United States Department of Interior
Fish and Wildlife Service
300 Westgate Center Drive
Hadley, MA 01035-9589

United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
One Blackburn Drive
Gloucester, MA 01930

April 12, 1995

Dr. Robert J. Behnke
Department of Fish and Wildlife Biology
Colorado State University
Fort Collins, Colorado 80523

Dear Dr. Behnke:

Enclosed is the draft Status Review for Anadromous Atlantic Salmon in the United States. Background and experience of committee members can assist the U.S. Fish and Wildlife Service and the National Marine Fisheries Service in making decisions based upon the best scientific and commercial data available (as required by the Endangered Species Act) for this species. Accordingly, we are seeking review of this document focusing on two aspects of the Status Review: (1) issues and assumptions relating to the biological and ecological information of the Status Review; and (2) scientific data relating to the factors involved with possible listing.

The Status Review is being sent out concurrently for review to Federal and State agencies and the interested public. The review period for this Status Review will end on May 26, 1995 at which time we will consider incorporating the comments we have received into a final Status Review.

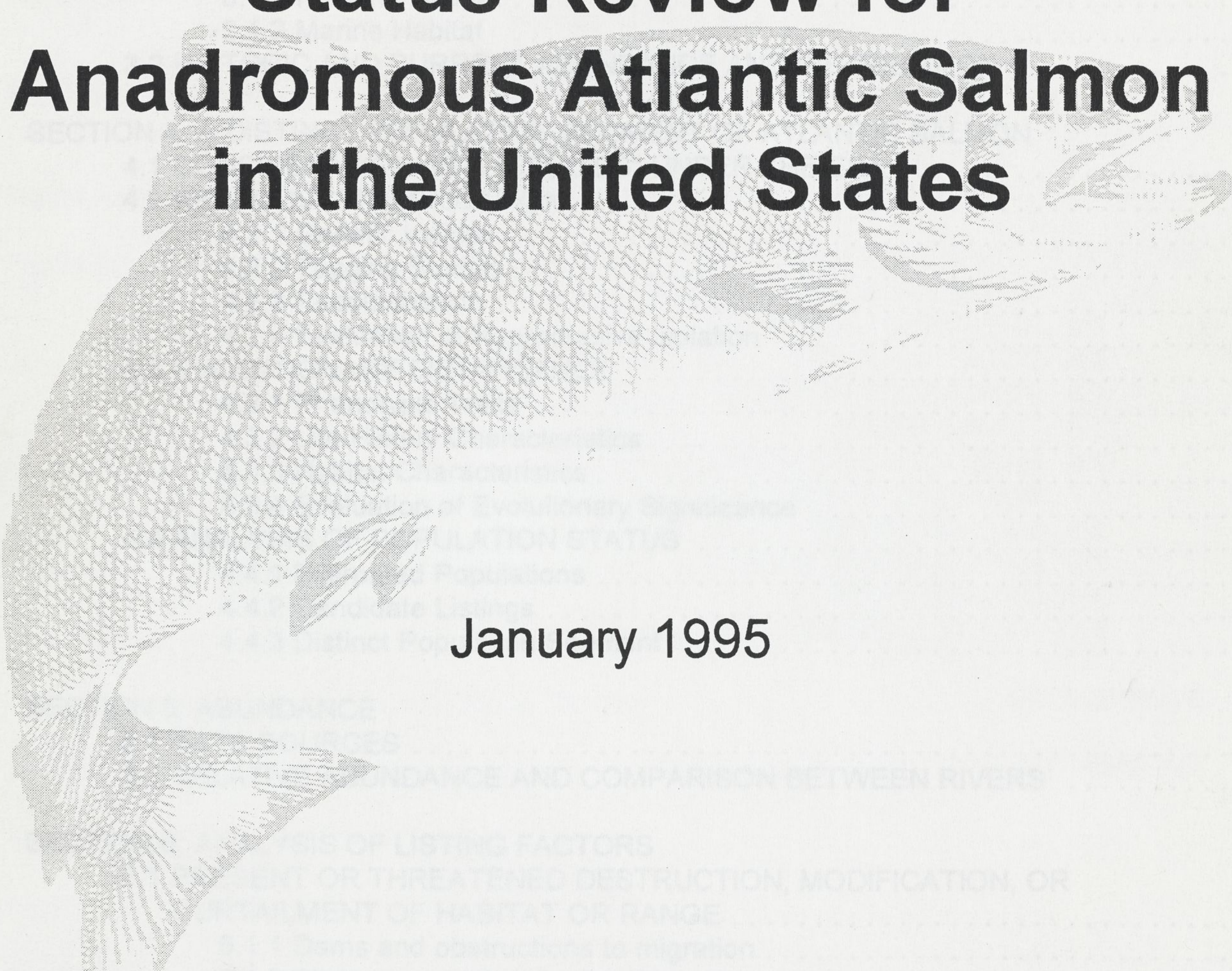
We appreciate your review and we will be most interested in your comments. Please forward your comments to me at, National Marine Fisheries Service, One Blackburn Drive, Gloucester, Massachusetts, 01930.

Sincerely,

Mary Colligan

Mary Colligan
Fish Biologist

Enclosure



Status Review for Anadromous Atlantic Salmon in the United States

January 1995

U.S. Department of Interior
U.S. Fish and Wildlife Service

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

This status review was published in draft form for the timely communication of information. It has not received complete formal review, editorial control, or detailed editing.

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SECTION 1: EXECUTIVE SUMMARY

In October and November of 1993, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (collectively "the Services") received identical petitions 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.

Concurrently, the Services initiated a study of the status of U.S. Atlantic salmon in relation to the ESA. The ESA defines species as "any subspecies of fish or wildlife or plants, and any **distinct population segment** of any species of vertebrate fish or wildlife that interbreeds when mature (emphasis added)." Distinct population segments (DPS) are particularly important to anadromous salmonines because their strong homing capability fosters the formation of discrete populations exhibiting important adaptations to local riverine ecosystems. Guidance on defining species under the ESA has been provided by the National Marine Fisheries Service (NMFS) in the context of listing decisions involving Pacific salmon. This guidance introduces a more precise definition called the Evolutionarily Significant Unit (ESU). Because the structure of Atlantic salmon populations is similar to Pacific salmonines, the ESU approach provides a practical framework for delineating Distinct Population Segments (DPS) of Atlantic salmon under the ESA. To qualify as a DPS, a population (or group of populations) must be reproductively isolated from conspecific populations and must be evolutionarily significant (i.e. contribute substantially to the ecological/genetic diversity of the species).

Naturally reproducing Atlantic salmon in U.S. rivers are substantially reproductively isolated from those in Canada. Tagging studies indicate that U.S. Atlantic salmon stocks do not stray far from their natal streams. In addition, there has been a lack of recolonization by Atlantic salmon in U.S. rivers where they have been extirpated. Given available information, the Atlantic Salmon Biological Review Team (Team) concluded that collectively wild river-specific populations of Atlantic salmon in the U.S. meet the criteria of reproductive isolation and are substantially reproductively isolated from Canadian stocks.

In examining the second criteria for a DPS, evolutionary significance, the Team considered the following three factors: phenotypic traits, life history traits, and habitat characteristics. Historic records indicate that distinct, locally adapted, Atlantic salmon stocks existed in river systems in the U.S. Genetic analyses and life history traits demonstrate that U.S. stocks of Atlantic salmon are distinct from stocks in Canada and Europe. Historically, adult spawners in U.S. rivers have been predominately two sea winter fish whereas many Canadian and European stocks return after one year at sea. The riverine habitat occupied by U.S. Atlantic salmon is distinctive in that it is located at the southern extent of the range of the species in North America. The continuous presence of U.S. Atlantic salmon in indigenous habitat provides evidence that important local adaptations have persisted. At present, differences are subtle and difficult to assess due to low abundance. The populations of anadromous Atlantic salmon present in the Sheepscot, Ducktrap, Narraguagus, Pleasant, Machias, East Machias and Dennys Rivers represent the last wild remnant of U.S. Atlantic salmon. All of these factors indicate that the DPS is evolutionarily significant. Atlantic salmon have persisted in these seven rivers and, collectively, are reproductively isolated from conspecific populations, and contribute substantially to the ecological/genetic diversity of the species as a whole. Candidate species status is recommended for existing river runs of naturally spawning Atlantic salmon whose link to native stocks and degree of persistence is not well understood. Candidate status is recommended for Atlantic salmon in the Kennebec River, Penobscot River, Tunk Stream and St. Croix River.

The Team evaluated the status of the seven river stocks that comprise the DPS of Atlantic salmon by analyzing trends in historic and current relative abundance and spawner escapement goal. The status of these populations 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. Species may be determined to be threatened or endangered due to any one or more 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 (Section 4(a)(a)(1)). Habitat for Atlantic salmon has been greatly reduced over time; recreational and commercial fishing has had a significant adverse impact on U.S. Atlantic salmon; finfish aquaculture has the potential to adversely impact wild U.S. Atlantic salmon and evidence suggests that poor marine survival continues to result in reduced returns to U.S. rivers. Collectively, the information summarized in this Status Review suggests that the DPS comprised of the unique Atlantic salmon populations in the Sheepscot, Ducktrap, Narraguagus, Pleasant, Machias, East Machias and the Dennys Rivers are is danger of extinction.

The Services prepared this status review as a supplement to the 12-month petition finding. For copies, contact Mary Colligan, National Marine Fisheries Service, at (508) 281-9116 or Paul Nickerson, U.S. Fish and Wildlife Service, at (413) 253-8615.

SECTION 2: INTRODUCTION

This report summarizes biological information gathered in conjunction with an Endangered Species Act (ESA) status review for current and historic U. S. populations of Atlantic salmon (*Salmo salar*). As amended in 1978, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. The Atlantic Salmon Biological Review Team, composed of staff from Region 5 of the U. S. Fish and Wildlife Service and the Northeast Region and Science Center of the National Marine Fisheries Service (collectively the "Services") is suggesting that a distinct population segment (DPS) comprised of seven individual river populations of Atlantic salmon is "distinct" for purposes of listing under the ESA. The Team also recommends four rivers for further review, classifying Atlantic salmon in these rivers as candidate species.

Prior to European settlement, Atlantic salmon were widely distributed in the New England states and supported important commercial and tribal fisheries. During the intervening years, construction of hundreds of dams reduced spawning habitat to a fraction of the historic amount, water was polluted to the extent that salmon could not survive in it, and Atlantic salmon were overexploited. The species began to disappear from natal rivers centuries ago, to the point that today only a remnant population occurs in a handful of rivers and streams in Maine. From the mid 1800's through the present time, numerous restoration efforts have been undertaken. In 1947, when known adult returns numbered only about 1,500, the Maine Atlantic Sea Run Salmon Commission was established in an effort to reverse the decline.

Improvements in water quality, installation of fish passage facilities, and increased public awareness all contributed to an atmosphere of hope for successful Atlantic salmon restoration throughout New England, thereby encouraging more partners to join the effort. Restoration projects were undertaken on the Penobscot, Merrimack, and Connecticut rivers. During the 1970's and early 1980's, returns increased and recreational fishing success in Maine was high. However, Atlantic salmon were being heavily exploited at sea by interception fisheries. Canadian and West Greenland fisheries had considerably reduced spawning escapement. In addition, the recreational fishery harvested 15-25% of the returning spawners. Those factors, coupled with worsening natural conditions at sea have drastically reduced Atlantic salmon abundance in many U.S. rivers during the past decade.

In 1991, the U.S. Fish and Wildlife Service 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 as well as state and private agencies to reverse the decline. During that same period, the NMFS was conducting an exhaustive five year study of the Narraguagus River to demonstrate to those regulating ocean harvests that U. S. streams could still produce Atlantic salmon. The study, now in its final year, has demonstrated that spawning and nursery habitat appears suitable and should produce more fish given adequate escapement levels.

Recently, the high seas interception fishery has been drastically reduced, but natural conditions in the marine environment remain poor, and U.S. Atlantic salmon runs have not shown any recovery. The sustained decline resulted in the Services being petitioned to add the Atlantic salmon to the Endangered Species List. 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. Team members are as follows: from the National Marine Fisheries Service - Douglas Beach, Protected Species Program Coordinator, Northeast Region, Gloucester, MA; Mary A. Colligan, Fishery Biologist, Habitat and Protected Resources Division, Northeast Region, Gloucester, MA; and John F. Kocik, Research Fishery Biologist, Population Dynamics Branch, Northeast Fisheries Science Center, Woods Hole, MA; and from the Fish and Wildlife Service - Dan C. Kimball, Regional Fisheries Supervisor, Region 5, Hadley, MA; 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. .

Acknowledgements

The status review for Atlantic salmon was conducted by the interagency Atlantic Salmon Biological Review Team (Team). Comments and supplemental information submitted by interested parties were reviewed by the Team and incorporated in this Review as appropriate. The Team would like to acknowledge the assistance of the staff of the Atlantic Sea Run Salmon Commission, Dr. Kevin Friedland and Ruth Haas-Castro of the NMFS Northeast Fisheries Science Center, and Dr. Robin Waples of NMFS Northwest Fisheries Science Center.

SECTION 3: BIOLOGICAL INFORMATION

3.1 LIFE HISTORY

Atlantic salmon have a relatively complex life history that extends from spawning and juvenile rearing in rivers to extensive feeding migration in 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 (Figure 3.1). The following sections detail their life history by riverine and marine habitats.

3.1.1 Riverine Habitat

Adult Atlantic salmon ascend the rivers of New England beginning in the spring and continuing into the fall with the peak occurring in June. It is thought that Atlantic salmon use olfactory stimuli to home to their natal streams (Stasko *et al.* 1973). Upstream migration can be stimulated by rising river temperatures and water flows. Water temperatures above 22.8° C and dissolved oxygen concentrations below 5 ppm can curtail migration (DeCola 1970). Adult salmon do not feed during their migration to spawning grounds. Spawning occurs in late October through November. After spawning in the fall, Atlantic salmon either return to the sea or overwinter in the river. A spawned out salmon in freshwater is called a kelt or black salmon. When the average salmon returns to the river it is 75 cm long and weighs approximately 4.5 kg. Good spawning habitat has a gravel substrate and adequate water circulation to keep the eggs well oxygenated (Peterson 1978). The water depth at spawning sites is typically 30 cm to 61 cm and water velocity averages 61 cm per second (Beland 1984). Spawning sites are typically located at the downstream end of riffles where water percolates through the gravel or at upwellings of groundwater (Danie *et al.* 1984). The optimal water temperature during the spawning period is less than 10° C, but it ranges from 7.2° C to 10.0° C (Jordon and Beland, 1981; Peterson *et al.* 1977). The female moves her tail back and forth to create a depression, called a redd, where she deposits her eggs. One or more males fertilize the eggs as they are deposited in the redd (Jordon and Beland 1981). The female then continues digging upstream of the deposition site to bury the fertilized eggs.

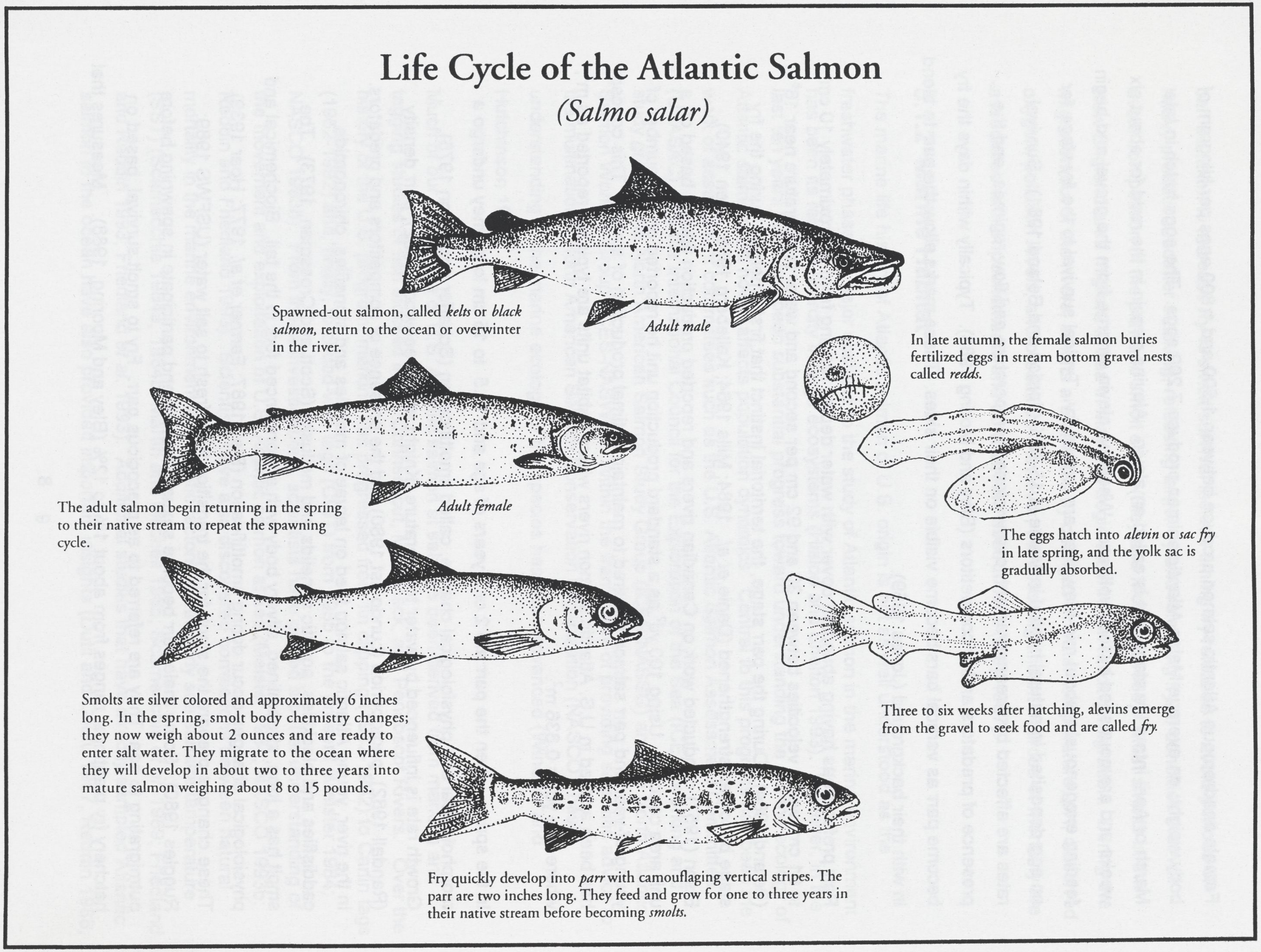


Figure 3.1 Life cycle of the Atlantic salmon.

Female anadromous Atlantic salmon produce between 1,500 and 1,800 eggs per kilogram of body weight; on average Maine Atlantic salmon produce 7,200 eggs. The eggs hatch in late March or April into a life stage that is called an alevin. Alevins remain in the redd for about six weeks and are nourished by their yolk sac. When the alevin emerge from the gravel and begin feeding exogenously, about mid-May, they are termed fry. Typical survival to the fry stage for an egg deposited in natural habitat in Maine is 15-35% (Jordon and Beland 1981). Survival rates are affected by stream gradient, overwintering temperature and flow regimes, and the presence of predators and/or competitors (Bley and Moring 1988). Typically within days the fry become parr as vertical bars become visible on their sides. These marks allow the parr to blend in with their background (Jones 1959).

Parr prefer areas having abundant cover with water depths ranging from approximately 10 cm to 61 cm, water velocities between 30 and 92 cm per second and water temperature near 16° C (Beland 1984). During the parr stage, the territorial instinct that first emerged during the fry stage becomes strengthened (Danie *et al.* 1984; Mills 1964; Kalleberg 1958; Allen 1940). Elson (1957) conducted work on Canadian rivers and reported production figures based on a unit area concept. Using 100 yd^2 as a standard production unit he reported on the number of young-of-year and parr salmon required to maintain optimal production of smolts. This concept has been applied in U.S. Atlantic salmon rivers where habitat units are typically reported as m^2, where one $yd^2 = 0.836\ m^2$.

In the spring, when the parr are 2 or 3 years of age and 12.5 to 15 cm long, they undergo a morphological and physiological change, called smoltification (Schaffer and Elson 1975). Growth rate is influenced by water temperature (Knight and Greenwood 1982), parr density (Randall 1982), photoperiod (Lundquist 1980) and the presence of competitors and predators. In the river, young Atlantic salmon feed on larvae of mayflies and stoneflies, chironomids, caddisflies and blackflies, aquatic annelids and mollusks (Scott and Crossman, 1973). The smolt has a long, streamlined, silvery body with a pronounced fork in the tail. Biochemical and physiological changes occur during smoltification (Bley 1987; Farmer *et al.* 1977; Hoar 1939). These changes prepare the smolt for the transition from fresh to salt water (USFWS 1989; Ruggles 1980). Some male parr become sexually mature and participate in spawning before outmigrating to sea. They are referred to as precocious parr. Fry to smolt survival, based on hatchery fry plantings, ranges from about 1% to 12% (Bley and Mooring, 1988). Measures that can be taken to increase fry to smolt survival include timing fry releases to avoid periods of heavy predation, scatter stocking, releasing larger fry and releasing fry at densities that will avoid competition in the parr and smolt stage (Bley and Mooring, 1988). Most smolts in the New England area migrate to sea in May and begin their ocean feeding migration. During the migration out of the rivers, smolts are affected by changes in water temperature, pH, dissolved oxygen, pollution levels, and predation. However, the most significant sources of mortality are associated with impoundments and downstream obstructions (Bley 1987).

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 its relative scarcity in large ecosystems (Hislop and Shelton 1993). However, in the last ten years there has been substantial progress toward understanding the marine ecology of Atlantic salmon and how it affects population dynamics. Central to this progress has been the work of assessment committees such as the U.S. Atlantic Salmon Assessment Committee (USASAC), and 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).

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) and, finally, 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 1987; 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 scientists better 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 3.2), undertaking long marine migrations from the mouth of U.S. rivers to 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/s^{-1} (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 congregations 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 in seabird colonies have indicated that U.S. post-smolts were 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 mixed stock complex. The U.S. contribution to the stock complex has probably always been relatively low because the proportion of accessible U.S. Atlantic salmon production habitat is less than in other countries.

Upon entry to the marine environment, post-smolts appear to feed opportunistically and primarily near the surface. Their diet includes invertebrates, terrestrial insects, amphipods, euphausiids, and fish (Hislop and Youngson 1984; Jutila and Toivonen 1985; Fraser 1987; Hislop and Shelton 1993). As post-smolts grow, fish become a more important component of their diet. Atlantic salmon post-smolts are preyed upon by gadids, whiting, cormorants, ducks, terns, gulls, and many other opportunistic predators because of their small size (Hvidsten and Mokkelgjerd 1987; Gunneroed *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 and the large number and variety of potential predators.

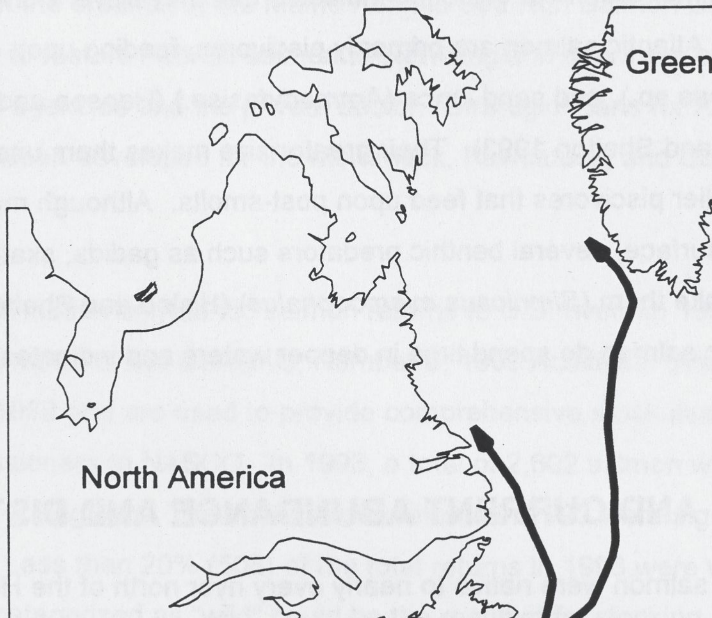


Figure 3.2 Generalized marine migration routes of U.S. origin Atlantic salmon.

