued existence of that population. The threat of predation to the DPS is significant today because of the very low numbers of adults returning to spawn and the dramatic increases in population levels of some predators known to prey on salmon. These include cormorants, sea birds, striped bass, and several species of seals.

Fish diseases have always represented a source of mortality to Atlantic salmon in the wild, though the threats of major loss due to disease are generally associated with salmon culture. Three recent events, occurring during the last three years, have increased the concern for disease as a threat to the DPS: (1) the appearance of ISA virus in 1996 on the North American continent within the range of the possible exposure of migrant DPS salmon; (2) the discovery in 1998 of the retrovirus SSSV within a DPS population; and (3) the new information available in 1999 on the potential impact of cold water disease on salmon. The nature of these three specific developments in terms of direct loss to the DPS from disease in the wild is extremely difficult to assess. Observations to date suggest that direct mortality may not be the major threat to the DPS from these diseases. However, there is an indirect threat through the impact of these diseases on the river-specific fish culture program implemented on six rivers to enhance maintenance and recovery of these imperiled populations. The impacts of ISA, SSSV, and CWD appear to be magnified when fish are held in culture environments. Diseases significantly degrade the effectiveness of fish culture techniques as a recovery tool and strategy for stock enhancement. The level of threat to the perpetuation and recovery of the DPS from salmon disease has significantly increased in the past three years.

Under the fourth listing factor, the BRT examined regulatory mechanisms for their ability to protect the Gulf of Maine DPS. A variety of state and federal environmental statutes and regulations are in place to address potential threats to Atlantic salmon and their habitat. These laws are complemented by international actions under NASCO and many interagency agreements and state-federal cooperative efforts. Implementation and enforcement of these laws and regulations must be strengthened to further protect Atlantic salmon. The appropriate state and federal agencies have established coordination mechanisms and have joined with private industries and landowners in partnerships for the protection of Atlantic salmon. These partnerships will be critical to the recovery of the species. As explained in Section 7.4, existing regulatory mechanisms have not removed all of the threats to wild Atlantic salmon.

Aquaculture practices were examined under the fifth listing factor, other natural or manmade factors affecting the continued existence of the DPS. Farm-raised or aquaculture Atlantic salmon escape during freshwater rearing, transport, or sea cage growout and enter rivers within the Gulf of Maine DPS. Available genetic data and visual observations indicate that aquaculture escapees may have successfully interbred with wild Atlantic salmon in the DPS. Under current aquaculture practices, this problem will persist because the escape of aquaculture salmon, and their interactions with wild stocks, is expected to increase with the continued growth of the aquaculture industry in the State of Maine. Escaped aquaculture salmon have been documented to disrupt redds of wild salmon, compete with wild salmon for food and habitat, interbreed with wild salmon, and transfer disease or parasites to wild salmon. This is of grave concern, particularly when the escapees are not of North American origin. The expanding use of reproductively viable European stock by the aquaculture industry has greatly increased the level of risk of negative consequences from introgression of aquaculture stock into wild populations. Scientific information indicates that interactions between wild and aquaculture salmon in the DPS may lead to decreased numbers of wild Atlantic salmon, and in the extreme, to extirpation of the wild stock. Comprehensive protective solutions to minimize the threat of interactions between wild and aquaculture salmon have not yet been implemented. The threat of these interactions is considered critical, given the fact that wild salmon stocks within the DPS are at low abundance levels and are particularly vulnerable to genetic intrusion or other disturbances caused by escaped aquaculture salmon.

Many of the threats to the Gulf of Maine DPS of Atlantic salmon evaluated during this review have been reduced significantly through the considerable efforts put forth by the State of Maine and public and private sector partners. The fact remains, however, that under current circumstances, it is the opinion of the BRT that the Gulf of Maine DPS of Atlantic salmon is in danger of extinction. Atlantic salmon in the Gulf of Maine DPS exhibit critically low spawner abundance and poor marine survival. These two key recovery factors are further compromised by the increased presence of threats which have been documented to negatively impact salmon stocks. Currently these threats include artificially reduced water levels, diseases and parasites, recreational and commercial fisheries, sedimentation, and genetic intrusion by commercially raised Atlantic salmon.

REFERENCES

Advisory Committee on Fishery Management. ICES (International Council for the Exploration of the Sea) . 1989. Report of the Working Group on North Atlantic Salmon. ICES.

Advisory Committee on Fishery Management. ICES (International Council for the Exploration of the Sea) . 1999. Report of the Working Group on North Atlantic Salmon. CM 1999/A CFM:14. ICES, Quebec City, Canada.

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

Alverson, D. L., and G. T. Ruggerone. Technical Advisory team . 1997. Escaped farm salmon: environmental and ecological concerns. Salmon Aquaculture Review Part B. discussion paper. Environmental Assessment office, Victoria, B.C.

Amiro, P. G. 1993. Bold barred owl downs parr. Atlantic Salmon Journal Summer: 9.

Anderson, J. 1988. Hunting and farming salmon. Bull. Aquacult. Assoc. Can./Bull. Assoc. Aquac. Can 88-1: 22-29.

Anthony, V. C. 1994. The significance of predation on Atlantic salmon. Pages 240-284 *in* New England Atlantic salmon management conference. National Marine Fisheries Service, Woods Hole, MA.

Armour, C., D. Duff, and W. Elmore. 1994. The Effects of Livestock Grazing on Western Riparian and Stream Ecosystems. Fisheries 19(9): 9-12.

ASA (Atlantic Salmon Authority). 1998. 1997 Endangered Species Project Report Annual Report Number 4. ASA, Bangor, Maine.

ASRSC (Atlantic Sea Run Salmon Commission). 1995. Maine Atlantic salmon restoration and management plan, 1995-2000. ASRSC, Bangor, Maine.

Atkins, C. G. 1874. On the salmon of eastern North America, and its artificial culture. Pages 227-335 *in* United States Commision of Fish and Fisheries Report of the Commissioner for 1872 and 1873, part II. Washington.

Atkins, C. G. 1874. Report of the Commissioner for 1872 and 1873. On the Salmon of Easstern North America, and It's Artificial Culture : 226-335.

Atkins, C. G. 1884. The biennial spawning of salmon (the Bucksport experiments). Pages 89-94 *in* American Fisheries Society, fourteenth annual meeting.

Bailey, J., and G. Friars. 1990. Inheritance of age at smolting in hatchery-reared Atlantic salmon (Salmo salar). Genetics in Aquaculture III; Aquaculture 85(1-4): 317.

Bailey, R. G. 1995. Description of the ecoregions of the United States. Miscellaneous Publication Number 1391(rev). 2nd edition. USDA Forest Service, Washington, D.C.

Bailey, R. G., and Working Group. 1995. Description of the Ecoregions of the United States. Second and expanded first edition. Washington, D.C.

Bailey, R. G. 1998. Ecoregions map of North America: explanatory note. miscellaneous publication No. 1548. USDA (United States Department of Agriculture), Washington, D.C.

Bair, S. H., and G. A. Rounsefell. 1951. An interim report on salmon restoration in the St. Croix, Aroostook, and St. John Rivers. U.S. Department of the Interior, Fish and Wildlife Service, Maine and New Brunswick.

Bakke, T. A. 1991. A review of the inter- and intraspecific variability in salmonid hosts to laboratory infections with *Gyrodactylus salaris* Malmberg. Aquaculture 98: 303-310.

Bakke, T. A., and P. D. Harris, 1998. Diseases and Parasites in Wild Atlantic Salmon (Salmo Salar) Populations. CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCIENCES 55(supp 1):247-266.

Bakke, T. A., P. A. Jansen, and L. P. Hansen. 1990. Differences in the host resistance of Atlantic salmon, *Salmo salar* L., stocks to the monogenean *Gyrodactylus salaris* Malmberg, 1957. Journal of Fish Biology 37(4): 577-587.

Barber, W. E., and R. J. Walker. 1988. Circuli spacing and annulus formation: Is there more than meets the eye? The case for sockeye salmon, *Oncorhynchus nerka*. Journal of Fish Biology 32(2): 237-245.

Barr, L. M. 1962. A life history of the chain pickerel, *Esox niger* Lesueur, in Beddington Lake, Maine. Master's thesis. University of Maine, Orono.

Barrett, R. T., N. Røv, J. Loen, and W. A. Montevecchi. 1990. Diets of shags *Phalacrocorax aristotelis* and cormorants *P. carbo* in Norway and possible implications for gadoid stock recruitment. Marine Ecology Progress Series 66: 205-218.

Baum, E. T. 1982. The Union River: an Atlantic salmon river management report. Pages 1-38 *in* ASRSC (Atlantic Sea Run Salmon Commission). Union & minor coastal drainages east of the Penobscot. State of Maine, ASRSC, Bangor.

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

Baum, E. T. 1991. History and status of the Atlantic salmon farming industry in Maine, USA. Working paper 1991-2, Study Group on North Atlantic salmon. International Council for Exploration of the Sea, Bangor, Maine.

Baum, E.T. 1997. Maine Atlantic Salmon A National Treasure. Atlantic Salmon Unlimited, Hermon, Maine.

Baum, E. T. (DFO) Division of Fisheries and Oceans . 1998. History and description of the Atlantic salmon aquaulture industry of Maine. Canadian Stock Assessment Secretariat Research Document. 98/152. Ottawa.

Baum, E. T., and et al. 1997. Maine Atlantic Salmon Management Plan Recommendations Pertaining to Staffing and Budget Matters. Report of the Maine Atlantic Salmon Authority to the

Standing Committee on Inland Fisheries and Wildlife . Maine Atlantic Salmon Authority, Bangor, Maine.

Baum, E. T., and R. M. Jordan. 1982. The Narraguagus River: an Atlantic salmon river management report. Pages 1-42 *in* ASRSC (Atlantic Sea Run Salmon Commission). Narraguagus & Pleasant. State of Maine, ASRSC, Bangor.

Baum, E. T., J. Marancik, and P. R. Nickerson. 1992. Prelisting recovery plan for Maine wild Atlantic salmon populations.

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., R. B. Owen, R. Alden, W. Nichols, P. Wass, and J. Dimond. Maine Atlantic Salmon Restoration and Management Plan 1995-2000.

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, Bangor, Maine.