Information on the overwintering of post-smolts is limited. Based upon scale analysis, 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 is needed to gain a better understanding of post-smolt Atlantic salmon distribution in the North Atlantic.

Most U.S. origin salmon spend two winters 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 are primarily piscivores, feeding upon capelin (*Mallotus villosus*), herring (*Alosa* sp.), and sand lance (*Ammodytes* sp.) (Hansen and Pethon 1985; Reddin 1985; Hislop and Shelton 1993). Their greater size makes them unavailable as potential prey to 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 are known to take them (*Simniosus microcephalus*) (Hislop and Shelton 1993). This suggests that Atlantic salmon do spend time in deeper waters and indicates the need for further behavioral studies.

3.2 HISTORIC AND CURRENT ABUNDANCE AND DISTRIBUTION

Anadromous Atlantic salmon were native to nearly every river north of the Hudson River (Atkins 1874; Kendall 1935). Beland (1984) reported that at least thirty-four Maine Rivers held Atlantic salmon populations at one time. Other sources report the number to be twenty-eight (McCrimmon and Gots 1979; Kendall 1935). The original range of Atlantic salmon in the U.S. (Figure 3.3) was from the Housatonic River in the south to the St. Croix River in the north (Kendall 1935; Scott and Crossman 1973). The historic Atlantic salmon run in the U.S. has been estimated to approach 500,000 (Beland 1984). The largest salmon runs in New England were in the Connecticut, Merrimack, Androscoggin, Kennebec and Penobscot Rivers. Beland (1984) reported that the original spawning and nursery habitat in Maine for Atlantic salmon was 476,577 units (1 unit = 100 m^2). The Maine Atlantic Sea Run Salmon Commission (ASRSC) reported that approximately 35% of the historic Atlantic salmon habitat in Maine was accessible in 1984 (Beland 1984). The amount of historic habitat and habitat currently accessible to Atlantic salmon in New England rivers are depicted in Figures 3.4 and 3.5.

By the early 1800's, the Atlantic salmon runs in New England had been severely depleted. The earliest impacts were from fishing and were quickly followed by water quality degradation and barriers to migration caused by the Industrial Revolution. Restoration efforts were initiated in the late 1800's, but had little success due to the presence of dams and the inefficiency of early fishways. Atlantic salmon runs had been eliminated from southern New England Rivers by 1865 (USFWS 1989). The loss of the Connecticut and Merrimack River populations shifted the southern extent of the species range almost 2° north in latitude. Directed recovery efforts in Maine began with the creation of the Maine Atlantic Sea Run Salmon Commission in 1947. Currently, efforts to restore Atlantic salmon to New England rivers are coordinated among federal and state agencies and the private sector. Strategic Plans for Atlantic salmon restoration have been developed for the Merrimack, Pawcatuck, and Connecticut Rivers and the rivers of Maine.

The following information on Atlantic salmon returns to U.S. rivers in 1992 and 1993 is taken from the Annual Report of the USASAC, Number 6, 1993 Activities. Annual reports have been published since 1988 and are used to provide comprehensive stock assessment information for the U.S. Commissioners to NASCO. In 1993, a total of 2,602 salmon was documented to return to 19 rivers in New England. The documented returns in 1993 were significantly less than those in 1992 (3,647). Less than 20% (508) of the total returns in 1993 were wild fish. It is important to note that fish categorized as "wild" could be the result of fry stocking. Nearly 90% (2,329) of all returning Atlantic salmon returned to Maine Rivers and more than three-quarters of the fish returned to the Penobscot River (1,769). The estimated number of returning Atlantic salmon was 3,123 in Maine rivers and a total of 3,433 for all New England rivers. By comparison the estimated return for 1992 was 5,039 adult Atlantic salmon. The USASAC reported that the 1988 fry release, the largest on record, produced one of the lowest return rates ever recorded (.06 adults/1000 fry).

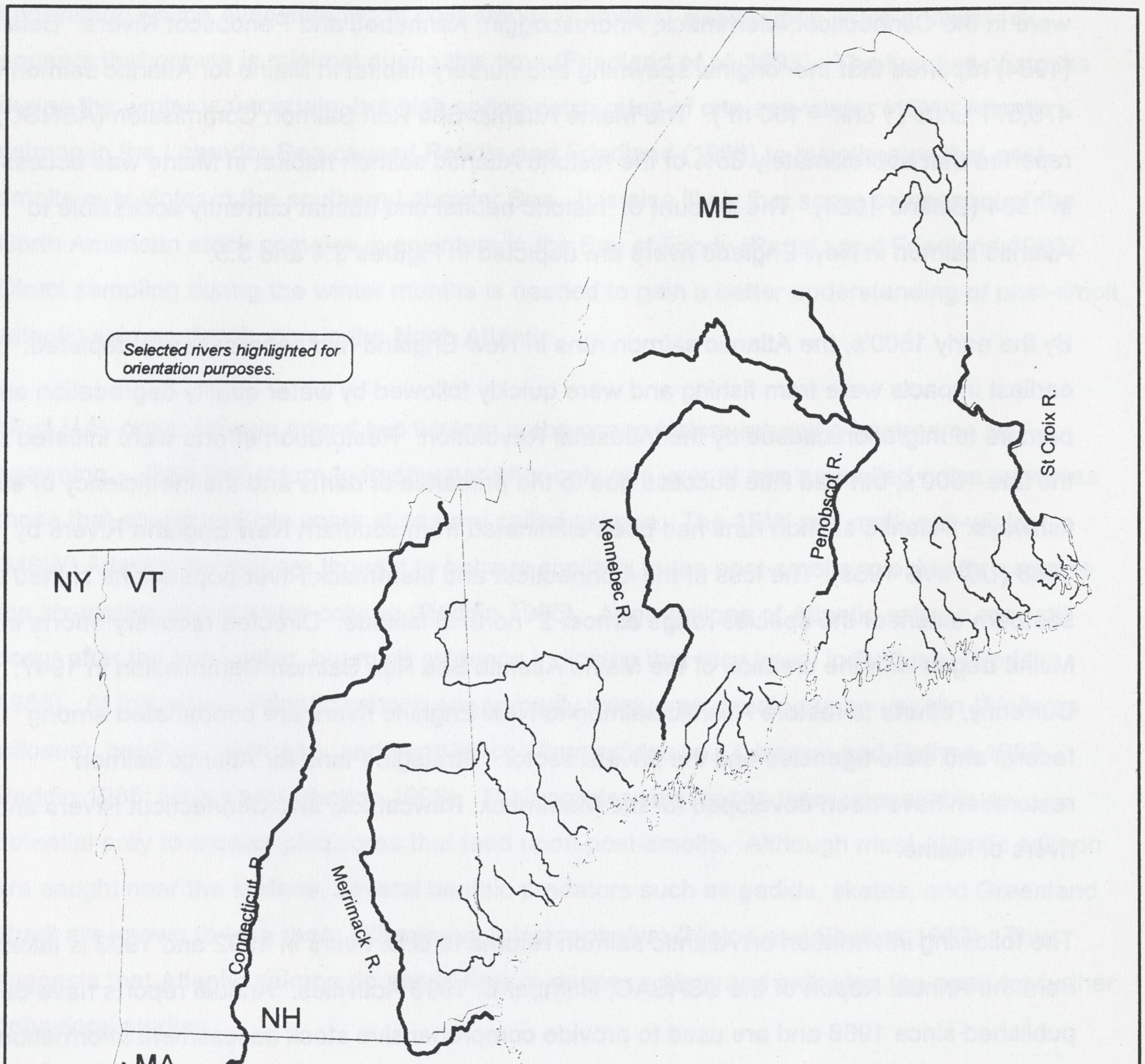
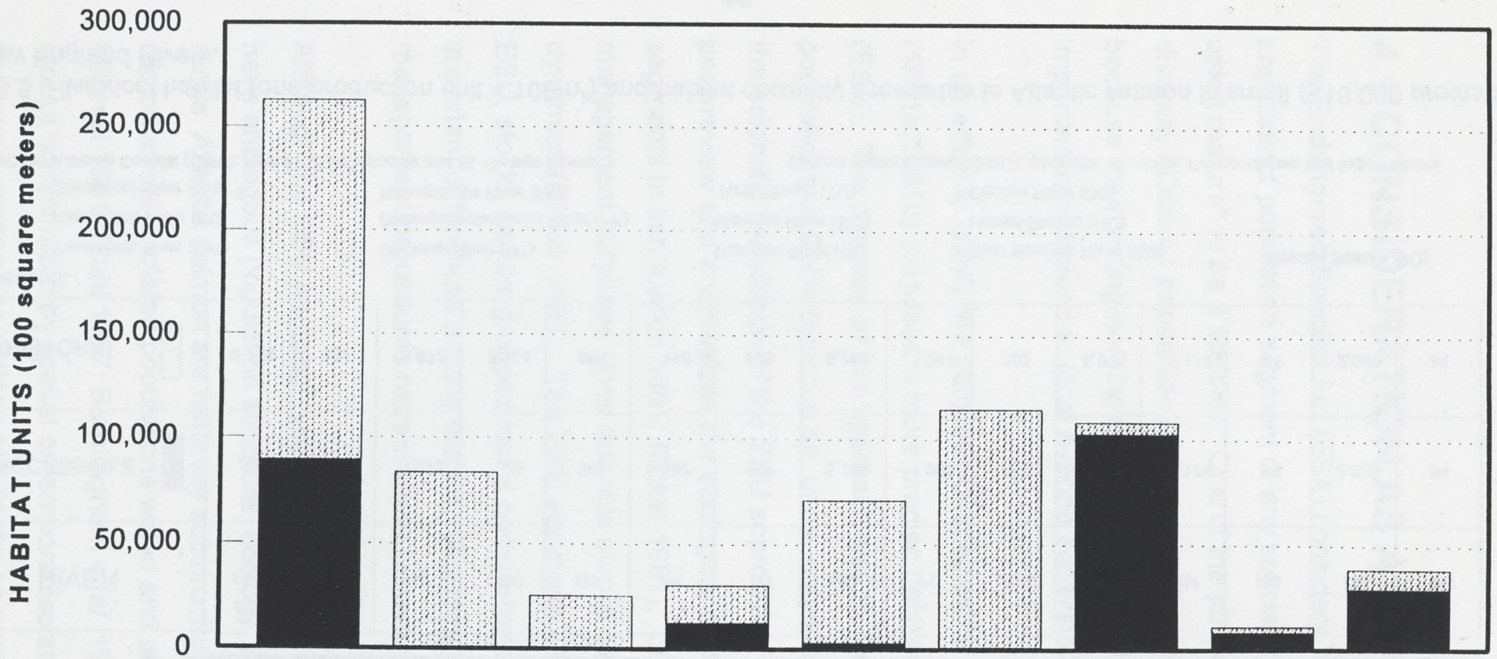


Figure 3.3 Historic U.S. Atlantic salmon rivers.

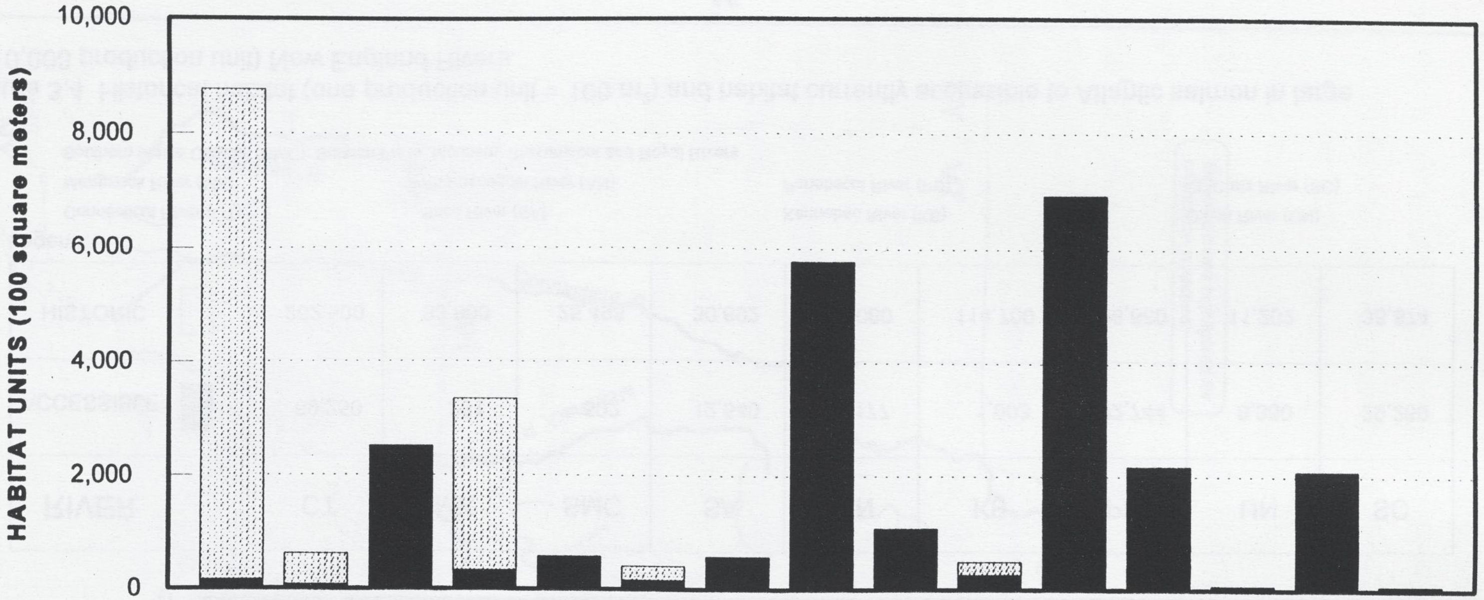


RIVER	CT	MK	SMC	SA	AN	KB	PB	UN	SC
ACCESSIBLE	89,250	251	502	12,540	3,177	1,003	102,744	8,360	29,260
HISTORIC	262,500	83,600	25,498	30,692	71,060	114,700	108,680	11,202	38,874

Legend:

Connecticut River (CT)
Merrimack River (MK)
Saco River (SA)
Androscoggin River (AN)
Kennebec River (KB)
Penobscot River (PB)
Union River (UN)
St. Croix River (SC)
Southern Maine Coastal (SMC): Salmon Fal ls, Mousam, Presumscot and Royal Rivers

Figure 3.4 Historical habitat (one production unit = 100 m^2) and habitat currently accessible to Atlantic salmon in large (>10,000 production unit) New England Rivers.



RIVER	PW	KN	SH	CMC	DT	PK	TU	NG	PL	EMC	MC	EM	HO	DE	BO
ACCESSIBLE	167	84	1,672	335	585	167	585	5,768	1,087	269	6,939	2,174	84	2,090	84
HISTORIC	8,778	627	1,672	3,344	585	418	585	5,768	1,087	502	6,939	2,174	84	2,090	84

Legend:

Pawcatuck River (PW)
Kennebunk River (KN)
Sheepscot River (SH)
Ducktrap River (DT)
Passagassawaukeag River (PK)
Narraguagus River (NG)
Pleasant River (PL)
Machias River (MC)
Tunk Stream (TU)
East Machias River (EM)
Hobart Stream (HO)
Dennys River (DE)
Boyden Stream (BO)
Central Maine Coastal (CMC): Pemaquid, M edomak and St. George Rivers
Eastern Maine Coastal (EMC): Chandler, O range, Pennamaquan and Indian Rivers

Figure 3.5 Historical habitat (one production unit = 100m^2) and habitat currently accessible to Atlantic salmon in small (<10,000 production unit) New England Rivers.

SECTION 4: A DISTINCT POPULATION SEGMENT OF ATLANTIC SALMON

4.1 CONSIDERATION AS A "SPECIES" UNDER THE ESA

The Endangered Species Act (ESA) considers "any subspecies of fish or wildlife or plants, and any distinct population segment 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. Distinct population segments are particularly important to anadromous salmonines because their strong homing capability fosters the formation of discrete populations exhibiting important adaptations to local riverine ecosystems (Utter *et al.* 1993).

In an effort to clarify the definition of species for *Oncorhynchus* sp. under the ESA, Waples (1991a;1991b) proposed a more precise definition called the Evolutionarily Significant Unit (ESU). The purpose of this approach was to create a definition of species for assessing populations of *Oncorhynchus* sp. 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 and sociological importance of distinct population segments in fish (Larkin 1981; Ricker 1981). Differences between stocks are important for management purposes since discrete stocks can vary in their productivity and population dynamics (Ricker 1981). The ESU approach differs from the stock concept because, as an ESU, stocks can be grouped into a comprehensive unit unless there are clear evolutionarily important differences among stocks. Grouping of stocks does not prevent stock-specific management procedures necessary to protect populations within a larger unit.

Although the ESU approach was developed for *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; King *et al.* 1993). Genetic exchange among stocks is minimized by spatial or temporal isolation during spawning. While straying occurs at low levels among populations of Atlantic salmon, it is typically not sufficient to prevent genetic divergence (Bermingham *et al.* 1991). The recognition of distinct Atlantic salmon stocks in

U.S. rivers was first described by Kendall (1935). 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 (Møller 1970; King *et al.* 1993). 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. Because the structure of Atlantic salmon populations is similar to that of Pacific salmonines, the ESU approach provides a practical foundation for delineating Distinct Population Segments (DPS) of Atlantic salmon under the ESA. The Team used the ESU policy to define the DPS, which is the unit included in the species definition in the ESA.

Using this framework and the underlying stock concept, the Team believes that a DPS of Atlantic salmon is a population or group of populations that is substantially reproductively isolated from other conspecific population segments and is evolutionarily significant (i.e. represent an important component in the evolutionary heritage of the species). The following sections address these criteria in the context of Atlantic salmon in the Northeastern U.S.

4.2 REPRODUCTIVE ISOLATION

To allow evolutionarily important differences to accrue in different population units, reproductive isolation does not have to be absolute, only strong enough for these differences to develop and be maintained (Wright 1978; Waples 1991b). Reproductive isolation can be maintained by geographical distance, behavioral differences, and/or temporal segregation. The occurrence of nonindigenous Atlantic salmon in a stream does not represent a breakdown of reproductive isolation unless these fish spawn successfully, their progeny survive to spawn, and their presence decreases the survival and fitness of native stocks. The Team examined genetics data, tagging studies, and recolonization rates to determine the reproductive isolation of U.S. Atlantic salmon populations.

4.2.1 Genetic Indices

Genetic differences among Atlantic salmon stocks have been linked to important adaptive morphological and life-history traits (Ritter *et al.* 1981; Saunders 1981). These adaptations are important to the survival of a DPS. Atlantic salmon populations in Britain and Wales were found to be distinct using mitochondrial DNA analysis, and 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 populations within as well as between drainages." Given the existence of distinct stocks, creating gene flow between previously reproductively isolated populations would likely result in a breaking up of adapted gene complexes that may affect a decrease in 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). These differences are strongly geographically patterned and, while variation is low compared to freshwater fish, it is consistent with results from other anadromous species. Using electrophoretic data, genetic differences have been found between U.S. and Canadian Atlantic salmon stocks and between populations in tributaries of the Mirimichi River in Canada (Møller 1970).

Studies examining the genetic differences among U.S. Atlantic salmon stocks have yielded inconclusive results (Roberts 1976; Bentzen and Wright 1992; King and Smith 1994; May *et al.* 1994; Schill and Walker 1994; Kornfield 1994). Bentzen and Wright (1992) and Kornfield (1994) found differences between some U.S. Atlantic salmon populations. Other researchers have not been able to demonstrate differences between these stocks (Roberts 1976; King and Smith 1994; May *et al.* 1994; Schill and Walker 1994). Schill and Walker (1994) surveyed five Random Amplified Polymorphic DNA (RAPD) markers in nine U.S. Atlantic salmon populations. Their data suggests a high degree of genetic contact occurs among the Atlantic salmon populations surveyed with estimates of gene flow at a rate of 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. While these data indicate that gene flow occurs between these populations, genetic differentiation of these populations may still occur (Wright 1978; Waples 1991b). While gene flow can act to intermix neutral alleles, selection for locally adapted alleles can counter homogenization (Slatkin 1987). Since these values are a measure of past and present gene flow between these populations, they may be artificially high due to mixing of stocks by past stocking practices in this region. As such, historic isolation of stocks may have been greater and present differences are not as great as what occurred historically.

Limitations in individual study designs and the duration of these experiments across generations has not allowed a comprehensive assessment of differences to date. Most genetic analyses focus on neutral characters, therefore they do not provide a conclusive measure of distinctness or ecological adaptation. Failure to find a significant genetic difference between stocks may be the result of technological limitations and does not necessarily mean that differences with a genetic basis do not exist. 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."

Given this historical basis and the uncertainty of preliminary genetics work, further analyses of Atlantic salmon genetics and morphology will be conducted to better understand differences and similarities among rivers. Studies conducted to date suggest that there are modest but statistically significant differences among at least some of the U.S. populations of Atlantic salmon, and larger differences between the U.S. populations and those in Canada. Until conclusive genetic data are presented, the most conservative approach is to manage Atlantic salmon in these rivers separately.

Additionally, 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). 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 stocks of Atlantic salmon, presumably a result of genetic drift. 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 U.S. rivers is difficult due to the paucity of information regarding the number of fish that returned from stocking efforts and their contribution to successive breeding populations. In several of these rivers, wild fish persisted through time and the influence of hatchery fish appears unclear or relatively limited. This uncertainty was important in assessing the status of present populations of Atlantic salmon in U.S. rivers relative to the ESA (section 4.4).

4.2.2 Tagging Studies

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 were from rivers other than where the smolts were originally stocked. In addition, some fish recorded in one river as strays eventually returned to their natal stream, which suggests that weir and trap recaptures may overestimate the number of fish that actually spawn in another river. Comparable data for wild Atlantic salmon in U.S. waters is not available. However, data for distinct wild Atlantic salmon 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 (Piggins 1987; Stabell 1984; 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 river-specific stocks have persisted in some U.S. river systems.

4.2.3 Recolonization

Where salmon populations in U.S. rivers were extirpated there has been a lack of recolonization by Atlantic salmon (Kendall 1935; Rounsefell and Bond 1949). Generally, a significant population is required in nearby rivers to provide a source for recolonization. Large rivers in the southern extent of the range of Atlantic salmon were not recolonized despite the presence of Atlantic salmon runs to the north. The relatively large distance between these southern rivers and the northern U.S. and Canadian rivers likely inhibited recolonization. Recolonization also did not occur in the northern range despite the fact that water quality improved and blockages to passage had been removed in many of these rivers. Wild returns to the Dennys River show no relationship to returns to the St. Croix River, which is in close proximity to the Dennys River and also flows into Passamaquoddy Bay (USASAC 1994). In addition, relatively large populations of Atlantic salmon exist in several Canadian rivers and natural re-colonization of northern U.S. rivers has not occurred. Historically, adult spawners in U.S. rivers have been predominantly two sea winter fish (Kendall 1935; USASAC 1994). Because many Canadian stocks return predominantly as grilse, and age-at-maturity appears to be at least partially genetic in nature, extensive recolonization by fish of Canadian origin could have decreased the age at maturity of U.S. stocks (Ritter *et al.* 1986).

4.2.4 Evaluation of Reproductive Isolation

Evidence indicates that naturally reproducing populations of Atlantic salmon in U.S. rivers are substantially reproductively isolated from stocks in Canada (Møller 1970). Within the U.S., Atlantic salmon stocks have shown some evidence of straying but recolonization from adjacent watersheds is undocumented. While some straying occurs, a conservative approach suggests that gene flow between wild populations was not adequate enough to eliminate all historic differences. More importantly, stock transfers may have a greater impact on gene flow between populations (section 4.3.1). Some U.S. populations have persisted over time, while others have been extirpated and are being restored with exogenous stocks (Connecticut and Merrimack Rivers). As such, several wild river-specific populations of Atlantic salmon in the U.S. appear to meet the criteria of reproductive isolation.

4.3 EVOLUTIONARY SIGNIFICANCE

A second criteria for a DPS is evolutionary significance, the substantial ecological and genetic importance of a population to the species as a whole (Waples 1991a and 1991b). In salmonines, adaptations to local ecosystems are important to the survival of populations and the survival of the species throughout its range (Utter *et al.* 1993). In examining the evolutionary significance of Atlantic salmon populations, we examined three factors: phenotypic traits, life history traits, and habitat characteristics.

4.3.1 Phenotypic Traits

It is difficult to assess the importance of phenotypic characteristics for Atlantic salmon since temporal variation within stocks is extensive and persistent (Blouw *et al.* 1988). 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 stock differences existed for some traits. This suggests that phenotypic traits are unique among these geographic locations. Historical differences in the size of mature, 2SW adults, among U.S. rivers was noted by Atkins (1874). In addition, differences in the shape and girth of Atlantic salmon were reported in some rivers (Kendall 1935). Recent studies and historical accounts of phenotypic traits suggest stock-specific differences existed historically and are now present. More research is needed on the adaptive significance of these traits to make a more definitive statement regarding the importance of these differences.

4.3.2 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. stocks of Atlantic salmon have been composed of predominately 2SW salmon from at least the late 1800's to the present (Atkins 1874, Kendall 1935; USASAC 1994). On the other hand, Canadian stocks and those of Europe, typically have a much higher grilse component. 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 influences run timing because they typically enter rivers earlier than grilse. Trends in run timing are now difficult to discern due to low spawner numbers and the lack of collection facilities on all rivers. Analyses of the rod catch in some Maine rivers has indicated that the timing of spawning runs has changed little in the past 50 years (ASRSC, unpublished data). Atkins (1874) also suggested differences in smolt outmigration timing between rivers. Data for recent smolt migration trends are not available. As such, we determined that differences in life history characteristics historically contributed to the distinctness of river populations. Given the history of persistent natural reproduction in several rivers, it was determined that an important component of this historic uniqueness may remain in several river systems.

4.3.3 Habitat Characteristics

Riverine habitat occupied by Atlantic salmon in the U.S. is distinctive. It is located at the southern extent of the range of the species in North America. These rivers provide a more productive juvenile nursery habitat than most Canadian river systems. U.S. rivers typically produce two-year smolts which are younger than those produced in rivers at the northern extreme of the range. Despite 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 than those experienced by more northern stocks.

Within the U.S., Atlantic salmon historically occurred in two general types of drainages: short (< 65 km long) coastal rivers with few tributaries, and relatively large river systems (> 160 km long) with numerous tributaries. Other differences also exist, ranging from soil types, the presence of headwater and mainstem lakes, gradient, and other physiochemical and geographic characteristics. These differences among watersheds may have resulted in the selection, improved survival, of fish with distinct genetic and ecological traits (Claytor *et al.* 1991). Similar differences have led to the development of distinct stocks of Atlantic salmon in other regions (Stahl 1987; Utter 1981; King *et al.* 1993); this was probably the case for U.S. populations as well. To survive at the extreme southern range of the species and in different river systems within that range, U.S. Atlantic salmon populations needed to be adapted to distinct physical challenges (Saunders 1981). These adaptations contribute to the distinctness of a population segment and make its survival important to the species as whole.

4.3.4 Evaluation of Evolutionary Significance

Review of phenotypic traits, life history traits and habitat characteristics provides strong evidence that U.S. stocks of Atlantic salmon are distinct from stocks in Canada and Europe. Among river systems in the U.S., historic accounts indicate that distinct locally adapted races existed (Atkins 1874; Kendall 1935). Available phenotypic, life history, and habitat data are limited, making the assessment of the evolutionary significance of these U.S. stocks difficult. The historic presence of these distinct traits and the persistence of the stock suggests that it is locally adapted and important to the genetic legacy of the species. The populations of anadromous Atlantic salmon in the Sheepscot, Ducktrap, Narraguagus, Pleasant, Machias, East Machias, and Dennys Rivers represent the last wild remnant of U.S. Atlantic salmon. Collectively, these rivers meet the criteria of evolutionary significance.

4.4 ANALYSIS OF POPULATION STATUS

U.S. Atlantic salmon populations were categorized into three groupings: Extirpated, Unique Stocks, and Candidate Species. A critical factor in determining the status of these stocks was the historic persistence of a substantial component of natural reproduction in each river. While it is unlikely that U.S. Atlantic salmon populations exist in a genetically pure native form, their continued presence in indigenous habitat suggests that important local adaptations still exist (Unique Stocks). The documented absence of wild Atlantic salmon from natal habitat for at least 2 generations (12 years) suggests the total loss of a native population under the most conservative scenario (Extirpated). Where available information was inconclusive regarding the persistence of a wild Atlantic salmon population, candidate species status is recommended (Candidate Species).

4.4.1 Extirpated Populations

Atlantic salmon in rivers south of the Kennebec River were extirpated by the mid-1800's (Atkins 1874; Kendall 1935; Table 4.1). Human activities moved the southern range of Atlantic salmon almost 2° north in latitude and eliminated three of the largest Atlantic salmon populations in the U.S., those of the Connecticut, Androscoggin and Merrimack Rivers. In addition, some populations north of the Kennebec River also were extirpated; most of these were in small rivers with less than one hectare of available nursery habitat. It is unlikely that Atlantic salmon in these small watersheds were able to maintain persistent spawning runs given human perturbations of the past century. The small size of these watersheds might have made these populations ephemeral, even under prehistoric conditions.

The Connecticut and Merrimack Rivers represented nearly 40% of historic U.S. Atlantic salmon habitat. These rivers are currently the focus of restoration efforts using nonindigenous stocks. 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. Reasons for these low return rates appear to be attributable to the loss of local adaptations associated with the extirpated stocks (Saunders 1981). 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 1977; Reisenbichler and McIntyre 1977). 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). The continuation of these programs, with a focus on the development of river-specific stocks, should allow Atlantic salmon to return to these major watersheds in the southern extent of their historic range. Restoration of Atlantic salmon in these watersheds will contribute to the biodiversity of these ecosystems.

4.4.2 Candidate Listings

Three of the rivers with Atlantic salmon stocks being proposed for candidate status have existing runs of naturally spawning Atlantic salmon. The presence of Atlantic salmon in Tunk Stream is unconfirmed. The persistence of these runs, and their link to native stocks, is not well understood. Candidate species designation will allow for the collection of additional information and a better understanding of their status relative to the ESA. The river populations being proposed as candidates are those in the Kennebec River, the Penobscot River, Tunk Stream and the St. Croix River (Figure 4.1; Table 4.1).

4.4.3 Distinct Population Segments

In rivers where runs of naturally spawning Atlantic salmon have persisted, important differences that contributed to the uniqueness of these stocks remain. The Atlantic salmon populations in the Sheepscot, Ducktrap, Narraguagus, Pleasant, Machias, East Machias, and Dennys Rivers meet the reproductive isolation and the evolutionary significance criteria and thus qualify as a distinct population segment for consideration under the ESA (Table 4.1). The criteria contained in Sections 4.2 and 4.3 has been applied to the populations in these rivers. According to the ESA, species may be determined to be endangered or threatened due to one or more of the five factors present in section 4(a)(1) of the ESA. The seven stocks of Atlantic salmon that comprise the DPS were analyzed according to those five factors; the analysis is presented in Section 6.0 for the seven rivers (Figure 4.1). In addition, the Team examined the abundance of these stocks since this is also important in determining their status (Section 5.0).

Table 4.1 Status of U.S. Atlantic salmon populations by river.

River System	Population Status	Currently Accessible Salmon Habitat (sq. m.)
Housatonic River	Extirpated	Not Available
Quinnipiac River	Extirpated	Not Available
Hammonassett River	Extirpated	Not Available
Connecticut River	Extirpated	74,613
Thames River	Extirpated	Not Available
Pawcatuck River	Extirpated	167
Pawtuxet River	Extirpated	Not Available
Blackstone River	Extirpated	Not Available
Merrimack River	Extirpated	251
Lamprey River	Extirpated	Not Available
Cocheco River	Extirpated	Not Available
Salmon Falls River	Extirpated	Not Available
Mousam River	Extirpated	Not Available
Kennebunk River	Extirpated	84
Saco River	Extirpated	* 12,540
Presumpscot River	Extirpated	84
Royal River	Extirpated	418
Androscoggin River	Extirpated	3,177
Kennebec River	Candidate Species	1,003
Sheepscot River	Unique Stock	1,672
Pemaquid River	Extirpated	84
Medomak River	Extirpated	0
St. George River	Extirpated	251
Ducktrap River	Unique Stock	585
Little River	Extirpated	0
Passagassawaukeag	Extirpated	167
Penobscot River	Candidate Species	102,744
Orland River	Extirpated	167
Union River	Extirpated	* 8,360
Tunk Stream	Candidate Species	585
Narraguagus River	Unique Stock	5,768
Pleasant River	Unique Stock	1,087
Indian River	Extirpated	84
Chandler River	Extirpated	84
Machias River	Unique Stock	6,939
East Machias River	Unique Stock	2,174
Orange	Extirpated	17
Hobart Stream	Extirpated	84
Dennys River	Unique Stock	2,090
Pennamaquan	Extirpated	84
Boyden Stream	Extirpated	84
St. Croix River	Candidate Species	29,260
St. John River Tributaries	Extirpated	56,612

* Habitat listed is accessible assuming a trap and truck program is utilized.

NOTES: 1) Extirpated status could result from complete blockage of the river or a small population size both of which indicate that long term persistence is unlikely

2) Source: unpublished data from ASRSC.

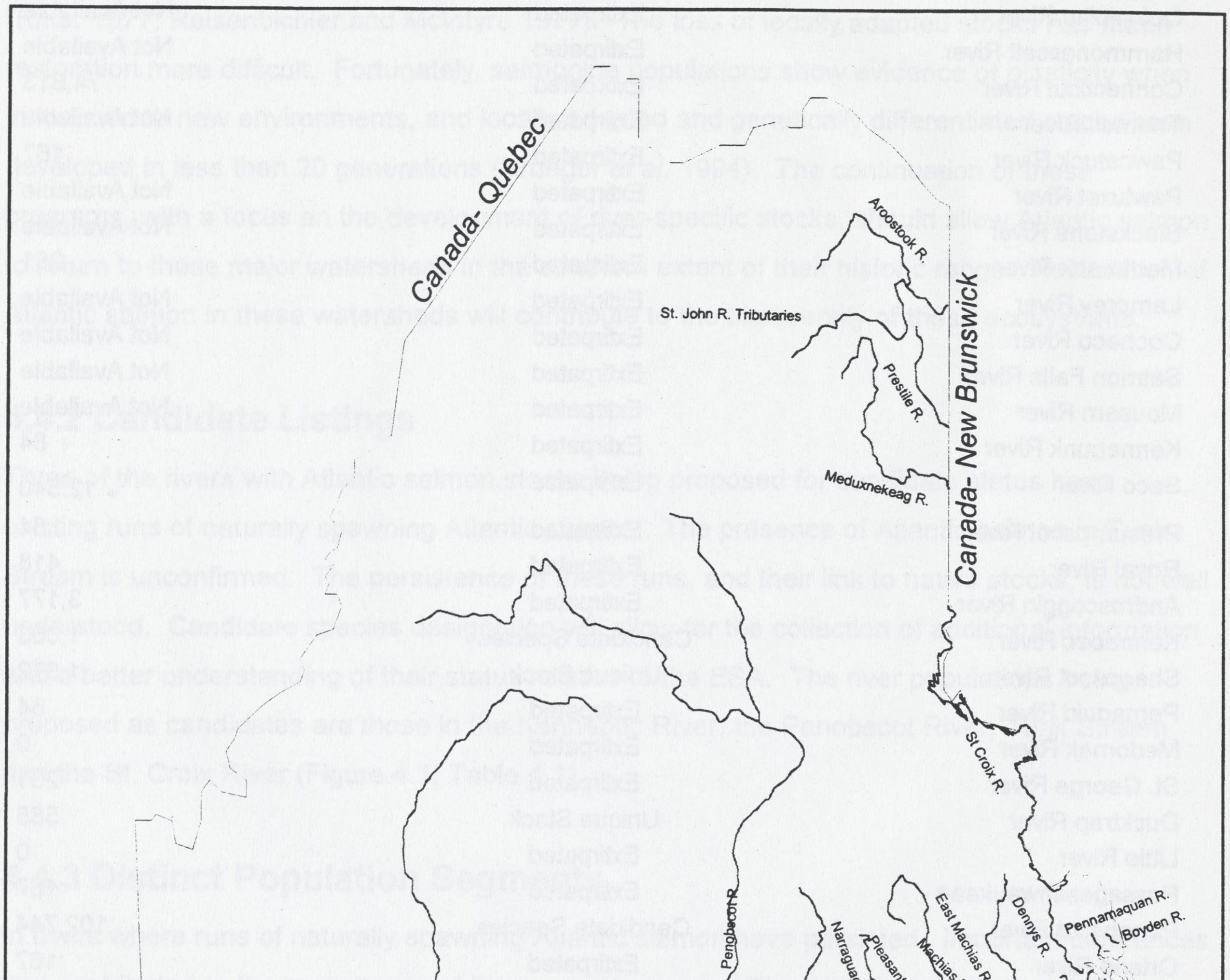


Figure 4.1 Historic Atlantic salmon river of Maine.

SECTION 5: ABUNDANCE

The abundance of a population is a critical concern in assessing the health of species under the ESA. While there is no quantitative guidance for determining if a species is endangered, an examination of abundance compared to historical levels and analysis of recent trends was used to determine the status of Atlantic salmon. 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 ASRSC and the USASAC.

5.1 DATA SOURCES

There is no long-term time series of Atlantic salmon abundance measured from a weir or fish trap in any Maine river included in the DPS. The best available data to provide an index of Atlantic salmon abundance are the minimal abundance data of the ASRSC that are published annually by the USASAC. These data index the abundance of Atlantic salmon returns to Maine rivers by sea age and origin (hatchery or wild). However, these data represent minimal estimates of Atlantic salmon runs because the estimates for most rivers are based primarily on rod catch. For some rivers, data are supplemented by trap and weir data collected prior to 1974 and since 1991. While angler data are subject to inaccuracy due to reporting inconsistencies, changes in regulations, changes in angler attitudes, and variation in catch rate due to climatic affects, they remain the primary historic data available for these river systems. Limited redd count data is available for some of these streams and is useful in determining the continued presence of spawning Atlantic salmon in rivers where rod catch is negligible (ASRSC, unpublished data).

As a first step, it was important to determine the origin of Atlantic salmon returning to Maine rivers to assess the health of wild stocks. The USASAC (1994) report lists two origins, hatchery or wild. Hatchery fish are discernable by distinct growth characteristics exhibited in their scales. Thus, scale reading can identify fish stocked as parr, 1+ smolts, or 2+ smolts. The component that the USASAC identifies as wild includes wild and fry stocked fish. For the purposes of this stock analysis pursuant to the ESA, the Team defined "wild" salmon as only those fish spawned and reared entirely in the wild. Fry stocked fish are those that were artificially spawned and reared to early fry stage before being scatter stocked in a drainage. With present technology and the lack of a feasible fry marking program, truly wild spawners and those fish stocked as fry are indiscernible. While it was our desire to determine the status of Atlantic salmon stocks using only returns of wild fish, this was not feasible for the entire time series. As such, Table 5.1 provides a summary of the percent of the spawning run that was natural origin (wild fish or stocked as fry) and highlights those years where fry stocking may have contributed to the natural run component.

5.2 RELATIVE ABUNDANCE AND COMPARISON BETWEEN RIVERS

Table 5.2 shows the trends in relative abundance of Atlantic salmon as indexed by angler catch and trap data from 1970 to 1993. These data show the general downward trend in abundance in all rivers. In addition to angler catch and trap data, ASRSC redd count data also indicate the recent decline in spawner abundance. Redd data are important as they give an index of the amount of spawning occurring in a watershed. For example, adjusted redd count data for the Dennys River has decreased from a high of 708 in 1978 to a low of 25 in 1993 (ASRSC, unpublished data). Redd data were particularly valuable in assessing spawning populations where angler catch declined to zero due to a combination of regulations, decreased angler effort and decreased fish abundance. These supplemental data were important in determining the status of the Pleasant River where no spawners have been detected by the rod catch index since 1987. Redd count data in the Pleasant River indicated that spawners were still returning to these streams from 1991 to 1993. As such, the best available indices of spawner abundance indicate populations are at low levels and a general decline has occurred. Specific data for individual rivers are given in Table 5.2 and in Section 6.0.

To compare rivers to each other and to the escapement required for adequate egg deposition, we used the North American Salmon Working Group (NASWG) method to estimate the escapement goal for each watershed. Since historical accounts of Atlantic salmon abundance are not very quantitative, this methodology provides a technique for comparing population abundance to habitat potential. This method assumes that a target egg deposition of 2.4 eggs/

m^2 is needed to fully seed a river. We then used an average female fecundity of 7,200 eggs/ female and a 1:1 male:female ratio to determine optimal escapement. For example:

With 100,000 m^2 of accessible habitat, target spawners would be:
100,000 m^2 * 2.4 eggs/ m^2 = 240,000 eggs;
240,000 eggs / 7200 eggs/ female = 33.333 females; and
33.333 * 2 = 66.67 = 67 Atlantic salmon.

Once the escapement goal is calculated, a standardized comparison can be made among the rivers of different size. We calculated the return as a percentage of escapement goal to standardize among rivers and compare run size to optimal escapement. This value was simply the percentage of the abundance index divided by escapement goal. For example:

An escapement goal of 67 spawners and index of 35 spawners:
(35/67) * 100 = 52.23% of escapement goal

Figures 5.2 and 5.3 illustrate the percent of the escapement goal reached from 1970 - 1993 for DPS rivers. Over the past 24 years, the Dennys and Narraguagus Rivers have had the best returns relative to available habitat, averaging 20% of their escapement goal. The Pleasant, Sheepscot, and Machias Rivers averaged between 10% and 12 %. However, recent downward trends in abundance have 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 indices that give a minimal estimate of run strength, the low levels of abundance are disturbing given the recent trend of declining relative abundance. The combination of low relative abundance and the low numbers relative to spawning requirements indicates that these populations are in peril.

Table 5.1 Origin (1.0 is 100% wild) of spawning runs in selected Maine Rivers from 1970-1993. Overall average for entire time series. Natural only for time series where wild and fry stocked returns possible (shaded). Wild only for time series where no fry stocked returns probable (unshaded).

YEAR	Dennys	E. Machias	Machias	Pleasant	Narraguagus	Ducktrap	Sheepscot	St. Croix	Penobscot	Kennebec
1970	1.00	1.00	0.94	1.00	0.90		1.00		0.01	
1971	1.00	0.83	0.84	1.00	0.68		1.00		0.02	
1972	1.00	0.75	0.71	1.00	0.73		1.00		0.03	
1973	0.98	0.83	0.80	1.00	0.84		1.00		0.01	
1974	1.00	0.50	0.72	1.00	0.84		1.00		0.00	
1975	1.00	0.73	0.80	1.00	0.98		1.00		0.01	0.03
1976	1.00	0.00	0.72	1.00	0.88		1.00		0.03	0.00
1977	1.00	0.67	0.60	1.00	0.94		1.00		0.00	0.00
1978	0.51	0.78	0.86	1.00	0.74		1.00		0.03	0.00
1979	1.00	0.72	0.88	1.00	0.84		1.00		0.01	0.10
1980	0.38	0.61	0.83	1.00	1.00		1.00		0.01	0.00
1981	0.37	0.29	0.64	1.00	0.70		1.00	0.49	0.01	0.00
1982	0.53	0.59	0.98	0.37	0.85		1.00	0.71	0.02	0.00
1983	1.00	0.63	1.00	1.00	0.79		1.00	0.34	0.06	0.00
1984	1.00	0.81	0.76	1.00	0.85		1.00	0.21	0.07	0.00
1985	0.70	1.00	0.84	1.00	1.00	1.00	1.00	0.47	0.07	
1986	0.53	0.62	0.61	1.00	0.56	1.00	1.00	0.50	0.08	
1987	1.00	0.43	1.00	0.56	0.70		0.40	0.54	0.08	0.40
1988	0.67	0.36	1.00		0.71		0.00	0.21	0.03	0.00
1989	0.08	0.29	0.56		0.69		0.60	0.40	0.06	0.00
1990	0.33	0.35	0.50		0.55	1.00	0.00	0.36	0.11	0.09
1991	0.86	0.40	0.50		0.72		0.00	0.31	0.27	0.00
1992	0.20	0.00	0.00		0.64		0.57	0.00	0.11	
1993	0.31		0.87		0.79		0.00	0.23	0.07	0.00
overall	0.73	0.57	0.75	0.94	0.79	1.00	0.77	0.37	0.05	0.04
natural only	0.54	0.28	0.49	0.94	0.68	1.00	0.20	0.31	0.08	
wild only	0.79	0.66	0.82	no ret	0.82	1.00	0.97	0.46	0.01	0.04

Table 5.2 Total Natural (Wild & Fry Stocked) Spawner Returns from USASAC (1994) data (minimal indices) and escapement goal (e-goal) for each river.

YEAR	Dennys	E. Machias	Machias	Pleasant	Narraguagus	Ducktrap	Sheepscot	St. Croix	Penobscot	Kennebec
1970	49	1	226	1	132		6		2	
1971	19	5	147	1	73		30		2	
1972	61	3	191	1	244		20		10	
1973	40	5	28	2	142		20		2	
1974	49	1	26	30	137		20		1	
1975	40	22	41	8	109		11		8	1
1976	20	0	18	1	28		10		20	0
1977	26	20	15	3	117		24		3	0
1978	38	46	90	16	98		35		55	0
1979	38	18	58	8	49		8		8	2
1980	73	38	65	5	115		30		20	0
1981	46	29	34	23	51		15	39	23	0
1982	20	22	55	7	67		15	70	72	0
1983	28	5	17	38	71		12	42	58	0
1984	68	38	25	17	58		22	51	134	0
1985	14	30	27	31	57	15	6	164	229	0
1986	8	8	28	19	25	15	11	162	353	0
1987	1	6	4	5	26	0	6	203	206	2
1988	6	5	8	0	27	0	0	80	88	0
1989	1	9	9	0	27	0	3	96	175	0
1990	11	17	1	0	28	3	0	40	352	4
1991	6	2	1	0	68	0	0	58	471	0
1992	1	0	0	0	47	0	4	0	268	0
1993	4	0	13	0	74	0	0	24	121	0
total	667	330	1127	216	1870	33	308	1029	2681	9
average	28	14	47	9	78	4	13	79	112	0
e- goal	139	145	463	72	385	39	111	1951	6840	67

Table 5.3 Natural Run Size as a Percentage of Escapement Goal for Available Habitat by river.