Beland, K. 1984. Strategic plan for management of Atlantic salmon in the state of Maine. Atlantic Sea Run Salmon Commission, Bangor, Maine.

Beland, K. F. 1982. The Tunk River: a report on the watershed potential for Atlantic salmon management. Pages 38-44 *in* ASRSC (Atlantic Sea Run Salmon Commission). Union & minor coastal drainage east of the Penobscot. State of Maine, ASRSC, Bangor.

Beland, K. F., and N. R. Dube. Atlantic salmon research addressing issues of concern to the National Marine Fisheries Service and the Maine Atlantic Salmon Authority; Final Project Report. Grant NA57FL0149. Maine Atlantic Salmon Authority, Bangor, Maine.

Beland, K. F., N. R. Dube, M. Evers, R. C. Spencer, and E. T. Baum. 1993. Atlantic Salmon research addressing issues of concern to the National Marine Fisheries Service and Atlantic Sea Run Salmon Commission. Annual Report, Grant NA29FL0131-01, Segment 1. Maine Atlantic Sea Run Salmon Commision, Bangor, ME.

Beland, K. F., N. R. Dube, M. Evers, G. Vander Haegen, R. C. Spencer, and E. T. Baum. 1994. Atlantic Salmon research addressing issues of concern to the National Marine Fisheries Service and Atlantic Sea Run Salmon Commission. Annual Report, Grant NA29FL0131-01, Segment 2. Maine Atlantic Sea Run Salmon Commision, Bangor, ME.

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 Commision, Bangor, ME.

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

Beland, K., and K. Friedland. 1997. Estimating freshwater and marine survival for Atlantic salmon cohorts spawned in 1989-1991, Narraguagus River, Maine., Monterey, California.

Bentzen, P., and J. M. Wright. Nucleotide sequence and evolutionary conservation of a minisatellite variable number tandem repeat cloned from Atlantic salmon, Salmo salar. Genome 36: 271-277.

Bentzen, P., and J. M. Wright. 1992. Single-locus DNA Fingerprinting of Atlantic Salmon form Maine and Newfoundland. Marine Gene Probe Laboratory, Dalhousie University, Halifax.

Bergan, P. I., D. Gausen, and L. P. Hansen. 1991. Attempts to reduce the impact of reared Atlantic salmon on wild in Norway. Aquaculture 98: 319-324.

Bermingham, E., S. H. Forbes, K. Friedland, and C. Pla. 1991. Discrimination between Atlantic salmon (*Salmo salar*) of North American and European origin using restriction analyses of mitochondrial DNA. Canadian Journal of Fisheries and Aquatic Sciences 48(5): 884-893.

Berst, A. H., and R. Simon. 1981. Introduction to the proceedings of the 1980 Stock Concept International Symposium (STOCS). Can. J. Fish. Aquat. Sci. 38(12): 1457-1458.

Bigelow, H. B. and W. C. Schroeder. 1953. The salmons. Family Salmonidae. Pages 119-133 *in* Fishes of the Gulf of Maine. U.S. Fish and Wildlife Service, Fishery Bulletin 74. Vol. 53. U.S. Government Printing Office, Washington, D.C.

Blair, A. A. 1956. Atlantic salmon tagged in east coast Newfoundland waters at Bonavista. Journal of the Fisheries Research Board of Canada 13(2): 219-232.

Bley, P. W. 1987. Age, growth, and mortality of juvenile Atlantic salmon in streams: a review. Biological Report 87(4). U.S. Fish and Wildlife Service, Washington, D.C.

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

Blouw, D. M., S. D. Saxon, and E. M. P. Chadwick. 1988. Temporal variation of meristic traits within an Atlantic salmon (*Salmo salar*) stock, and implications for stock identification. Canadian Journal of Fisheries and Aquatic Sciences 45(8): 1330-1339.

Booth, R. K., J. D. Kieffer, K. Davidson, A. T. Bielak, and B. L. Tufts. 1995. Effects of late-season catch and release angling on anaerobic metabolism, acid-base status, survival, and gamete viability in wild Atlantic salmon (Salmo salar). Canadian Journal of Fisheries and Aquatic Sciences 52(2): 283-290.

Brobbel, M. A., M. P. Wilkie, K. Davidson, J. D. Kieffer, A. T. Bielak, and B. L. *. Tufts, 1996. Physiological Effects of Catch and Release Angling in Atlantic Salmon (Salmo Salar) at Different Stages of Freshwater Migration. Canadian Journal of Fisheries and Aquatic Sciences 53(09):2036-2043.

Bryant, F. G. 1956. Stream surveys of the Sheepscot and Ducktrap River systems in Maine. Special Scientific Report - Fisheries No. 195. United States Fish and Wildlife Service, Washington, D.C.

Buckley, D. B. 1999. Summary of Maine Atlantic salmon collections for broodstock and genetic analyses 1990-1998. USFWS (U.S. Fish and Wildlife Service), East Orland, Maine.

Carlin, B. 1954. Tagging of salmon smolts in the River Lagan. Report / Institute of Fresh-Water Research, Drottningholm 36: 57-74.

Carr, J. M., J. M. Anderson, F. G. Whoriskey, and T. and Dilworth, 1997. The occurance and spawning of cultured Atlantic slamon (Salmo salar) in a Canadian river. ICES Journal of Marine Science 54:1064-1073.

Chadwick, E. M. P. 1987. Causes of variable recruitment in a small Atlantic salmon stock. American Fisheries Society Symposium 1: 390-401.

Chadwick, E. M. P. 1993. Measuring marine exploitation of Atlantic salmon in Canada. Pages 184-202 *in* D. Mills, editor. Salmon in the sea and new enhancement strategies. Fishing News Books, Blackwell Scientific, Cambridge, Massachusetts.

Claytor, R. R., and E. Verspoor. 1991. Discordant phenotypic variation in sympatric resident and anadromous Atlantic salmon (*Salmo salar*) populations. Canadian Journal of Zoology 69(11): 2846-2852.

Clifford, S. L., P. McGinnity and A. Ferguson. 1997. Genetic changes in an Atlantic salmon population resulting from escaped juvenile farm salmon. Journal of Fish Biology 52(1): 118-127.

Clifford S. L , McGinnity P, and Ferguson A, 1998 Feb. Genetic changes in Atlantic salmon (Salmo salar) populations of northwest Irish rivers resulting from escapes of adult farm salmon. Canadian Journal of Fisheries & Aquatic Sciences 55(2):358-363.

Cohen, E. B., D. G. Mountain, and R. O'Boyle. 1991. Local-scale versus large-scale factors affecting recruitment. Canadian Journal of Fisheries and Aquatic Sciences 48(6): 1003-1006.

Copeland, T. A. U.S. Fish & Wildlife Service. 1998. Atlantic salmon river specific stocking program form federal hathceries in Maine-1997. U.S. Fish & Wildlife Service, East Orland, Maine.

Copeland, T. A., T. K. King, and D. Bean. U.S. Fish & Wildlife Service. 1998. Atlantic salmon spawning activities at Craig Brook National Fish Hatchery 1990-1997. U.S. Fish & Wildlife Service, East Orland, Maine.

Crozier, W. W. 1993. Evidence of genetic interaction between escaped farmed salmon and wild Atlantic salmon (Salmo salar L.) in a Northern Irish river. Aquaculture 113: 19-29.

Crozier, W. W., and I. J. J. Moffett. 1995. Application of low frequency genetic marking at GPI-3 and MDH-B1,2 loci to assess supplementary stocking of Atlantic salmon, Salmo salar.L, in a Northern Irish stream. Fisheries Management and Ecology 2: 27-36.

Cummins, K. W., J. L. Minshall, J. L. Sedell, C. E. Cushing, and R. C. Petersen. 1984. Stream Ecosystem Theory. Verhandlungen International Vereinigung Limnologie 22: 1818-1827.

Cushing, C. E., C. D. McIntire, K. W. Cummins, G. W. Minshall, R. C. Petersen, J. R. Sedell, et al., 1983. Relationships among chemical, physical, and biological indices along river continua based on multivariate analyses. Archiv Fur Hydrobiologie. Stuttgart 98(3):317-326.

Cutting, R. E. 1963. Penobsoct River salmon restoration. Atlantic Sea Run Salmon Commission, Bangor, Maine.

Danie, D. S., J. G. Trial, and J. G. Stanley. 1984. Species profiles: life histories and environmental requirements of coastal fish and invertebrates (North Atlantic): Atlantic salmon. FWS/OBS-82/11.2, TR EL-82-4. U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers.

Danielsdottir, A. K., G. Marteinsdottir, F. Aranson, and S. Gudjonsson, 1997. Genetic sructure of wild and reared Atlantic salmon (Salmo salar L.) populations in Iceland. ICES Journal of Marine Science 54:986-997.

DeCola, J. N. 1970. Water quality requirements. U.S. Department of the Interior Federal Water Quality Administration, Needham Heights, Massachusetts.

DFO. 1998. Atlantic salmon Abundance Overview for 1997. Stock Status Report D0-02. DFO.

Dube, N. R., and J. S. Fletcher. 1982. The East Machias River: an Atlantic salmon river management report. Pages 39-68 *in* ASRSC (Atlantic Sea Run Salmon Commission). Machias and East Machias. State of Maine, ASRSC, Bangor.

Dube, N. R., and R. M. Jordan. 1982. The Pleasant River: an Atlantic salmon management report. Pages 43-69 *in* ASRSC (Atlantic Sea Run Salmon Commission). Narraguagus & Pleasant. State of Maine, ASRSC, Bangor.

Dunbar, M. J., and D. H. Thomson. 1979. West Greenland salmon and climatic change. Meddelelser Om Gronland 202(4): 1-19.

Duncan, I. 1978. Evidence for an oncovirus in swimbladder fibrosarcoma of Atlantic salmon Salmo salar L. Journal of the Fish Diseases 1(1): 127-131.

Dutil, J.-D., and J.-M. Coutu. 1988. Early marine life of Atlantic salmon, *Salmo salar*, postsmolts in the northern Gulf of St. Lawrence. Fisheries Bulletin 86(2): 197-211.

Egusa, S. 1992. Bacterial kidney disease in salmonids: outline. Pages 287 *in* S. Egusa. Infectious Diseases of Fish [*Sakana no Kansensho*]. Translated from Japanese edition.Amerind Publishing Co. Private Limited, New Delhi.