YEAR	Dennys	East Machias	Machias	Pleasant	Narraguagus	Ducktrap	Sheepscot	St. Croix	Penobscot	Kennebec
1970	35.16%	0.69%	48.85%	1.38%	34.29%		5.38%		0.03%	
1971	13.63%	3.45%	31.77%	1.38%	18.96%		26.91%		0.03%	
1972	43.77%	2.07%	41.28%	1.38%	63.38%		17.94%		0.15%	
1973	28.70%	3.45%	6.05%	2.76%	36.89%		17.94%		0.03%	
1974	35.16%	0.69%	5.62%	41.40%	35.59%		17.94%		0.01%	
1975	28.70%	15.18%	8.86%	11.04%	28.31%		9.87%		0.12%	1.49%
1976	14.35%	0.00%	3.89%	1.38%	7.27%		8.97%		0.29%	0.00%
1977	18.66%	13.80%	3.24%	4.14%	30.39%		21.53%		0.04%	0.00%
1978	27.27%	31.74%	19.45%	22.08%	25.46%		31.39%		0.80%	0.00%
1979	27.27%	12.42%	12.54%	11.04%	12.73%		7.18%		0.12%	2.99%
1980	52.38%	26.22%	14.05%	6.90%	29.87%		26.91%		0.29%	0.00%
1981	33.01%	20.01%	7.35%	31.74%	13.25%		13.45%	2.00%	0.34%	0.00%
1982	14.35%	15.18%	11.89%	9.66%	17.40%		13.45%	3.59%	1.05%	0.00%
1983	20.09%	3.45%	3.67%	52.44%	18.44%		10.76%	2.15%	0.85%	0.00%
1984	48.80%	26.22%	5.40%	23.46%	15.07%		19.73%	2.61%	1.96%	0.00%
1985	10.05%	20.70%	5.84%	42.78%	14.81%	38.44%	5.38%	8.41%	3.35%	0.00%
1986	5.74%	5.52%	6.05%	26.22%	6.49%	38.44%	9.87%	8.30%	5.16%	0.00%
1987	0.72%	4.14%	0.86%	6.90%	6.75%	0.00%	5.38%	10.41%	3.01%	2.99%
1988	4.31%	3.45%	1.73%	0.00%	7.01%	0.00%	0.00%	4.10%	1.29%	0.00%
1989	0.72%	6.21%	1.95%	0.00%	7.01%	0.00%	2.69%	4.92%	2.56%	0.00%
1990	7.89%	11.73%	0.22%	0.00%	7.27%	7.69%	0.00%	2.05%	5.15%	5.98%
1991	4.31%	1.38%	0.22%	0.00%	17.66%	0.00%	0.00%	2.97%	6.89%	0.00%
1992	0.72%	0.00%	0.00%	0.00%	12.21%	0.00%	3.59%	0.00%	3.92%	0.00%
1993	2.87%	0.00%	2.81%	0.00%	19.22%	0.00%	0.00%	1.23%	1.77%	0.00%
habitat	2090	2174	6940	1087	5775	585	1672	29264	102593	1003
e- goal	139	145	463	72	385	39	111	1951	6840	67
average	28	14	47	9	78	4	13	79	112	0
index/ goal	19.94%	9.49%	10.15%	12.42%	20.24%	9.40%	11.51%	4.06%	1.63%	0.71%

* There is no time series data available for Tunk Stream, however it contains 585 m^2 habitat units and has an escapement goal of 39.

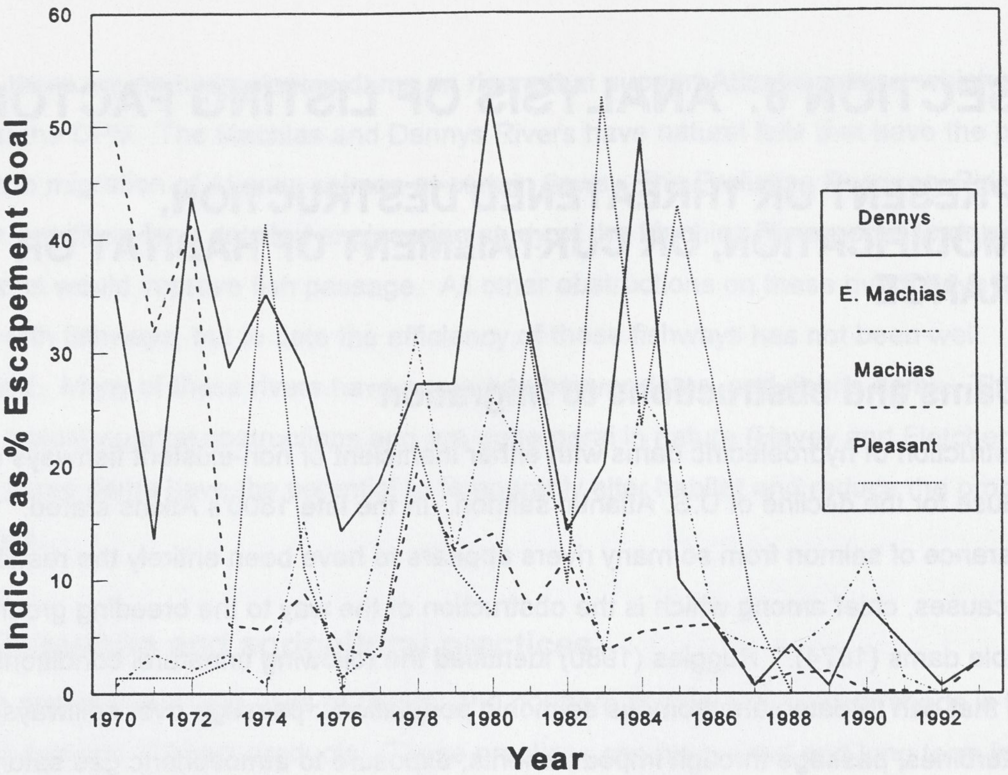


Figure 5.2

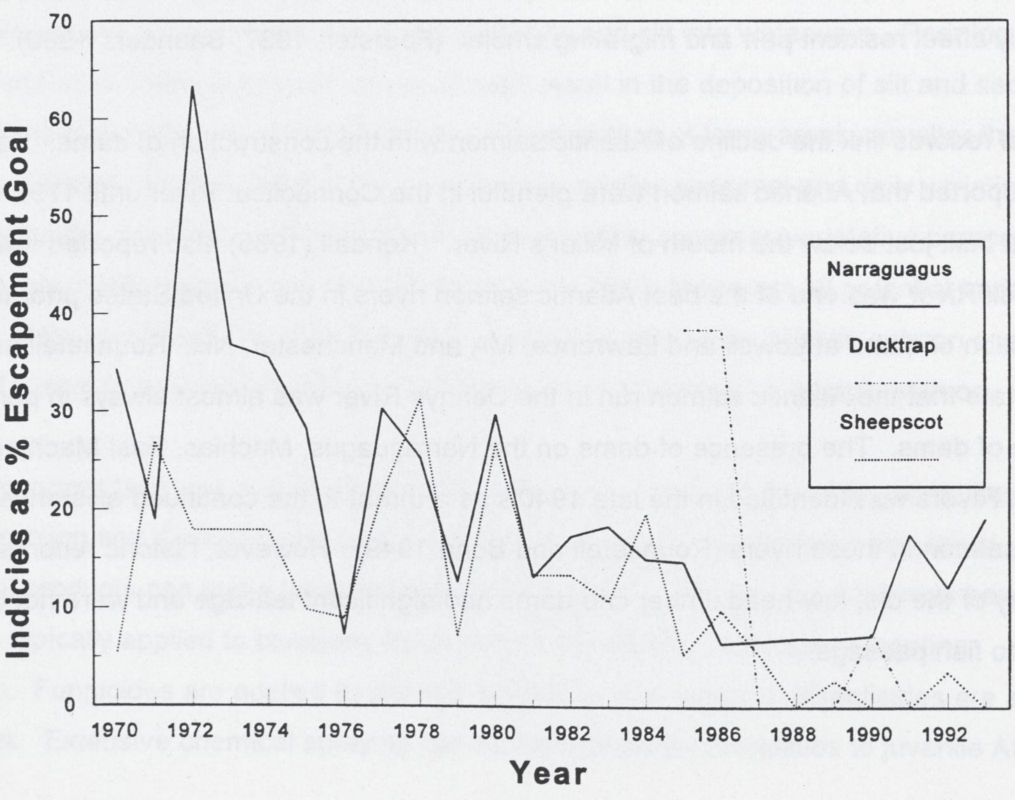


Figure 5.3

SECTION 6: ANALYSIS OF LISTING FACTORS

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

6.1.1 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 which are included 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. 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.

6.1.2 Silviculture and agricultural practices

One of the predominant land uses of central and northern coastal Maine watersheds is the growth and harvest of forest products. These practices can 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 result in the deposition of silt and sediment in habitat occupied by juvenile Atlantic salmon. 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 which are used to suppress vegetative competitors can negatively impact aquatic and riparian vegetation. While these are all potential impacts, numerous state and federal laws exist to prevent adverse effects on Atlantic salmon and other species. Current forest practices are not considered a major threat to Atlantic salmon.

Another important land use in eastern Maine watersheds is lowbush blueberry agriculture. 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 which 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 is 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. As is the case with forestry practices, blueberry agriculture is heavily regulated by both state and federal laws. In addition, the Cooperative Extension Service from the University of Maine and the Soil Conservation Service work closely with the industry to ensure the best methods are used for chemical application. Current agricultural practices are not considered a major threat to Atlantic salmon.

6.1.3 Peat mining

Many eastern Maine river watersheds hold deposits of peat. Peat mining has the potential to release pollutants such as peat fiber, arsenic residues and other chemical residues. Accelerated run-off from roads leading to bogs as well as large unvegetated areas can alter flow regimes and consequently limit juvenile Atlantic salmon production. 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. As part of the studies, juvenile abundance was found to be lower in the West Branch than elsewhere in the Narraguagus River. Fluctuations in the pH level of freshwater environments have been identified as a limiting factor for Atlantic salmon (Peterson *et al.* 1980).

6.1.4 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. 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 which 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).

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).

The Environmental Protection Agency (EPA) currently issues National Pollutant Discharge Elimination System (NPDES) permits in the state of Maine. The EPA has recently undertaken a major initiative to have all water programs incorporate a watershed approach. The Maine Department of Environmental Protection (DEP) and EPA have established a five year plan for permit issuance by watershed. Discharges into the Penobscot River and areas east of the river will be considered in fiscal year 1997, whereas permits for discharges in the area between the Kennebec and Penobscot Rivers will be issued in fiscal year 1998.

The Maine Wild Atlantic Salmon Stewardship Program was initiated by the USFWS in 1994. Program activities include angler surveys and habitat surveys and weir and trap installation and maintenance. The information to be obtained as a result of these activities will be very valuable because much of the habitat information currently available for these rivers and other rivers in Maine was collected in the 1950's and 1960's.

6.2 OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC, OR EDUCATIONAL PURPOSE

6.2.1 Foreign Interceptory Fisheries

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 (Møller Jensen 1986; O'Connell *et al.* 1992). The 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 (Møller Jensen 1986). 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 harvest 1SW Atlantic salmon of U.S. origin (ICES-NASWG 1993). In addition, a fraction of the U.S. stock is 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 executed in the spring and summer. Patterns of 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 (Reddin and Friedland 1993). Exploitation in other parts of Canada, Nova Scotia for example, is believed to be primarily on 1SW or 2SW Atlantic salmon that are migrating to their natal streams in Canada.

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.

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 would have occurred by this time. 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). The marine exploitation of U.S. stocks of Atlantic salmon occurs primarily 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-NASSG 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 of 1SW or older Atlantic salmon tagged in Maine from 1963 to 1984, 53% were recovered in West Greenland and 47% in Canada. Of those caught 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 1993). The historic catch and current status of these fisheries is described by country in the following sections.

6.2.1.1 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 (Møller Jensen 1986). Over 99.8% of the historic catch was contributed by the West Greenland component (ICES-NASWG 1993). The remaining fish were landed in East Greenland. The fishery in West Greenland is truly a mixed stock fishery, with fish recorded from the U.S., Canada, Iceland, and nine European countries (Møller Jensen 1986). 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 (Møller Jensen 1984).

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 uses 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 Model estimates the number of Maine origin Atlantic salmon harvested at West Greenland. For U.S. stocks, this 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 method includes a proportional noncatch fishing mortality rate of 0.2. Based on this method, estimated harvest averaged 7,524 fish between 1976 and 1992. The estimator ranged from a minimum of 1,950 Atlantic salmon in 1992 to a maximum of 30,492 in 1980. This estimator accounts only for the catch of Maine-origin fish.

The Carlin Tag Harvest Model also measures only U.S. Atlantic salmon of Maine origin. This 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). The model was last used to estimate 1991 harvests. The number of Carlin tags at large has been reduced substantially as these tags have been replaced by CWTs. Estimates using this method 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 has only been in use since 1988, when large CWT programs began (ICES-NASWG 1988). The CWT are 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 CWT collected in the fishery is raised by the ratio of CWT 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.

6.2.1.2 The Canadian Fisheries

Historically, Atlantic salmon fisheries in Canada have operated in all of the Atlantic Provinces. These fisheries intercept fish of Canadian or U.S. origin (ICES-NASWG 1993). 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 1993). From this peak, harvests declined to less than 1,500 mt by the middle 1950's (ICES-NASWG 1993). Starting in 1955 with the setting of an opening date for the Newfoundland commercial fishery, 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 started 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. May (1993) and Chadwick (1993) predict the end of commercial Atlantic salmon fishing in Canada's waters, with the exception of native subsistence fisheries, by the year 2000.

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). The Carlin Tag Harvest Model is the primary measure of Canadian harvest of U.S. origin fish. This harvest measure is based on only U.S. Atlantic salmon of Maine origin. As in the West Greenland fishery, the phasing out of Carlin tags in favor of CWT has reduced the number of tags at large substantially. Estimates using the Carlin method averaged 1,056 Maine Atlantic salmon (1966-1991) and ranged from 105 fish in 1972 to 4,631 fish in 1980. CWT estimates were based on a methodology similar to that used in West Greenland calculations (ICES-NASWG 1990). For 1991, the CWT estimates of harvest totaled 1,783 U.S. origin Atlantic salmon, with 1,050 estimated from Maine rivers, 593 from the Connecticut River, and 140 for the Merrimack River (ICES-NASWG 1993).

6.2.1.3 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 North American stock complex in West Greenland has been quite variable, and no overall trend is evident. Between 1974 and 1991, the average minimum exploitation rate was 37% and the average maximum was 55% in the West Greenland fishery. Exploitation rates in 1983 and 1984 were particularly low, and were reinforced by low harvest levels (ICES-NASWG 1993). In contrast, exploitation rates between 1985 and 1988 were nearly double 1983-1984 levels, despite quotas in place to limit total harvest (Møller Jensen 1988; ICES-NASWG 1993). The increase in exploitation rate was likely due to a lower abundance (Rago *et al.* 1993). 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 these 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 there was too small to account for a large fraction of the total 2SW returns to North American streams (Rago *et al.* 1993).

Marine exploitation rates of Maine stocks have also been assessed by the ICES-NASWG (1993). These estimates include catch data for 1SW and 2SW fish taken in the West Greenland and Newfoundland fisheries and homewater returns (ICES-NASWG 1990). In 1991, the extant exploitation rate of 2SW Maine origin Atlantic salmon was 97%, among the highest recorded since 1967. A liberal estimate of the average overall exploitation rate for the 1SW catch of the two fisheries is 60%, assuming a natural mortality rate of 12% (ICES-NASWG 1993). The ICES-NASWG also calculated the potential exploitation of U.S. Maine origin Atlantic salmon stocks based on the fraction of the stock that is available in West Greenland or Canada. This is similar to the run reconstruction model in that the exploitation rate varies with the geographical distribution of the fish. In these models, the average exploitation rate in the Canada fishery varies from 27% if 90% of the stock is available to 73% if 10% of the stock is available. In the West Greenland fishery, exploitation varies from 36% if 90% of the stock is available to 79% if only 10% of the stock is available. These examples illustrate the importance of the distribution of the U.S. Atlantic salmon stocks when exploitation rates are calculated.

The run reconstruction model also provides minimum and maximum estimates of the abundance of North American stocks in West Greenland (Rago *et al*. 1993). The estimated abundance of the North American stock complex decreased dramatically between 1974 and 1991. Yearly abundance is estimated before the fisheries occur, so declines in abundance do not relate to fishery removals in a year.

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. Therefore, the quotas, buyouts, and closures of these fisheries should result in increased returns of Atlantic salmon to the North American streams.

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, we calculated the potential return to these rivers in the absence of the West Greenland and Canada fisheries. We used the prefishery abundance of the Maine component of the Atlantic salmon caught in the fisheries and raised this value to total U.S. fish using the ratio of Maine returns to Connecticut, Merrimack, and Pawcatuck River returns; we then subjected the total U.S. prefishery stock to an instantaneous monthly mortality rate of 0.01 for 11 months (ICES-NASWG 1993; Rago *et al.* 1993). With this scenario, returns to U.S. streams would have averaged 6,428 from 1968 to 1989. The projected returns averaged 2.5 times larger than the observed rates and ranged from a factor of 0.9 in 1978 to 6.8 in 1971. As such, in the absence of the West Greenland and Labrador fisheries, returns of spawners to U.S. rivers could potentially increase 2.5 fold.

6.2.1.4 Regulation

The United States joined with other North American 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 American stocks. 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 Commissioners. NASCO achieves its goals by controlling the exploitation by one member nation of Atlantic salmon which originated within the territory of another member nation. The participation of the U.S. in NASCO provides it with a way to curtail interception fisheries of U.S. origin fish to the extent that such fisheries may compromise the success of the very substantial long-term commitment on the part of the states and the federal government to restore the Atlantic salmon stocks in the Northeast.

As was stated in detail in Section 6.2.2.1, commercial harvesting of U.S. origin Atlantic salmon on the high seas historically contributed to the depletion of the stock. However, ongoing harvesting restrictions, described below, are greatly reducing 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 will phase 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 quota (NEFSC 1993; Vigfússon and Ingólfsson 1993). This action effectively reduced the quota to a 12 mt subsistence fishery (NASCO 1993b). Plans for a similar buyout have been made for 1994 (Vigfússon and Ingólfsson 1993).

Over the past decade, only 90,000 wild 2SW Atlantic salmon (on average) have returned to spawn in U.S. and Canadian rivers. Fishery managers believe that the number of returning spawners needed to sustain these stocks currently is 194,000. As a result of NASCO's reduction of the 1994 West Greenland catch, the number of returning spawners should reach 185,000 (more than 95 percent of the target) this year. In the next 3 years of the management plan, 100 percent of the target (194,000 spawners) will be protected by adjusting the annual quota. In Canada, the Newfoundland fishery is under a five year moratorium and licenses are being purchased by the government. The Labrador fishery is now managed by quotas; the 1993 quota of 89 metric tons represents a reduction of 92% below the 1990 quota level. The current and projected effect of these extensive reductions in fishing pressure is that the numbers of Atlantic salmon returning to U.S. rivers to spawn over the next five years could more than double.

6.2.2 Domestic Commercial and Recreational Fishery

6.2.2.1 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 1993). 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 ASRSC in 1948. The commercial harvest in the Penobscot that year was a mere 40 fish, weighing a total of 400 pounds.

In October of 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, the U.S. investment in the State/Federal restoration program, and to strengthen the U.S. position in international negotiations. The FMP prohibits possession of Atlantic salmon in the Exclusive Economic Zone (EEZ) through a prohibition on possession. 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 reports that fewer than

100 salmon per year are caught incidental to other commercial fisheries in the coastal waters of Maine.

6.2.2.2 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 are 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. Historically, the average exploitation rate in Maine rivers has been estimated to be approximately 20% of the run (Beland 1984). 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. At present, legal exploitation of U.S. sea-run stocks of Atlantic salmon within the U.S. is limited to sport catch in Maine rivers (ICES-NASWG 1993). The one exception is in the Merrimack River. In 1993 an interim fishery for reconditioned captive broodstock kelts was initiated. The exploitation rates of U.S. Atlantic salmon stocks by anglers has been quite variable and recent data are summarized in NASCO (1993b) and USASAC (1994). The FMP for U.S. Atlantic salmon states that recreational fishermen constitute the most significant source of exploitation to New England Atlantic salmon populations in homewaters.

During the 1970's, recreational fishermen were taking as much as 15-25% of the annual return. In retrospect, this level of harvest was likely too high especially in light of the extensive high seas commercial harvest. As the 1980's progressed and runs decreased, the ASRSC imposed increasingly restrictive regulations on the recreational harvesting of Atlantic salmon in Maine. 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 number of Atlantic salmon caught and killed declined from the previous year whereas the number caught and released increased. In 1993 the rod catches on the seven rivers in the DPS were the lowest recorded since 1948 when ASRSC was created. The allowable annual harvest for these rivers was reduced from ten salmon in the 1980's to one grilse in 1994. No harvest is permitted on the Pleasant River. Even though the recreational harvest has now been limited to grilse, 2SW fish can be indirectly taken on these rivers through catch-and-release fishing. In addition, Atlantic salmon parr are vulnerable to harvest by trout anglers. The mortality associated with this activity has not been documented. There are numerous, although unsubstantiated, reports of poaching activities on Maine rivers. When returns of wild fish to the Maine rivers are as low as they have been in recent years, any source of mortality may pose a risk to the distinct population segment.

6.3 DISEASE AND PREDATION

6.3.1 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. For centuries, humans have also preyed upon and harvested Atlantic salmon using spears, nets, weirs, traps, fish wheels and hook and line. 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, smallmouth bass, belted kingfishers, the herons, American merganser, barred owls, otter, and mink (White 1936; White 1939a; White 1939b; Elson 1941; Godfrey 1957; Piggins 1959; Warner 1972; Larsson and Larsson 1975; 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, herring gulls, and black-backed gulls (White 1939b; Dow 1953; Blair 1956; Barr 1962; Warner 1972; Larsson 1977; Larsson 1985; van der 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 1958; Thurow 1966; Meister and Gramlich 1967; Rae 1973; Hvidsten and Mokkelgjerd 1987; Hvidsten and Lund 1988; Smith 1988; Barrett *et al*. 1990; Greenstreet *et al*. 1993; Massachusetts Cooperative Fish and Wildlife Research Unit, unpublished data). 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. Gadoid fishes such as cod, saithe, pollack and whiting are known to feed on post-smolts (Piggins 1959; 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 has 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. For waters of the eastern U.S., EEZ, gray seal 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 is 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. More promising results may be realized if efforts are directed at riverine, estuarine, and near shore environments. What is evident, is that additional studies are needed to identify predators, quantify their numbers, and determine their impact on Atlantic salmon in rivers where wild stocks occur and in rivers where attempts are now being made to restore Atlantic salmon.

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, is not well understood. Interactions with other salmonines has 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 1981).

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 is 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 affects (Hearn 1987; Fausch 1988).

6.3.2 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 (Secombes 1991); in New England, 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*. 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. One marine parasite of particular concern is the skin parasite *Gryodactylus salaris*. 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. White (1940) found that with severely infested fish, the skin was loose, often exposing flesh. 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 areas where there are no farms (NASCO 1993a).

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 ones to New England waters include furunculosis, bacterial kidney disease (BKD), and vibriosis (Mills 1971; Gaston 1988; Roberts and Olafsen 1993; Egusa 1992). Furunculosis was found in wild Atlantic salmon on the East Coast of Scotland during the period 1927-1935 and caused severe mortalities (Mackie *et al.* 1930-1933). It 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 is 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).

Bacterial kidney disease is a chronic infection of salmonine fishes in culture environments. Once established, it may 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 (Roberts and Olafsen 1993; Gaston 1988; Egusa 1992). There is not a high frequency of occurrence of BKD in New England. It has never been detected in smolts or sea-run salmon in federal hatcheries located in New England.

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 9° C, and resembles the condition referred to as "Hitra disease" in Norway (Gaston 1988).

Roberts (1993) reports that Atlantic salmon show a limited number of viral diseases in culture, but common ones include infectious pancreatic necrosis (IPN) and salmon papilloma. IPN is endemic in New England and in the Canadian Maritime Provinces. The little that is known about the disease suggests that it is not fatal to Atlantic salmon. 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 which can occur on wild and farmed fish in the first or second year of life. Fungi are encountered by most salmon 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 (Roberts and Olafsen 1993; Gaston 1988).

6.4 INADEQUACY OF EXISTING REGULATORY MECHANISMS

6.4.1 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 6.2 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 6.1 and they are explained in greater detail on subsequent pages.

Table 6.1 Existing Regulatory Mechanisms

Law or Agreement	Habitat Protection								
	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	pending
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	
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 Aquaculture Lease Requirements (PL 1991, c. 381, subsection 2)									X

North Atlantic Salmon Conservation Organization (NASCO).

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. Three Commissioners for the U.S. are appointed by the President and work under the auspices of the U.S. State Department. The Commissioners determined that they needed advice and input from scientists involved in Atlantic salmon research and management throughout New England and asked the New England Atlantic Salmon Committee (NEASC) to create such an advisory committee. NEASC is comprised of state and federal fishery agency chiefs who designate personnel to serve on the "NASCO Research Committee", which was formed in 1985. The NASCO Research Committee meets semi-annually to discuss the terms of reference for upcoming meetings of the International Counsel for the Exploration of the Sea (ICES) and NASCO, as well as respond to inquiries from NASCO Commissioners.