Egusa, S. 1992. Furunculosos in salmon: outline. Pages 159-160 *in* S. Egusa. Infectious Diseases of Fish [*Sakana no Kansensho*]. Translated from Japanese edition.Amerind Publishing Co. Private Limited, New Delhi.

Egusa, S. 1992. Red mouth disease of salmon: outline. Pages 214 *in* S. Egusa. Infectious Diseases of Fish [*Sakana no Kansensho*]. Translated from Japanese edition.Amerind Publishing Co. Private Limited, New Delhi.

Egusa, S. 1992. Vibrio disease: outline. Pages 125-130 *in* S. Egusa. Infectious Diseases of Fish [*Sakana no Kansensho*]. Translated from Japanese edition.Amerind Publishing Co. Private Limited, New Delhi.

Egusa, S. 1992. Water mold disease: outline. Pages 369-370 *in* S. Egusa. Infectious Diseases of Fish [*Sakana no Kansensho*]. Translated from Japanese edition.Amerind Publishing Co. Private Limited, New Delhi.

Einum, S., and I. A. Fleming. 1997. Genetic divergence and interactions in the wild among native, farmed and hybrid Atlantic salmon. Journal of Fish Biology 50: 634-651.

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

Elson, P. F. 1941. Eels as a limiting factor in salmon production. MS report of the Biological Station. No. 213. Fishery Research Board of Canada.

Elson, P.F. 1975. Atlantic salmon rivers smolt production and optimal spawning: an overview of natural production. Int. Atl. Salm. Found. Spec. Publ. Series 6: 96-119.

Farmer, G.J., D. Ashfield, and J.A. Ritter. 1977. Seawater acclimation and parr-smolt transformation of juvenile Atlantic salmon, *Salmo salar*, Freshwater and Anadromous Division, Resourc. Branch, Fish. Mar. Serv., Tech. Rep. Serv. MAR/T-77-3.

Farmer, G. J., J. A. Ritter, and D. Ashfield. 1978. Seawater adaptation and parr-smolt transformation of juvenile Atlantic salmon, *Salmo salar*. Journal of the Fisheries Research Board of Canada 35(1): 93-100.

Fausch, K. D. 1988. Tests of competition between native and introduced salmonids in streams: what have we learned? Canadian Journal of Fisheries and Aquatic Sciences 45(12): 2238-2246.

Fausch, K. D., and R. J. White. 1986. Competition among juveniles of coho salmon, brook trout, and brown trout in a laboratory stream, and implication for Great Lakes tributaries. Transactions of the American Fisheries Society 115(3): 363-381.

Fay, J. J., and M. Nammack, editors. 1996. Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act. Federal Register 61(26):4722-4725.

Ferguson, A., E. verspoor, T. Cross, Garcia Vazquez, F. Medale, and C. Garcia De Leaniz Caprile. 1990 May. An assessment of the genetic consequences of the deliberate and inadvertent introduction of non-active Atlantic salmon into natural populations. Third European Marine Science and Technology Conference (MAST Conference) .

Fleming, I. A., and S. Einum, 1997. Experimental tests of genetic divergence of farmed from wild Atlantic salmon due to domestication. ICES Journal of Marine Science 54:1051-1063.

Fletcher, J. S. 1955. Machias River: salmon restoration. Maine Atlantic Salmon Commission, Augusta, Maine.

Fletcher, J. S. 1960. Dennys River drainage: fishery management and restoration. Atlantic Sea Run Salmon Commission, Bangor, Maine.

Fletcher, J. S., R. M. Jordan, and K. F. Beland. 1982. The Machias River: an Atlantic salmon river management report. Pages 1-38 *in* (ASRSC) Atlantic Sea Run Slamon Commission. Machias & East Machias. State of Maine, ASRSC, Bangor.

Fletcher, J. S., and A. L. Meister. 1966. Machias River salmon runs. Pages 21-23 *in* Atlantic Sea Run Salmon Commission. Bienniel report July1, 1964-June 30, 1966.

Fletcher, J. S., and A. L. Meister. 1982. The St. Croix River: an Atlantic salmon river management report. State of Maine, Atlantic Sea Run Salmon Commission, Bangor.

Foerster, R.E. 1937. Comparative studies of the natural and artificial propagation of sockeye salmon. Proc. Pac. Sci, Congress 5(1993): 3593-3597.

Fraser, P. J. 1987. Atlantic salmon, *Salmo salar* L., feed in Scottish coastal waters. Aquaculture and Fisheries Management 18(2): 243-247.

Friars, G., J. Bailey, and K. Coombs. 1990. Correlated responses to selection for grilse length in Atlantic salmon. Genetics in Aquaculture III; Aquaculture 85(1-4): 171-176.

Friars, G., J. Bailey, and F. O'Flynn. 1989. An overview of selection practices in the Salmon Genetics Research Program. Proceedings of Canada-Norway Finfish Aquaculture Workshop, September 11-14, 1989.; Can. Tech. Rep. Fish. Aquat. Sci. 1761: 49-59.

Fried, S. M., J. D. McCleave, and G. W. LaBar. 1978. Seaward migration of hatchery-reared Atlantic salmon, *Salmo salar* smolts in the Penobscot River estuary, Maine: riverine movements. Journal of the Fisheries Research Board of Canada 35(1): 76-87.

Friedland, K., and J. Kocik. U.S. Department of Commerce. 1998. Atlantic salmon. NOAA Technical Memorandum; Status of Fishery Resources off the Northeastern United States for 1998. NMFS-NE-115. National Marine Fisheries Science Center, Woods Hole, Massachusetts.

Friedland, K. D., D. G. Reddin, and J. F. Kocik. 1993. Marine survival of North American and European Atlantic salmon: effects of growth and environment. ICES Journal of Marine Science 50: 481-492.

Friedland, K. D., D. G. Reddin, and J. F. Kocik. 1993. The production of North American and European Atlantic salmon: Effects of post-smolt growth and ocean environment. ICES; Copenhagen (Denmark); ICES Council Meeting (Collected Papers) : 31.

Gaston, P. B. 1988. Atlantic salmon culture for restoration. U. S. Fish and Wildlife Service, Newton Corner, Massachussetts.

Gausen, D., and V. Moen. 1991. Large-scale escapes of farmed Atlantic salmon (*Salmo salar*) into Norwegian rivers threaten natural populations. Canadian Journal of Fisheries and Aquatic Sciences 48(3): 426-428.

Gibson, R. J., and R. E. Cutting. 1993. Production of Juvenile Atlantic Salmon, Salmo Salar , in Natural Waters. Pages 268 *in* . Canadian Special Publication of Fisheries and Aquatic Sciences. Vol. 118.

Gibson, R. J. 1973. Interactions of juvenile Atlantic salmon (*Salmo salar* L.) and brook trout (*Salvelinus fontinales* (Mitchell)). International Atlantic Salmon Foundation Special Publication 4: 181-202.

Gilbert, J. R., and N. Guldager. 1998. Status of harbor and gray seal populations in Northern New England. 14-16-009-1557. Orono, Maine.

Gjedrem, T., and H. M. Gjoen. 1995. Genetic variation in susceptibility of Atlantic salmon, Salmo salar L., to furunculosis, BKD and cold water vibriosis. Aquaculture Research 26: 129-134.

Glebe, B. D., and R. L. Saunders. 1986. Genetic factors in sexual maturity of cultured Atlantic salmon (Salmo salar) parr and adults reared in sea cages. Salmonid Age At Maturity., Can. Spec. Publ. Fish. Aquat. Sci. No. 89 : 24-29.

Godfrey, H. 1957. Feeding of eels in four New Brunswick salmon streams. Progress Reports of the Atlantic Coast, Fisheries Research Board of Canada (67): 19-22.

Goodwin, H. A. 1942. The Atlantic salmon in the Dennys River. Master's thesis. University of Maine, Orono.

Grant, W. Stewart (editor). 1997. Genetic effects of straying of non-native hatchery fish into natural populations: Proceedings of the Workshop. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-NWFSC-30, 130p.

Greenstreet, S. P. R., R. I. G. Morgan, S. Barnett, and P. Redhead. 1993. Variation in the numbers of shags *Phalacrocorax aristotelis* and common seal *Phoca vitulina* near the mouth of an Atlantic salmon *Salmo salar* river at the time of the smolt run. Journal of Animal Ecology 62: 565-576.

Gross, M. R., 1998. One Species With Two Biologies: Atlantic Salmon (Salmo Salar) in the Wild and in Aquaculture. Canadian Journal of Fisheries and Aquatic Science 55(supp 1):131-144.

Gunnerød, T. B., N. A. Hvidsten, and T. G. Heggberget. 1988. Open sea releases of Atlantic salmon smolts, *Salmo salar*, in central Norway, 1973-83. Canadian Journal of Fisheries and Aquatic Sciences 45(8): 1340-1345.

Haines, T. A. 1981. Acidic precipitaion and its consequences for aquatic ecosystems: a review. Transactions of the American Fisheries Society 110(6): 669-707.

Hansen, L. P., and B. Jonsson. 1994. Homing of Atlantic salmon: effects of juvenile learning transplanted post-spawners. Animal Behavior 47: 220-222.

Hansen, L. P., and P. Pethon. 1985. The Food of Atlantic salmon, *Salmo salar* L., caught by long-line northern Norwegian waters. Journal of Fish Biology 26: 553-562.

Hard, J. J., R. P. Jones, M. R. Delarm, and R. S. Waples. NMFS-NWFSC. 1992. Pacific salmon and the use of artificial propagation under the Endangered Species Act. U.S. Department of Commerce Technical Memo. NMFS-NWFSC-2.

Harrington, William C. 1946. Report of the Commission to Study the Atlantic Salmon.

Håstein, T., and T. Lindstad. 1991. Diseases in wild and cultured salmon: possible interaction. Aquaculture 98: 277-288.

Havey, K. A. Tunk River drainage: fish management and restoration. Maine Department of Inland Fisheries and Game, Augusta, Maine.

Havey, K. A. 1963. St. Croix River: fish management and restoration. Maine Department of Inland Fisheries, Machias, Maine.

Havey, K. A., and J. S. Fletcher. The Pleasant River: fish management and restoration. Maine Department of Inland Fisheries and Game, Augusta, Maine.

Hearn, W. E. 1987. Interspecific competition and habitat segregation among stream-dwelling trout and salmon: a review. Fisheries 12(5): 24-31.

Heen, K., J. Thorpe, N. Ridler, R. L. Monahan, C. Mahnken, and J. Lindbergh. 1993. The distribution of salmon aquaculture. Pages 10-58 *in* K. Heen, R. L. Monahan, and F. Utter, editors. Salmon Aquaculture. Fishing News Books, Oxford.

Heggeberget, T. G. e. al. 1993. Interactions between wild and cultured Atlantic salmon: a review of the Norwegian Experience . Fisheries Research 18: 123-146.

Herbinger, C., and G. Newkirk. 1990. Sources of family variability for maturation incidence in cultivated Atlantic salmon. Genetics in Aquaculture III; Aquaculture 85(1-4): 153-162.

Hindar, K., and B. Jonsson. Impacts of Aquaculture and Hatcheries on Wild Fish. Proceedings of the World Fisheries Conference : 70-87.

Hindar, K., N. Ryman, and F. Utter. 1991. Genetic effects of aquaculture on natural fish populations. Aquaculture 98: 259-261.

Hindar, K., N. Ryman, and F. Utter. 1991. Genetic effects of cultured fish on natural fish populations. Can. J. Fish. Aquat. Sci. 48: 945-957.

Hindar Kdir, A. Ferguson, A. Youngson, and R. Poole. 1990 May. Hybridisation between escaped farmed Atlantic salmon and brown trout: frequency, distribution, behavioural mechanisms and effects on fitness. Third European Marine Science and Technology Conference (MAST Conference) .

Hindar, K., N. Ryman, and F. Utter. 1991. Genetic effects of cultured fish on natural fish populations. Canadian Journal of Fisheries and Aquatic Sciences 48(5): 945-957. Aquaculture 98: 259-261.

Hislop, J. R. G. and A. F. Youngson. 1984. A note on the stomach contents of salmon caught by longline north of the Faroe Island in March 1983. ICES C.M. 1984/M:17.

Hislop, J. R. G., and R. G. J. Shelton. 1993. Marine predators and prey of Atlantic salmon (*Salmo salar* L.). Pages 104-118 *in* D. Mills, editor. Salmon in the sea and new enhancement strategies. Fishing News Books, Oxford.

Hoar, William S. 1976. Smolt transformation: evaluation, behavior and physiology. J. Fish. Res. Board of Canada. 33(5): 1233-1252.

Hoffman, G. L. 1967. Parasites of North American freshwater fishes. University of California Press, Los Angeles.

Honey, K., L. Churchill, and P. Mancuso. 1993. Aquaculture lease inventory. Maine Department of Marine Resources, West Boothbay Harbor, Maine.

Hopley, C. W. Temporal and geographic variability in survival of sea-ranched Coho and Chinook salmon in North America. NOAA technical report NMFS 102: Marine Ranching. 102. Olympia, Washington.

Horton, G.E., J. Marancik, F. Griffiths, D. Beach, and T. King. 1995. Wild Atlantic Salmon Rivers in Maine: 1994 Field Activity Report. USFWS and Maine Atlantic Salmon Authority, East Orland and Cherryfield, Maine.

Horton, G., M. Evers, R. Spencer, and E. Baum. Maine Atlantic Salmon Authority. 1998. 1997 Endangered Species Project Report. Contract No. 14-48-0005-93-9035; Annual report number 4. Maine Atlantic Salmon Authority, Bangor, Maine.

Hovey, S. J., D. P. F. King, D. Thompson, and A. Scott. 1989. Mitochondrial DNA and allozyme analysis of Atlantic. Journal of Fish Biology 35 Supplement A: 253-260.

Hutchings, J. A. 1991. The threat of extinction to native populations experiencing spawning intrusions by cultured Atlantic salmon. Aquaculture 98: 119-132.

Hutchings, J. A., and M. E. B. Jones. 1998. Life history variation and growth rate thresholds for maturity in Atlantic salmon, Salmo salar. Canadian Journal of Fisheries and Aquatic Sciences 55 (suppl.1): 22-47.

Hvidsten, N. A., and R. A. Lund. 1988. Predation on hatchery-reared and wild smolts of Atlantic salmon, *Salmo salar* L., in the estuary of River Orkla, Norway. Journal of Fish Biology 33(1): 121-126.

Hvidsten, N. A., and P. I. Møkkelgjerd. 1987. Predation on salmon smolts, *Salmo salar* L., in the estuary of the River Surna, Norway. Journal of Fish Biology 30: 273-280.

ICES International Council for the Exploration of the Sea. 1999. No 7. Extract of the report of the Advisory Committee on Fishery Management; North Atlantic salmon stocks. ICES, Copenhagen, Denmark.

ICES-NASSG (International Council for the Exploration of the Sea-North American Salmon Study Group). 1993. Report of the study group on North American salmon fisheries, Woods Hole Massachusetts, USA 15-19 February 1993. Doc. C.M. 1993/Assess:9. International Council for the Exploration of the Sea, Copenhagen.

ICES-NASWG (International Council for the Exploration of the Sea-North Atlantic Salmon Working Group). 1990. Report of the North Atlantic Salmon Working Group, Copenhagen, 15-22 March 1990. Doc. C.M. 1990/Assess: 11. International Council for the Exploration of the Sea, Copenhagen.

ICES-NASWG (International Council for the Exploration of the Sea-North Atlantic Salmon Working Group). 1994. Report of the North Atlantic Salmon Working Group, Reykjavik, 6-15 April 1994. Doc. C.M. 1994/Assess: 16. ICES, Copenhagen.

ICES-NASWG (International Council for the Exploration of the Sea-North Atlantic Salmon Working Group). 1996. Report of the North Atlantic Salmon Working Group, Moncton, Canada 10-19 April 1996. ICES CM 1996/ Assess:11 Ref.:M. ICES, Canada.

Institute of Aquaculture. 1988. The reduction of the impact of fish farming on the natural marine environment. A report prepared for the Nature Conservancy Council., University of Stirling, Scotland.

Järvi, T. 1989. The effect of osmotic stress on the anti-predatory behaviour of Atlantic salmon smolts: a test of the 'Maladaptive Anti-predator Behaviour' hypothesis. Nordic Journal of Freshwater Research 65: 71-79.

Jensen, J. M., and W. H. Lear. 1980. Atlantic salmon caught in the Irminger Sea and at east Greenland. Journal of the Northwest Atlantic Fisheries Society 1: 55-64.

Johnsen, B. O., and A. J. Jensen. 1991. The *Gyrodactylus* story in Norway. Aquaculture 98: 289-382.

Johnson, S. L. 1988. The effects of the 1983 El Niño on Oregon's coho (*Oncorhynchus kisutch*) and chinook (*O. tshawytscha*) salmon. Fisheries Research 6(2): 105-123.

Jones, J. W. 1959. Some parasites and diseases of salmon. Pages 159-167 *in* J. W. Jones. The salmon. Harper & Brothers, New York.

Jones, M. L. 1991. Biotic constraints to Atlantic salmon restoration in Lake Ontario: a report to the Atlantic salmon steering committee. Great Lakes Salmonid Unit, Maple.

Jonsson, B., N. Jonsson, and L. P. Hansen. 1991. Differences in life history and migratory behaviour between wild and hatchery-reared Atlantic salmon in nature. Aquaculture 98: 69-78.

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

Jutila, E. and J. Toivonen. 1985. Food composition of Salmon Post-Smolts (*Salmo salar* L.) in the Northern part of the Gulf of Bothnia. ICES C.M. 1985/M: 21.

Kålås, J. A., T. G. Heggberget, P. A. Bjørn, and O. Reitan. 1993. Feeding behaviour and diet of goosanders (*Mergus merganser*) in relation to salmonid seaward migration. Aquatic Living Resources 6: 31-38.

Kalleberg, H. 1958. Observations in a stream tank of territoriality and competition in juvenile salmon and trout (*Salmo salar* L. and *S. trutta* L.). Report / Institute of Fresh-Water Research, Drottningholm 39: 55-98.

Kazakov, R. V., and L. M. Khalyapina. 1981. Oxygen consumption of adult Atlantic salmon (*Salmo salar* L.) males and females in fish culture. Aquaculture 25(2-3): 289-292.

Kehoe, F. The effect of double-crested cormorant predation on the Salmon Genetics Research Program (SGRP). 1987; 29 Pp; SGRP TECH. REP.; No. 66 .

Kendall, W. C. 1894. Notes on the Freshwater Fishes of Washington County, Maine. Bulletin of the United Staes Fisheries Commission 14: 43-54.

Kendall, W. C. 1935. The fishes of New England: the salmon family. Part 2 - the salmons. Memoirs of the Boston Society of Natural History: monographs on the natural history of New England. Vol. 9. (1). Boston, Massachusetts.

Kendall, W. C. 1939. Founders of fish culture: Charles Grandison Atkins - a pioneer who blazed the trail. Progressive Fish Culturist (No. 25): 12-17.

Kenney, M. K., and J. R. Gilbert. 1994. Increase in harbor and gray seal populations in Maine. 50-ENAF-2-00064. Orono, Maine.

Kincaid, H., L. Mengel, and J. Johnson. 1994. Meristic and morphometric evaluation of parr from Atlantic Salmon stocks collected from the Downeast River of Maine in 1992-1993. Preliminary report submitted to the Federal Atlantic Salmon Technical Working Group. National Biological Survey, Research and Development Laboratory - Wellsboro, Pennsylvania.

King, D. P. F., S. J. Hovey, D. Thompson, and A. Scott. 1993. Mitochondrial DNA variation in Atlantic salmon, *Salmo salar* L., populations. Journal of Fish Biology 42: 25-33.

King, T., and M. C. Smith. 1994. Allozyme Analysis and RFLP Analysis of PCR Amplified Regions of Mitochondrial DNA from Minimally Invasive Sampling in Atlantic Salmon Inhabiting the Downeast Rivers of Maine. Completion Report submitted to the Atlantic Salmon Technical Working Group. National Biological Survey, Leetown Science Center, Aquatic Ecology Laboratory, Kearneysville, WV.