Convention for the International Council for the Exploration of the Sea (ICES) (24 U.S.A. I080; T.I.A.S. 7628).

The Convention was established in I973 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 various study groups.

Fishery Conservation and Management Act of 1976, (16 USCA §1801 et seq.).

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 6.2.2.1, a fishery management plan for Atlantic salmon was implemented by the New England Fishery Management Council and the Assistant Administrator for Fisheries in 1987.

The Atlantic Sea Run Salmon Commission (ASRSC).

The ASRSC, established through legislative act by the State of Maine in 1947, is comprised of five members: the Maine Commissioner of Inland Fisheries and Wildlife (permanent chairman), the Maine Commissioner of Marine Resources, and three citizens of the State of Maine appointed by the Governor. The Commission has the authority to promulgate rules and regulations pertaining to the take of Atlantic salmon from waters of the State of Maine and to institute remedial action where averse conditions have been shown to exist and such action has been shown to be required.

Cooperative Agreement: U.S. Fish and Wildlife Service and the State of Maine.

An agreement initiated on May 9, 1962, and most recently renewed October 1, 1987, created 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 marshall scientific expertise for addressing appropriate research, a Technical Advisory Committee was established as part of the Agreement.

Cooperative Agreement: National Marine Fisheries Service 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. 66l-66; 48 Stat. 40l), 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 U.S. Fish and Wildlife Service and the National Marine Fisheries Service 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 (l6 U.S.C. 79la-8254; 4l Stat. l063), 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 l972 (33 U.S.C. l25l-l376).

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 U.S. Fish and Wildlife Service and the National Marine Fisheries Service for impacts on fish and wildlife.

Fish and Wildlife Act of l956 (l6 U.S.C. 742a-742j; 70 Stat. lll9), 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 (l6 U.S.C. 777-77k; 64 Stat. 430), as amended.

This Act, commonly referred to as the "Dingell-Johnson 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. This Act includes a section entitled New England Fishery Resources Restoration Act of 1990 which is directed at the restoration of Atlantic salmon in selected New England rivers. The Services are to coordinate the establishment and implementation of basin-wide fishery restoration plans in cooperation with state and local resource agencies and other interested parties.

Anadromous Fish Conservation Act (l6 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 l969 (42 U.S.C. 432l-4347; 83 Stat. 852).
Public Law 9l-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.

Convention for the Conservation of Salmon in the North Atlantic Ocean.
This treaty was ratified by the United States in l982. The treaty 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.

INTERSTATE AND INTERAGENCY COMMITTEES
In accordance with various interagency cooperative agreements, the following governmental agencies participate directly in New England salmon programs: United States Fish and Wildlife Service, National Marine Fisheries Service, United States Forest Service, Maine Department of Marine Resources, Maine Department of Inland Fisheries and Wildlife, and the Maine Atlantic Sea Run Salmon Commission.

The following committees have the potential to significantly influence issues related to Atlantic salmon, specifically in Maine rivers.

Maine Technical Advisory Committee - established l980.

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 Atlantic Sea Run Salmon Commission.

New England Atlantic Salmon Committee - established l984.

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 l985.

This group of fish health specialists was originally established by the New England Atlantic Salmon Committee to address policy issues 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 l987.

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.

Three major landowners in coastal eastern Maine (Baskahegan Company, Champion International Cooperation and Georgia Pacific Corporation) have recently announced the formation of project S.H.A.R.E., Salmon Habitat and River Enhancement. This program is designed to be a model of cooperative land use management and a voluntary public/private approach to resource conservation and enhancement.

SUMMARY

A variety of state and federal environmental statutes and laws 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 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 have not removed the threat aquaculture poses to wild Atlantic salmon. Consequently, there is a need to take further action to address this potential threat.

4.2 Aquaculture: Atlantic Salmon Farming

6.4.2.1 Production and Location of Sites

An expansion of Atlantic salmon aquaculture has occurred in the North Atlantic since the early 1970's. The largest production now occurs in Scandinavian (Norway 140,000 tons) and European (Scotland 36,101 tons) countries (NA 1993; Heen *et al.* 1993). 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 finfish aquaculture production in Maine increased from an estimated 454 mt in 1988 to 7,067 mt in 1993, of which 6,713 mt were Atlantic salmon (Honey *et al.* 1993).

The rapid growth in salmon aquaculture is due to the development of a new technology. Atlantic salmon are now grown or "farmed" in net-pens or cages rather than "ranched", a method where salmon smolts are released at tidewater sites and return as adults for harvest. Unlike salmon ranching, farming does not rely on site fidelity of the species, and provides enhanced opportunities for management to maximize yields and economic benefits (White 1988).

Farmed Atlantic salmon have been documented in the wild and occur because of escapement and release from salmon aquaculture facilities (ICES-NASWG 1994; NAC 1993; Bergan *et al.* 1991; Lura and Saegrov 1991). 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). 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 1994). Farms are located on the west side of Campobello Island around Deer Island and near Back Bay, New Brunswick, and some are within 20 km of the Dennys Rivers (Figure 6.1).

Most Atlantic salmon farms in the U.S. are located in Cobscook Bay near Eastport, Maine, but some are located as far south along the Maine coast as Blue Hill Bay near Tremont. There are 25 farms operating in Maine (Maine Division of Marine Resources, unpublished data 1994; Honey *et al.* 1993). Farmed Atlantic salmon that have either escaped or have been released from farms have been found in the St. Croix, Penobscot, and East Machias Rivers (Baum 1991). Sixteen U.S. farms are located within 20 km of the mouth of the St. Croix River and 15 farms are located within 20 km of the Dennys River. There are 4 farms within 20 km of the mouth of the East Machias and Machias Rivers (Figure 6.1). The extent to which Atlantic salmon stocks, or other salmonine stocks from outside of North America, are present in salmon farms located in the state of Maine is not known.

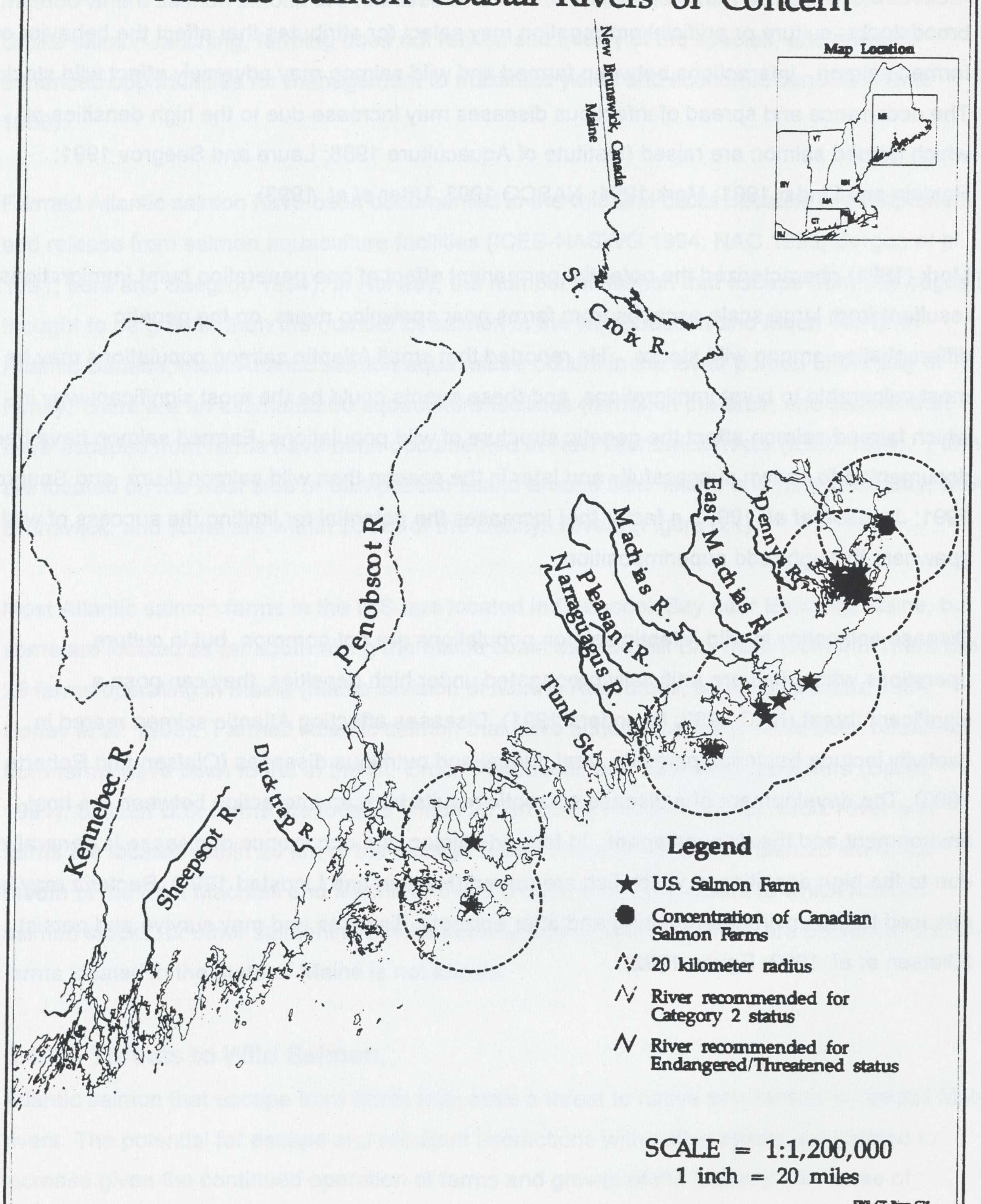
6.4.2.2 Threats to Wild Salmon

Atlantic salmon that escape from farms may pose a threat to native populations in coastal Maine rivers. The potential for escape and resultant interactions with native stocks is expected to increase given the continued operation of farms and growth of the industry. Because of selection in the hatchery or culture environment, farmed salmon are expected to become less fit for life in the wild. However, there is concern about the potential adverse effects that farmed salmon could have on native stocks should they escape or be released to the wild. In farmed salmon, genetic variability may decrease due to random genetic drift in comparatively small broodstocks; culture or artificial propagation may select for attributes that affect the behavior of farmed salmon. Interactions between farmed and wild salmon may adversely affect wild stocks. The occurrence and spread of infectious diseases may increase due to the high densities at which farmed salmon are raised (Institute of Aquaculture 1988; Laura and Saegrov 1991; Hastein and Lindst 1991; Mork 1991; NASCO 1993; Utter *et al.* 1993).

Mork (1991) characterized the potential permanent effect of one generation burst immigrations, resultant 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. Farmed salmon have been documented to spawn successfully and later in the season than wild salmon (Lura and Seagrov 1991; Jonsson *et al.* 1991), a factor that increases the potential for limiting the success of wild spawners through redd superimposition.

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 (NAC 1993; Saunders 1991). Diseases affecting Atlantic salmon reared in captivity include bacterial, parasitic, viral, fungal and nutritious diseases (Olafsen and 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 *et al.* 1993; Egusa 1992).

Figure 6.1. Locations of Salmon Farms Relative to Atlantic Salmon Coastal Rivers of Concern



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 for some diseases it has been documented for a distance of at least seven kilometers (Hastein and Lindstad 1991). Adverse effects of disease transmission from Atlantic salmon farms to wild stocks are not well documented, but investigations are becoming more numerous. Studies have shown an interaction for furunculosis, IPN, and two parasitic diseases: a free-living amoeba, *Thedamoeba* sp, and a skin parasite, *Gyrodactylus salaris* (NAC 1993).

6.4.2.3 Regulations and Permitting

The U.S. aquaculture industry is subject to state and federal laws and regulations.

The law in the state of Maine includes:

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 to review and comment on the effects of fish and wildlife of activities proposed to be undertaken or permitted by the U.S. Army Corps of Engineers.

These regulations and laws regulate 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 recently amended Public Law 1991, c. 381, subsection 2, specific to aquaculture to prohibit the importation or introduction into any waters of the state, 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. 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.

The North American Commission (NAC) of NASCO has recognized the potential for adverse fish health, genetic, and ecological effects on native Atlantic salmon stocks through introductions and transfers (NAC 1992). The NAC has developed protocols that include a zoning concept for the introduction and transfer of salmonids in the Commission area. The protocols have not yet been enacted as law in the U.S. and currently provide only guidance for fishery resource managers and the aquaculture industry.

Three Zones are identified, 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. 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 in Zone II, reproductively viable non-indigenous species and reproductively viable Atlantic salmon stocks non-indigenous to the NAC area are not to be introduced into watersheds or into the marine environment.

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.

6.5 OTHER NATURAL OR MANMADE FACTORS AFFECTING ITS CONTINUED EXISTENCE

6.5.1 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 effectively integrates all natural mortality factors and, if applicable, fishing mortality. If smolts are counted very close to the marine environment, the return rate indexes only marine survival. If the smolts are enumerated at stocking into upstream reaches, then assessments of return rates also 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 *et al*. 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). Bley and Moring (1988) noted 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 *et al.* (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 somewhat 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). However, recent return rates have been decreasing for several 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 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 Mills (1989) found that SST influenced Atlantic salmon marine distribution. Atlantic salmon were common in 4° to 10° 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 and Friedland (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, we still do not understand the mechanisms responsible for reduced survival. 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 and Friedland 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 speculate that mortality is controlled by the interaction of growth and predation.

6.5.2 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 (Ritter 1977). 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. 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 includes 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, natural return. For six of the seven rivers in the DPS, with the exception of the Ducktrap River which showed no difference, the average percentage of the run that was of natural (wild or fry stocked) origin was higher during years not influenced by fry stocking. 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 seven rivers will benefit, in the way of an improved percentage of run that is natural, from river-specific stocking.

The Team has determined that artificial propagation, with a river-specific stock, 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 National Marine Fisheries Service 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 seven rivers with unique stocks, is consistent with maintaining distinctness of these stocks.

In determining whether or not the hatchery fish should be considered part of the listable entity on the west coast, 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 specific stocks of Atlantic salmon from the DPS rivers of Maine should be included in the distinct population segment being proposed for listing. The Atlantic salmon from these rivers currently being held for artificial propagation, as well as their progeny, should be included in the listed unit. It is important to note that listing decisions and recovery is 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.

SECTION 7.0: RIVER PROFILES

7.1 KENNEBEC RIVER

The River. The Kennebec River watershed drains an area of 1,526,287 ha or approximately one-fifth of the state of Maine. It is the third largest watershed lying wholly in New England, flowing from the border of the United States and Canada, 240 km to the Atlantic Ocean. The former range of Atlantic salmon extended to the headwaters of the West Branch, a distance of 232 km from the sea. A large portion of the drainage is located in Somerset County, but the river also flows through Franklin, Kennebec, Penobscot, Waldo, Sagadahoc, and Androscoggin counties. The upper two-thirds of the basin is hilly and mountainous, and the lower third has a more gentle topography typical of southern Maine coastal areas. The Kennebec River flows into Merrymeeting Bay, a large freshwater tidal bay. The Androscoggin River, a comparatively large river, as well as other smaller rivers also flow into the Bay.

History. Kendall (1935) reported that the river, in its pristine condition, was scarcely surpassed by any Atlantic salmon river in the country. At Carratunk Falls, located approximately 20.6 km upstream from Augusta, it was easy for two men to load a boat with Atlantic salmon in one day. Atlantic salmon flourished as late as the 1870's, then declined rapidly as a result of the construction of dams and pollution. The first dam on the river, Edwards Dam, was constructed in 1837 in Augusta, but no fishway was built (Wells 1869; Savage 1973). On six occasions from 1837 to 1870, the dam breached. A fishway was installed in 1880, but by 1892 it was no longer operating (Squires 1985). The dam again breached in April of 1974 and was repaired in October of that year. Habitat available to Atlantic salmon in years prior to the construction of dams has been estimated to have been 114,532 units (one unit = 100 m^2; Beland 1984). With the potential of 2.4 smolts per unit, the historical production for the river approached 274,000 smolts. Early reports suggest there were attempts to rebuild stocks in the river but they were abandoned in 1892 (Kendall 1935).

Present Status. The upper reaches of the basin continue to provide forest products for industry and are also developing into an important recreational area. Agriculture is also important to the economy in rural portions of the basin. Industrial activity is located primarily in the southern portion of the basin. Flows in the basin are highly regulated by dams. There are 11 dams on the main stem between Augusta and Moosehead Lake, none of which have fish passage facilities for sea-run Atlantic salmon. Most of the major tributaries with potential spawning and rearing habitat have one or two dams, and they too lack fish passage facilities. Accessible habitat located downriver from Edwards Dam is now estimated to include 1,003 units with a production potential of 2,400 smolts (ASRSC 1994b). During the period 1965-1968 a total of 15,973 smolts were released into this river system (Beland 1984). An additional 5,000 parr were released in 1967 (Beland 1984). It is likely that parr and smolts released in the river were of stocks from other Maine rivers (ASRSC 1994a). Atlantic salmon have not been released in the Kennebec River since those stockings. In recent years, Atlantic salmon have been observed in tributaries downriver from Edwards Dam, the first dam on the river. There is evidence that suggests Bond Brook, and Togus and Eastern Streams may support Atlantic salmon. Recent surveys (ASRSC, unpublished data) have documented the presence of adults and juveniles in these waters. Additional information is required to characterize these stocks and to better understand their relevance to the historical maintenance and persistence of Atlantic salmon in the Kennebec River.

Listing Criteria. Two sections in the river have health advisories for the consumption of fish due to dioxin contamination. Contamination is associated with processes in the pulp, paper and tanning industries. These sections include a 90 km reach of the river from Skowhegan to Merrymeeting Bay and a 21 km reach of the West Branch of the Sebasticook River from Hartland to Pittsfield. Portions of Messalonskee Stream have high levels of coliform bacteria and low dissolved oxygen, and reaches of the Sebasticook River have high levels of bacteria, low dissolved oxygen and significantly impaired aquatic communities. The lower Kennebec River has low dissolved oxygen concentrations and bacteria problems in reaches downstream from Waterville/Winslow and Augusta (Maine Department of Environmental Protection 1990; Maine State Planning Office 1993). Activities associated with silviculture, agriculture, and industry can negatively affect Atlantic salmon stocks through point and non-point sources of pollution, but the magnitude and effect of these activities in the lower river is not known. The river and its estuary have a diverse assemblage of fishes, birds, and mammals, many of which are known to compete with and prey on Atlantic salmon. The effects and magnitude of competition and predation by these species in the riverine, estuarine, and marine environments is not known. At present, there are no Atlantic salmon farms located within 20 km of this river.

RECOMMENDATION: Sufficient information is not available at this time to indicate that Atlantic salmon in the Kennebec River warrant protection under the ESA. Additional studies are needed. Consequently, the Atlantic salmon population within the river is recommended for candidate status.

Specific Information Needs/Research Questions:

- To what extent did refugia downstream of the lowermost dam, Edwards Dam, allow runs to persist?
- Were upstream stocks lost or integrated into downstream runs?
- What is the origin of the present population? Was it derived from out-of-basin stocking (i.e. salmon that stray from natal rivers) or has some component of the native stock persisted?
- How many wild fish are returning to the river and to what extent is natural reproduction taking place?

Applicable Listing Criteria:

- Mortality in the marine environment.
- Predation in riverine and estuarine environments.
- Degradation of habitat.
- Inadequate fish passage facilities.

7.2 SHEEPSCOT RIVER

The River. 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, 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.

History. 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. Atkins (1887) indicated that remnant runs of anadromous fish 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).

Enhancement of salmon stocks began in 1948 and continued, for all but nine years, through 1976. More intensive stocking efforts resumed in 1982 and continued through 1991 (Figure 7.1). Fry, parr and smolt have been released in the river. Parr were primarily released in early years, and smolts have been released since the 1960's. The estimated total number of fry, parr and smolt released is 149,000, 436,511, and 170,292, respectively. Stock from Maine rivers were released in 1948 and 1949, but during the period 1948-1968 stocks from Canada were introduced. Maine rivers stock were used during the period 1971-1991 (Figure7.1) (FWS 1948-1955; USFWS 1956; ASRSC 1994a; USASAC 1994; Beland 1984; Meister 1982).

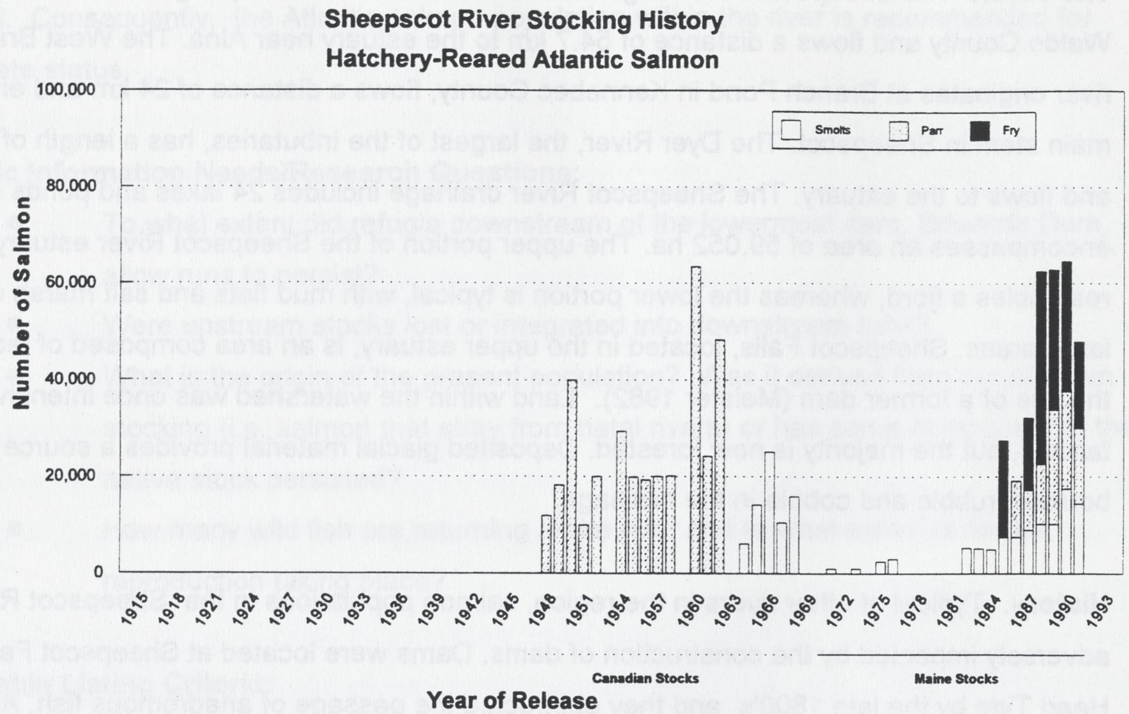


Figure 7.1 Stock origin and number of hatchery-reared Atlantic salmon (fry, parr and smolts) released in the Sheepscot River during the period 1915-1993.

Present Status. Bryant (1956) identified approximately 1,672 production units (one unit = 100 m^2) of habitat in the drainage. Important habitat for salmon is located on the main stem downstream from Coopers Mill Dam, the upper West Branch near Weeks Mills, and the lower 8 km of the West Branch. Estimates indicate there are 1,672 production units, and with a potential of 2.4 smolts per unit, production potential is estimated at 4,000 smolts (ASRSC 1994b; Meister 1982; Bryant 1956). All historic Atlantic salmon habitat is currently accessible (Figure 3.5). Recreational catch records provide additional information on the abundance and persistence of Atlantic salmon in the river. The relative abundance of mature salmon that return to the river has been monitored by using angler catch data. Rod catches for the period 1953-1992 have varied from zero in 1953 to 40 in 1966, with an average catch of 15 salmon (USASAC 1994; Meister 1982). Fletcher and Meister (1966) reported that anglers have typically captured from 15 to 20 percent of the adult run in the river. Recent data for the period 1988-1992 show that recreational catches ranged from one fish in 1988 to nine in 1990. No salmon have been released in the river since 1991. A river specific broodstock program was initiated in 1993 and it is expected that fish will be available for release in 1996.