King, T. L., W. B. Schill, B. A. Lubinski, M. C. Smith, M. S. Eackles, and R. Coleman. 1999. Microsatellite and mitochondrial DNA diversity in Atlantic salmon with emphasis on small coastal drainages of the Downeast and Midcoast of Maine. USGS-BRD-Leetown Science Center, Kearneysville, West Virginia.

Kocik, J. F., K. F. Beland, and T. F. Sheehan. Atlantic salmon overwinter survival and smolt production in the Narraguagus River. O-99-NEC-1. Woods Hole, Massachusetts.

Kocik, J. F. F. K. D. Marine Issues Relevant to the Evaluation of the Endangered Species Act for Atlantic Salmon.

Kornfield, I. 1994. Identification of wild, hatchery, and cultured Atlantic salmon: discrimination by genetic fingerprinting. Final Report NA26fd0043-01. Department of Zoology, University of Maine, Orono.

Kornfield, I., J. Bailey, K. Beland, and C. Ritzi. 1995. Report of the salmon genetics committee govenor's maine Atlantic salmon task force. Preliminary.

Koslow, J. A., K. R. Thompson, and W. Silvert. 1987. Recruitment to northwest Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) stocks: influence of stock size and climate. Canadian Journal of Fisheries and Aquatic Sciences 44(1): 26-39.

Krueger, C. C., D. L. Perkins, R. J. Everett, D. R. Schreiner, and B. May. 1994. Genetic variation in naturalized rainbow trout (*Oncorhynchus mykiss*) from Minnesota tributaries to Lake Superior. Journal of Great Lakes Research 20(1): 299-316.

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.

Land & Water Resources Council. 1999. Land & Water Resources Council 1998 Annual Progress Report Atlantic Salmon Conservation Plan for Seven Maine Rivers; Annual Progress Report .

Larkin, P. A. 1981. A perspective on population genetics and salmon management. Canadian Journal of Fisheries and Aquatic Sciences 38(12): 1469-1475.

Larsson, H.-O. 1977. The influence of predation after release on the result of salmon smolt planting. C. M. 1977/M: 44. International Council for the Exploration of the Sea.

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

Lichatowich, J. 1993. Ocean Carrying Capacity. DRAFT. Mobrand Biometrics, Inc, Vashon Island, Washington.

Lund, R., and L. Hansen. 1991. Identification of wild and reared Atlantic salmon, Salmo salar L., using scale characters. Aquaculture and Fisheries Management 22(4): 499-508.

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.

Lundqvist, H., and G. Fridberg. 1982. Sexual maturation versus immaturity: Different tactics with adaptive values in Baltic salmon (*Salmo salar* L.) male smolts. Canadian Journal of Zoology 60(8): 1822-1827.

Lura, H., and F. Okland. 1994. Content of synthetic astaxanthin in escaped farmed Atlantic salmon, *salmo salar* L., ascending Norwegian rivers. Fisheries Management and Ecology 1: 205-216.

Lura, H., and H. Sægrov. 1991. Documentation of successful spawning of escaped farmed female Atlantic salmon, *Salmo salar*, in Norwegian rivers. Aquaculture 98: 151-159.

MacCrimmon, H. R., and B. L. Gots. 1979. World distribution of Atlantic salmon, *Salmo salar*. Journal of the Fisheries Research Board of Canada 36(4): 422-457.

MacKenzie, C. , J. R. Moring. 1988. Estimating Survival of Atlantic Salmon During he Intragravel Period. N. Am. J. Fish. Mgmt. 8(1): 45-59.

Magnhagen, C. 1988. Predation risk and foraging in juvenile pink (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*). Canadian Journal of Fisheries and Aquatic Sciences 45(4): 592-596.

Maine Department of Environmental Protection. 1990. Expected water quality changes from removal of the Edwards Dam, Augusta. Maine Department of Environmental Protection, Augusta, Maine.

Maine State Planning Office. 1993. Kennebec River resource management plan: balancing hydropower generation and other uses. Natural Resources Policy Division, Maine State Planning Office, Augusta, Maine.

Marine Laboratory Aberdeen. 1998. Minimizing the Interaction of Cultured and Wild Fish: A Comprehensive Evaluation of the Use of Sterile, Triploid, Atlantic Salmon. AIR3-CT94-2216. Final Report 1994-1998.

Marshall, L. 1998. Atlantic salmon Southwest New Brunswick outer-Fundy SFA 23. Stock status report D3-13 (1998). Maritimes Regional Advisory Process: Department of Fisheries and Oceans, Nova Scotia.

Martin, J. H. A., and K. A. Mitchell. 1985. Influence of sea temperature upon the numbers of grilse and multi-sea-winter Atlantic salmon (*Salmo salar*) caught in the vicinity of the River Dee (Aberdeenshire). Canadian Journal of Fisheries and Aquatic Sciences 42(9): 1513-1521.

Martin, M. F. 1995. Examination of temperature as it relates to juvenile Atlantic salmon habitat in four Downeast Maine salmon rivers . A.B. 1995.5. Machias, Maine.

Mather M. [Letter to Joseph Mckeon]. 1994.

Maxwell, J. R., C. E. Edwards, M. E. Jensen, S. J. Paustian, H. Parrott, and D. M. Hill. 1995. A hierarchical framework of aquatic ecology units in North America (Neararctic Zone). General Technical Report NC-176. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

May, A. W. 1993. A review of management and allocation of the Atlantic salmon resource in Atlantic Canada. Pages 220-232 *in* D. E. Mills. Salmon in the Sea. Fishing News Books, Blackwell Scientific, Cambridge, Massachusetts.

May, B., D. L. Perkins, and R. L. Sawyer. 1993. Genetic analysis of fish genomes and populations; Interim Progress Report . U.S. Fish and Wildlife Service, Cooperative Agreement # 14-16-0009-1553, Work Order #23.

May, B., D. L. Perkins, and R. L. Sawyer. 1994. Genetic analysis of fish genomes and populations: allozyme variation within and among Atlantic salmon (*Salmo salar*) from Downeast rivers of Maine. U.S. Fish and Wildlife Service, Cooperative Agreement # 14-16-0009-1553, Work Order #23.

McCabe, G. T. Jr. 1976. An intensive survey of fish populations in the St. Croix River between Vanceboro and Woodland, Maine. Final Report to the U.S. Fish and Wildlife Service (FWS Contract No. 14-16-0008-1192). University of Maine, Migratory Fish Institute, Orono.

McCarl, B. A., and R. B. Rettig. 1983. Influence of hatchery smolt releases on adult salmon production and its variability. Canadian Journal of Fisheries and Aquatic Sciences 40(11): 1880-1886.

McConnell, S. K., P. O'Reilly, L. Hamilton, J. M. Wright, and P. Bentzen. 1995. Polymorphic microsatellite loci from Atlantic salmon (Salmo salar): genetic differentiation of North American and European populations. Canadian Journal of Fisheries and Aquatic Sciences 52(9): 1863-1872.

McCrimmon, H. R. 1954. Stream studies on planted Atlantic salmon. Journal of the Fisheries Research Board of Canada 11(4): 362-403.

McGinnity, P., C. Stone, J. B. Taggart, D. Cooke, D. Cotter, R. Hynes, et al., 1997. Genetic impact of escaped farmed Atlantic salmon (salmo salar L.) on native populations: use of DNA profiling to assess freshwater performance of wild, farmed, and hybrid progeny in a natural river environment. ICES Journal of Marine Science 54:998-1008.

McKenna, J. E. 1996. Potential impacts of cultured Atlantic salmon on aquatic resources in the Gulf of Maine: a synthesis of the literature. Tunison Laboratory of Aquatic Science, National Biological Service, Cortland, New York.

McKnight, I. 1978. Sarcoma of the swim bladder of Atlantic salmon (Salmo salar L.). Aquaculture 13(1): 55-60.

Meister, A. L. 1962. Atlantic salmon production in Cove Brook, Maine. Transactions of the American Fisheries Society 91(2): 208-212.

Meister, A. L. 1982. The Sheepscot River: an Atlantic salmon river management report. State of Maine, Atlantic Sea Run Salmon Commission, Bangor.

Meister, A. L. 1984. The marine migrations of tagged Atlantic salmon (*Salmo salar* L.) of USA origin. C.M. 1984-M: 27. Anadromous and Catadromous Fish Committee, International Councel for the Exploration of the Sea, Copenhagen.

Meister, A. L., and F. J. Gramlich. 1967. Cormorant predation on tagged Atlantic salmon smolts. Final report of the 1966-67 Cormorant - Salmon Smolt Study. Atlantic Sea Run Salmon Commission, Orono, Maine.

Meyers, T. F. The program to restore Atlantic salmon to the Conneticut River. Pages 11-21 *in* S. Calabi and A. Stout, Editors. A Hard Look at Some Tough Issues; Proceedings of the New England Atlantic Salmon Management Conference. New England Salmon Association, Newburyport, Massachusetts.

Mills, D. H. 1964. The ecology of young stages of Atlantic salmon in the River Bran, Rosshire. Dept. Agric. Fish. Of Scotland, Freshwater Salmon Fish. Res.

Mills, D. 1971. Disease. Pages 91-99 *in* D. Mills. Salmon and trout: a resource, its ecology, conservation and management. St. Martin's Press, New York.

Mills, D. 1971. Parasites. Pages 86-91 *in* D. Mills. Salmon and trout: a resource, its ecology, conservation and management. St. Martin's Press, New York.

Mills, D. 1971. Predation. Pages 83-85 *in* D. Mills. Salmon and trout: a resource, its ecology, conservation and management. St. Martin's Press, New York.

Minshall, G. W., K. W. Cummins, R. C. Petersen, C. E. Cushing, D. A. Bruns, J. R. Sedell, et al. 1985. Developments in stream ecosystem theory. Canadian Journal of Fisheries and Aquatic Sciences 42: 1045-1055.

Minshall, G. W., R. C. Petersen, K. W. Cummins, T. L. Bott, J. R. Sedell, C. E. Cushing, et al. 1983. Interbiome Comparison of Stream Ecosystem Dynamics. Ecological Monographs 53(1): 1-25.

Minshall, G. W., E. Hitchcock, and J. R. Barnes. 1991. Decomposition of rainbow trout (*Oncorhynchus mykiss*) carcasses in a forest stream ecosystem inhabited only by nonanadromous fish populations. Canadian Journal of Fisheries and Aquatic Sciences 48(2): 191-195.