Listing Factors. No known significant water quality perturbations have occurred in the basin; water quality is generally good, with some evidence of woody debris from logging and the forest products industry. Aerial spraying to control insect infestations has occurred periodically throughout the years, and pesticides could enter the aquatic environment if not properly applied. Forest product and agricultural activities, including raising livestock, may result in point and non-point sources of pollution which can adversely affect salmon and habitat. Landlocked salmon and warmwater fishes including pickerel and smallmouth bass are present in the drainage. Other fish, birds, and mammals are found in the river and estuary and may compete with and prey on salmon. The extent to which these species affect salmon in the riverine, estuarine and marine environments is not known. There are no Atlantic salmon farms located near the river.

RECOMMENDATION: The unique stock of Atlantic salmon in the Sheepscot River is part of a DPS of coastal Atlantic salmon and should be managed separately. The DPS is threatened with extinction and a listing action is warranted.

Status of the Stock and Applicable Listing Criteria:

- Severe decline in absolute numbers of adult returns and failure to achieve adequate escapement (Tables 5.2 and 5.3; Figure 5.3).
- Incomplete data documenting genetic characteristics of salmon in the river.
- Mortality in the marine environment.
- Predation in riverine and estuarine environments.
- Degradation of habitat.

7.3 DUCKTRAP RIVER

The River. The Ducktrap River is relatively small compared to other salmon rivers in Maine. It originates in Tilden Pond in Belmont, has a drainage area of approximately 5,600 ha, and flows for a distance of 10.7 km to Lincolnville where it enters Penobscot Bay. There are 4 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 river banks rise sharply from the stream to heights that exceed 30.5 m (Bryant 1956).

History. Historical information about riverine obstructions is limited. Wells (1869) reported that a wooden dam approximately 4m 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. Records show that Atlantic salmon were first stocked in the river in 1985 when 15,000 fry were released. Atlantic salmon were released in the river during the period 1985-1990, and total releases are estimated at 82,690 fry (ASRSC 1994a). No salmon have been released since 1990.

Present Status. Most salmon habitat is found in the main stem, but habitat is also located in Kendall Stream. Recent estimates indicate there are approximately 585 production units (one unit = 100 m^2) of habitat in the drainage. With a potential of 2.4 smolts per unit, the production is estimated at 1,400 smolts (ASRSC 1994b; Spencer 1990). A river specific broodstock program has not yet been established for the Ducktrap River due to lack of adequate facilities. It is likely that facilities will not be available in the near future. The recreational catch of salmon on the Ducktrap River has been monitored since 1985. There are no records of rod catch prior to that date. Rod catch data show 15 salmon taken in 1985 and 1986, and 3 in 1990. However, in

1990, 37 redds were found in drainage indicative of the fact that salmon entered the river. Redd count data for the period 1985-1993 show a high of 61 redds in 1987 and a low of 8 redds in 1988 (USASAC 1994; Spencer 1991).

Listing Factors. Water quality is good, 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. Beaver are found in the drainage and efforts to control their impact on habitat have been undertaken. There are no man-made obstructions to fish passage. Salmon typically do not enter the river until September and October when freshets increase river flow. Warmwater fishes inhabit headwater ponds and may be found in the river. Fish, birds, and mammals may compete with and prey on salmon in the river. The effect and magnitude of competition and predation by these species in the riverine, estuarine, and marine environments is not known. There are no Atlantic salmon farms in proximity to the river.

RECOMMENDATION: The unique stock of Atlantic salmon in the Ducktrap River is part of a DPS of coastal Atlantic salmon and should be managed separately. The DPS is threatened with extinction and a listing action is warranted.

Status of the Stock and Applicable Listing Criteria:

- Severe decline in absolute numbers of adult returns and failure to achieve adequate escapement (Tables 5.2 and 5.3; Figure 5.3).
- Incomplete data documenting genetic characteristics of salmon in the river.
- Mortality in the marine environment.
- Predation in riverine and estuarine environments.
- Degradation of habitat.

7.4 PENOBSCOT RIVER

The River. The Penobscot River drains an area of 2,219,630 ha and is the largest river in the state of Maine. The river has two branches, the East Branch and the West Branch, and two major tributaries, the Mattawamkeag and the Piscataquis Rivers. It is reported that the basin contains 624 lakes and ponds and 1,604 streams (Cutting 1963). The estuary, narrow at its head and broad at the ocean confluence, is approximately 51 km long with head of tide at Bangor. Small streams flow to the estuary downstream from Bangor.

The topography throughout the drainage is mostly rolling plains interspersed with hilly areas. Peat bogs are found throughout the basin, and there are pronounced kames and eskers resultant from glacial drift. The Penobscot and Passamaquoddy Indian Nations hold interest in lands in the basin. The Penobscot Indian Reservation includes 119 islands in the river between Old Town and Mattawamkeag (Baum 1983).

History. Major land use changes in the headwaters of the basin occurred in 1840 when a dam was built at the outlet of Chamberlain Lake, and a 244 meter-long canal was cut from Telos Lake to Chamberlain Lake. As a result, flowage from Allagash, Telos, and Chamberlain Lakes, and Round Pond were diverted from the St. John River to the Penobscot River (Pratt 1946). Natural falls were historically present throughout the basin, and by the late 1800's many man-made structures were present as well. Reports suggest that both falls and structures impeded the passage of salmon and other anadromous fish (Baum 1983). Although fish passage facilities were constructed in the 1870's at mainstem dams, periodically some were not effective (Baum 1983; Cutting 1963; Pratt 1946; Kendall 1935).

The impacts of river obstructions and commercial harvest on salmon were evident as early as 1871, the year in which propagation of salmon for enhancement of stocks began (Pratt 1946; Cutting 1963; Kendall 1936). The Craig Brook National Fish Hatchery located in East Orland, Maine was an integral part of early salmon enhancement efforts. As early as 1872 this hatchery provided salmon for enhancement of Penobscot River stocks. Throughout its history the hatchery raised salmon from eggs received from Canada and from broodstock captured in the river, its tributaries, and other Maine rivers. State facilities also raised salmon for release in the river and they included Tunk Lake Hatchery near Cherryfield, Palermo Hatchery, Palermo, and

Cold Stream Hatchery in Enfield. Eggs for the early enhancement program (1871-1920) were obtained from fish captured in the Penobscot River commercial fishery and brought to the Craig Brook National Fish Hatchery. During the period 1921-1938 eggs were obtained primarily from Canada (Pratt 1946, Bureau of Fisheries 1921-1938), except for three years (1934, 1938, and 1939) when no Canadian eggs were received. In 1931, eggs were also obtained from salmon captured in Souadabscook Stream, a small flowage that reaches the estuary about 11 km downstream from Bangor (Bureau of Fisheries 1931, 1932).

Salmon were abundant in the river in the early 1800's but because of the construction of dams, overfishing, and pollution, populations were severely reduced. During the 1960's few salmon were seen in the river and then only in the lower sections. Records of commercial landings (Figure 7.2) show a harvest of approximately 190,000 pounds in 1888, but only 40 salmon were captured in 1947, and in that year the commercial fishery was closed (Baum 1993; Cutting 1963; Pratt 1946; and Kendall 1935).

The abundance of salmon was low for the period 1938-1968 but recreational catch, trap catch, and the incidental commercial harvest of salmon suggest that runs continued in the main stem and lower reaches of the river (Beland 1984; Rounsefell and Bond 1949). Recreational catches of salmon in the 1950's provide evidence of the persistence of salmon in the basin until that time (Figure 7.2). Angling for salmon was at a low during the 1960's, a period when a decrease in the abundance of salmon and poor water quality discouraged interest in river resources.

A trap was installed at Bangor Dam in 1940 and 52 salmon were captured and used as broodstock; broodstock were also captured in the Dennys (23) and Machias (2) Rivers in 1940 (Bureau of Fisheries 1938; FWS 1940). Captures at the trap continued with moderate success for the period 1940-1950. At times, river flow was low which resulted in ineffective trap operation. Broodstock were then captured out-of-basin, most notably at sites in the Machias and Narraguagus Rivers (1946: Penobscot 1, Machias 99; 1948: Penobscot 12, Machias 23; 1949: Penobscot 1, Machias 169, Narraguagus 61; and 1950: Penobscot 29, Machias 71) (FWS 1946-1950). Trap captures on the Penobscot River were not reported for the period 1951-1968, but Machias River broodstock were captured in 1961, and 46 salmon of known hatchery origin were captured in the Orland River in 1967 and used as broodstock. During the period 1951-1967, releases of juvenile salmon in the river included a mix of stocks from the

Machias and Narraguagus Rivers, and Canadian rivers (FWS 1951-1955; USFWS 1956; ASRSC 1994a).

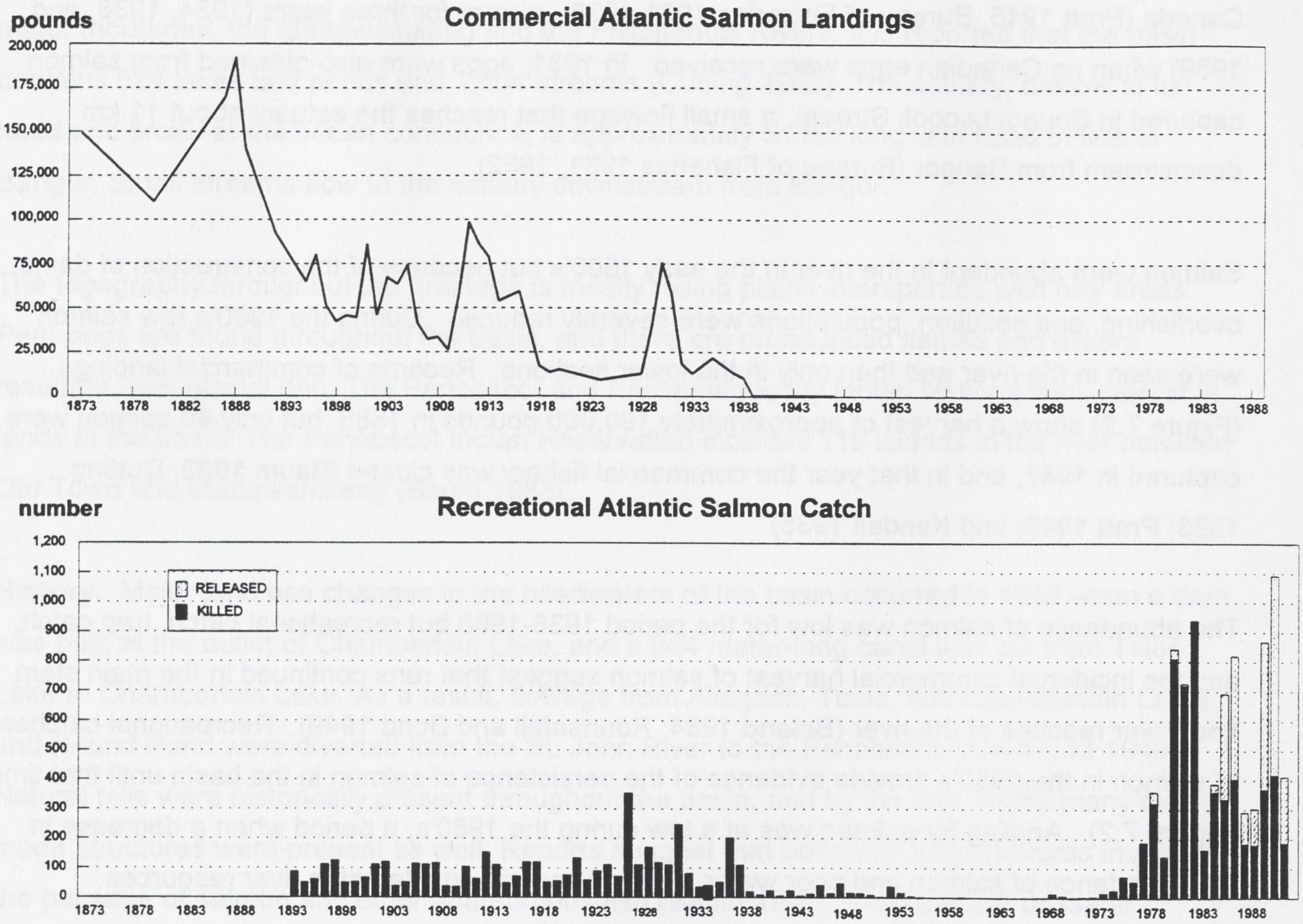


Figure 7.2 Commercial landings (upper panel) and recreational catch (lower panel) of Atlantic salmon in the Penobscot River during the period 1873-1993.

The trap at Bangor Dam was returned to operation from 1969 to 1980 and a trap installed at Veazie Dam in 1978 has remained in operation to date. Broodstock captured in these traps provided gametes that resulted in the subsequent release of juvenile salmon in the river. Records show that with few exceptions, juvenile salmon were released annually in the river during the period 1872-1993. Since 1968, only stocks from the Penobscot River and other Maine rivers have been released in the drainage. The number of fry, parr and smolt released is estimated to be 4,978,426; 4,610,525; and 9,197,633 respectively (Figure 7.3). The total number of salmon released in the basin was approximately 18,786,584 (ASRSC 1994a; USASAC 1994; Beland 1984; Pratt 1946; Bureau of Fisheries 1939; FWS 1940-1956; USFWS 1957-1968).

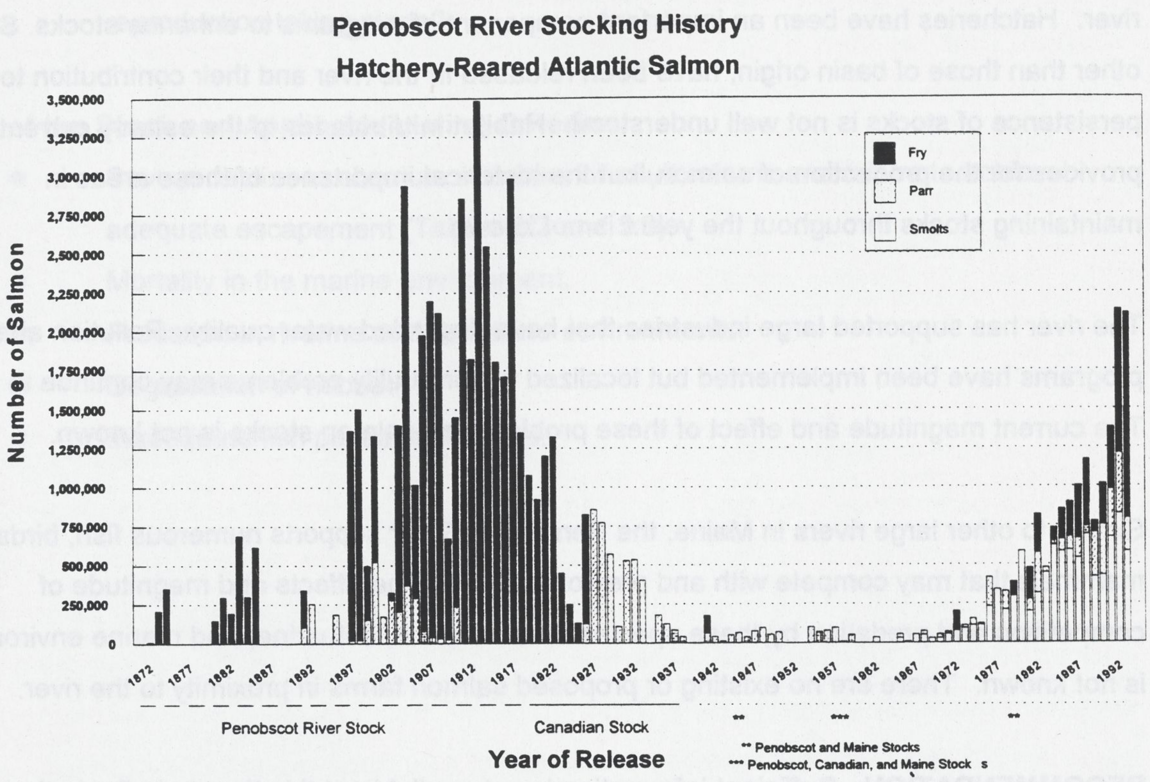


Figure 7.3 Stock origin and number of hatchery-reared Atlantic salmon (fry, parr and smolts) released in the Penobscot River during the period 1872-1993.

Present Status. Fish passage facilities are now integrated with all man-made obstructions on the main stem of the river. Dams with fishways are located in Bangor (breached dam), Veazie, Old Town, Milford, West Enfield and Mattawamkeag. Seven tributaries of moderate size, and other, smaller tributaries, reach the estuary downstream from Bangor Dam. Moderate size tributaries include the Orland River, Marsh, Mill, Sedgekedunk, and Kenduskeag Streams and Cove and Felts Brooks. These are waters where the presence of salmon has been documented (ASRSC 1994). In 1978 the Bangor Dam breached and salmon were provided access to habitat upstream of Veazie Dam as well as access to Eaton Brook, areas where salmon have been documented in recent times. Including habitat in the brooks, streams and rivers that flow to the estuary, the river contains an estimated 102,828 production units (one unit = 100 m^2).

With a potential of 2.4 smolts per unit, production potential is estimated to be 246,000 smolts (Baum 1982; ASRSC 1994b).

Listing Criteria. There is a need to develop additional information about salmon stocks in the river. Hatcheries have been an important component of programs to enhance stocks. Salmon, other than those of basin origin, have been released in the river and their contribution to the persistence of stocks is not well understood. Habitat in tributaries to the estuary currently provides for the production of salmon, but the historical importance of these areas in maintaining stocks throughout the years is not known.

The river has supported large industries that have degraded water quality. Pollution abatement programs have been implemented but localized water quality problems may continue to persist. The current magnitude and effect of these problems on salmon stocks is not known.

Similar to other large rivers in Maine, the Penobscot River supports numerous fish, birds and mammals that may compete with and prey on salmon. The effects and magnitude of competition and predation by these species in the riverine, estuarine, and marine environments is not known. There are no existing or proposed salmon farms in proximity to the river.

RECOMMENDATION: Sufficient information is not available at this time to indicate that Atlantic salmon in the Penobscot River warrant protection under the ESA. Additional studies are needed. Consequently, the Atlantic salmon population within the river is recommended for candidate status.

Specific Information Needs/Research Questions:

- To what extent did refugia downstream of the lowermost dam allow runs to persist?
- Were upstream populations lost or integrated into downstream runs?
- What is the relationship between the current population in tributaries downstream from Bangor Dam and the hatchery stock?
- If a downstream run persisted, how was it impacted by stocking practices in the mainstem?

- What is the origin of the hatchery stock? Was it developed primarily from the Penobscot River or from stock transfers? Has the genetic integrity of the Penobscot stock been compromised or substantially "domesticated"?
- How many wild fish are returning to the watershed and to what extent is natural reproduction taking place?

Status of the Stock and Applicable Listing Criteria:

- Severe decline in absolute numbers of adult returns and failure to achieve adequate escapement (Tables 5.2 and 5.3).
- Mortality in the marine environment.
- Predation in riverine and estuarine environments.
- Degradation of habitat.
- Inadequate fish passage facilities.

7.5 Tunk Stream

The River. Tunk Stream originates at Tunk Lake in Sullivan and Township 10 S.D., Hancock County. The drainage covers an area of approximately 10,400 ha, and includes 17 lakes and ponds. The stream has a length of approximately 25.7 km, and it flows to Gouldsboro Bay in Steuben. Tunk Lake has a surface area greater than 810 ha and is the largest lake in the drainage. It is a deep, coldwater lake that supports a variety of game fishes. Tunk Lake and other headwater lakes hold brook, brown, and lake trout as well as landlocked salmon, species that have been popular with anglers throughout the years. Lands within the drainage are sparsely settled and mostly forested. Agricultural lands are located throughout the drainage and some are now overgrown. The headwater lakes with dams store water and stabilize flows throughout the year.

History. Dams were constructed in the drainage in the 1800's but there is little information about their persistence. The remnants of some dams may now obstruct fish passage at low flows. Dams are located at the outlet of Long and Round Ponds, and habitat for sea-run salmon is limited upstream from these obstructions. Beaver inhabit the basin and their dams may obstruct passage during periods of low flow (Beland 1982; Havey 1956). Atlantic salmon fry were released in the stream in 1949, 1950 and 1951. Introductions of coho salmon were also made in 1949 and 1950, but there is no evidence of their persistence in the drainage. An estimated 95,000 Atlantic salmon fry were stocked in the stream and records show that Canadian stocks (50,000) were released in 1949, and Maine river stocks were released in the two subsequent years (FWS 1949-1951). Surveys conducted by Havey (1956) documented that the stream supported a small run of salmon. He reported that past and existing obstructions may have limited the runs and reduced production. Beland (1982) summarized data obtained in the 1950's, 1960's and 1970's showing densities of parr at sites in the stream. Since no known releases of salmon in the stream have occurred since 1951, the data provides evidence that salmon have persisted in the stream.

Present Status. Important spawning and nursery habitat is found in the stream reaches from Spring River Lake to Downing Pond; from Route 182 to Smithville; and from Smithville to Stueben. Estimates indicate that there are 585 production units (one unit = 100 m^2) of habitat. With a potential of 2.4 smolts per unit, the production potential of the basin is estimated at 1,400 smolts (Havey 1956; Beland 1982; ASRSC 1994b). The presence of parr has not been documented through recent surveys, but these surveys have not been as thorough as those completed in past years (ASRSC 1994, unpublished data). Stream surveys to document the presence of parr in the stream are ongoing, and it is likely that they will continue for the next few years.

Listing Factors. Remnants of a sawmill exist on Round Pond and sawdust waste has been documented in the pond and in the stream near the outlet of the pond. The accumulation of sawdust in this area does not appear to present a threat to salmon in the stream (Havey 1956; Beland 1982). Warmwater gamefish are not present in the drainage. Headwater lakes support coldwater fishes which may enter the stream and compete with and prey on salmon. Alewives and blueback herring ascend the stream in spring and are harvested commercially at sites in Unionville. The impact of these commercial operations on salmon in the stream is not known. Similar to other coastal Maine drainages, Tunk Stream flows to an estuary that supports an assemblage of fish, birds, and mammals that may compete with and prey on salmon. The extent to which these species affect salmon in the riverine, estuarine, and marine environments is not known. Proposals have been submitted to authorities in Maine to site two salmon farms within 20 km of the mouth of the stream. The size of these farms, and the stock characteristics of fish to be reared are not known.

RECOMMENDATION: Sufficient information is not available at this time to indicate that Atlantic salmon in Tunk Stream warrant protection under the ESA. Additional studies are needed. Consequently, the Atlantic salmon population within Tunk Stream is recommended for candidate status .

Specific Information Needs/Research Question:

- Does a population of Atlantic salmon exist in the river, and, if so, has it persisted?

Applicable Listing Criteria:

- Mortality in the marine environment.
- Predation in riverine and estuarine environments.
- Degradation of habitat.
- Proposed salmon farms within 20 km of the stream mouth.

7.6 NARRAGUAGUS RIVER

The River. 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 blueberry production and forest products.

History. As early as 1874 there were five wooden dams in Cherryfield located within 1.6 km of tidewater. The dams were used to control river flow for the operation of mills and for the storage and transport of logs. Atkins (1887) reported that the dams had adversely affected Atlantic salmon runs in the river. It was not until the early 1900's that the river was opened 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 and the last obstruction to Atlantic salmon, was breached in 1951.

Atlantic salmon stock enhancement began with the release of fry in 1918 (Figure 7.4). The release of fry, parr or smolts continued periodically throughout the years. Records indicate that Atlantic salmon were released in all but 24 years during the period 1918-1993. Fry were released in years prior to 1940 and the total number stocked is estimated at 2,519,752. Parr were released from the 1940's through the early 1960's and the total number released is estimated at 717,804. Smolts have been released since 1962 and the total number is estimated at 446,298. To date, a total of approximately 2,519,752 Atlantic salmon have been released in the river (ASRSC 1994a; USASAC 1994; Beland 1984; Baum and Jordan 1982). Penobscot River and Canadian stocks were released in early years and Baum and Jordan (1982) reported undesirable results from Canadian stocks. Greater than 70 percent of the Atlantic salmon that returned were small, late-run, grilse. They were predominantly males and contributed little to egg deposition in the river. Similar results were observed for smolts of Canadian origin released in the 1960's. Beginning in 1969, all Atlantic salmon released were stocks obtained from fish captured in Maine rivers.