Møller, D. 1970. Transferrin polymorphism in Atlantic salmon (*Salmo salar*). Journal of the Fisheries Research Board of Canada 27(9): 1617-1625.

Moller Jensen. 1986. Exploitation and migration of salmon on the high seas, in relation to Greenland. Atlantic Salmon: Planning For the Future. The Proceedings of the Third International Atlantic Salmon Symposium, Held in Biarritz, France, 21-23 October, 1986 : 438-457.

Montevecchi, W. A., D. K. Cairns, and V. L. Birt. 1988. Migration of postsmolt Atlantic salmon, *Salmo salar*, off northeastern Newfoundland, as inferred by tag recoveries in a seabird colony. Canadian Journal of Fisheries and Aquatic Sciences 45(3): 568-571.

Moring, J. R., J. Marancik, and F. Griffiths. 1995. Changes in Stocking Strategies for Atlantic Salmon Restoration and Rehabilitation in Maine, 1871-1993. Pages Uses and effects of cultured fishes in aquatic ecosystems, American Fisheries Society. Bethesda, Maryland.

Mork, J. 1991. One-generation effects of farmed fish immigration on the genetic differentiation of wild Atlantic salmon in Norway. Aquaculture 98: 267-276.

Myers, R. A., and N. J. Barrowman, 1996 Oct. Is Fish Recruitment Related to Spawner Abundance? Fishery Bulletin [FISH. BULL.] 94(4):707-724.

Myers, R. A., J. A. Hutchings, and R. J. Gibson. 1986. Variation in male parr maturation within and among populations of Atlantic salmon, Salmo salar. Canadian Journal of Fisheries and Aquatic Sciences 43(6): 1242-1248.

NAC/NASCO (North American Commission/North Atlantic Salmon Conservation Organsization). 1992. Protocols for the introduction and transfer of salmonids. NAC(92)24.

NASCO. North American Commission; Report of Activities 1998/1999 NAC Scientific Working Group on Salmonid Introductions and Transfers. NAC(99)6. NASCO, Edinburgh, Scotland.

NASCO (North Atlantic Salmon Conservation Organization). 1993. Impacts of salmon aquaculture. CNL(93)29.

NEFMC (New England Fishery Management Council). 1987. Fishery management plan for Atlantic salmon: incorporating an environmental assessment and regulatory impact review/initial regulatory flexibility analysis . New England Fishery Management Council, Saugus, Massachusetts.

New England Salmonid Health Committee. 1997. New England salmonid health guidelines. Revised edition. Connecticut Department of Environmental Protection, Burlington, Connecticut.

Nielsen, E. E., M. M. Hansen, and V. Loeschcke, 1997. Analysis of microsatellite DNA from old scale samples of Atlantic salmon Salmo salar: A comparison of genetic composition over 60 years. Molecular Ecology 6(5):487-492.

Nielsen, J. L. 1998. Population genetics and the conservation and management of Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 55(1): 145-152.

NMFS (National Marine Fisheries Service). 1997. Gray seal (*Halochoerus grypus*): western north atlantic stock. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments - 1996. NOAA Technical Memorandum NMFS-NE-114. U.S. Department of Commerce, National Oceanic and Atmosphice Administration, NMFS, Norhtheast Fisheries Science Center, Woods Hole, Massachusetts.

NMFS (National Marine Fisheries Service). 1997. Harbor seal (*Phoca vitulina*): western north atlantic stock. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments - 1996. NOAA Technical Memorandum NMFS-NE-114. U.S. Department of Commerce, National Oceanic and Atmosphice Administration, NMFS, Norhtheast Fisheries Science Center, Woods Hole, Massachusetts.

NMFS (National Marine Fisheries Service). 1997. Harp seal (*Phoca groenlandica*): western north atlantic stock. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments - 1996. NOAA Technical Memorandum NMFS-NE-114. U.S. Department of Commerce, National Oceanic and Atmosphice Administration, NMFS, Norhtheast Fisheries Science Center, Woods Hole, Massachusetts.

NOAA (National Oceanic and Atmospheric Administration). 1993. Atlantic salmon. Status of Fishery Resources off the Northeastern United States for 1993. NOAA Technical Memorandum. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA.

O'Connell, M., and J. M. Wright, 1997 Sep. Microsatellite DNA in fishes. Reviews in Fish Biology and Fisheries 7(3):331-363.

O'Connell, M. F. O., J. B. Dempson, and D. G. and Reddin. 1992. Evaluation of the impacts of major management changes in the Atlantic salmon (*Salmo salar* L.) fisheries of Newfoundland and Labrador, Canada, 1984-1988. ICES Journal of Marine Science 49: 69-87.

Olafesen, J. A., and R. J. Roberts. 1993. Salmon disease: The microbial ecology of fish aquaculture. Pages 166-186 *in* K. Heen, R. L. Monahan, and F. Utter, editors. Salmon Aquaculture. Fishing News Books, Oxford.

Ouellette, D. R. 1999. A summary of weir activities on four Maine salmon rivers 1992-1998. USFWS (U.S. Fish and Wildlife Service), East Orland, Maine.

Park, L. K., and P. Moran, 1994. Developments in Molecular Genetic Techniques in Fisheries. Reviews in Fish Biology and Fisheries 4(3):272-299.

Parrish, D. L., R. J. Behnke, S. R. Gephard, S. D. McCormick, and G. H. Reeves. 1998. Why aren't there more Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 55(1): 281-287.

Payne, R. H. 1974. Transferrin variation in North American populations of the Atlantic salmon, Salmo salar. Journal of the Fisheries Research Board of Canada 31(6): 1037-1041.

Payne. R.H., A. R. Child, and A. Forrest. 1971. Geographical variation in the Atlantic salmon. Nature 231: 250-252.

Pearcy, W. G., and J. P. Fisher. 1988. Migrations of coho salmon, *Oncorhynchus kisutch*, during their first summer in the ocean. Fisheries Bulletin 86(2): 173-195.

Peterman, R. M. 1987. Review of the components of recruitment of Pacific salmon. American Fisheries Society Symposium 1: 417-429.

Peterson, R. H. 1978. Physical characteristics of Atlantic salmon spawning gravel in some New Brunswick, Canada, Streams. Can. Fish. Mar. Serv. Tech. Rep. No. 785: 1-28.

Peterson, R. H., P. G. Daye, and J. L. Metcalfe. 1980. Inhibition of Atlantic salmon (*Salmo salar*) hatching at low pH. Canadian Journal of Fisheries and Aquatic Sciences 37(5): 770-774.

Peterson, R. H., H. C. E. Spinney, and A. Sreedharan. 1977. Development of Atlantic salmon (*Salmo salar*) eggs and alevins under varied temperature regimes. Journal of the Fisheries Research Board of Canada 34(1): 31-43.

Piggins, D. 1987. Comparative features of the returns of wild and ranched salmon to the salmon research trust's installations, western Ireland. ICES; Copenhagen (Denmark); ICES Council Meeting 1987 (Collected Papers) : 9.

Polyanskii, Yu. I., and B. E. Bykhovskii. 1959. Parasitofauna of sea fish. Pages 187-193 *in* Proceedings of the conference on fish diseases. Leningrad. Academy of Sciences of the U.S.S.R., Ichthyological Committee, Moscow-Leningrad.

Porter, T. R., and J. A. Ritter. 1984. Possible causes of low abundance of Atlantic salmon in Canada - 1983. Doc. C.M. 1984/M: 28. Anadromous and Catadromous Fish Committee, ICES (International Council for the Exploration of the Sea), Copenhagen.

Pratt, V. S. 1946. The Atlantic salmon in the Penobscot River. Master's thesis. University of Maine, Orono.

Rae, B. B. 1960. Seals and Scottish fisheries. Marine Research No. 2. Department of Agriculture and Fisheries for Scotland, Edinburgh.

Rae, B. B. 1966. News items: salmonids in fish stomachs. Scottish Fisheries Bulletin (25): 33.

Rae, B. B. 1973. Further observations on the food of seals. Journal of Zoology : Proceedings of the Zoological Society of London 169: 287-297.

Rae, B. B., and W. M. Shearer. 1965. Seal damage to salmon fisheries. Marine Research No. 2. Department of Agriculture and Fisheries for Scotland, Edinburgh.

Rae, B. B. 1969. The food of cormorants and shags in Scottish estuaries and coastal waters. Marine Research No. 1. Department of Agriculture and Fisheries for Scotland, Edinburgh.

Rae, B. B. 1967. The food of cod in the North Sea and on west of Scotland grounds. Marine Research No. 1. Department of Agriculture and Fisheries for Scotland, Edinburgh.

Rago, P. J., D. G. Reddin, T. R. Porter, D. J. Meerburg, K. D. Friedland, and E. C. E. and Potter. ICES (International Council for the Exploration of the Sea). 1993. A continental run reconstruction model for the maturing component of North American Atlantic salmon: analysis of the fisheries in Greenland and Newfoundland-Labrador. ICES CM 1993/M:25. ICES.

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. 1985. Atlantic salmon (*Salmo salar*) on and east of the Grand Bank. Journal of the Northwest Atlantic Fisheries Society 6(2): 157-164.

Reddin, D. G., and W. M. Shearer. 1987. Sea-surface temperature and distribution of Atlantic salmon in the Northwest Atlantic Ocean. American Fisheries Society Symposium 1: 262-275.

Reddin, D. 1988. Ocean life of Atlantic salmon (Salmo salar L.) in the Northwest Atlantic. Pages 483-511 In: D. Mills and D. Piggins [eds.] Atlantic Salmon: Planning For the Future. The Proceedings of the Third International Atlantic Salmon Symposium, Held in Biarritz, France, 21-23 October, 1986. Timber Press, Portland, Oregon.

Reddin, D. G., and P. B. Short. 1989. Postsmolt Atlantic salmon in the Labrador Sea. C.M. 1989/M:9. ICES, Copenhagen.

Reddin, D. G. and P.B. Short. 1991. Postsmolt Atlantic salmon (*Salmo salar*) in the Labrador Sea. Can. J. Fish. and Aq. Sci. 48(1): 2-6.