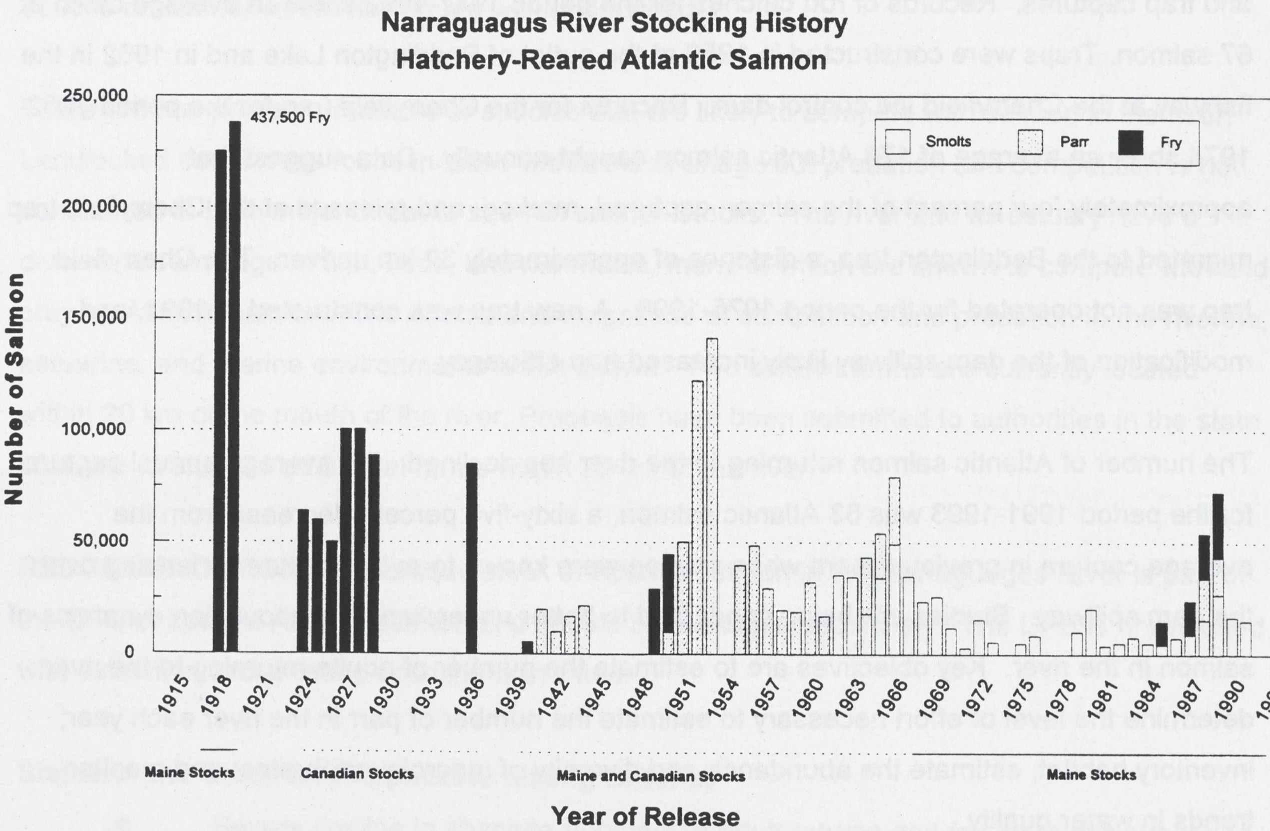


Figure 7.4 Stock origin and number of hatchery-reared Atlantic salmon (fry, parr and smolts) released in the Narraguagus River during the period 1915-1993.

Present Status. 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 directs them to the ladder and trap facilities. Approximately one-third of the habitat for salmon is located upstream from Beddington Lake. The West Branch and other smaller tributaries have relatively small areas of habitat suitable for salmon. An estimated 4,822 production units (one unit = 100 m^2) are available to salmon in the river. With a potential of 2.4 smolts per unit, the production potential is estimated at 11,554 smolts (Baum and Jordan 1982; ASRSC 1994b). No salmon were released in the Narraguagus River in 1992 or 1993. A river specific broodstock program was initiated in 1992 and fry are expected to be released in 1995.

The number of salmon that have returned to the river has been monitored through angler catch and trap captures. Records of rod catches for the period 1947-1992 show an average catch of 67 salmon. Traps were constructed in 1959 at the outlet of Beddington Lake and in 1962 in the fishway at the Cherryfield ice control dam. Records for the Cherryfield trap for the period 1962-1974 show an average of 173 Atlantic salmon caught annually. Data suggest that approximately four percent of the salmon captured, marked, and released at the Cherryfield trap migrated to the Beddington trap, a distance of approximately 32 km upriver. The Cherryfield trap was not operated for the period 1975-1990. A new trap was constructed in 1991, and modification of the dam spillway likely increased trap efficiency.

The number of Atlantic salmon returning to the river has declined; the average annual capture for the period 1991-1993 was 63 Atlantic salmon, a sixty-five percent decrease from the average capture in previous years when salmon were known to avoid capture by leaping over the dam spillway. Studies are being conducted to better understand the population dynamics of salmon in the river. Key objectives are to estimate the number of adults returning to the river; determine the level of effort necessary to estimate the number of parr in the river each year; inventory habitat; estimate the abundance and diversity of macroinvertebrates; and monitor trends in water quality.

Listing Criteria. Hexazinone (velpar) has been detected at sites in the 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).

Lands throughout the watershed are managed for forest products and the production of blueberries. Activities associated with silviculture and agriculture can adversely affect Atlantic salmon and habitat. Atlantic salmon spend an extended time in freshwater, and the quantity and quality of habitat defines the limits of production. Land alterations, water withdrawals, and point and non-point sources of pollution are actions associated with agriculture and silviculture and may adversely affect Atlantic salmon. The magnitude and effect of these activities and actions on salmon in the river is not well understood.

There are few primary predators or species that are likely to compete with salmon in the 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 its estuary have a diverse assemblage of fish, birds, and mammals, many of which are known to compete with and prey on Atlantic salmon. The effects and magnitude of competition and predation in the riverine, estuarine, and marine environments is not known. Two salmon farms are currently located within 20 km of the mouth of the river. Proposals have been submitted to authorities in the state of Maine to site two additional farms within 20 km of the river.

RECOMMENDATION: The unique stock of Atlantic salmon in the Narraguagus River is part of the DPS of coastal Atlantic salmon and should be managed separately. The DPS is threatened with extinction and a listing action is warranted.

Status of the Stock and Applicable Listing Criteria:

- Severe decline in absolute numbers of adult returns and failure to achieve adequate escapement (Figure 5.3).
- Failure to achieve adequate escapement (Tables 5.2 and 5.3).
- Incomplete data documenting genetic characteristics of salmon in the river.
- Mortality in marine environment.
- Predation in riverine and estuarine environment.
- Degradation of habitat.
- Proposed and operating salmon farms within 20 km of river (Figure 6.1).

7.7 PLEASANT RIVER

The River. The Pleasant River watershed in Washington County is the smallest watershed in Maine that supports a self-sustaining run of Atlantic salmon. The river originates at Pleasant River Lake in Beddington, drains an area of 22,015 ha, and 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 material which may 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).

History. Foster and Atkins (1869), Stilwell and Smith (1879), and Atkins (1887) reported that the construction of a dam at Columbia Falls impeded the upstream migration of Atlantic salmon. Rounsefell and Bond (1949) reported that salmon production in the 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, usually in late fall. North Branch Stream is the only tributary having 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 additional habitat for salmon. 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. The Pleasant River was first stocked with fry beginning in 1918, and this continued with some lapses until 1925. It was again stocked during the period 1985-1991 with an estimated total of 2,314,137 fry. Parr were stocked in 1940, 1954-1955, 1957-1958, 1963-1965, and 1988-1989, with an estimated total of 101,537 parr. Smolts were stocked in 1966, 1968, 1975-1976, 1978, 1980-1982, and 1985-1990, with an estimated total of 99,459 smolts (Figure 7.5).

Approximately 2,515,133 Atlantic salmon have been released in the river, with annual releases ranging from 1,024 smolts in 1976 to 600,000 fry in 1918 (ASRSC 1994a; USASAC 1994; Dube and Jordan 1982; ASRSC, unpublished data; Bureau of Fisheries 1917-1939). Atlantic salmon from various sources were used which included stocks from the Penobscot, Union, Narraguagus, and Machias Rivers, as well as stocks from Canadian rivers (Figure 7.5). Atkins (1874, 1887) reported that the average annual catch in the river in the early 1870's was estimated at 75 Atlantic salmon, but the catch declined to one fish in 1880. Records of recreational catch provide information about the abundance and persistence of Atlantic salmon in the basin. From 1955-1981, the total rod catch of Atlantic salmon for the river was 1,001. The last reported catch was in 1987. Atlantic salmon fishing in the river is now open to catch-and-release only.

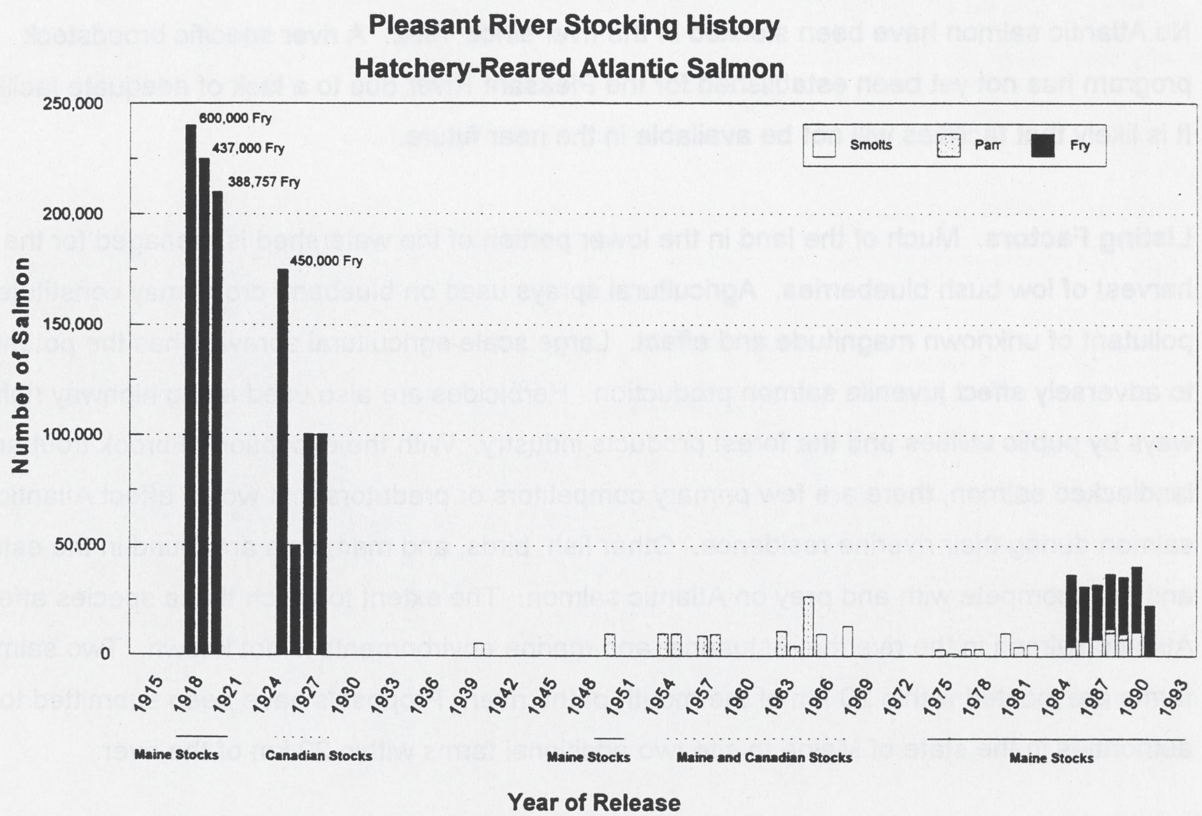


Figure 7.5 Stock origin and number of hatchery-reared Atlantic salmon (fry, parr and smolts) released in the Pleasant River during the period 1915-1993 .

Present Status. Atlantic salmon habitat in the basin is located in Eastern Little River, North Branch Stream below the falls, and the main stem of the river below Saco Falls (Dube and Jordan 1982). With the addition of fish passage facilities at Saco Falls in 1955, available habitat now exceeds that which was present historically (Figure 3.5). There are 1,087 production units (one unit = 100 m^2) of habitat. With a potential of 3.6 smolts per unit, the production potential is estimated at 3,900 smolts (ASRSC 1994b; Beland 1984). Recent habitat surveys (ASRSC unpublished data) found 36 obstructions, mostly beaver dams, in the basin. Beaver dams in the basin are typically partial obstructions and are ephemeral in nature (Havey and Fletcher 1956). The dams have the potential to alter habitat and may reduce the production of Atlantic salmon. Since 1975 the ASRSC has attempted to control beaver by trapping and removing dams in affected areas.

No Atlantic salmon have been stocked in the river since 1992. A river specific broodstock program has not yet been established for the Pleasant River due to a lack of adequate facilities. It is likely that facilities will not be available in the near future.

Listing Factors. Much of the land in the lower portion of the watershed is managed for the harvest of low bush blueberries. Agricultural sprays used on blueberry crops may constitute a pollutant of unknown magnitude and effect. Large scale agricultural spraying has the potential to adversely affect juvenile salmon production. Herbicides are also used along highway right-of-ways by public utilities and the forest products industry. 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. Other fish, birds, and mammals are found in the estuary and may compete with and prey on Atlantic salmon. The extent to which these species affect Atlantic salmon in the riverine, estuarine, and marine environments is not known. Two salmon farms are located within 20 km of the mouth of the river. Proposals have been submitted to the authorities in the state of Maine to site two additional farms within 20 km of the river.

RECOMMENDATION: The unique stock of Atlantic salmon in the Pleasant River is part of the DPS of coastal Atlantic salmon and should be managed separately. The DPS is threatened with extinction and a listing action is warranted.

Status of the Stock and Applicable Listing Criteria:

- Severe decline in absolute numbers of adult returns and failure to achieve adequate escapement (Tables 5.2 and 5.3; Figure 5.2).
- Incomplete data documenting genetic characteristics of salmon in the river.
- Mortality in the marine environment.
- Predation in riverine and estuarine environments.
- Degradation of habitat.
- Proposed and operating salmon farms within 20 km of river (Figure 6.1).

7.8 MACHIAS RIVER

The River. 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 now being studied to determine if passage can be improved. The studies are being conducted as part of the prerecovery plan for Atlantic salmon in the 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 *et al.* 1982). The Machias and East Machias Rivers share a common estuary. The estuary is elongate, approximately 9.6 km in length, but relatively narrow.

History. 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).

Records indicate that salmon were stocked in the Machias River beginning in 1882, but most releases occurred from 1940 to 1992 (U.S. Commission of Fish and Fisheries 1874-1890; Fletcher *et al.* 1982; Beland 1984; USASAC 1994). Out-of-basin stocks were used and included Penobscot River and Union River stocks, as well as stocks from Canadian rivers (Figure 7.6). Fletcher (1955) reported that stocking efforts in the early 1950's were relatively unsuccessful, and salmon that did return to the river were likely from stocks reared in the river as wild fish. Returns from salmon stocked during the period 1962-1970 were low, and included a large grilse component which was attributed to the Canadian origin of the stock. The grilse component of the run decreased in the 1970's, perhaps because the stocks released in the river during that time were from the Machias River and other Maine rivers.

Fry were stocked in 1882-1883, 1920, 1922, 1950, 1986, and 1988-1992. The total number of fry stocked is estimated at 369,149. An estimated total of 788,336 parr was stocked throughout the years 1940-1943, 1947-1953, 1957-1962, 1983, and 1985-1991. An estimated 468,898 smolts were stocked in 1961, 1963-1974, 1976, 1978-1979, and 1982-1992. To date, an estimated 1,783,920 salmon have been released into the Machias River (Figure 7.6) (U.S. Commission of Fish and Fisheries 1874-1890; Fletcher *et al.* 1982; Beland 1984 ASRSC 1994a; USASAC 1994). No salmon were released in the river in 1993. A river-specific broodstock program was initiated in 1992, and juvenile salmon from the program were released in 1994.

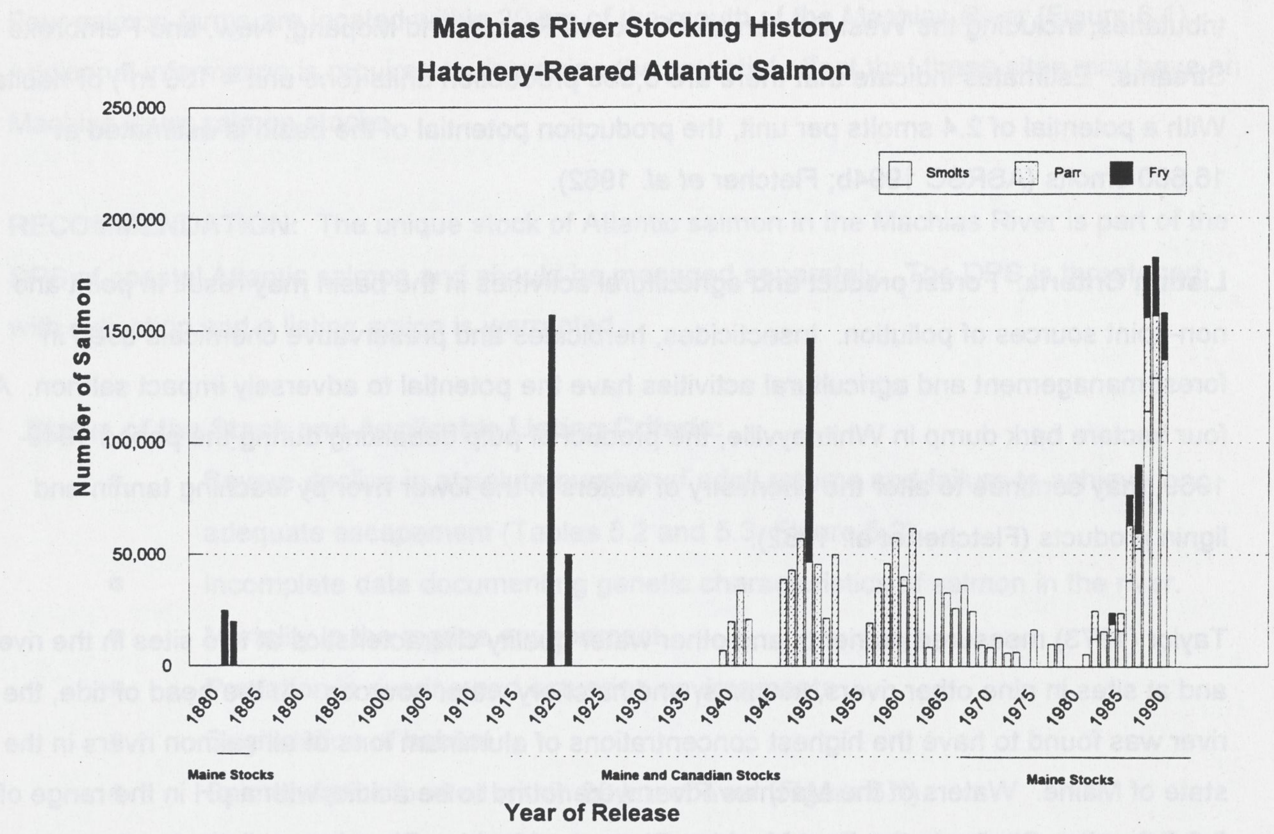


Figure 7.6 Stock origin and number of hatchery-reared Atlantic salmon (fry, parr and smolts) released in the Machias River during the period 1880-1993.

The number of salmon that have returned to the river has been estimated from trap captures at Harwood and Whitneyville Dams and from records of rod catches. Trap captures for the period 1949-1970 ranged from a low of approximately 160 salmon in 1950 to a high of approximately 800 salmon in 1959; rod catches for the same period ranged from a low of approximately 5 salmon in 1953 to a high of 125 in 1961 (Fletcher *et al.* 1982). Estimated returns to the river during the period 1970-1992 ranged from a high of 240 in 1970 to a low of 2 in 1991.

Present Status. Habitat surveys (ASRSC, unpublished data) have been conducted on major spawning tributaries which include Old, New and Mopang Streams. 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 ephemeral, but if they persist, they may pose problems for salmon and adversely affect habitat by inundating riffle-pool complexes and runs. Salmon habitat is located in the main stem and tributaries, including the West Branch and Crooked Rivers, and Mopang, New, and Pembroke Streams. Estimates indicate that there are 6,939 production units (one unit = 100 m^2) of habitat. With a potential of 2.4 smolts per unit, the production potential of the basin is estimated at 16,600 smolts (ASRSC 1994b; Fletcher *et al.* 1982).

Listing Criteria. Forest product and agricultural activities in the basin may result in point and non-point sources of pollution. Insecticides, herbicides and preservative chemicals used in forest management and agricultural activities have the potential to adversely impact salmon. 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 river by leaching tannin and lignin products (Fletcher *et al.* 1982).

Taylor (1973) measured nutrients and other water quality characteristics at two sites in the river and at sites in nine other rivers, streams, and hatchery water sources. At the head of tide, the 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 which may be attributed to peat bogs as well as bark wastes and detritus from logging operations.

The river and estuary have diverse assemblages of fish, birds, and mammals that may compete with and prey on salmon. Landlocked salmon, pickerel, and smallmouth bass are found in the watershed, but the extent of competition and predation is not known.

There is evidence to suggest that predation by cormorants in the estuary may adversely affect salmon in the river. Meister and Gramlich (1968) 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. Recent studies of cormorant predation in the watershed have not been conducted. Cormorant abundance is thought to have increased in the last decade and the effects on the salmon population is not known. In addition, the NMFS has received reports of seals congregating near the river mouth in the spring during alewife runs.

Four salmon farms are located within 20 km of the mouth of the Machias River (Figure 6.1). Additional information is required to determine the potential effect that these sites may have on Machias River salmon stocks.

RECOMMENDATION: The unique stock of Atlantic salmon in the Machias River is part of the DPS of coastal Atlantic salmon and should be managed separately. The DPS is threatened with extinction and a listing action is warranted.

Status of the Stock and Applicable Listing Criteria:

- Severe decline in absolute number of adult returns and failure to achieve adequate escapement (Tables 5.2 and 5.3; Figure 5.2).
- Incomplete data documenting genetic characteristics of salmon in the river.
- Mortality in the marine environment.
- Predation in riverine and estuarine environments.
- Degradation of habitat.
- Salmon farms located within 20 km of river (Figure 6.1).

7.9 EAST MACHIAS RIVER

The River. The East Machias River originates at Pocomoonshine Lake in the towns of Princeton and Alexander in Washington County, Maine. The river has a drainage of 65,009 ha, 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 share a common estuary and the lower 3.2 km of the estuary are common to both rivers (Dube and Fletcher 1982).

History. 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. Existing fishways were inefficient, but once repaired, salmon runs were reported to increase (Foster and Atkins 1868). 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. Fletcher (1960b) reported that salmon were known to spawn in Chase's Mill Stream, Northern Stream, Seavey Brook and in the main stem. 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 small run.

Fry were stocked in the East Machias River in 1917 and during the period 1985-1991. The total number of fry released was approximately 325,655. The number of parr stocked in 1940, 1975, 1984, and during the period 1988-1991 was approximately 65,552. Smolts were stocked in 1966, 1973, 1975, 1976, 1978-1980, 1982, and during the period 1985-1991; the total number stocked was approximately 150,850 (Figure 7.7). Penobscot River and Union River stocks were used in all years, and in total, approximately 542,057 salmon were released (ASRSC 1994a; ASRSC 1994b; Beland 1984; USASAC 1994; Dube and Fletcher 1982). No salmon were released in the river in 1993. A river-specific broodstock program was initiated in 1992, and juvenile salmon from the program were released in 1994.

Records of rod catch for the period 1953-1992 show an average catch of 22 salmon. Annual catch varied from no fish in 1955 to a high of 100 in 1981. Dube and Fletcher (1982) speculated that high flows during spring may impede the migration of salmon through the Machias River gorge. Consequently, salmon destined for the Machias River may be temporarily redirected to the East Machias River and captured in the recreational fishery.

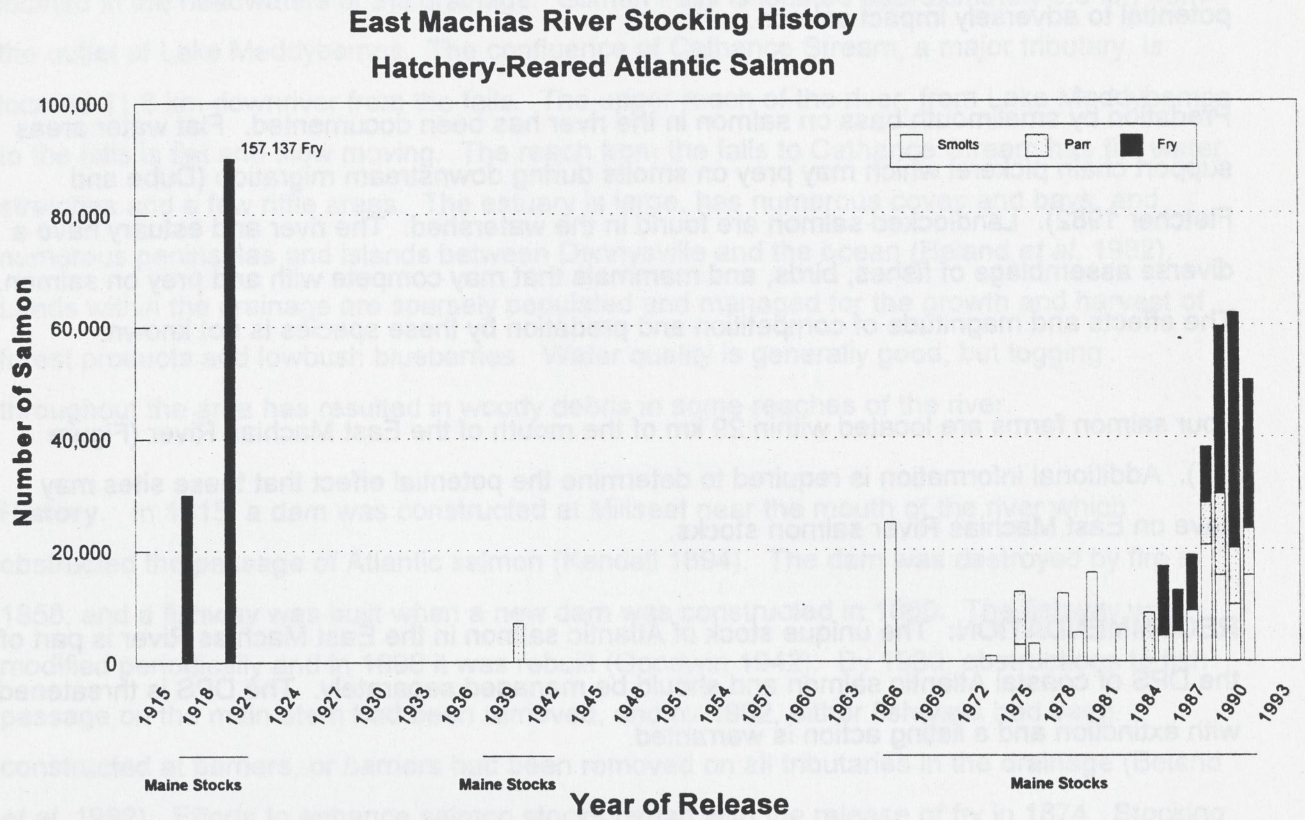


Figure 7.7 Stock origin and number of hatchery-reared Atlantic salmon (fry, parr and smolts) released in the East Machias River during the period 1915-1993.

Present Status. Surveys in 1993 documented that the main stem of the river was free of obstructions. 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). Important salmon production areas include Great Meadow and Wigwam Riffles, and Munson Rips at the outlet of Round Lake on the main stem; Chase's Mill and Northern Streams; and Seavey Brook. The river has an estimated 1,817 production units (one unit = 100 m^2), and with a potential of 2.4 smolts per unit, production potential is estimated to be 5,200 smolts (Dube and Fletcher 1982; ASRSC 1994b).

Listing Criteria. Land use in the watershed includes the growth and harvest of forest products and lowbush blueberries. Chemicals used in commercial blueberry cultivation, herbicides used in forest management, and pesticides used to control spruce budworm infestations have the potential to adversely impact salmon.

Predation by smallmouth bass on salmon in the river has been documented. Flat water areas support chain pickerel which may prey on smolts during downstream migration (Dube and Fletcher 1982). Landlocked salmon are found in the watershed. The river and estuary have a diverse assemblage of fishes, birds, and mammals that may compete with and prey on salmon. The effects and magnitude of competition and predation by these species is not known.

Four salmon farms are located within 29 km of the mouth of the East Machias River (Figure 6.1). Additional information is required to determine the potential effect that these sites may have on East Machias River salmon stocks.

RECOMMENDATION: The unique stock of Atlantic salmon in the East Machias River is part of the DPS of coastal Atlantic salmon and should be managed separately. The DPS is threatened with extinction and a listing action is warranted.

Status of the Stock and Applicable Listing Criteria:

- Severe decline in absolute numbers of adult returns and failure to achieve adequate escapement (Tables 5.2 and 5.3; Figure 5.2).
- Incomplete data documenting genetic characteristics of salmon in the river.
- Mortality in the marine environment.
- Predation in the riverine and estuarine environments.
- Degradation of habitat.
- Salmon farms within 20 km of the river mouth (Figure 6.1).

7.10 DENNYS RIVER

The River. The Dennys River originates in Lake Meddybemps in the town of Meddybemps, Washington County, Maine. It has a drainage area of 34,188 ha, and 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. Gilman Falls is located approximately 9.6 km from the outlet of Lake Meddybemps. The confluence of Cathance Stream, a major tributary, is located 11.8 km downriver from the falls. 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 woody debris in some reaches of the river.

History. In 1815, a dam was constructed at Millseat near the mouth of the river which 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). Efforts to enhance salmon stocks began with the release of fry in 1874. Stocking continued until 1889 after which no salmon were released until 1918. Since 1918, Atlantic salmon have been stocked in the river in all but 32 years. Approximately 3.5 million fry were stocked in the river in the early 1800's. Parr were primarily stocked in years prior to the 1960's, during which an estimated 756,551 were stocked. Smolts have typically been stocked since 1965, and to date approximately 237,689 have been released (Figure 7.8). In total, approximately 4,532,994 Atlantic salmon have been released in the river (ASRSC 1994a; USASAC 1994; Beland *et al.* 1982; Bureau of Fisheries 1917-1939). Fry of Penobscot River origin were stocked prior to 1920, but during the 1920's releases also included fry from Canadian rivers (Figure 7.8). During the period 1957-1968 parr from Canadian stocks were released. Smolts of Canadian origin were released in 1965, 1966, and 1968; however, smolts released during the period 1975-1991 were stocks obtained from the Penobscot and Union Rivers. A river specific broodstock program was initiated in 1992 following the capture of sea-run adults. Fry were available for release in the river in 1993 and 1994. It is anticipated that fish from the program will continue to be released in the river in future years.

In the early 1880's, the river yielded from 200 to 1000 salmon annually to net fisherman (Rounsefell and Bond 1949). There is evidence to suggest that the river was the first in the state of Maine where angling for sea-run salmon occurred (Kendall 1894). Angling for salmon became quite popular in the early 1900's. The Dennys River Sportsman's Club, formed in 1936, eventually purchased the commercial fishing rights on the river. Rod catch records show an average annual catch of about 50 fish for the period 1937-1992. In recent years, the catch has been poor, with seven fish recorded in 1991 and five in 1992 (Goodwin 1942; Rounsefell and Bond 1949; Beland *et al.* 1982; ASRSC 1994).

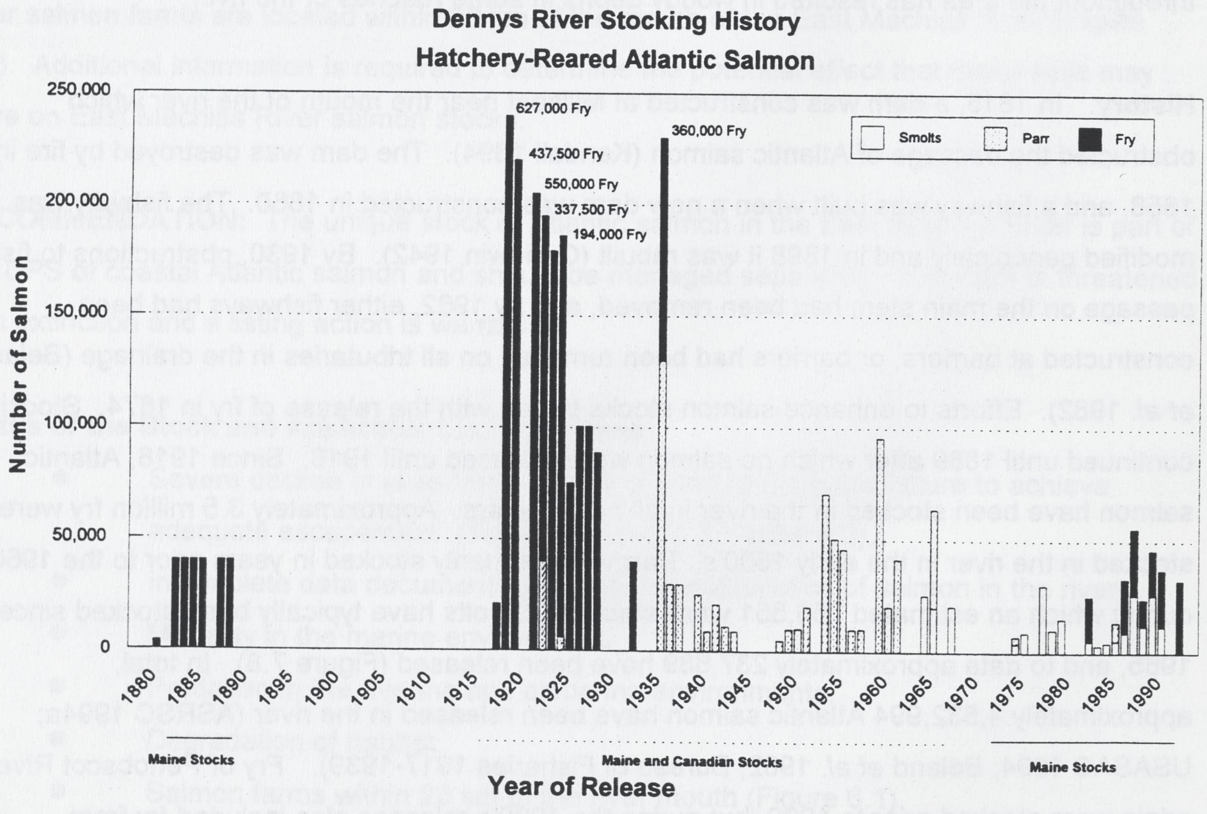


Figure 7.8 Stock origin and number of hatchery-reared Atlantic salmon (fry, parr and smolts) released in the Dennys River during the period 1880-1993.

Present Status. 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. Surveys have identified 1,747 production units (one unit = 100 m^2) of habitat, and with a potential of 3.6 smolts per unit, the production potential is estimated at 6,270 smolts (ASRSC 1994b; Fletcher 1960; Beland *et al.* 1982).

Listing Criteria. Lands in the watershed are managed for the production of forest products and lowbush blueberries. Large scale land alteration has occurred from logging operations and there is use of pesticides and herbicides by both forest products and agricultural industries. Deforestation, road construction, water withdrawals, and chemical applications have the potential to adversely affect salmon in the watershed. Smallmouth bass and landlocked salmon inhabit headwater lakes. 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 and prey on salmon. The extent to which these species affect salmon in the riverine, estuarine, and marine environments is not known. Sixteen Atlantic salmon farms are located within 20 km of the mouth of the river (Figure 6.1). Salmon farms located in New Brunswick, Canada may also be within proximity of the Dennys River estuary, but, to date, their exact locations have not been documented.

RECOMMENDATION: The unique stock of Atlantic salmon in the Dennys River is part of the DPS of coastal Atlantic salmon and should be managed separately. The DPS is threatened with extinction and a listing action is warranted.

Status of the Stock and Applicable Listing Criteria:

- Severe decline in absolute numbers of adult returns and failure to achieve adequate escapement (Tables 5.2 and 5.3 ; Figure 5.2).
- Incomplete data documenting genetic characteristics of salmon in the river.
- Mortality in the marine environment.
- Predation in riverine and estuarine environments.
- Degradation of habitat.
- Salmon farms within 20 km of the river mouth (Figure 6.1).

7.11 St. Croix River

The River. The St.Croix River has a drainage area of 388,500 ha and contains approximately 100 lakes and ponds. It has two major drainages, the east and west branches, that join at Grand Falls flowage and form the main stem which flows to Passamaqauoddy Bay. The east branch originates in Washington and Aroostock Counties, Maine and in York and Charlotte Counties, New Brunswick, Canada. This branch forms the international boundary between the United States and Canada. The west branch originates in Washington, Hancock, and Penobscot Counties, Maine and is primarily a series of large lakes. The head of tide is located in Calais, an area where the tidal range approaches 6.1 m. Approximately 62% of the drainage lies within the United States. The watershed is sparsely populated with industrial development located in the lower portion of the basin. There are two Native American reservations located in and near the watershed. The reservations of the Passamaquoddy tribe are located in Indian Township and at Pleasant Point in Perry, Maine.

History. Understanding the impacts of watershed development on salmonine resources in the St. Croix River is difficult because of the paucity of historical data regarding the use of riverine resources both in the U.S. and Canada. Dams constructed prior to the 1800's partially blocked the river, but Atkins (1874) reported that the Union Dam constructed in 1825 at tidewater completely obstructed the migration of anadromous fish. Accounts suggest that salmon persisted in the lower river (Rathbun and Wakeham 1897) for over 40 years until 1869 when the Union Dam and an upstream dam at Baring were each fitted with a fishway. In the ensuing years, other dams were constructed along the river. By the 1930's, because of pollution and riverine obstructions, salmon were eliminated from the river above Woodland Dam in Baileyville, Maine (Fletcher and Meister 1982; McCabe 1976).

The Canadian Cottons dam (Cotton Mill Dam) in Milltown, New Brunswick is located a short distance upstream from the point of tidal influence. This dam and Woodland Dam had been provided with timber fish ladders in the early years but the ladders deteriorated and were removed. By the 1950's spawning salmon were restricted to a short river section downstream from the Cotton Mill Dam (Bair and Rounsefell 1951). It was not until 1960 that fish passage facilities were constructed at this dam.

Both U.S. and Canadian fishery resource agencies had programs to enhance salmon stocks in the river. Available data from the U.S. shows that salmon were first released in the river in small numbers (50,000 fry) in 1874. Fry were stocked until the mid-1950's, but all juvenile life stages have been released in recent years (Figure 7.9). The origin of fry released included Maine rivers and Canadian stock, however, since 1968 only stocks from Maine rivers have been used. Known releases included approximately 2.7 million fry, 4.0 million parr, and 1.0 million smolt (U.S. Commission of Fish and Fisheries 1874-1890; Bureau of Fisheries 1925-1928; FWS 1940, 1949; Fletcher and Meister 1982; Beland 1984; ASRSC 1994a).

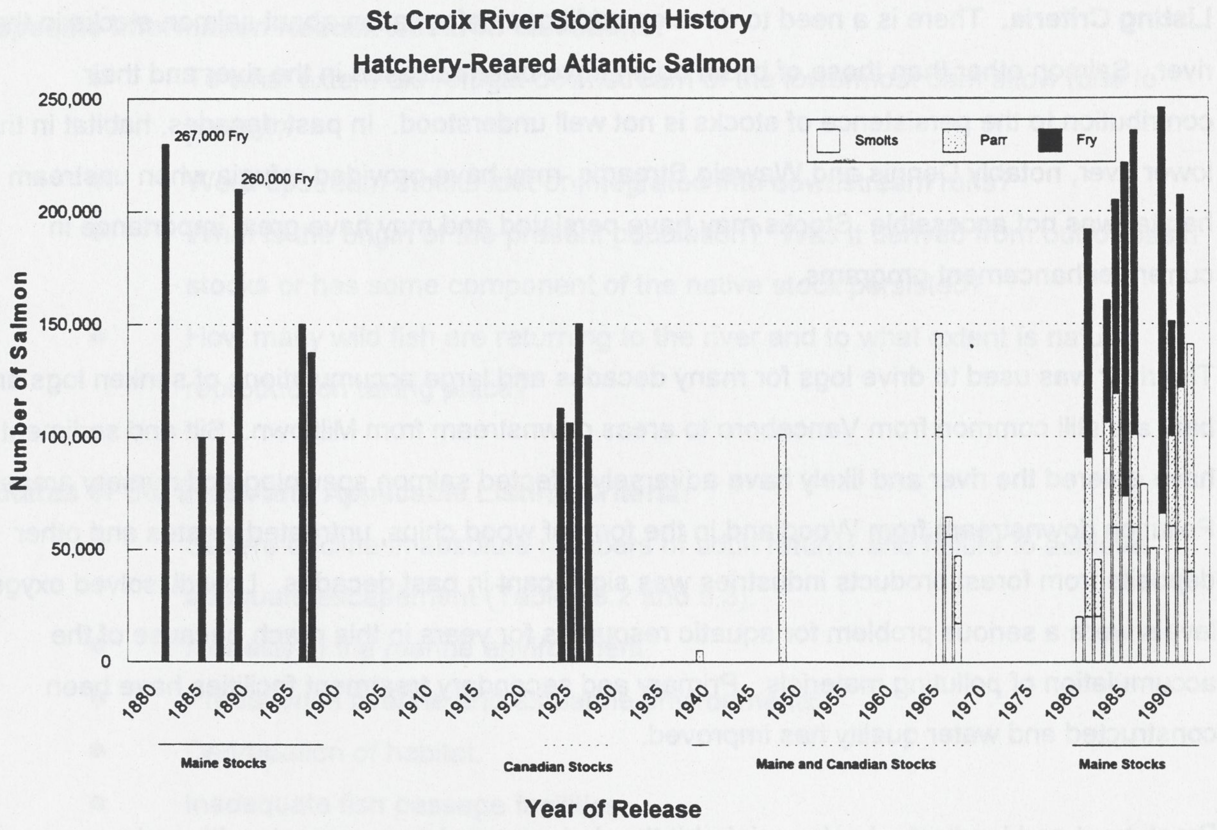


Figure 7.9 Stock origin and number of hatchery-reared Atlantic salmon (fry, parr and smolts) released in the St. Croix River during the period 1880-1993.

Present Status. The construction of dams resulted in the inundation of riverine habitat and altered flow regimes, yet much of the historical habitat suitable for adult spawning and juvenile rearing is still available. Today, all dams on the east branch from Calais to Vanceboro have fishways that allow salmon access to much of their historic range (Fletcher and Meister 1982).

Important salmon production areas in the east branch are located from Vanceboro to Little Falls, Little Falls to Loon Bay, and Loon Bay to Grand Falls; in the main stem from Grand Falls to Woodland, and Woodland to Calais; and in tributaries which include Bolton, Palfrey, and Scott Brooks, Wapsaconhagan, Magurrewock, Waweig, and Dennis Streams, the Little Digdeguash and Canoose Rivers, and at the outlet of numerous lakes. Estimates indicate a minimum of 29,260 production units (one unit = 100 m^2) of habitat, and with a potential of 3 smolts per unit, the production potential is 87,500 smolts (ASRSC 1994b; Fletcher and Meister 1982; Havey 1963).

Listing Criteria. There is a need to develop additional information about salmon stocks in the river. Salmon other than those of basin origin have been released in the river and their contribution to the persistence of stocks is not well understood. In past decades, habitat in the lower river, notably Dennis and Waweig Streams, may have provided refugia when upstream habitat was not accessible. Stocks may have persisted and may have great importance in current enhancement programs.

The river was used to drive logs for many decades and large accumulations of sunken logs and bark are still common from Vanceboro to areas downstream from Milltown. Silt and sediment have entered the river and likely have adversely affected salmon spawning and nursery areas. Pollution downstream from Woodland in the form of wood chips, untreated wastes and other deposits from forest products industries was significant in past decades. Low dissolved oxygen levels were a serious problem for aquatic resources for years in this reach because of the accumulation of polluting materials. Primary and secondary treatment facilities have been constructed and water quality has improved.

Brook trout and landlocked salmon inhabit the drainage and may compete with and prey on sea-run salmon. Chain pickerel and smallmouth bass were introduce in the drainage in the 1800's and are now well established (McCabe 1976). These species are known to prey on salmon (Barr 1962; Warner 1972), but the predator-prey interactions in the river are not well understood. The river and estuary have a diverse assemblage of fish, birds, and mammals many of which are known to compete with and prey on salmon. The effects and magnitude of predation by these species on salmon in the riverine, estuarine, and marine environments is not known.

Although the St. Croix River flows to upper Passamaquoddy Bay, most salmon farms are located in the lower portion of the Bay and a considerable distance from the mouth of the river (Figure 6.1).

RECOMMENDATION: Sufficient information is not available at this time to indicate that Atlantic salmon in the St. Croix River warrant protection under the ESA. Additional studies are needed. Consequently, the Atlantic salmon population within the river is recommended for candidate status.

Specific Information Needs/Research Questions:

- To what extent did refugia downstream of the lowermost dam allow runs to persist?
- Were upstream stocks lost or integrated into downstream runs?
- What is the origin of the present population? Was it derived from out-of-basin stocks or has some component of the native stock persisted?
- How many wild fish are returning to the river and to what extent is natural reproduction taking place?

Status of the Stock and Applicable Listing Criteria:

- Severe decline in absolute numbers of adult returns and failure to achieve adequate escapement (Tables 5.2 and 5.3).
- Mortality in the marine environment.
- Predation in riverine and estuarine environments.
- Degradation of habitat.
- Inadequate fish passage facilities.
- Limited control over river management due to international boundary.

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APPENDIX OF ACRONYMS AND TERMS

ASRSC	Maine Atlantic Sea Run Salmon Commission
DPS	Distinct Population Segment, term from the ESA definition of species which includes "any distinct population segment of any species of vertebrate fish...which interbreeds when mature."
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit - term defined by NMFS as part of its policy on applying the definition of species under the ESA to Pacific salmon
ICES	International Council for the Exploration of the Seas, the official research component of NASCO
NAC	North American Commission, regional component of NASCO
NASCO	North American Salmon Conservation Organization, intergovernmental organization established by the Convention for the Conservation of Salmon in the North Atlantic Ocean
NASSG	North American Salmon Study Group, subgroup of ICES
NASWG	North American Salmon Working Group, subgroup of ICES
NEFSC	New England Fishery Management Council
Services	Term used to collectively refer to the NMFS and USFWS
Team	Atlantic Salmon Biological Review Team, composed of members from NMFS and USFWS
USASAC	United States Salmon Assessment Committee, the Research Committee for the U.S. delegation to NASCO (prior to 1988 it was called the NASCO Research Committee)

~~Winter~~ Spring/96

At. salmon

— Fisheries 1995 20(12):48 (Spec. Regs.)

S. salar in

7 Maine rivers proposed for threatened status USFWS + NMFS (announced Sept. 28) – can't be listed until current moratorium on listing is lifted (extends through Sept. 96)

due to ocean harvest, low survival rates, land use, hatchery practices

Sheepscot, Ducktrap, Narraguagus, Pleasant, Machias, East Machias, and Dennys. Populations in Kennebec, Penobscot, St. ~~[illegible]~~ Croix, Tunk Stream, not warranted due to inadequate sci. info.

Proposal allows incidental take from regulated activities (sport fishing) – gave Maine leading role in management – Maine will develop conservation plan.

— for copy proposed rule: NMFS, 1 Blackburn Dr., Gloucester MA 01930 or FWS 300 Westgate Center Dr., Hadley MA 01035.

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