Reddin, D. G., D. E. Stansbury, 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. and K. F. Friedland. 1993. Marine environmental factors influencing the movement and survival of Atlantic salmon. Pages 79-103 In D. E. Mills [ed.] Salmon in the Sea. Fishing News Books, Blackwell Scientific, Cambridge, MA.

Refstie, T. 1990. Application of breeding schemes. Genetics in Aquaculture III; Aquaculture 85(1-4): 163-169.

Reisenbichler, R. R. Walton, J. M., and D. B. Houston, editors. 1984. Outplanting: potential for harmful genetic changes in naturally spawning salmonids. Proceedings of the Olympic wild fish conference. Fisheries Technology Program, Peninsula College, Port Angeles, Washington.

Reisenbichler, R. R., and J. D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, Salmo gairdneri. Journal of the Fisheries Research Board of Canada 34(1): 123-128.

Restore: the North Woods, Biodiversity Legal Foundation, and J. W. and Elliot, Petitioners. 1993. In the office of Endangered Species U.S. Fish & Wildlife Service United States Department of the Interior; Petition for a rule to list the anadromous Atlantic salmon (Salmo salar) under the Endangered Species Act, 16 U.S.C. Sec. 1531 et seq. (1973) as Amended.

Richardson, P. L. 1993. Tracking Ocean Eddies; Drifting below the surface, floats reveal energetic masses of swirling water that transport salt and energy. American Scientist 81: 261-268.

Ricker, W. E. 1981. Changes in the average size and average age of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences 38(12): 1636-1656.

Ritter, J. A. 1975. Lower ocean survival rates for hatchery-reared Atlantic salmon (*Salmo salar*) stocks released in rivers other than their native streams. Doc C.M. 1975/M: 26. International Council for the Exploration of the Sea, Anadromous and Catadromous Fish Committee, Halifax.

Ritter, J. A. 1989. Marine migration and natural mortality of North American Atlantic salmon (*Salmo salar* L.). No. 2041. Canadian Manuscript Report of Fisheries and Aquatic Sciences.

Ritter, J. A., G. T. Farmer, R. K. Misra, T. R. Goff, J. K. Bailey, and E. T. Baum. 1986. Parental influences and smolt size and sex ratio effects on sea age at first maturity of Atlantic salmon (*Salmo salar*). Pages 30-38 *in* D. J. Meerburg, editor. Salmonid age at maturity. Canadian Special Publication of Fisheries and Aquatic Sciences 89, Ottawa.

Roberts, F. L. U.S. Fish & Wildlife Service. 1976. Biochemical genetics of the Atlantic salmon Salmo salar. Research Contract No. 14-16-0008-829. Orono, Maine.

Roberts, F. L. 1970. Atlantic salmon (Salmo salar) chromosomes and speciation. Transactions of the American Fisheries Society 99(1): 105-111.

Rounsefell, G. A., and L. H. Bond. 1949. Salmon Restoration in Maine. Research Report No. 1. Atlantic Sea-Run Salmon Commission of the State of Maine, Bangor.

Ruggles, C. P. 1980. A review of the downstream migration of Atlantic salmon. Canadian Technical Report of Fisheries and Aquatic Sciences. Freshwater and Anadromous Division Research Branch, Department of Fisheries and Oceans, Halifax.

Rye, M., and K. Lillevik. 1990. Survival in the early fresh-water period in Atlantic salmon (Salmo salar) and rainbow trout (Salmo gairdneri): Heritabilities for survival and genetic correlation between survival and growth. Genetics in Aquaculture III; Aquaculture 85(1-4): 328-329.

Saegrov, H., K. Hindar, S. Kalas, and H. Lura, 1997. Escaped farmed Atlantic salmon replace the original salmon stock in the River Vosso, western Norway. ICES Jounral of Marine Science 54:1166-1172.

Saunders, J. W. 1960. The effect of impoundment on the population and movement of Atlantic salmon in Ellerslie Brook, Prince Edward Island. Journal of the Fisheries Research Board of Canada 17(4): 453-473.

Saunders, R. L. 1981. Atlantic salmon (*Salmo salar*) stocks and management implications in the Canadian Atlantic Provinces and New England, USA. Canadian Journal of Fisheries and Aquatic Sciences 38(12): 1612-1625.

Saunders, R. L. 1986. The scientific and management implications of age and size at sexual maturity in Atlantic salmon (Salmo salar). Salmonid Age At Maturity., Can. Spec. Publ. Fish. Aquat. Sci. 89: 3-6.

Saunders, R. L. 1986. The thermal biology of Atlantic salmon: influence of temperature salmon culture with particular reference to constraints imposed by low temperatures. Report / Institute of Fresh-Water Research, Drottningholm 63: 77-90.

Saunders, R. L. 1991. Potential interactions between cultured and wild Atlantic salmon. Aquaculture 98: 51-60.

Saunders, R. L., A. P. Farrell, and D. E. Knox. 1992. Progression of coronary arterial lesions in Atlantic salmon (Salmo salar) as a function of growth rate. Canadian Journal of Fisheries and Aquatic Sciences 49(5): 878-884.

Saunders, R. L., E. B. Henderson, B. D. Glebe, and E. J. Loudenslager. 1983. Evidence of a major environmental component in determination of the grilse: larger salmon ratio in Atlantic salmon (*Salmo salar*). Aquaculture 33(1-4): 107-118.

Savage, P. M. 1973. Inventory of dams on Maine waterways. Executive Department, State of Maine, Augusta, Maine.

Scarnecchia, D. L., Á. Ísaksson, and S. E. White. 1989. Oceanic and riverine influences on variations in yield among Icelandic stocks of Atlantic salmon. Transactions of the American Fisheries Society 118(5): 482-494.

Scarnecchia, D. L. 1984. Climatic and oceanic variations affecting yield of Icelandic stocks of Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 41(6): 917-935.

Scarnecchia, D. L. 1984. Forecasting yields of two-sea-winter Atlantic salmon (*Salmo salar*) from Icelandic rivers. Canadian Journal of Fisheries and Aquatic Sciences 41(8): 1234-1240.

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

Schill, W. B., and R. L. Walker. 1994. Genetic Evaluation of Atlantic Salmon Populations of the "Downeast" Rivers of Maine: RAPD Markers. National Biological Survey, National Fish Health Research Laboratory; Kearneysville, West Virginia.

Schom, D., M. Mules, R. Morgan, J. Thorpe, and R. Alderson. 1984. North American and European Atlantic salmon (Salmo salar). Genetics 107(3, pt. 2): 96s.

Scott, W. B. and E. J. Crossman. 1973. Atlantic salmon. Pages 192-197 *in* Freshwater Fishes of Canada. (Bulletin 184). Department of Fisheries and Oceans, Scientific Information and Publications Branch, Ottawa.

Secombes, C. J. 1991. Current and future developments in salmonid disease control. Pages 81-87 *in* Interactions between fisheries and the environment. Proceedings from the Institute of Fisheries Management. University of Aberdeen, Scotland.

Siebenmann, M. 1995. Macroinvertebrates of the Narraguagus River as long-term indicators of water quality and as food base for juvenile Atlantic salmon. Master's thesis. University of Maine, Orono.

Siebenmann, M., and K. E. Gibbs. 1994. Macroinvertebrates of the Narraguagus River as long-term indicators of water quality. A preliminary report to the Maine Atlantic Sea Run Salmon Commission. University of Maine, Orono.

Skaala, O., and K. Hindar. ICES (International Council for the Exploration of the Sea)/ NASCO. 1997. Genetic changes in the R. Vosso salmon stock following a collapse in the spawning population and invasion of farmed salmon. Interactions between salmon culture and wild stocks of Atlantic salmon: the scientific and management issues. NASCO, Bath, England.

Slatkin, M. 1987. Gene flow and the geographic structure of natural populations. Science 236: 787-792.

Smith, H. M. 1898. The salmon fishery of Penobscot Bay and River in 1895 and 1896. U.S. Fish Commission Bulletin 17: 113-124.

Solomon, D. J. 1985. Salmon stock and recruitment, and stock enhancement. Journal of Fish Biology 27(suppl. A): 45-57.

Solomon, D. 1978. Some observations on salmon smolt migration in a chalkstream. Journal of Fish Biology 12(6): 571-574.

Spencer, R. C. 1991. 1990 Ducktrap River Atlantic salmon management update. Atlantic Sea Run Salmon Commission, Bangor, Maine.

Squires, T. S. 1985. History of the Augusta dam as it relates to fish passage from 1834 through 1892. Andadromous Fish Division, Department of Marine Resources.

Staahl, G. Genetic population structure of Atlantic salmon. POPULATION GENETICS AND FISHERY MANAGEMENT.; 1987; Pp. 121-140; PUBL. WASH. SEA GRANT .

Staahl, G. 1981. Genetic differentiation among natural populations of Atlantic salmon (Salmo salar) in northern Sweden. Fish Gene Pools.; Ecol. Bull. 34: 95-105.

Stabell, O. 1984. Homing and olfaction in salmonids: A critical review with special reference to the Atlantic salmon. Biological Review of the Cambridge Philosophical Society 59(3): 333-388.

Ståhl, G. 1987. Genetic population structure of Atlantic salmon. Pages 121-140 *in* N. Ryman and F. Utter, editors. Population genetics & fishery management. University of Washington Press, Seattle.

Stanley, J. G. and J. Trial. 1995. Habitat Suitability Index Models for Non Migratory Freshwater Life Stages of Atlantic Salmon. National Biological Service. Biological Science Report 3. Washington, D.C.

Stasko, A. B. , A. M. Sutterlin, S. A. Rommell, Jr. and P. F. Eslon. 1973. Migration-orientation of Atlantic Salmon (Salmo salar). Int. Atl. Salmon. Found. Spec. Publ. Series 4(1): 119-138.

Stokesbury, M. J., and G. L. Lacroix, 1997. High incidence of hatchery origin Atlantic slamon in the smolt output of a Canadian River. ICES Journal of Marine Sciences 54:1074-1081.

Stolte, L. W. Atlantic Salmon Restoration in the Merrimack River Basin. Pages 22-35 *in* S. Calabi and A. Stout, Editors. A Hard Look at Some Tough Issues; Proceedings of the New England Atlantic Salmon Management Conference. New England Slamon Association, Newburyport, Massachusetts.

Stolte, L. 1981. The forgotten salmon of the Merrimack. Department of the Interior, Northeast Region, Washington, D.C.

Taggart, J. B., E. Verspoor, P. T. Galvin, P. Moran, and A. Ferguson. 1996. A minisatellite DNA marker for discriminating between European and North American Atlantic salmon (Salmo salar). Canadian Journal of Fisheries and Aquatic Sciences 52(11): 2305-2311.

Taggart, J., and A. Ferguson. 1990. Minisatellite DNA fingerprints of salmonid fishes. Animal Genetics 21(4): 377-389.

Taylor, E. B. 1991. A review of local adaptation in Salmonidae, with particular refernece to Pacific and Atlantic salmon. Aquaculture 98: 185-207.

Tessier, N., L. Bernatchez, and J. M. Wright. 1997. Population structure and impact of supportive breeding inferred from mitochondrial and microsatellite DNA analyses in land-locked Atlantic salmon Salmo salar L. Molecular Ecology 6: 735-750.

The Salmon Research Agency of Ireland Incorporated. 1998. Annual Report No. 43: The annual reports of the salmon research agency of Ireland incorporated follow in sequence to those of its predecessor. No. 43. The Salmon Research Agency of Ireland Incorporated, Newport, Co. Mayo.

Thorpe, J. E., and K. A. Mitchell. 1981. Stocks of Atlantic salmon (*Salmo salar*) in Britain and Ireland: discreteness and current management. Canadian Journal of Fisheries and Aquatic Sciences 38(12): 1576-1590.

Thorpe, J. E., L. G. Ross, G. Struthers, and W. Watts. 1981. Tracking Atlantic salmon smolts, *Salmo salar* L., through Loch Voil, Scotland. Journal of Fish Biology 19(5): 519-537.

Thurow, F. 1966. Beiträge zur biologie und bestandskunde des Atlantischen lachses (*Salmo salar* L.) in der Ostsee. Berichte Der Deutschen Wissenschaftlichen Kommission Fur Meeresforschung 18(3/4): 223-379.

Tracy Copeland. [Letter to Tim King]. 1996 Dec 11.

U.S. Atlantic Salmon Assessment Committee. NASCO. 1996. Annual report of the U.S. Atlantic salmon assessment committee report No.8-1995 Activities. 1996/8. NASCO, Nashua, New Hampshire.

USASAC (U. S. Atlantic Salmon Assessment Committee). 1994. Annual report of the U.S. Atlantic Salmon Assessment Committee: Report No. 6-1993 Activities. Annual Report 1994/6. Turners Falls, Massachusetts.

USASAC (U.S. Atlantic Salmon Assessment Committee). 1997. Annual report of the U.S. Atlantic Salmon Assessment Committee: Report No. 9 - 1996 Activities. Annual Report 1997/9. Hadley, Massachusetts.

USASAC (U.S. Atlantic Salmon Assessment Committee). 1999. Annual Report of the U.S. Atlantic Salmon Assessment Committee . 1999/11. USASAC, Gloucester, Massachusetts.

USFWS (U. S. Fish and Wildlife Service). 1989. Final environmental impact statement 1989-2021: restoration of Atlantic salmon to New England rivers. Department of the Interior, U.S. Fish and Wildlife Service, Newton Corner, MA.

USFWS (Unites States Fish and Wildlife Service). 1994. 1996 Survey of Atlantic salmon parr in two tributaries, Kennebec River, Maine. Office of Fishery Assistance, USFWS, Laconia, New Hampshire.

Utter, F., K. Hindar, and N. Ryman. 1993. Genetic effects of aquaculture on natural salmonid populations. Pages 144-165 *in* K. Heen, R. L. Monahan, and F. Utter, editors. Salmon Aquaculture. Fishing News Books, Oxford.

Utter, F. M., J. E. Seeb, and L. W. Seeb. 1993. Complementary uses of ecological and biochemical genetic data in identifying and conserving salmon populations. Fisheries Research 18: 59-76.

Utter, F. M. 1981. Biological criteria for definition of species and distinct intraspecific populations of anadromous salmonids under the U.S. Endangered Species Act of 1973. Canadian Journal of Fisheries and Aquatic Sciences 38(12): 1626-1635.

van den Ende, O. 1993. Predation on Atlantic salmon smolts (*Salmo salar*) by smallmouth bass (*Micropterus dolomeiu*) and chain pickerel (*Esox niger*) in the Penobscot River, Maine. Master's thesis. University of Maine, Orono.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Candaian Journal of Fisheries and Aquatic Science 37(1): 130-137.

Verspoor, E. 1986. Reduced genetic variability in hatchery stocks of Atlantic salmon in eastern Canada (Mini-Symposium on "Population Genetics in Regard to Fisheries and Mariculture"). ICES; Copenhagen (Denmark); ICES Council Meeting 1986 (Collected Papers) : 17.

Verspoor, E. 1988. Identification of stocks in the Atlantic salmon . Present & Future Atlantic Salmon Management : 37-46.

Verspoor, E., 1997. Genetic diversity among Atlantic salmon (Salmo salar L.) populations. ICES Journal of Marine Science 54:965-973.

Verspoor, E., N. H. C. Fraser, and A. F. Youngson. 1991. Protein polymorphism in Atlantic salmon within a Scottish river: Evidence for selection and estimates of gene flow between tributaries. Aquaculture 98: 217-230.

Wang, L., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams. Fisheries. 22(6): 6-12.

Waples, R. S. 1991. Pacific Salmon, *Oncorhynchus* sp., and the definition of "Species" under the Endangered Species Act. Marine Fisheries Review 53(3): 11-21.

Warner, K. 1972. Further Studies of Fish Predation on Slamon Stocked in Maine Lakes. The Progressive Fish-Culturist 34(4): 217-221.

Watt, W. D., C. D. Scott, and W. J. White. 1983. Evidence of acidification of some Nova Scotian rivers and its impact on Atlantic salmon, *Salmo salar*. Canadian Journal of Fisheries and Aquatic Sciences 40(4): 462-473.

Webb, J. H., A. F. Youngson, C. E. Thompson, D. W. Hay, M.J. Donagy, I.S. McLaren. 1983. Spawning of escaped farmed Atlantic salmon, Salmo salar L,, in western and northern Scottish rivers: egg deposition by females. Aquat. Fish. Manage. 24(5): 663-670.

Webb, J. H., D. W. Hay, P. D. Cunningham, and A. F. Youngson. 1991. The spawning behaviour of escaped farmed and wild adult Atlantic salmon (*Salmo salar* L.) in a northern Scottish river. Aquaculture 98: 97-110.

Wells, W. 1869. Water-power of Maine. Hydrographic Survey of Maine. Sprague, Owen & Nash, Printers to the State, Augusta, Maine.

West Coast Chinook Salmon Biological Review Team. 1997. Review of the status of Chinnok salmon (Oncorhynchus tshawytscha) from Washington, Oregon, California, and Idaho under the U.S. Endangered Species Act.

White, H. C. 1936. The food of kingfishers and mergansers on the Margaree River, Nova Scotia. Journal of the Biological Board of Canada 2(3): 209-309.

White, H. C. 1939. Bird control to increase the Margaree River salmon. Bulletin No. 58. Fisheries Research Board of Canada, Atlantic Biological Station, Ottawa.

White, H. C. 1939. Factors influencing descent of Atlantic salmon smolts. Journal of the Fisheries Research Board of Canada 4(5): 323-326.

White, H. C. 1939. The food of *Mergus serrator* on the Margaree River, N. S. Journal of the Fisheries Research Board of Canada 4(5): 309-311.

White, S. 1988. Anticipating the "blue revolution": the growth of the salmon farming industry and its public policy implications. Anadromous Fish Law Memo 45, Portland, Oregon.

Wiley, M. J., S. L. Kohler, and P. W. Seelbach, 1997. Reconciling Landscape and Local Views of Aquatic Communities: Lessons From Michigan Trout Streams. Freshwater Biology. Oxford 37(1):133-148.

Wilkie, M. P., M. A. Brobbel, K. Davidson, L. Forsyth, and B. L. *. Tufts, 1997. Influences of temperature upon the postexercise physiology of Atlantic salmon (Salmo Salar). Canadian Journal of Fisheries and Aquatic Sciences 54(03):503-511.

Windsor, M. L., and P. Hutchinson. 1990. The potential interactions between salmon aquaculture and the wild stocks- a review. Fisheries Research 10: 163-176.

Windsor, M. L., and P. Hutchinson. 1994. International management of Atlantic salmon, *Salmo salar* L., by the North Atlantic Salmon Conservation Organization, 1984-1994. Fisheries Management and Ecology 1(1): 31-44.

Wolk, K. 1988. Atlantic salmon swim bladder sarcoma virus. Pages 349-351 *in* K. Wolf, editor. Fish viruses and fish viral diseases . Cornell University; Ithaca, New York.

Wood, C. C. 1987. Predation of juvenile Pacific salmon by the common merganser (*Mergus merganser*) on eastern Vancouver Island II: Predation of stream-resident juvenile salmon by merganser broods. Canadian Journal of Fisheries and Aquatic Sciences 44(5): 950-959.

Wright, S. 1978. Variability within and among natural populations. Pages 580 p. *in* . Evolution and the genetics of populations. Vol. 4. Chicago Press, Chicago, Illinois.

Youngson, A. F., and E. Verspoor, 1998. Interactions Between Wild and Introduced Atlantic Salmon (Salmo Salar). Canadian Journal of Fisheries and Aquatic Sciences 55(supp 1):153-160.

Youngson, A. F. e. al. 1997. Interactions between salmon culture and wild stocks of Atlantic salmon: the scientific and management issues. ICES Journal of Marine Sciences 54: 963-964.

Youngson, A. F., J. H. Webb, C. E. Thompson, and D. Knox. 1993. Spawning of escaped farmed Atlantic salmon (Salmo salar): Hybridization of females with brown trout. Can. J. Fish. Aquat. Sci. 50(9): 1986-1990.

Ziegler, R. L. 1988. Stream resource utilization of sympatric and allopatric juvenile brown (*Salmo trutta*) and steelhead trout (*Salmo gairdneri*). Master's thesis. Michigan State University, East Lansing.